Acoustic Analysis of Voice of Cerebral Palsied Children.

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A dissertation submitted as part fulfilment of final year M.Sc. (Speech and Hearing).

All India Institute of Speech & Hearing
Mysore

MAY 1998

DEDICATED

in the name of Allah

TO MY PARENTS

CERTIFICATE

This is to Certify that This dissertation entitled **"Acoustic** Analysis of Voice of Cerebral Palsied Children" *has been prepared under my supervision and guidance.*

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CERTIFICATE

This is to Certify that this Dissertation entitled **"Acoustic** Analysis of Voice ofi Cerebral Palsied Children" *is the bonafide work in part fulfilment for the degree of* **Master of Science (Speech and Hearing)** *of the student with Register No.* M9615.

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DECLARATION

*This dissertation entitled "**Acoustic Analysis of Voice of Cerebral Palsied Children**" is the result of my own study under the guidance of **Dr. N.P. NATARAJA,** Professor and H.O.D. Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other diploma or degree.*

Mysore
May, 1998

Reg. No. M 9615

ACKNOWLEDGEMENTS

I will be very grateful to my teacher, respected guide, ***Dr. N.P. NATARAJA,*** *Professor and H.O.D., Department of Speech sciences, All India Institute of Speech and Hearing, Mysore, without whose constant guidance I would not have completed the disserrtation.*

Thank you Sir, for everything you have done.

I would like to thank ***Dr. (Miss) S. NIKAM,*** *Director, All India Institute of Speech and Hearing, Mysore, for permitting me to take up this topic as my dissertation.*

Thanks to ***Mrs. SRIDEVI*** *and* ***Miss LALITHA,*** *for their timely help.*

Thanks to staff of ***Malabar Spastic Society, Kannur*** *for helping me in carrying out the data collection.*

Thanks to all the subjects of this study without whose co-operation this study would not have been possible.

No words to express my feelings and thanks towards my friends ***NOUSHAD*** *and* ***SADEEP*** *for their continuous source of inspiration, which I needed the most.*

Thanks to ***Sri VENKA TESH,*** *for your efficient typing.*

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INTRODUCTION

Since time immemorial. man has shown interest in exploring nature and understanding several natural process. Growth of science in this century has accelerated such endeavours. Progress in technology has been immensely helpful in understanding many natural process inhuman anatomy and physiology, as well as diagnosis and treatment of many disorders.

A major consideration of research workers in speech science and speech language pathology has been to attempt to describe and explain the manner in which human speech system operates. 'System' is used here to refer to the interacting the interdependent components of a functional unit that is only partially accessible to direct observation (Attanasia, 1987). Speech, a motor act consists of complex ballistic movements. Unlike many motor activities, speech requires a complex blend of actions in synchrony to produce even the simplex response (Kelso, Tuller and Harris, 1983). Sensory motor integration is a necessary condition for normal speech production.

The production of voice is a complex process. It depends on the synchrony between the respiratory, the phonatory, the resonatory and the articulatory system which inturn requires precise control by the central nervous system. Hirano (1981) states that "during speech and singing, the higher order centers including the speech centers in the cerebral cortex control voice production and all the activities of the central nervous system is finally reflected in muscular activity of the voice organs". Because of the interdependence of the respiratory phonatory, articulatory and the resonatory system during the process of voice production disturbance in any one of the system may lead to deviant or abnormal voice quality. Hence voice plays a major role in speech and hence in communication. .

There are various means of analysing voice, developed by different workers, to note the factors which are responsible for creating an impression of a particular 'voice' (Hirano, 1981; Natraja, 1972; Rashmi, 1988; Anitha, 1994).

The psychoacoustic evaluation of voice is done based on pitch, loudness and quality of voice sample. Due to its subjectivity the perceptual judgement of voice has been considered less worthy than the objective measurements. There are other objective methods like electromyography, stroboscopy, ultrasound glottography, ultra high speed photography, photo electric glottography, electroglottography, aerodynamic measurements, acoustic analysis, etc.

Presently acoustic analysis is gaining more importance. Hirano (1981) states that "This may be one of the most attractive methods of assessing phonatory function or laryngeal pathology because its non-invasive and provides objective and quantitative data. Acoustic analysis can be done using methods such as spectrography, peak analysis, inverse filtering computer based methods and others.

As mentioned earlier speech is a highly integrated physiological motor act. For each speech sound there is a separate neuromuscular configuration that involves as a functional unit, all musculature of the speech organ. Any disturbances of this neuromuscular configuration as a result of the weakness, paralysis or incoordination of the speech musculature or as a result of lesions in the nerves supplying the musculature, results in speech dysfunctions.

Cerebral palsy is such as condition where in motor dysfunction secondary to CNS damage before, during or shortly after birth occurs (Boone, 1972). Cerebral palsied children have sensory, motor, perceptual, behavioural and emotional problems. Speech abnormalities are often seen in them as all the subsystems of speech production: respiration, phonation, resonation, articulation and prosody are affected (Barnes, 1983).

Predictably, these changes in the subsystems of speech production leads to change in the acoustic characteristic of speech. Therefore acoustic characteristics of voice in cerebral palsied children are studied to note their deviation from comparable normal children of same age group.

Since these acoustic characteristics reflects the changes in the vocal system and its function, they have been used to study the nature and function of the speech mechanism. Although the physiologic and phonetic interpretation of acoustic data are uncertain, they are useful in testing certain hypothesis about changes in anatomy, motor control and physiological functions. Thus in the event of abnormal structural and functional changes, there will be a corresponding change in the acoustic characteristic of speech. Therefore an insight into the varied characteristic of speech would in turn facilitate in differentiating normal from abnormal. This well inturn lead to effective management. The respiratory abnormalities, inability to extend the exhalation, abnormal vocal fold vibration, abnormal resonance, malpositioning of articulators may all contribute to poor voice characteristics in cerebral palsied children.

Some of the above parameters have been found to be affected in cerebral palsied children (Duffey, 1954;

McDonald and Chance, 1964; Palmer, 1953; Rutherford, 1944; Warnars, 1993).

Not much information is available in Indian context on these parameters in cerebral palsy. So the present Study aims at studying the changes in acoustic parameters in the voice of cerebral palsied.

STATEMENT OF THE PROBLEM

The problem was to know how the aerodynamic and acoustic parameter changed in cerebral palsy.

The present study, therefore, aims at analysing some of the acoustic aspects of the voice of cerebral palsied.

Totally 57 subjects, both males and females, age ranging from 3-10 years were considered for study. This consist of 42 normal subject and 15 cerebral palsied subject. All normal subjects were normal in terms of speech, language and hearing and attending normal school. Cerebral palsied subjects consists of eight spastic quadriplegics, five spastic diplegics and two athetoid quadraplegics ranging from mild-moderate in severity.

Three trials of maximum phonation duration of /a/, /i/ and /u/ were recorded for all the subjects. Using the data on vowel prolongation, the following were obtained using computer analysis.

a. Maximum phonation duration

b. Fundamental frequency

c. Speed of fluctuation in frequency in phonation

d. Extent of fluctuation in frequency in phonation

e. Speed of fluctuation in intensity in phonation

f. Extent of fluctuation in intensity in phonation

g. Intensity range in phonation

h. Frequency range in phonation

i. Rise time in phonation

j. Fall time in phonation

Recording of three repetition of three sentences were made for all the subject. This was analysed for

1. Speaking fundamental frequency

2. Frequency and intensity range in speech.

Main hypothesis

There is no significant difference in the acoustic parameters between cerebral palsied subjects and normal subjects.

AUXILLARY HYPOTHESES

1. There is no significant difference between cerebral palsied subjects and normal subjects and normal subjects across different parameters.

2. There is no significant difference between spastic diplegic, athetoid quadriplegic and spastic quadriplegic when each of parameters was compared to normal subjects of same age group.

3. There is no significant difference between three types of cerebral palsied subjects: spastic diplegic, athetoid quadriplegic and spastic quadriplegic in terms of these parameters.

a. Maximum phonation duration
b. Fundamental frequency in phonation
c. Fundamental frequency in speech
e. Speed of fluctuation in frequency in phonation
d. Extent of fluctuation in frequency in phonation
g. Speed of fluctuation in intensity in phonation
f. Extent of fluctuation in intensity in phonation
i. Frequency range in speech
j. Intensity range in phonation
k. Intensity range in speech
h. Frequency range in phonation
1. Rise time in phonation
m. Fall time in phonation

IMPLICATIONS OF THE STUDY

This study provides information regarding the changes in maximum phonation duration, fundamental frequency in phonation, speaking fundamental frequency, speed and extent of fluctuation in frequency and intensity, frequency range in phonation and speech, intensity range in phonation and speech, rise time and fall time of phonation in cerebral palsied subjects.

This information will be helpful in

1. differential diagnosis of voice disorders and childhood neurogenic developmental disorders.

2. estimating the importance of neuromuscular control of voice production.

3. planning the management strategies of cerebral palsied.

REVIEW OF LITERATURE

Language is undoubtedly the most important factor that differentiates human beings from other aninals. Language constitutes both a set of symbols (codes) and set of procedures (rules). These combines to form words, phrases and sentences. Language is in itself a system of abstract logic. It allows human beings to extend their rational ability. Indeed it has often been virtually equated with human beings' abstract logical ability (Chomsky, 1966).

Although there are various ways of using language, the sending and receiving of spoken messages are the most frequent and important ways of sharing the thoughts and relations to each other. Speech may be viewed as the unique methods of communication evolved by human beings to suit the uniqueness of their mind. By its great flexibility it permits human beings to produce a variety of signals commensurate with the richness of their imaginations. Speech may be defined as a form of oral communication in which the transformation of information takes place by means of acoustic energy. The speech wave forms are the result of interaction of one or more source with the vocal tract filter system (Fant, 1960).

Speech is produced without observable efforts by human beings. The range of speech variation is immense and yet considered normal. Only a small part of information is conveyed by speech. Less than one per cent of this is used for linguistic purpose, as such the rest gives other kind of information about the specific character of vocal tract of the speaker, which enables one to recognise the speaker's voice, physical well-being and emotional state, attitude towards the entire context in which the speech event occurs. It can also carry other information about the speaker with reference to the conventions of social class, occupation and style.

Speech is considered as skilled, willful and elaborate movements of muscles used for initiating vocal sounds, plus the molding of these sounds into meaningful, oral communication. The production of speech is exercised by the simultaneous, highly coordinated and specifically differentiated functions of various organ systems, respiration, phonation and articulation.

Speech is a motor activity which is controlled by the nervous system. The nervous system comprises of central and peripheral divisions. The most highly specialised system, the central nervous system, consists of nervous tissue contained within the cranium and the spinal column. Three kinds of nerve fibre branch out from the central nervous system (CNS).

1. The afferent fibre connecting the sense organs of the body with CNS.

2. The efferent fibres connecting the CNS with the striate muscles of the body.

3. The fibres inter-connecting the central and the autonomic systems.

The fibres that branch out from the CNS comprise the peripheral system. The central and the peripheral systems together constitute the cerebro-spinal system. The axones of the individual nerve cells or neurones of the peripheral system are the pathways for the transmission of the impulses to and from the CNS. A nerve trunk may be motor, sensory or mixed, i.e. efferent, afferent or both. The three kinds of nerve fibre carried by various trunks in the CNS play different roles in the sensory-motor processes of speech.

a. The afferent fibers most important in speech are those carried by eighth cranial nerve, the auditory nerve through the agency of which one hears others and oneself and thus learns to perceive and produce speech.

b. Motor fibres innervating the muscles of respiration, phonation and articulation are distributed through many cranial and spinal trunks.

c. The fibres that inter-connect the autonomic nervous system with the CNS thus providing for the inter-play of emotional reactions in the two systems (are also carried by many cranial and spinal trunks).

d. The afferent nerves connect the CNS to the peripheral sense organs of sight, hearing, taste, smell and touch and also with the internal sense organs of pain, pressure and movement- These nerves bring to the CNS impulses that cause sensation, states of feeling and also impulses that serve merely to condition the behaviour of the CNS without directly colouring the fields of consciousness.

The efferent nerves connect the CNS with the skeletal muscles which includes the muscles of the abdomen, diaphragm, larynx, pharynx, velum, tongue, jaw and lips. These nerves carry not only the voluntary impulse to those muscles, but also the impulses from the centres of the CNS (over which one has little, if any, direct voluntary control), eg. gagging and sneezing, and also the impulses from CNS centres over which one has partial voluntary control, eg. swallowing, crying, sleeping, smiling and breathing.

Several nerves play important roles in the process of speech. Of the twelve pairs of nerves that emerge from the important in speech are the trigeminal nerve (5th), facial nerve (7th), auditory nerve (8th), glosso-pharyngial nerve (9th), vagus nerve (10th), accessory nerve (11th) and hypoglossal nerve (12th).

Several pairs of nerve trunks emerge from the CNS through special foramina in the neck portion of the column. Small branches from the first, second and third trunks carry motor fibres to the pharynx, velum and the posterior root of the tongue. Small branches from various cervical nerves join with a larger branch from each fourth cervical trunks to the diaphragm. Various cervical trunks carry motor fibres to the muscles employed in forced inhalation.

Twelve pairs of nerve trunks emerge through foramina in the costal vertebrae. These trunks carry motor fibres to the muscles of inhalation and exhalation.

The autonomic nervous system, as a whole, is more definitely a motor system than the CNS. The autonomic nervous system is primarily an agency for distributing motor impulses to the viscera. CNS has a highly developed system of afferent nerves which check and guide the movements of the muscles. In order to make this control more effective, a highly organised set of fibres has been developed connecting the afferent ani efferent nerves. This associative inter-nuncial or inter-calary fibres make it possible to inter-connect any afferent with any efferent neurone.

The fitres that directly connect the CNS with muscles tissue are called Lower Motor Neurons. Every impulse to the muscles reaches via one of these Lower Motor Neurons.

The cell body of the lower motor neurons lies within the CNS. The derdrites of this cell synapses with other motor neurons that bring impulses to it from various centres of the CNS. Each of these centres may thus control a lower motor neuron by sending impulses to it over the connecting neurons. All these connecting motor fibres are called Upper Motor Neurons.

The various centres in the CNS do not have equally ready access to and control the lower motor neurons. Some centres are more directly in control of certain muscles than others. Some are able to exercise control only under certain conditions, some are of about equal authority on the hierarcy of the CNS, some are master centres, some are distinctly subordinate.

The centres of control of the CNS are located throughout the system, extending from the sacral division of the spinal cord to the cerebrum; but in general those having the greatest control are located higher in the CNS, i.e. further from the sacrum and in the brain, closer to the anterior pole. The lowest centres are those concerned with the simple reflex; the highest, those of cerebrum are concerned with the process of volition.

Some of the centres important in speech are: (given below in the general order of the hegemony of the CNS).

1. The hypothalamus and thalamus
2. The basal ganglia
3. The cerebellum
4. The medulla oblangata
5. The reticular system
6. The cerebral cortex

1. The hypothalamus are located in the centre for the control of visceral organs involved in emotional reactions.

2. The thalamus: Many have attributed speech and language as the function of the dominant thalamus. Coppa et al. (1979) maintained that the left thalamus contributed to the semantic level of the verbal behaviour which was initially controlled by the marginal areas of the language.

Ojemann et al. (1971) proposed that the left thalamus was involved with attention mechanisms which were important to control storage and retrieval of both long term and short term memory.

Ojemann (1976) also noted that left thalamic mechanisms secured to be involved in the coordination of motor and respiratory aspects of speech.

Penfield and Roberts (1959) suggested that the thalamus was a major integrating centre between the frontal and parietal cortical language areas by means of projection fibres. Thus from the reviewed data it seems that dominant thalamus does participate in speech and language functions.

Above the thalamus are the basal-ganglia, consisting of the thalamus and the striate bodies. These are the emotional centres that colour and sometimes block speech. These ganglia or nuclei are located deep within the cerebrum on either side of the midline.

3. The cerebrum: Cerebellum is a clearing house for all impulses sent to the striped muscles of the body. Without this centre, a given set of muscles could engage in only one activity at a time, because these acts require the coordination of largely overlapping sets of muscles and in some instances require opposing movements.

This organ also maintains the body in a state of balance with respect to the pull of gravity. For this the cerebellum holds the striped muscles of the body in a constant state of stretch (muscular tone). When the tonus is increased by any myopathalogical or neuropathalogical cause, the condition is called 'spasticity'. When the tone is decreased, pathalogically the condition is called flacidity.

The cerebellar function in motor control are thought to be in:

1. The biasing of the muscle spindles to ensure that spindle formation of the appropriate nature is supplied to the higher centres as a movement is performed.

2. The integration and interpretation of afferent information.

3. To exercise a revisory control over the command issued by motor cortex.

Boylls (1975) argued that damage to cerebellum leads to disturbance of entire acts or sequence of movement or there will be evidence of a breakdown in the temporal relationships of movements. Thus cerebellum plays an important role in the temporal relationships of movements. Thus the cerebellum plays an important role in speech, a finely coordinated motor act.

4. The medulla oblangata: The bulbous portion of the spinal cord extending in the cranium is medulla oblangata. Various centres are located here, among them the pneumo-taxic

centre, which controls the rate and depth of respiratory movements is also present and is important for speech.

5. The reticular formation: All sensory input enter brain proper via thalamus. Parallel with the sensory nerves via the thalamus is a series of reticulate structures through which the incoming stimuli pass and in which they are sorted out. Those impulses that are meaningful to the individual are relayed to the cerebral centres, in which they can produce appropriate reaction. Those impulses that are relatively meaningless are shunted out of cerebral circuits. In co-operation with the sensory areas of cerebrum, the reticular formation serves as an arousal mechanism to alert the individual to meaningful patterns of stimulation. The process of attention and alarm are negotiated by the cooperation between the reticular formation and the auditory centre of the left cortex.

6. The cerebral cortex: The outer superficial grey matter of the cerebral hemisphere is know as Cerebral Cortex. It contains about 14 billion cells and about 200 million incoming and outgoing projection fibres (Kapper's et al 1960). the cortical cells and their fibres constitute a dense matter network that permits tremendously complicated pattern of activity.

In the outer grey surface of the cerebrum are various centres used in control of speech:

a) At the occipital pole of each cerebral hemisphere is the primary sensory area of vision.

b) On the upper edge of the temporal lobe of each hemisphere is the primary sensory area for hearing.

c) On the front border of each parallel lobe, just on the edge of the fissure that separates it from the frontal lobe is the somesthetic area, the centre for feeling pain, pressure, touch, cold, heat and movement.

d) On the posterior border of each frontal lobe, just across the fissure form the somesthetic area is the primary motor area for the control of all the striped muscles of the body.

Expect for the hypothalamus and the visual, auditory and the somesthetic areas of cerebral cortec, each of the centres is potentially the point of control from which any given lower motor neuron serving the musculture of the speech organs may receive impulses from many centres. It cannot serve all simultaneously. During speech, the lower motor neurons are almost completely responsive to impulses from the cerebral cortex. In the functioning of the cerebral control of the muscles directly to the lower motor neurons concerned but also transmits inhibiting impulses to the other centres, thus restraining their activity.

The sensory centres involved in speech assist the motor areas of the cortex in the processes of motor co-ordination to learn, guide and check the movements of speech organs. For this certain connective pathways are necessary between the sensory and the motor areas.

West and Ansberry (1968) quote: . . . . . "normally the areas of the cerebral cortex that are developed to perform this function of association lie either in one hemisphere or the other. These areas developed only on one side of the cortex are the association areas. In a right handed person association area most important in motor speech lies close to and in front of the lower end of the primary motor area and is called 'Brocas'area. Corpus callosum connects the two hemisphere of the cerebrum. Thus it is possible to control the motor system from centres located only on one side. The control exerted by these association centres is by relaying selected impulses from the sensory areas. The association areas of the cortex are more inhibiting then executory in their motor effects; normally they never excite a muscle group without inhibiting its antagonistic group.

They frequently delay the passage of an impulse to the motor outlets of the brain and this provides for the element of timing the most motor co-ordications required.

Speech is thus built up by conditioning the association areas by impulses from the visual area, the auditory area and the somethetic area. For each speech sound there is a separate neuro-muscular configuration that involves as a functionally unit, all the musculature of speech organ. The crucial event essential for the voice production is vibration of the vocal folds. It converts DC airstream to AC air-stream, converting aerodynamic energy to acoustral energy. From this point of view, the paremeters involved in the process of phonation can be divided into three major groups:

1) The parameters which regulate the vibratory pattern of vocal folds.

2) The parameters which specify the vibratory pattern of vocal folds.

3) The parameters which specify the nature of sound generated.

Hirano (1981) has further elaborated on this by stating that "the parameters"which regulate the vibratory patterns of the vocal folds can be divided into two groups:

Physiological and Physical. The physiological factors are succinately put, related to the activity of the respiratory, phonatory and articulatory muscles.

The physical factors include the expiratory force, the conditions of vocal folds and the state of vocal tract.

Expiratory force is the energy source of phonation and the state of brancho-pulmonary system and the thoraxic cage. The condition of vocal folds which are the vibrators is described with respect to the position, shape , size, elasticity and viscosity of the vocal folds. It is influenced by the laryngeal muscles, conditions of vocal folds (pathological) and adjacent structures. The stat of vocal tract,m the channel between the glottis and the lips, affects the vibratory pattern of the vocal folds to a certain extent and it is regulated chiefly by the articulatory muscles.

The vocal fold movement is controlled by a subtle, delicate interplay of various muscles which work in pairs and groups. The adduction vocal folds is brought about by lateral crico- arytenoid and arytenoid muscles. Contraction of arytenoid muscles draw the muscular process posteriorly, thus toaing out the vocal process. When just the lateral crico- arytenoid muscles are contracted, the arytenoid cartilages are rotated so that the muscular process are pulled anteriorly and the vocal processes are toed inward to produce the glottal configuration required for the production of a whisper. Simultaneous contraction of lateral crico-arytenoid and arytenoid muscles approximate the arytenoid carteleges and the vocal folds os that their medial borders are parallels. The result of combined action of muscles is such that vocal folds are tightly approximated and if exhalation is initiated, the vocal folds will be set into vibration to produce a laryngeal tone.

An increases in tension and a concommitant decrease in mass of the vocal folds is primarily responsible for an increase in pitch. This is brought about by the antagonistic action of circo-thyroid and thyro-arytenoid muscle with an assist from posterior crico-arytenoid muscles.

Lowering of the pitch is brought about by the action of thyro-arytenoid muscle which draws the arytenoid and the thyroid cartilage towards one another, to shorten and relax the vocal ligament. Medial compression at low pitches is probably facilitated by the lateral crico-arytenoid muscles. The accessory fibres carried by the vagus nerve supplies the intrinsic muscles of larynx controlling the vocal fold vibration.

Speech output depends on the adequate functioning of respiratory, phonatory, resonatory and articulatory mechanism. Each of these sub-systems contributes equally to the ultimate speech output in terms of adult standards. It has been seen that young infants produce speech which are quite unlike those of adult speech output. (Smith and Mclean Muse 1986) in terms of temporal patterning. Overall resonance and spectral characteristics though they may seem similar perceptually (Zlatin 1925, Stark et al 1976, Oiler, 1978, Buhr, 1980) This may be because of immature sub-system in terms of structure, function, neuro-muscular connections, etc. The respiratory phonatory, resonatory and axticulatory systems contribute to speech output.

Respiratory System

The primary function of the respiratory apparatus is to ventillate the lungs for 02 -CO_2 exchange. This function, however, has been modified in humans to allow for oral communication. The respiratory system starts at nose and mouth, proceeds down the pharynx, passes through the larynx down the trachea or wind pipe and then enters into increasingly branched tubes (bronchi, bronchioles) until the final multitudinous sub divisions ending at the alveolar sacs of the lungs. AS the lungs are made up of elastic, non-muscular tissue and adhere to the inside of chest wall through plural linkage, they assume the shape of the cavity that encloses them. It is the muscular and recoil forces of thorax that alter the shape of cavity , changing the air pressure within the cavity which causes air to reach in or out of the lungs. The framework of respiratory apparatus is the skeletal structure of the torso which includes the spinal column, shoulder, griddle, ribcage and pelvic griddle. Breathing is controlled by the action of a group of muscles. The important muscles that control the inhalatory phase of respiration are diaphragm and thoracic muscle. During exhalation action of internal oblique, external oblique, rectus abdominis, transverse abdominal and transverse thoracic muscles are involved.

A number of layered feedback mechanism monitor breathing in human beings to ensure that the respiratory system met physiological demands of normal and strenuous activity. Mechanical stretch receptors in lung tissue monitor the degree of inflation of lungs and activate control system that limits the depth, i.e, magnitude of inspiration. Central and peripheral chemoreceptors monitor the level of dissolved C02 and 02 and PH of our blood and CSF. These feedback mechanisms sustain the ventilatory condition that are necessary to sustain life. These chemo-receptive feedback mechanism acts rapidly to make small changes in respiration. (Lieberman & Lierbman 1973) Breathing is managed by a complicated respiratory reflex involving the two vagus nerves and two phrenic nerves from the cervical section of the spinal cord-

Breathing for speech is essentially the same process as breathing for life, consisting of two phases: inhalation and exhalation. Speech is produced by the displacement of a column of air during exhalation. During speech inspiration becomes shorter than expiration. Air is taken into the lungs and then held for a slow release to allow for an extended period of speech while maintaining a constant subglottal pressure that range from about 8-10 cm of H_2O (Bouhuys 1974), (Araper,Lade Foged & Whitteridge 1960); (Lieberman 1967), (Liebarman 1968).

This steady air pressure is maintained through out the length of expiration. The length of expiration and depth of inspiration that proceeds an expiration are keyed to the length of the unit of speech that they are going to produce. (Liebrman & Lieberman (1973).

ResOnatory System

Resonance is the modification of the vocal tone as the airstream passes through the nasal and oropharynx and mouth. The modification or amplification creates the individual characteristics of the voice. Resonators of human body are three tubes, the cavities of which contain column of air. These tubes are pharynx (nasopharynx, laryngo-pharynx), the mouth and the nose (a double tube). Besides these tubes there are larynx itself, the trachea and the bronchi and also sinuses (frontal, maxillary, thymoid and sphenoid sinuses). the most significant of these cavities are mouth and pharynx. Their importance lies in their extreme adjustibility as to their own length and diameter and as to the diameter and length, of -heir orifices or openings.

Due to the shape of vocal tract above (and below), the larynx, various harmonics are resonated to create a much more complex sound. The majority of the resonance effect appears in the ability to articulate. Nasal resonance acts as a continuous and universal modifier to the voice. (Greene 1980). The remarkable characteristics of human vocal resonator is that its shape can be altered by the movements of articulators. The speech sounds which are known as vowels, diphthongs, semi-vowels and masals are the result of filtering the periodic wave produced at the glottis through the vocal tract which varies its configuration and thereby its resonant frequencies for each sound. The cavity variations and resonance changes make the sounds distinctive.

Articulatory system

Articulation refers to the ability to modify or valve the voice stream into specific sounds that can be formed into words, sentences of a language. According to Power (1971) that "Articulation can be defined as the production of speech sounds by the stopping or constructing the vocalised or non-vocalised breath stream by movements of the lips, tongue, velum or pharynx".

Articulation occurs by the movement of structures associated with oral cavity. By varying the size and shape of the cavity different sounds are created. Tongue is the most important structure in articulation. It alters the size and shape of the oral and pharyngeal cavities producing most consonants by movements near to or against teeth, gums and palate. Movement of articulators are necessary both for producing resonance characteristics of vocal tract.

Articulatory muscles are innervated by cranial nerves i.e, trigeminal nerve (5th) innervating the buccinator and the tensor palatini and the facial nerve innervates the remaining musculature of face. The tongue is innervated by hypo-glossal nerve (12th) while soft palate by glosso-pharyngeal and vagus nerve. So articulation is a fine motor act that requires precise control and timing of articulators.

Phonatory System :-

Phonation is the sound production by the larynx. The crucial event for voice production is the vibration of vocal folds which is controlled by a subtle and delicate interplay of various muscles. Efficient phonatory behaviour depends on co-ordination between inspiratory and expiratory muscles which are then, must be co-ordinated with laryngeal, velopharyngeal and articulatory muscles valving activity. The vocal product of this complex co-ordination is monitored primarily by the auditory system.

The nature of sound generated is chiefly by the vibratory pattern of the vocal folds. It can be specified both in acoustic terms and in psychoacoustic terms. The psycho-acoustic, parameters are naturally dependent upon the acoustic parameters. The acoustic parameters are fundamental frequency, intensity, waveform, acoustic spectrum and their time related variations. The psychoacoustic parameters are pitch, loudness, and quality of the voice and their time related variations.

Analysis of such acoustic parameters have been considered to be useful in knowing about the developmental disorder and thus in the treatment of developmental disorders of speech.

In many important respects, the development of motor control for speech is on instance of the more general problem of the development of skilled action. In defining this general problem of serially ordered acts, the performance of which is modified to achieve diminishing variability increased anticipation and improved economy. These attributes is seen highly appropriate to describe the development of motor control for speech (Kent, 1980).

Over the past two or three decades considerable research effort has been directed towards obtaining an understanding of the organization and control of the process by which children learn to produce speech. Such research has involved observations of the aerodynamic and acoustic characteristic of speech (Mou, Zimmerman and Smith, 1976).

Hirano (1981) has pointed out that the acoustic analysis of voice signal may be one of the most attractive methods for assessing phonatory function or laryngeal pathology because it is non-invasive and provides objective and quantitative data. The technique of acoustic analysis has promising future as a diagnostic tool in the management of voice disorders. Many acoustic parameters, derived by various methods, have been reported to be useful in differentiating between the pathological voice and the normal voice. Hirano (1981) goes onto say that all the previous reports are preliminary reports and that further extensive basic and clinical research is required in order to obtain some algorithm for diagnostic purposes.

Further, a clinician will not really know who- to expect with a medical diagnosis having a complete physical description of the laryngeal together with some adjectives like "hoarse" for "rough", until he actually sees the case (Michael and Wendhal, 1971). On the other hand, if the clinician receives report which include measures of frequency ranges, respiratory function, jetter, volume-velocity of airflow during sustained phonation, etc., in the form of a voice profile, the clinician can compare these values to the norms for each one of the parameters and thus have a relatively good idea as to how to proceed with therapy even before seeing the patient. Moreover, periodic measurement of these parameters during course of therapy may well provide a useful index as to the success of the treatment.

Human neuromotor system involves a complex act. For any motor act to take place a co-ordination in terns of muscle strength, speed of movement, apropriate range of excursion, accuracy of movement, motor steadiness and nuscle tone is required. Damage that impairs one or more of these neuromuscular functions may affect motor production (Netsell, 1984).

Speech is a highly integrated physiological motor act and basically results by three motor processes; exhalation, phonation and articulation.

For exhalation muscles of thorax and abdomen are responsible; for phonation, muscles of larynx; and for articulation, muscles of articulators like lips, tongue, cheek, jaw, pharynx and velum are responsible.

For each, speech sound there is a separate neuro-muscular configuration that involves as a functional unit, all the musculature of the speech organ.

Any disturbance of this neuromuscular configuration as a result of the weakness, paralysis or in co-ordination of the speech musculature or as a result of lesions in the nerves supplying the musculature, results in speech dysfunctions.

The most common cause of the impairment of motor speech in children is cerebral palsy.

Cerebral palsy

Cerebral palsy is a complex and multidimensional childhood disorder. It was first described more elaborately by Little in 1852. Phelps coined the term cerebral palsy in 1936. An individual with cerebral palsy is physically disabled, primarily because of faulty links between the brain and parts of the body.

Bobaths (1954) viewed cerebral palsy as a sensorimotor disorder which was not one condition, but a group of conditions occurring as a result of abnormal brain development or brain damage. Cruickshank and Raus (1955) regarded cerebral palsy as one component of a broader brain damage syndrome that comprised of neuromotor dysfunction, psychological dysfunction, convulsions and behaviour disorders of organic origin.

Abbott (1956) defined cerebral palsy as a disorder of neurological disability caused by a lesion in the motor centres of the brain. This brain damage resulted not only in a loss of functional muscular control but also in sensory disturbances. For Perlstein (1961) the term cerebral palsy had no specific meaning it generally indicated some injury or damage to a person's brain which resulted in a difficulty in control of movements. He defined cerebral palsy as a condition characterised by paralysis, weakness or non-coordination or other aberration of motor function due to pathology in the motor control centres of the brain.

According to Westlake (1961) cerebral palsy was not a single type of neuromuscular disorder but a group of disturbances occurring as a result of involvement of cortical or subcortical motor control areas. Boone (1972) defined cerebral palsy as a motor dysfunction secondary to central nervous system damage to the organism before, during or shortly after birth. To a physiotherapist, cerebral palsy is a neuromuscular disability caused by non-progressive lesions in the motor centres of the brain (Chainani, 1971).

These definitions of cerebral palsy generally agree with each other and share three common features. The cause of the disorder is brain pathology; the brain damage occurring early in life in young or yet to develop central nervous system; the disorder is a complex set of symptomatology and not a single disability; and the major symptoms are those of motor dysfunction.

In addition, definitions of cerebral palsy should account for the extreme variability of the disorder in that some cerebral palsied individuals may present a very mild single disability while many others may suffer from any combination of disabilities of physical and psycho-behavioural nature. The impairment may be detected only as a mild loss of fine muscular control or as a severe multi facet problem involving head and trunk ability, limbs, hearing vision and speech. This neurological disability can affect the overall behaviour including both receptive and expressive abilities (Berry and Eisenson, 1962). The neuromuscular manifestations may be regarded as the most obvious symptom of cerebral palsy, but other symptoms of mental retardation, abnormal speech and language development, disorders in sensory perception (auditory, visual, etc.) and behavioural manifestations such as distractibility, hyperactivity, etc. must also be taken into account by a clinician (Berry and Eisenson, 1962; Boone, 1972). Thus complexities of the problem include all the basic and higher functions, namely, neuromuscular, psychological, sensorimotor and behavioural abilities.

Incidence of cerebral palsy

Various studies have shown the incidence of cerebral palsy to be 1-2 per 1000 of live birth among all ages (Asher and Schonell, 1950; Woods, 1956; Cohen, 1957; Anderson, 1957; Perie et al., 1957).

Regarding the incidence of different types of cerebral palsy, various study agree with each other and conclude that spastic cerebral palsy is the most frequent (70%) followed by athetoid (10%), ataxic (10%) and tremor (10%) (Woods, 1956; Brandet, Westgard and Nielson, 1956-57; Anderson, 1957; Hansen, 1960).

Classification of cerebral palsy

To classify various manifestations of cerebral palsy into watertight categories is rather extremely unrealistic since, manifestations share more than one definite feature.

Based on the neuromuscular symptoms of the disorder, the nomenclature and classification committee of the American Academy of cerebral palsy (AACP) formulated the following classification. The classification includes physical characteristics topography, etiology as well as supplemental handicaps and funcational capacity of the patients (Donhoff and Robenault, 1960).

A. Spasticity

B. Athetos is

  1. Tension athetosis
  2. Non-tension athetosis
  3. Dystonea
  4. Tremor

C. Rigidity

D. Ataxia

E. Tremor

F. Atonia

G. Mixed

H. Unclassified

Generally based on most obvious type of neuro-musuclar disability, three major categories are identified (Berry and Eisenson, 1962).

1. Spasticity
2. Athetosis
3. Ataxia

The description of these types as presented here is based on an appraisal of several works such as Crickmay (1966), Berry and Eisenson (1962), Boone (1972), Pohl

(1950), McDonal and Chance (1964) and many others. The description concentrates on the localization of brain pathology, major motor and neuromuscular symptoms.

Spasticity

Spasticity results from a lesion in the pyramidal tract arising from the primary motor area in the frontal lobe of cerebral cortex. The later research (Berry and Eisenson, 1962) indicate that the pathology for this deficit can occur at other sites as well, namely, the extrapyramidal region, the premotor area, the striate bodies, basal nuclei, midbrain and pons, on the extra pyramidal circuit.

In spasticity there is a release of the postural stretch reflexes from central inhibition and exaggerated muscle tone due to increased excitation from other neural areas and there is an interruption of normal phasic muscle responses. The alternative contraction and relaxation is emphasized by the disturbed sequence of tensor and flexor responses of muscles. When a movement is attempted, the resistance to movement by the antagonists which are normally inhibited increases enormously and prolonged involuntary muscular spasms are created. Normally the central governors in the CNS select, time and grade contraction of muscles and in spasticity this ability is lost and therefore there is an exaggerated responses to all stimuli (Magoun and Rhines, 1947).

Typically this syndrome is characterised by exaggerated contractions of muscles subjected to stretch (stretch reflex), clonic movements constituting alternating contractions and relaxations and increased resistance to movement. The muscle tone may vary from a mild degree to an extreme rigidity depending the exact site of lesion and the extent of the involvement of the extrapyramidal system. There is a loss of voluntary movements along with a return to a lower level of integration with primitive synergistic patterns of movement.

Bobath (1954) point out that basically all spastic patients show some abnormal postural patterns. For instance, if they are in a supine position they show strong extensor spasticity and if they lie in a prone position, a flexor spasticity is seen. In a spastic, the normal patterns of movement are replaced by a mass reflex action of muscles of either flexor or extensor type.

The spasticity may be mild, moderate or severe. In a typical picture of severe spasticity, the patient walks with a dysrhythmic, jerky gait, the legs turned inward, the knees adducted, the heel lifted from the ground, the arms flexed against gravity and the wrist and fingers flexed. In some mild cases the symptoms may be limited to strabismus, drooling, hyperactivity and distractibility. In very mild cases the only diagnostic sign may be the 'extended' appearance of the fingers and rotation of the wrists in reaching for objects.

Athetosis

Here the site of lesion is extrapyramidal system. Some consider it to be the basal ganglia. The areas and tracts covering the extrapyramidal system are, however, still undetermined and controversial (Berry and Eisenson, 1962; McDonald and Chance, 1964). Some consider extra-pyramidal system to be consisting of the extrapyramidal zone in the cerebral cortex, nuclei in the thalamus, midbrain, pons and the fiber tracts connecting these areas and to join fibres with the pyramidal tracts mediating voluntary responses. Some add even cerebellum to these. The studies (Ford, 1952; Berry and Eisenson, 1962; Denhoff and Robinault, 1960) conclude that the site and degree of damage to the extrapyramidal system would determine the specific characteristics of the motor behaviour of the athetoid.

Athetoid show same abnormal postural patterns as spastics. They have involuntary movements which appear as a series of twisting and writhing movements progressing from proximal (in parts closest to midline of body) to distal (parts farther away from midline). They alternate abrupt and misdirected movements with the rigid postures of the spastic but the athetoid maintains these postures only fleetingly. These constantly changing postures, however, recur quite frequently and regularly. The fingers are generally hyper extended and abducted, the wrists flexed, the forearm bent forward so that the palm of the hand is down, the plantal part of the sole of the foot flexed and inverted. Slow writhing movements are seen emphasized in hands and arms. These movements get aggravated by voluntary attempts and when emotional. Bobath (1960) described three categories of these involuntary movements in athetosis, namely, (1) intermittent tonic spasms, (2) mobile spasms and (3) fleeting localized contractions. These are reported to absent at sleep and minimized at rest. Athetoids exhibit a fluctuating muscle tone varying from hypotonicity to hypertonicity.

Typically this syndrome is characterized by abnormal, slow and writhing, involuntary movements involving skeletal musculature. The muscle tone is usually increased but it is not constant and the muscles may have normal tone or may be even flaccid. Because of the varying muscle tone and type of involuntary movements, different clinical types of athetosis such as tension athetosis, dystonic athetosis, shudder athetosis, etc. are produced. Hence a single clinical picture of athetosis is difficult to be formed and it is extremely unrealistic to do so (Karlin and Karlin and Curren, 1970).

Ataxia

This type motor deficit is ascribed to lesions in the cerebellum and/or to the pathways which conjoin it with the cerebral cortex and brainstem. However, it has been found that it cannot always be ascribed to damage to one neurological area since athetoids can also be ataxic or ataxies can also have athetosis. Hence it is speculated that multiple lesions scattered over the cortex and the brain stem may involve the extrapyramidal system including cerebellum at many different points (Berry and Eisenson, 1962).

In terms of neuromuscular abilities, the symptoms constitute lack of equilibrium and co-ordination in voluntary muscle activity. The inco-ordination is found to result from an inability to integrate the components of direction, rate and force in the muscular synergy. In pure ataxia, muscular tone is permanently reduced. In practice, ataxics fluctuate from hypotonicity to hypertonicity since they also share features of athetosis.

The localization of brain lesions is highly varying in all the three types of cerebral palsy although there is general opinion that the pyramidal system, the basal ganglia

£nd cerebellum are the common sites of lesion in spasticity athetosis and ataxia respectively. This extreme variation in terms of the etiology and consequently, the symptomatology throws light, we feel, on the difficulties to obtain a true clinical picture and that each case should be treated as unique in the clinical set up.

There is also a great deal of evidence that neurological characteristics may change as the nervous system matures from birth to adolescence (Denhoff and Robinault, 1960). Other classification systems of cerebral palsy are (1) topographic classification which classifies cerebral palsy based on morphology of parts of the body involved (limbs in particular) like monoplegia, paraplegia, hemeplegia, traplegia, quadreplegia, diplegia and double hemeplegia, (2) etiological classification, based on time of occurance of brain damage, (3) supplemental classification, (4) functional capacity classification which deals with severity of problem and (5) therapeutic classification considering the extent of therapeutic efforts required.

Although it is not clear as to how specifically and narrowly a cerebral palsy individual can be categorized along these, it is understood that a patient can be evaluated against all these classifications and a profile and a descriptive classification obtained.

Speech characteristics in cerebral palsy

Motor disability in cerebral palsy as a primary symptom can affect the intelligibility and articulation - voice -prosody of speech, thus hindering the oral communication. Because of the extreme variability of the disorder, however, the speech in cerebral palsy is severely affected with poor intelligibility and dysarthxia (some times no speech at all) or speech can have little or no deviation from the normal.

Neuromuscular involvement in case of cerebral palsy leads to speech defects in 20% of the cerebral palsied population (Denhoff, 1958). New Jersy study reports speech defects to be a major occurance in all groups of cerebral palsy (Hopkins et al., 1954).

Denhoff and Holden (1951) reported that spastics have fewer hearing and speech problem than athetoid, who have most difficulty with speech.

Dunsdon (1952) found speech defects in 70% of her cases. Speech disorders are much common in athetoid than in spastic children.

Floyer (1955) found a speech defect in 46 of Liverpool school age children with cerebral palsy and athetoid accounted for 88% of speech defects.

According to Berry and Eisenson (1962), spastic speech is recognized by its slow rate, laboured production, grave articulatory problems which arise due to inability to form fine, synchronous movements of tongue, lips, palate and jaw, lack of vocal inflection guttural or breathy quality of voice, uncontrolled volume, abrupt changes in pitch, all in disagreement with the content of expression. The speech of athetoid is found to have a varying gradations of a pattern of irregular, shallow and noisy and breathy, whispered, hoarse and ventricular phonation. Articulation problem varies from slight dysarthria to extreme case of unintelligible speech. The speech characteristics of ataxic include monotonous voice or voice characteristic that change spasmodically in terms of pitch, loudness, and quality, poor and imprecise articulations which vary from being moderately intelligible to extremely unintelligible slur.

Boone (1972) groups the speech characteristics of cerebral palsy along seven dimensions namely, (1) pitch characteristic variations, (2) loudness variations, (3) laryngeal and resonance quality variations, (4) respiratory variations, (5) articulatory variations, (6) prosody variations, (7) overall general impression of intelligibility and bizarreness.

This approach of categorization offers the clinician a ready description of the patients speech behaviour while a classification such as spastic speech and athetoid speech may not help to locate the differences and abilities of individual cases (Boone, 1972). The variability of the disorder from individual to individual is an important factor. The primary motor disability would make normal articulation, prosody and voice impossible in some whereas it might not affect similar other cases in any manner.

Emotional factors like distractibility, poor self concept, etc. may cause excessive spasticity, athetosis or ataxia which would preclude normal speech pattern which would in turn increase the respective tension or the like. Thus effects are circular in nature.

Voice disorder

The respiration, abnormal vocal fold vibration leading onto faulty phonation and abnormal resonance may all contribute to poor voice characteristics such as pitch, loudness and quality. Inability to extend the exhalation would seriously limit the phonation duration and capacity necessary for speech production. The malpositioninc of articulators like the tongue, palate and mandible may all lead to improper resonance and hence poor voice quality.

McDonald and Chance (1964) says that when child attempts to produce controlled exhalations, he may develop muscular spasms which spreads to laryngeal musculature causing laryngeal spasms. There can be (1) adductor spasm in which the vocal cords are held together when phonation may be initiated with difficulty. (2) Abductor spasm where vocal cords are held slightly apart on phonation leading to a breathy voice production. (3) Sudden variation in tension of laryngeal muscles which leads onto corresponding variations in pitch, intensity and quality.

Rutherford (1944) studied voice characteristics (loudness pitch and quality) rate and rhythm of speech of cerebral palsied and attempted to differentiate between athetotic and spastic groups of cerebral palsy. He took two groups of cerebral palsied athetoid (N = 48), spastic (N = 74) and control group (N = 67) of normal children. It was found that there was no clear-cut separate entity as cerebral palsied speech that was particularly characteristic of the group. However some difference was seen. Athetotic speech tended towards slower, more jerky speech than speech of spastic group and it had more loudness more low pitch and more monotony and breathiness.

Duffey (1954) revealed that athetoid had a faster reading rate, higher pitch, larger pitch range and faster rate of pitch change than spastic cerebral palsy.

Palmer (1953) suggest that laryngeal block might interfere with adequate phonation. He calls attention to the proper functioning of intrinsic laryngeal structure in consummating the delicate adjustment of vocal cords for satisfactory glottal vocal attack for speaking.

Berry and Eisenson (1956) reported that in athetoid speakers, obstruction of breath stream either by partial obstruction of the vocal folds or by extreme constriction of oropharynx may result in noisy breathing which appear prior to vocal initiation.

Clement and Twitchell (1959) studied dysarthria in cerebral palsy in terms of deficits in phonation, respiration and articulation in this pathological group and suggested a physiological interpretation of the deficit. Twenty subjects (age 3-12 years) belonging to two groups of spastic quadriplegia and bilateral athetosis were evaluated. The spastic dysarthria (of spastic quadreplegic group) in terms of phonation, was characterized by high pitch, monotone, weak intensity, breathy quality with abnormal nasal resonance and broken phonation. Athetotic was, on the other hand characterized by a low pitch, sudden uncontrolled rising inflections, weak, forced and varying intensity, throaty quality with large amount of pharyngeal resonance. Spastic dysarthria showed shallow inspiration and forced expiration with spasmodic and broken rhythm while athetotic dysarthria was accompanied by a shallow but varying and uncontrolled inspiration and a forced uncontrolled expiration with a jerky and uncontrolled rhythm. In terms of articulation, both groups showed impairment of lingua-dental sounds on production because of tongue placement abnormalities.

Spastic had low pitched, loud voice with hoarseness and athetoid showed extreme variation in pitch, varying loudness and harsh quality of voice. Both the group had vocal deficits with the spastic group performing slightly better than athetoids (Berry and Eisenson, 1962). Same result was found in study by Shyamala (1988). Athetoid tended toward slower and more jerky speech than speech of spastic group and it had more loudness, more low pitch and breathiness (Rutherford, 1944).

Bohme and Stimmfolge (1963) investigated 32 patients (23 - infantile spastic diplegia, 4 - spastic hemiplegia, 3 - chorea with athetosis, 2 - athetosis) from phoniatric point of view. Dysarthria was seen in 16 cases, 10 of which had some disorder of phonation which was established as hyperkinetic voice disorder.

Murthy (1972) studied 114 cerebral palsied individual (ages 18 months to 15 years) and found that phonatory changes include harsh and spastic voice. Hypernasality was found to a lesser degree than spastic voice. Articulators like tongue and lips move slowly vith limited range and rapid alternative movements are slow. Soft palate moves slowly and little on phonation but responds well to gag reflex.

Crickmay (1972) revealed that reflex inhibitory posture has positive effect on voice and speech production of children with cerebral palsy. He says that when child is fully adjusted to reflex inhibitory posture, his respiratory musculature free from spasticity, begins to work normally. As a result he produces greater volume of air with a consequent strengthening of vocal tone. Freedman and Heed (1979) compared voice samples before and after utilization of reflex inhibitory posture in 6 spastic cerebral palsied children and came to a conclusion that reflex inhibitory posture had a positive effect on subjects voice particularly in areas of frequency and intensity.

An extraneous vocal behaviour comprising of non-standard meaningless sound prior to actual vocalization has been noted and studied by few. Haphazard, extraneous, meaningless or non-standard speech behaviour may be defined as those vocal "noises" emitted during speech production which are not accepted phonological components of words of language spoken West, Ansberry and Carr, 1957). Berry and Eisenson (1956) earlier had discussed these atypical patterns in terms of inco-ordinated "relace and linkage" concerned with breathing Van Riper (1954) also had attributed these unnatural pauses and graspings to faulty breathing patterns. Farmer and Lencione (1977) analyzed spectrographically and phonetically such extraneous vocal behaviour in 14 cerebral palsied speakers (9 subjects were athetotic and 5 predominantly spastic) aged 8-44 years. 71% of subjects demonstrated pre-vocalizations. These were found to occur more and with longer mean durations in athetoic speakers than in spastic speakers. The acoustic nature of this extraneous behaviour may be described as nasalized, neutral vowel occurring with or without nasal consonant. Prevocalization appeared to result from inadequate control of vocal tract in time and other extraneous vocal behaviours may indicate other compensatory devices used to achieve developmentally production of adult phonology.

Farmer (1977) confirmed the earlier findings that for all athetoic speakers, pre-vocalizations occurred more frequently and that they were generally of a longer duration before voiced and voiceless stops.

Pruszewkz et al. (1977) performed neurologic and phonatric examination in 54 patients (age 1-19 years) with extrapyramidal form of cerebral palsy. He found a correlation between severity of neurologic syndrome, intensity of phonatric symptoms, intellectual level and bioelectric activity of brain in patients studied. He concluded that speech and voice disorder in those cases result from muscle inco-ordination of peripheral speech and voice organs and depend on intensity of neurologic disturbance.

Wit et al. (1993) studied three non-invasive maximum performance task (MPT), i.e. maximum sound prolongation, fundamental frequency range and maximum repetition rate in 11 spastic cerebral palsied children (age 6.4-11.10 years). The study showed that spastic dysarthric group scored poorer than control group on all parameters except S/2 ratio and ratio of syllable duration. In maximum repetition rate, maximum intersubject variability was seen for syllable duration for spastic dysarthric than for controls.

Respiratory problem in cerebral palsy

A typical breathing pattern may be one of the cause for poor speech proficiency in cerebral palsy. Laryngeal dysfunction is usually related to cerebral palsy child. Speech breathing pattern in cerebral palsy, the breathing disability frequently come very close to the limits of life, leaving very little flexibility for the modification necessary for speech (Palmer, 1954).

Floyer (1955) gave the breathing problem and the associated speech symptoms in cerebral palsied children as shown below.

Breathing problem	Associated speech symptoms
Rapid rate	Little vocalizing in infants
Difficulty in taking deep inhalation	Often produces only 1 or 2 syllables on an exhalation
Difficulty in controlling a prolonged exhalatory movement	Difficulty in initiating vocalization
	Noticeable escape of air before initiation of vocalization
	Produces only a few syllables on exhalation
Antagonistic diaphragmatic abdominal and thoracic movement	Difficulty in sustaining vocalization because of insufficient air if antagonism occur on inhalation
	Interruption of vocalization if antagonism occur during exhalation
Involuntary movement in respiratory musculature	Varied loudness of voice interruptions of vocalization

Hardy and Rembolt (1959) revealed that inspiratory capacities and expiratory reserve volume are reduced in cerebral palsied individuals when compared to normals. Expiratory reserve volume is the most reduced and in many there is a complete absence of expiratory reserve volume. This suggest that with their inefficient valving of air stream, they would be unable to generate as much intraoral pressure as need for speech production. 1. Totally paralyzed palate, 2. relatively adequate palatal action during one type of speech activity (repeated syllable), but relative immobility during continuous speech and 3. incordinate movements and incomplete closure during speech precluded build up of intraoral breath pressure (Hardy, 1961).

Therefore, the present study aims at investigating some aerodynamic (maximum duration of phonation) and acoustic (mean fundamental frequency in phonation and speech, mean intensity, frequency and intensity range in phonation and speech,fluctuation in frequency and intensity, rise and fall time of phonation, speed and extent of fluctuation) aspects of voice of cerebral palsied children.

MAXIMUM PHONATION DURATION

The measurement of maximum phonation duration has been suggested as a clinical tool for evaluating vocal function for the past three decades. Arnold (1955) has stated that "... A good criterion for the general quality of voice immediately available by determining the phonation duration." Yanagihara et al (1966) have reported that the efficiency of the vocal function could be demonstrated by evaluating the maximum duration of phonation. Boone (1977) has written that measures of sustained phonation of vowels such as /a/ can provide information about an individuals efficiency in using the respiratory system for phonation. Gould (1975) stated that the maximum phonation time gives an indication of the overall status of laryngeal functioning and of tension in the larynx, and of any neuromuscular disability. A short phonation time with a large air escape suggests a neuromuscular deficit such as laryngeal nerve paralysis.

Several authors have suggested 'norms' for maximum duration of phonation. These norms were found to vary from 10 seconds for consonants in children to 30 seconds for vowels (Arnold, 1955), in normal-voiced individuals. According to Van Riper (1963), normal-individuals should be able to sustain a front, middle and back vowel for atleast 15 seconds without difficulty, while Fairbanks (1960) reported a normal duration of 20 to 25 seconds. Clinically MPD values smaller than 10 sec should be considered as abnormal (Hirano, 1983). The table 1, presents normal values for MPT reported by several investigators. The average is greater for males (25-35 secs) than for females (15-25 secs).

MPT in children has also been studied. A child should have an adequate supply of air and be able to maintain steady phonation sufficient for effective speech communication. The measurement of MPD is an index of this ability (Wilson, 1979).

Westlake and Rutherford (1961) maintained that a child with a normal voice should easily sustain a tone for 20 seconds or larger after a few trials. Olsen, Perez, Burk and Platt (1969) found that average MPT to be 12.8 secends, for normally speaking boys and girls between 5 and 10 years of age. Bless and Saxman (1970) studied MPT in boys and girls aged 8 and 9 years, and found MPT for girls was 19 seconds and for boys 16 seconds. These results were contrary to most of the other studies in that, the girls had a longer MPT that the boys. Further, the results obtained by Coombs (1976) in her study of children with varying degrees of hoarseness, indicated no significant relationship between sex and phonation time. The difference may reflect the compounding aspects of hoarseness on the duration.

Shigemori (1977) investigated MPD in school children. The MPD was found to increase with age. The difference between males and females was not significant except among the seventh grade children.

Author(s)	N	Sex	Average	Range
Hayashi (1940)	20	M	22 25(/i/)	
Suzuki (1944)	21 19	M F	24.8 17.4	15-37 10-24
Nishikawa (1962)	10 10 10	Singer M F		19-38 16-29 12-21
Patacek and Sander (1963)	40	M	I 24.7 II 25.7 III 24.9	13.6-41.7 14.3-48.0 12.3-59.0
	40	F	I 16.8 II 16.7 III 17.9	9.3-34.0 9.2-29.8 8.4-39.7
Sawashima (1966)	70 78	M F	29.7 20.3	
Yanagihara et al. (1966)	11 11	M F	30.2 22.5	20.4-50.7 16.4-32.7
Ishiki et al. (1967)	5 5	M F	31 17	22-51 9-36
Hirano et al. (1968)	25 25	M F	34.6 25.7	
Shigemori (1977)	25 25	M F	30.1 17.0	15.8-66.6 9.4-26.2

Table a: Normal values of MPT (in seconds) in adults

Launer (1971) measured MPT for /a/, /u/ and /i/ in children aged 9 through 17 years. There was no statistically significant difference between the three vowels. Phonation time increased with age increase and boys had longer sustained phonation time than girls.

Cunningham - Grant (1972) reported that MPT for the 6, 7 and 8 year old girls was considerably higher than those found by Launer (1971). However, the 6-, 7- and 8 year old boys fairly well fit into the developmental standard of Launer's boys.

Age	Time (secs)	
	F	M
6	11.70	11.74
7	10.57	11.77
8	15.27	12.97

Table b: Average MPT (in seconds) for /a/, /i/ and /u/ (Cunningham-Grant, 1972)

Lewis, Casteel and McMohan (1982) found no statistically significant relationship between the length of phonation time and age, using 8- and 10- year olds. However, contrary to the above studies, Ptacek et al (1966) found that MPT decreased as a function of increasing age. Harden and Looney (1984) have measured maximum sustained phonation of /a/, /u/ and /i/ in 160 kindergarden children with mean age of 5.2 years. Subjects were grouped based on sex and presence or absence of a voice disorders. Stop watch measurements of each subject's MPT were compared with graphic level recorder. The results indicated that:

1. The factor of sex had no significant effect on maximum phonation duration.

2. The effect of normal voice group did result in a significant group with the voice disordered group achieving shorter phonation than the non-voice-disordered groups.

3. The phonation time obtained from two measurement procedures correlated significantly. Results also suggest that the vowel effect on maximum phonation time was significant for both the groups. The vowel /i/ was phonated significantly longer than either /a/ or /u/ for males to females in both groups.

This lack of agreement in the results of different studies made several investigators to study variables which effect maximum phonation duration. Variables investigated include vital capacity and air flow rate (Yanagihara et al 1966; Isshiki et al 1967; Yanagihara and Von Leden, 1967; Becket-, 1971), vocal pitch and intensity (Ptacek and Sanders, 1963; Yanagihara et al 1966;Yanagihara and Koike, 1967), Phonation volume (Yanagihara et al 1966; Yanagihara and Koike, 1967), sex (Ptacek and Sanders 1963; Yanagihara and Von Leden, 1967; Coombs, 1976), age (Launer, 1971, Coombs, 1976), and height and weight (Launer, 1971).

Several researchers have investigated the effect of vital capacity on the Maximum Phonation Time. Yanagihara and Koike (1967) indicated that the air volumes available for maximally sustained phonation (that is, phonation volume) varied in proportion to the vital capacity and air available, and this was specific to the sex, height, age and weight of individuals. Additionally, they suggested that longer phonation time is generally related to longer phonation volume. They concluded that maximum sustained phonation is achieved by three physiological factors:

1. Total air capacity available for voice production.
2. The expiratory power.
3. The adjustment of the larynx for efficient air usage, that is, the glottal resistance.

The results of a study of Isshiki et al (1967) indicated that the none of the experimental subjects utilised the total vital capacity for the production of the longest phonation. The amount of air volume expired during the longest phonation ranged from 68.7% to 94.5% of the subjects vital capacity. Yanagihara and Koike (1967) obtained similar findings with the percentages ranging from 50 to 80% for males and from 45 to 70% for females. Lewis, Casteel and Mcmohan (1982) found a significant and dominant relationship between vital capacity and the length of sustained phonation of /a/. They also suggested that given twenty trials, the maximum phonation time obtained could reflect utilization of a higher percentage of the vital capacity.

The amount and the kind of training an individual had, has been considered as yet another variable affecting the duration. Lass and Michael (1969) indicated the athletes generally do better than non-athletes and trained singers do better than nonsingers. However, the results obtained by Sheela (1974) were contrary to the above findings. She found no significant relationship between phonation duration and trained or untrained singers. The phonation duration ranged from 15 to 24 seconds in trained singers and 10 to 29 seconds in untrained singers.

The position of the individual while phonating, has been considered as another factor affecting the measure. Sawashima (1966), however found no significant difference in the MPT in the standing or sitting positions.

Many investors have specified the number of trails used to obtain maximum duration of phonation; however, most of the studies have been based on three trials (Yanagihara et al 1966; Yanagihara and Koike, 1967; Yanagihara and Von Leden 1967; Launer, 1971; Coombs 1976). Sanders (1963) found MPT with twelve trials and found no difference between the first and the twelth trial.

Stone (1976) indicated that adults demonstrated greater maximum duration of /a/ when fifteen trials were used. Lewis, Casteel and McMohan (1982) have found that the practice of utilising three trials to determine the MPT is inadequate, for it does not represent a 'true' measure of the maximum duration. They report that it was not until the fourteenth trial that fifty percent of their subjects produced the maximum phonation and not until the twentieth trial, did all their subjects produce maximum phonation duration. The authors believe this finding to be not only statistically significant, but also, more importantly, clinically significant.

Although many researchers have suggested the effect of height and weight to the length of phonation time (Arnold and Luchsinger, 1965; Michael and Wendahl, 1971); Lewis, Casteel and McMohan (1982) found no statistically significant relationship between them. Also Sawashima (1966) reported no significant difference in MPD in the standing and sitting position.

Ptacek and sander (1963) appear to be the first to suggest that the maximum duration of phonation may be influenced by the frequency and SPL of the phonation. Also, males could sustain phonation longer than females, especially at low frequencies and sound pressure levels. Then as both frequency and SPL increased, the phonation times between males and females tended to become more similar. However a considerable degree of variability among subjects was still evident in that significant differences existed for frequencies and sound pressure levels for male phonations, but not for female phonations. Conversely, the frequency-sound pressure level interaction was significantly for the females but not for the males. Different results were found by Lass and Michael (1969). They report that for low frequency phonations of both males and females, and for the moderate frequency phonations of the males, there was a general tendency for phonation time to increase as a function of sound pressure level. However, in the high frequency phonations for both males and females, there was a tendency for phonation time to decrease as the sound pressure level increased.

Yanagihara et al (1966) and Yanagihara and Koike (1967) measured the maximum phonation time at three different vocal pitches-low medium and high - in normal adults. Phonation time was reduced at high pitches for both men and women. The figures for men were 28.4 seconds for low pitch, 30.2 seconds for medium pitch, and 23.7 seconds for high pitch; while those for females were 21.7 seconds for low pitch, 22.5 seconds for medium pitch and 16.7 seconds for high pitch.

Shashikala (1979) studied the maximum phonation time at optimum frequency, +50 Hz, +100Hz, +200Hz and -50Hz, and reported that the maximum phonation time was longer at the optimum frequency than at other frequencies, in both males and females, when the optimum frequency was measured using an objective method of locating the optimum frequency as described by Nataraja (1972).

Komiyama and Buma (1973) measured maximum phonation taking account of the intensity of the voice. Measurements were made in fortissimo, mesoforte and pianissimi in varying pitches. The results indicated that the "phonation time" in fortissimo showed the minimum value compared with the value of mesoforte or pianissimo phonation in various pitches. They also observed the "phonation capacity" by integration of voice intensity with phonation time and reported that "phonation capacity" was diminished and showed a remarkable decrease in fortissimo phonation during the regular transition.

Maximum duration of phonation has been used as a diagnostic tool for some time. A significant reduction below normal levels can be related to inadequate voice production.

An abnormally short maximum phonation duration was found in cases of recurrent laryngeal nerve paralysis. The maximum phonaticn time varies depending on the cord position in recurrent laryngeal nerve paralysis (Shigemori, 1977).

Jayaram (1975) reported significantly lower maximum phonation duration in a dysphonic group than in a matched normal group. Further, while a significant difference in maximum duration of phonation was reported between males and females in the normal group, no such difference was evident in the dysphonic group. These results are similar to those reported by Coombs (1976), wherein no significant difference was observed with respect to the maximum duration of phonation, between males and females with hoarseness.

Ptacek and Sanders (1963)appear to be the first to relate the maxinum duration of phonation to the perception of "breathness". Although none of the voices of their subjects were considered to be non-normal, they were able to divide their subjects into two groups - long phonators and short phonators. When these two groups were judged as to the degree of breathness from least to most on seven-pointsclae, they found that the long phonators tended to be judged as less breathy, than the short phonators. In addition, perceived breathiness decreased as a function of increased intensity and, high frequency phonations tended to be rated as more breathy, than corresponding low frequency phonations.

Studies of maximum phonation duration in cerebral palsied is few. West take & Rutherford (1961) noted variability among cerebral palsied children in their ability to phonate and prolong phonation. He suggested that C.P child should be able to sustain voice on exhalation phase for a minimum of 10 sec. Cerebral palsy children require too many intakes of breath for sustaining life processes may not be capable of sufficient sustaining of phonation for adequate phasing and consequently need to develop breath control and voice production long before actual production of speech. Also tension produced by motor deficiency may interfere with phonation process (Rutherford 1950).

Warnass (1993) study revealed that spastic cerebral palsied has a maximum length of phonation for vowel /a/ and /i/ to be 2 sec and 10 sec for /s/. According to him this reflects poor control of the individual over phonation and laryngeal valving mechanism Wit et al (1993) measured maximum phonation duration of 11 control normal subjects and

11 spastic cerebral palsied individual (age 6.4 -11.10 yrs). Results indicated that spastic cerebral palsied showed poorer (5.59 sec) then control group (15.8 sec).

FUNDAMENTAL FREQUENCY IN PHONATION

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

"The quality and loundness of voice are normally dependent upon the frequency of vibration. Hence it seems apparent that frequency is an important parameters of voice " (Anderson 1961). There are various objective methods to measure the Fo of the vocal folds.

The changes in voice with age and within the speech of an individual have been subject of interest to speech scientists. Various investigations dating back to 1939 have provided data on various vocal attributes at successive developmental stages from infancy to,old age. Fairbanks(1940, 1949), Curry (1940), Snidecor (1943), Hanky (1949), Mysak (1950), Samuel (1973), Usha Abraham (1978), Gopal (1980) and Kushal Raj (1983), are some among those who have studied the changes in fundamental frequency of voice with age.

The aging trend for males with respect to the mean fundamental frequency is one of a progressive lowering of; pitch level from infancy through middle age followed by a progressive raise in the old age (Mysak, 1966).

However, among females, the mean fundamental frequency levels of the 7 and 8 8 year olds was the highest. A progressive lowering of fundamental frequency level is then seen till the age of a young adult female. No significant change is seen from young adulthood to the aged group which is in contrast to the male population (Mysak, 1966).

The voice of a new born has been found to be around 400Hz (Grutzman and Plateau, 1905, Indira, 1982). Upto puberty there is little difference between the voice of boys and girls. The voice change is prominent at puberty. In majority of the cases this change takes place without appreciable pitch breaks during speech. But in some, a period of pitch breaks are observed, due to the inability of the individual to control the laryngeal muscles because of sudden changes in the larynx due to growth. Pitch breaks, however, have been observed in the children, long before the onset of puberty. In an examination of sixty children between the ages of seven and eight years, Fairbanks (1950), could find pitch breaks in both sexes. Therefore, the voice changes in puberty should be interpreted as the intensification of a process that begins already at a much earlier period (Broadnitz, 1959).

Eguchi and Hirsh (1969) state that "It is well known that the fundamental frequencies of children and adult females are higher than those of the adult male". They further add that, "children have a fundamental frequency of about 300Hz even upto the age of 8 and 10 years. There is no significant difference if fundamental frequency of speech between 7 and 8 years, or between boys and girls of those ages (Fairbanks, Herbert and Hammond, 1949; Faribanks, Wiley and Larsman, 1949; Potter and Steinberg, 1950; Peterson and Barney 1952) .

The fundamental frequency values are distinguished by sex only after the age of 11 years, although small sex difference might occur before that age (Kent, 1976).

The fundamental frequency drops slightly during the first three weeks or so, but then increases until about the fourth month of life, after which it stabilizes for a period of approximately five months. Beginning with the first year, fundamental frequency decreases sharply until about three years of age, when it makes a more gradual decline, reaching to the onset of puberty at 11 or 12 years of age. A sex difference if apparent by the age of thirteen years, which marks the beginning of a substantial drop male voices, the well known adolescent voice change in the case of females. the decrement in fundamental frequency from infancy to adulthood among females is somewhat in excess of an octave, whereas males exhibit an overall decrease approaching two octaves (Kent, 1976).

Studies on the Indian population have shown that, in males, the lowering in the fundamental frequency is gradual till the age of 10 years, after which, there is a sudden marked lowering in the fundamental frequency, which is attributable to the changes in the vocal apparatus at puberty. In the case of females, a 'gradual lowering of fundamental frequency is seen (George, 1973; Usha, 1979; Gopal, 1980; Kushal Raj, 1983).

Peterson et al (1985) have investigated using multivariable statistical analysis of various parameters of voice as related to puberty in choir boys. They selected 48 boys age ranging from 8-10 years. The results of this statistical analysis depicted that sexual Hormon Binding globulin (SHBG) is a predictive factor of the change in Fo from childhood to adulthood voice in boys.

Thus, the lowering of fundamental frequency is seen both in case of males and females with age, and these variations are attributed to the anatomical and physiological changes with age.

The study of fundamental frequency obviously has clinical implications. Cooper (1974) used spectrographic analysis, as a clinical tool to determine and compare the fundamental frequency in dysphonics before and after vocal rehibilitation.

Shantha (1973) and Jayaram (1975) found a significant difference in habitual frequency measures between normals and dysphonics.

Kene and Wellen (1985) studied the acoustical measurement of 10 children with vocal nodules, age ranging from 6.1 years to 11.6 years which included 6 males and 4 females. Results of this study showed a significant correlation between clinical judgements of severity on the V7ilson scale and pitch and amplitude pertubation measures from children pathological voices was demonstrated. Subjects rated as more severe on the Wilson scale had greater pitch and amplitude pertubations than subjects with less severe ratings.

Thus it is apparent that measurement of the fundamental frequency is important in the diagnosis and the treatment of voice disorders and also reflects the neuromuscular development in children (Kent, 1976). Study regarding fundamental frequency in phonation in cerebral palsied in Indian context is limited. So present study aims at studying this parameter.

FUNDAMENTAL FREQUENCY IN SPEECH

An evaluation of the fundamental frequency in phonation, may not represent the habitually used fundamental frequency of an individual. Many investigators have studied fundamental frequency as a function of age and in various pathological conditions. Difference types of speech samples, i.e, phonation reading, spontaneous speech and singing have been used in different studies. In literature one often finds comparisons of results of difference studies. But it is not clear whether the same type of speech sample have been considered for such comparisons. And further it is not clear whether all the speech samples would yield the same results. However clinical experience has shown that the subjects use difference fundamental frequencies under different conditions. To verify this clinical impression an experiment was conducted by Nataraja and Jagadeesh (1984). They studied fundamental frequency in phonation, reading, speaking and singing and also the optimum frequency in 30 normal males and females. They observed that the fundamental frequency increased from phonation to singing with speaking and reading in between.

Michael, Hollien and Moore (1965) studied the speaking fundamental frequency characteristics of 15, 16 and 17-year old girls, in order to determine the age at which adult female speaking fundamental frequencies are established. Their results indicated that females attain adult speaking fundamental frequencies by fifteen years of age. It seems necessary, therefore, to study the girls fourteen years of age and younger, in order to determine when adult frequencies are first evidenced (Michael, Hollien and Moore, 1965) .

Kushal Raj (1983) studied the speaking fundamental frequency as a function of age, in children between four and twelve years. He reported that the fundamental frequency, both in the case of males and females, decreases with age, males showing a sudden decrease around eleven years of age. No significant difference in fundamental frequency was found until the age of eleven years, between males and females. The fundamental frequencies of the vowels /a/, /i/, /u/, /e/ and /o/, occurring in speech, indicated that the fundamental frequency of vowel /a/ was the lowest in both males and females, /u/ was the highest for males and /i/, the highest for females.

The age dependent variations of mean speaking fundamental frequency reported by Bohme and Hecker (1970) indicate that the mean speaking fundamental frequency decreases with age up to the end of adolescence. A marked lowering takes place during adolescence in men. In advanced age, mean speaking fundamental frequency becomes higher in men but is slightly lowered in women.

Michael and Welten (1985) studied the developmental trends in vocal fundamental frequency 14 young children between the age of 11 to 25 months, an age period characterised by changes in physiological and linguistic development. Subjects were grouped into 3 month age intervals reflecting a continum of physical development and were audiotape recorded during spontaneous speech productions. Acoustic analysis of average Fo and Fo variability was performed. Fo variability was found to decrease as subject age increased as did segment durations. They also concluded that when viewed with in the overall developmental period and in comparison with data from other studies of younger and older children, average Fo during this age is consistent with a decreasing trend throughout early childhood.

Soorenson (1989) studied the fundamental frequency characteristics of 30 children between the ages of 6 and 10 years were investigated in a variety of speech tasks. The results indicated that average fundamental frequency across tasks for the boys is approximately 262Hz and for girls approximately 28lHz. Statistical analysis indicated that there was no significant difference in the Fo of boys and girls in this age range. High vowels were found to have higher Fo values than low vowels, sustained vowels had higher fundamental frequency values than either spontaneous speech or reading for both groups of speakers.

Gilbert and Campbell studied the speaking fundamental frequency in three groups (4 to 6 years, 8 to 10 years and 16 to 25 years) of hearing impaired individuals, and reported that the values were higher in the hearing impaired groups when compared to values reported in the literature for normally hearing individuals of the same age and sex.

Mo much information is available on fundamental frequency in speech of cerebral palsied. Duffy (1954) analysed the speech of cerebral palsied individuals by means of an instantaneous fundamental frequency recorder. He detected pitch characteristics which were related to different types of cerebral palsy.

FLUCTUATIONS IN FREQUENCY AND INTENSITY

Perturbations are defined as the cycle-to-cycle variations in period and amplitude. To date, relatively few attempts have been made to measure perturbations in fundamental frequency and intensity, in children, although such a measure may have value in describing the stability of laryngeal control (Lieberman, 1963). Basma, Truby and Lind (1965) proposed that an infant's neurological maturity night be evaluated from such factors as the stability of laryngeal co-ordinations and the mobility of vocal tract components during crying.

Though information on the cycle-to-cycle variations in fundamental frequency and amplitude as a function age are scant, many investigators have found these measures to be useful in describing the voice characteristics of both normal and pathological speakers (Koike, 1969, 1973; Hollien, Michael and Doherty, 1973; Murry and Doherty, 1977; Smith Weinberg, Feth and Horii, 1978; Horii 1979, 1980). This irregularity in vibration has been implicated as a physical correlate of rough or hoarse voices (Mathes and Miller, 1947; Bowler, 1964; Coleman, 1960, 1969, 1971; Moore and Thomson, 1965; Wendahl, 1966; Isshiki 1966; Michael, 1966; Coleman and Wendahl, 1967; Yanagihara, 1967; Takashi and Koike, 1975; Hirano et al 1977; Deal and Emanuel, 1978).

Hollien, Michael and Doherty (1973) using sustained vowels, obtained measures of frequency perturbation similar to those Liberman (1961) which they called the jitter factor. This jitter factor (JF) was defined as the cycle-to-cycle period variations relative to the average speaking fundamental frequency. They suggested that when vocalization other than sustained phonation is used to examine the cycle-to-cycle variations is period, the perturbations may possibly be due to involuntary and/or learned phonatory behaviour associated with meaningful speech patterns produced by the speakers. As sustained phonation reduces the variability due to learned speech patterns and eliminates the differential loading of the glottis related to changes in vocal tract configuration a more valid assessment of the frequency perturbations associated with laryngeal behaviour may be obtained using only sustained phonation. Horii (1979) further cautions against the use of connected speech due to the random perturbation associated with "mechano-physiologic"limitations of the glottal source which may accompany such samples. However, Hammarberg et al (1968) analyzed the amplitude and period variations that occur in connected speech and obtained a representative samples of voice qualities.

Baer (1980) explains vocal jitter as inherent to the method of muscle excitation based on the neuromuscular models of the frequency fundamental and muscle physiology. He has tested his model using EMG from cricothyroid muscle and voice signals and claims neuromuscular activity as the major contributor for the occurance of perturbation.

Many workers have compiled normative data for Shimmer and Jitter. Horii (1979) reported an average shimmer of 0.39dB for vowels /a/, /i/ and /u/. However, in a later study Horii (1980) and Wilcoxon and Horii (1980) noted Jitter and/or Shimmer differences among different vowels. Wilcox and Horii (1980) found that /u/ was associated with significantly smaller Jitter (0.55%), than /a/ or /i/ (0.68% and 0.69% respectively). Studying older subjects, Horii also found both Jitter and Shimmer to be smallest for /u/ intermediate for /i/ and greatest for /a/. On the other hand, a trend towards greater Jitter for high vowels than low vowels was reported by Johnson and Michael (1969) who examined twelve English vowels. Zemlin (1962) reported a significantly greater Jitter for /a/ than /i/. Horii (1982) found no significant difference in either Shimmer or Jitter values between eight English vowels and obtained an average jitter value 0.75% and an average shimmer value of 0.17 dB.

However, in a recent study, Sorenson and Horii (1983) found that jitter and shimmer values to differ for the three vowels /a/, /i/ and /u/. The mean directional jitter factor was 49.3% with a range of 34.6% (men /u/) to 62.7% (women/i/), while the average directional shimmer factor was 59.7% with a range of 43.5% (men/i/) to 72.6% (women /u/). Directional factors for shimmer were on the average, 10% higher than directional factors for jitter.

They also reported that for both the groups (men and women), /u/ had the highest directional jitter factors, /a/ was the lowest and /i/ was intermediate. The vowel /i/ had the highest shimmer factor for the men and /a/ was intermediate. For the women, the results of these two vowels were reversed.

The magnitude jitter values for the man and the magnitude shimmer values for the women followed the same pattern as the directional factors. The female magnitude jitter and the male magnitude shimmer, however, did not follow the patters of the directional factors. Their analysis also indicated that the magnitude values and the directional factors can vary independent of each other. In other words, the magnitude factors and the directional factors do not necessarily have the same pattern.

Research has shown that the intensity, the fundamental frequency level and the type of phonatory initiation and termination are some factors which affect the jitter magnitude in sustained phonation (Moore and Von Leden, 1958; Jacob, 1968 Koike, 1973; Hollien et al 1973).

Koike (1973) observed differences in the perturbation values for the initiations of the vowel (soft versus breathy) and suggested that different mechanisms are responsible for the two onsets.

Shimmer in any given voice is dependent at least upon the modal frequency level, the total frequency range, and the sound pressure level relative to each individual voice (Michael and Wendahl, 1971). Ramig (1980) postulated that shimmer and jitter values should increased when subjects are asked to phonate at a specific intensity, and/or as long as possible. White head and Emanuel (1974) found vocal fry productions were perceived to be relatively rough compared to the modal register phonations and manifested elevated spectral noise level, comparable to those associated with simulated abnormally rough phonations. This is explained by Wendahl (1963, 1966) and Coleman (1969) who indicated that when two audible complex waves manifest equal amounts of wave aperiodicity, the wave with the higher fundamental frequency will tend to be heard as least rough. At comfortable vocal intensity and fundamental frequency, however, normal speakers appear to have average jitter of 1% or less during the middle portions of phonation. For example, Jacob (1968) reported a median value of 6%. Hollien et al (1973), Koike (1973) and Horii (1979) found an average jitter of about 0.5% for male adult speakers.

Horii (1980) found a significant correlation between shimmer and jitter supporting the notion that similar sets of physical forces (such as vocal fold tension, mass length and subglottal pressure) underline the regulation of the individual fundamental period and intensity of laryngeal sounds.

In addition, jitter and shimmer has been applied to the early detection of laryngeal pathology (Lieberman 1961; 1963), defined pitch perturbation as the difference in periods of adjacent glottal pulse and suggested that what he termed "the pitch perturbation factor", that is, the percentage of discrete perturbation exceeding 0.5 msec, might be a useful index in detecting a number of laryngeal diseases.

Hecker and Kruel (1971) suggested that there might be, in addition to the pitch perturbation factor, a "directional perturbation factor", which he defined as the algerbraic sign, or rate of progression, rather than simply the absolute magnitude of difference between glottal periods- Applying this criterion, he reported a significantly higher "directional perturbation factor" in pathologic speakers than those in normal speakers. The magnitudinal perturbation factor of Lieberman, on the other hand, did not differentiate the two conditions. However, Koike (1973) obtained lower mean magnitude perturbation in normal voices than in pathologic voices.

Koike (1968) showed that a relatively slow period modulation of vowel amplitude was observed in patients with laryngeal neoplasms. He reasoned from this that the measurement and analysis of such modulation might be useful in assessing laryngeal pathology.

Crystal and Jackson (1970) measured both the fundamental frequency and amplitude perturbation of voices in persons with varying laryngeal conditions and concluded that several purely statistical measures of the data they extracted might be useful as guidelines in detecting laryngeal dysfunction.

Koike (1973) investigated the pitch periods of voice produced by pathologic speakers, and found that discrimination between laryngeal tumor and laryngeal-paralysis was possible.

The perturbation factors, both directional and magnitudinal, during sustained vowels, are significant in discriminating normal talkers from those with laryngeal cancer (Murry and Doherty, 1980).

Von Leden and Koike (1970) found a significant correlation between subjects with various laryngeal diseases (Laryngitis, edema, myasthenia laryngis, bilateral adductor paralysis, unilateral paralysis, nodule, hematoma, cyst granuloma benign neoplasms, multiple papilloma, intrinsic and extrinsic carcinoma, senile, spastic and psychosomatic dysphonia) and different types of amplitude modulations and affirmed the potential value of short-term perturbations in the acoustic signal for diagnostic purposes. Their data suggested four different types of amplitude modulations, which in turn correlates with clinical groupings.

Kitajina and Gould (1976) studied the vocal shimmer during sustained phonation in normal subjects and patients with laryngeal polyps and found the values of vocal shimmer to range from 0.04dB to 0.21dB in normals and from 0.08dB to 3.23dB in the case of vocal polyps. Although some overlap between the two groups was observed, they noted that the measured value may be a useful index in screening for laryngeal disorders or for diagnosis of such disorders and differentiation between the two groups.

Sorenson, Horii and Leonard (1980) pointed out that the average jitter was significantly greater under anesthesia than under normal conditions, and that the jitter difference v/as more prominent at high frequency phonation, indicating that high frequency phonations are more dependent on laryngeal mucosal feedback.

Smith et al (1978) analyzed the voice of oesophageal speakers and indicated that the magnitude of vocal jitter present in the vowels was substantially larger than that in normal speakers, and speakers with laryngeal/vocal disturbance.

Considerable caution must be taken in interpreting these data, however, because gross changes in wave periods (upto an octave in extent) were reported to be characteristic not only of pathologic voice but also of vocal recordings taken from adolescent boys and girls, preadolescent children of both sexes, and from postmenarcheal females (Fairbanks et al 1949; Curry, 1940; Duffy, 1958).

The fluctuations in frequency and intensity in a given phonation sample may indicate the physiological (Neuromuscular) or pathological changes in the vocal mechanism. No information regarding these two variables in cerebral palsied children is available. Hence it was considered that this information may be useful in understanding the physiological and pathological conditions of the vocal system in cerebral palsied.

FREQUENCY RANGE IN PHONATION AND SPEECH

Humans are capable of producing a wide variety of acoustic signals. Success in decoding acoustic speech signals assumes that the speaker will produce : (1) acceptable phonemes, variously sequenced or combined (2) changes in the use of time, (3) changes in fundamental frequency, and (4) changes in intensity or energy. These four comprise the basic elements of verbal communication (Bracket, 1971).

The patterned variations of pitch over linguistic units of differing length (syllables, words, phrases, clauses, paragraphs), yield the critical prosodic feature, namely intonation (Freeman, 1982). In other words, during speech, the fundamental frequency of phonation varies. This range is called the speech range or the speech frequency range (Hirano, 1981). Variations in fundamental frequency and the extent of range use also relate to the intent of the speaker as discussed by Fairbanks and Pronovast (1939). More specifically, the spread of frequency change use corresponds to the mood of the speaker, that is, as skinner (1935) reports, cheerful animated speech exhibits greater range use than serious, thoughtful speech. Changes in duration and fundamental frequency during syllable elements of words are basic to the melody and rhytnm patterns unique to English.

Stressed syllables are perceived as being higher in pitch than unstressed syllables (Freeman, 1982).

Relatively little is known about developmental changes in the range or variability of fundamental frequency. Most of the literature on the new borne infant's cry appears to have the capability of extending this range appreciably in either direction. Ringel and Kluppel (1964) reported a range of 290-508Hz for ten infants aged 4 to 10 hours. Fairbanks (1942) observed a range of 153-188 Hz for an infant in the first month of life and a range of 63-2f3Hz for the first nine months of life. McGlone's (1966) investigation of children aged between one and two years revealed a total range of 16.2 tones, or about two octaves. Van Oordt and Drost (1963) concluded from a study of 126 children in two age groups (0 to 5 years and 6 to 16 years) that "... even in very young children the physiological range of the voice has a broad, almost 'adult range ..." and that, the change in the frequency of the speaking voice parallels that of the lowest reachable physiological tone . . ." . Their data indicate that even young children have a fundamental frequency range of two-and-one-half to three octaves. If a conclusion is forced from these rather limited data, it would be that the range of vccal frequency, does not change appreciably during maturation (Kent, 1976).

As far as variability of fundamental frequency is concerned, the most extensive study is that of Eguchi and Hirsh (1969), who collected data for 84 subjects representing adulthood and the age levels of 3-13 years, at one year intervals for the vowels /i/, /x/, /u/, /s/, /a/ and /o/, as produced in the sentence contexts. The variability of fundamental frequency progressively decreased with age until a minimum was reached at about 10 to 12 years. This is taken as an index of the accuracy of the laryngeal adjustments during vowel production, then the accuracy of control improves continuously over a period of atleast 7 to 9 years.

The discovery that fundamental frequency variability diminishes with age has important implications for the quantitative investigation of speech development. It is not known at what age, this apparent refinement of control begins to occur (Kent, 1976). Sheppard and Lane (1968) in a study of two infants during the first 141 days of life, reported a rather small and constant variability in fundamental frequency values. However, Prescott (1975) discovered small developmental increases in the fundamental frequency variability within the first nine months of life. Possibly, at the same time that a child gains control over the accuracy of his laryngeal adjustments, he begins to vary fundamental frequency to achieve intonation-like effects. Of course to some degree, accuracy of adjustment is requisite to controlled variation. Concerning this subject, students of infant intonation have revealed evidence that definite patterns are established during the first year of life (Kent, 1976).

General conclusions about the diagnostic value of fundamental frequency variability are difficult to make because such measurements are helpful in certain pathological conditions but not in others (Kent, 1976).

Study of frequency range in cerebral palsy is few Wit et al (1993) reported that spastic cerebral palsied group showed poorer scores than normal in fundamental frequency range. Normals had a range of 25.3 (min 167.5 Hz to max 725.2 Hz) while spastic had a range of 13.4 (min 221.0 Hz to max 491.6 Hz).

Warnas (1993) reported that cerebral palsied children peak fundamental frequency was found to be lower than expected for patients age and sex. According to him the minimum fundamental frequency was 226 Hz and maximum fundamental frequency is 392 Hz.

INTENSITY RANGE IN PHONATION AND SPEECH

The study of phonology also includes intensity change or variations in energy. Increasing or decreasing total speech power, as discussed by Mol and Uhlenbach (1956), is one of the means of achieving dominance of syllables, words or phrases. Changes of energy signify degrees of emotional involvement, such as shouting when angry. Use of intensity changes also reveals speakers perception of physical and psychological distance.

Danste (1970), Komiyana (1972) and Coleman et al (1977) proposed a graphic representation of the fundamental frequency-intensity profile. The graph was named "phonotogram" by Damste and "Phonogram" by Komiyama. Rauhut, et al (1979) proposed the term "voice Area" for the representation of maximal or minimal intensity of voice as a function of pitch.

Coleman et al (1977) in a study of the fundamental frequency-sound pressure level profiles of adult males and females, noted an increase in SPL with an increase in frequency up till a certain limit, after which a decrease is seen with further increase in frequency. Generally, most subjects fundamental frequency - SPL profiles manifested a change in both minimum and maximum SPL curves at 60 to 80% fundamental frequency level.

According to Coleman et al. (1977), the average intensity range of phonation (in SPL re: 0.0002 dynes/cm) at a single fundamental frequency is 54.8 dB for male and 51 dB for female subjects.

Coleman and Mott (1978) found lower SPL ranges for female children (10 years to 13 years) than those for adult females. Further, they observed that the musical range, in terms of fundamental frequency and SPL, is more restricted, that is, it lies within the boundaries of the physiological range. The mean physiological SPL range was found to be 159 dB, while the mean musical SPL range was 58 dB.

Empirically, it is well known that disorders of vocal intensity constitute one of the important components of voice disorders. However, measurement of vocal intensity, as a clinical diagnostic tool has not proved as popular as that of fundamental frequency in voice clinics.

Darley et al. (1969) in a report on the speech characteristics of dysarthric patients, reported equal and excess stress and monoloudness is one of the characteristics. In a spectrographic analysis of ataxic dysartria, Nataraja and Indira (1982), observed equal stress in the pathologic subject, while variations in terms of intensity on each syllable were seen in the speech of the normal subject.

Not much information is available regarding the changes in the range of intensity in cerebral palsy. Clarke and Hcops (1980) in his study on 50 cerebral palsied children reported that cerebral palsied had a mean speech sound pressure level of 74.24 dB (spastics had 74.1 and athetoid had 74.5 dB).

Rising and falling time of phonation

Imaizumi et al. (1980) while investigating the possibility of utilizing a sound spectrography for a multidimensional analysis of pathological voices, measured the rising time and falling time of sustained vowels as two of the parameters, among the nine acoustic parameters studied. These two parameters were measured on an amplitude display. The rising time was defined as the time required for the increase in overall amplitude from a value of 10% of the steady level of 90%. The falling time was defined as the time span required for the decreases from 90% to 10% of the steady level.

Birren (1956) in evidence of importance of such measures says, "the systematic study of age changes in speed of response and timing appears to be one of the most advantageous ways of exploring the nature of age changes in behaviour and the aging nervous system.

There are few studies on age related changes on these parameters. Rashmi reported a gradual decrease in rise time and a gradual increase in fall time in the age range studied (4 years to 15 years). Vanaja (1986) studied these parameters in age range 16-65 years and reported no significant changes.

Howell and Rosen (1983) measured the rise times of voiceless affricates and fricatives, when the test material occurred in sentences, in isolated words and in isolated nonsense syllables. The rise time of affricates were significantly shorter than those of fricatives. Rise time varied with the type of test material and for all types of material were significantly longer than those reported by Gerstman (1957). They also pointed out that because rise time varies with the type of test material, no auditory sensitivity asingle rise time value can be responsible for the perceptual distinction between voiceless affricates and fricatives.

Many pathological conditions are more apparent during the transitional phases of phonation, including the onset and the termination of phonation and hence of speech. In this connection further extensive clinical and basic research is required (Hirano, 1981).

No study regarding rise and fall time measurements in cerebral palsy is available in Indian context. So the present study aims at studying these two parameters in cerebral palsied children.

METHODOLOGY

This study was designed to investigate the phonatory abilities of cerebral palsied children of both sexes. It was planned to obtain the following parameters by analysing the voice and speech of cerebral palsied children, as these parameters have been reported be useful in differentiating different types of voice disorders and also reflecting the condition of various systems involved in voice production.

The parameters were:

1. Maximum duration in phonation
2. Fundamental frequency in phonation
3. Speaking fundamental frequency
4. Speed of fluctuation in frequency of phonation
5. Extent of fluctuation in frequency of phonation
6. Speed of fluctuation in intensity of phonation
7. Extent of fluctuation in intensity of phonation
8. Frequency range in phonation
9. Intensity range in phonation
10. Frequency range in speech
11. Intensity range in speech
12. Rise time in phonation
13. Fall time in phonation

SUBJECTS

A total of 15 cerebral palsied children of both sexes (8 males and 7 females) age ranging from 3-10 years were randomly selected for the study. This included seven spastic quadriplegic, six spastic diplegic and two athetoid quadriplegics ranging in severity from mild-moderate. Judgement regarding the severity was based on the reports provided by the Physiotherapist and Neurologist of the cerebral palsy centre.

These subjects were examined by a qualified speech and language pathologists and considered as CP and diagnosed as belonging to either spastic diplegic, athetoid quadriplegic or spastic quadriplegic group.

The subjects were selected from a special school and the criteria for selection were

1. being otologically normal

2. having no associated problems like visual inacuity, mental retardation, etc. at the time of testing.

3. having Malayalam as mother tongue.

4. Age ranging from 3 to 10 years.

As indicated by tables Ml and M2 showing the distribution of subjects, the cerebral palsied children were distributed in the age ranges from 3 to 10 years. In order to match the distribution of subjects it was decided to

Group	Normals							Cerebral palsied						
	Age in years							Age in years						
	3-4	4-5	5-6	6-7	7-8	8-9	9-10	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Males	3	3	3	3	3	3	3	2	1	1	1	1	1	1
Females	3	3	3	3	3	3	3	1	1	1	1	1	1	1

Table Ml showing the distribution of subjects of both the groups in terms of age and sex

Sex	Spastic		Athetoid	
	Quadriplegia	Diplegia	Quadriplegia	Diplegia
M	2	4	2	-
F	5	2	-	-

Table M2 showing the distribution of subjects of cerebral palsy group in terms of sex and type of cerebral palsy include subjects from 3 to 10 years, in seven age groups both males and females, thus 3 normal males and 3 normal females were included under each age group, i.e. a total of 42 subjects (21 males and 21 females). All normal subjects were normal in terms of speech language and hearing and attending normal school. These children were examined by speech language pathologists and considered normal.

Test Environment

Recording was carried out in a quiet room. The subjects were seated comfortably with the microphone at a distance of 6 cms from the mouth of the subject. Occupants of the test room were the investigator and the subject only.

INSTRUMENTS USED

- AIWA PQ 1824 stereo tape recorder with microphone
- Meltrack cassettes
- VSS-12 bit A/D converter with speech interface unit and head phone/speaker
- A Pentium (Intel - 100 MHz) computer with 8 MB ram, VGA and high resolution colour monitor.

The instruments were arranged as shown in block diagram (Fig. 1).

Test material

Maximum duration of sustained phonation of the vowels /a/, /i/ and /u/ were recorded in order to measure, mean fundamental frequency, frequency range, intensity range, speed and extent of fluctuations in frequency and in intensity, rise and fall time, and maximum duration of phonation. Speech material consisted of three Malayalam sentences "O:nam Vannu" (Onam came), "Oru ila" (one leaf) and "it li a: a" (this is a rat). Picture cards were used for the description and to elicit the speech from the subjects. Three samples of each sentences were considered for analysis. The above given sentences were selected as they were found to be within the vocabulary of children of the age range studied and it contained all vowels of Malayalam.

Procedure

The data was collected in two steps.

Step I: In the first step the maximum phonation duration was recorded. The subjects were instructed as follows:

"Take a deep breath and say /a/ as long as you can. Do not stop and breath in between".

This was demonstrated to each subject by the investigator to confirm that the instructions were understood by the subject. Only when the investigator was satisfied that the instructions were understood by the subject, recording was done. The subjects were then asked to phonate /i/ and /u/ in a similar manner. Three trials of each phonation were recorded.

Step II: In the second step, speech samples were recorded. The subjects were instructed as follows.

"Now I will say a sentence about the picture in the card. You have to repeat whatever I say". This was demonstrated and traials were given till the investigator was satisfied about the speech output/response.

Then the investigator uttered the sentence ("O:nam Vannu" and the repetitions by the subject were recorded. Before recording was done, each subjects were given few trials, so that he could repeat as soon as he is asked to do so. Similarly the other two sentences ("Oru ila" and "it li a:n ") were recorded.

Thus for each subject, a total of 18 samples (three trials of each 3 vowel phonations and 3 trial of each of three sentences) were recorded.

ANALYSIS

Tape recorded samples were used for the analysis to obtain the required parameters from phonation and speech.

1. Maximum phonation duration of vowels

The recorded samples of phonation of vowels were played back, and the duration of phonation were measured using a stop watch. The phonation duration of all the three trials of all three vowels /a/, /i/ and /u/ was measured.

The longest phonation duration among the three trials was considered the maximum phonation duration, in seconds, for each vowel for each subject. Thus the phonation duration for each vowel for each subject of both the groups was obtained.

I.Measurement of fundamental frequency of phonation

Measurement was carried out by using the setup as given in Fig. 1.

```
                                                  PC with
                              SIU &               Pentium
Tape recorder————>   A/D converter————————> 100 MHz
```

Fig. 1: Block diagram showing the arrangement of equipment used for analysis of voice and speech

The tape recorded speech samples were digitized at 16000 Hz sampling frequency using a 12 bit analog to digital convertor (ADC). INTON programme (VSS, Bangalore) of Vaghmi Software Package was used to extract the F_0 values using a Pentium processor.

The phonation signal was read in blocks or frames of 40 msec duration each. Auto correlation technique was used to estimate the average F_0 over this block of 40 msec. Intensity was measured as the RMS value in dB. Successive blocks were spaced by 10 msec. The minimum and maximum limits for F_0 measurement were 50 and 800 Hz. The analysis of the voice signal yielded the following parameters, by digital display on the monitor of the computer.

Fundamental frequency

2. Mean fundamental frequency
3. Fundamental frequency range
4. Speed of fluctuation in frequency
5. Extent of fluctuation in frequency

Intensity

6. Intensity range
7. Speed of fluctuation in intensity
8. Extent of fluctuation in intensity

The average of three readings was considered for obtaining parameters 2, 4, 5, 7, 8, 9, 12 and 13 where the highest values of the three values was considered for parameters 2, 6, 10 and 11.

9. Measurement of speaking fundamental frequency

To determine the speaking fundamental frequency the same experimental set up and procedure as above was used to digitize and analyze the speech samples. INTON programme (VSS, Bangalore) in Vaghmi Software Package was used to extract speaking fundamental frequency. The mean fundamental frequency for all the three sentences were directly read on the screen. Along with this

10. Frequency range in speech and

II. intensity range in speech were also displayed on the screen.

The values of all the parameters were noted.

Measurement of rise time and fall time of phonation

For this measurement, phonation of three vowels were selected and measurement carried out using the same set up earlier. F_0 INT programme (VSS, Bangalore) in Vaghmi Software Package was used to measure the rise time and fall time in phonation.

To measure the rising time, the initial portion of the phonation of the digitized vowel /a/ was processed using the computer programme F_0 INT and the display was obtained on the screen. Then, using the cursor, the time at the beginning, i.e. 0 dB and the time at the starting point of steady portion of intensity were noted. The difference (in milli seconds) between the two readings (from the beginning of the intensity curve going up from the base line to the beginning of the steady portion) provided the rising time (Fig. 2).

The final portion of the phonation of the digitized vowel was processed by computer programme and the display obtained on the screen. Then, using the cursor, the time at the end of the steady portion of intensity and the end, i.e. where the curve merged with the base line were noted. The time difference (in milli seconds) between the readings (from the end of the steady portion of the intensity curve to the point where the intensity curve merged with the base line) provided the falling time (Fig. 3). Using the above described procedure, the rising time and falling time for all the three samples /a/, /i/ and /u/ were determined for each subject. The average of the three values was taken as the rising time and falling time for /a/, /i/ and /u/ for each subject.

Thus the values for all parameters were obtained for 42 normal subjects and 15 cerebral palsied subjects. The obtained values were then tabulated and subjected to statistical analysis to determine the mean, standard deviation, range and significance of difference. Mann-Whitney 'u' test was used to determine the significance of difference between the obtained values.

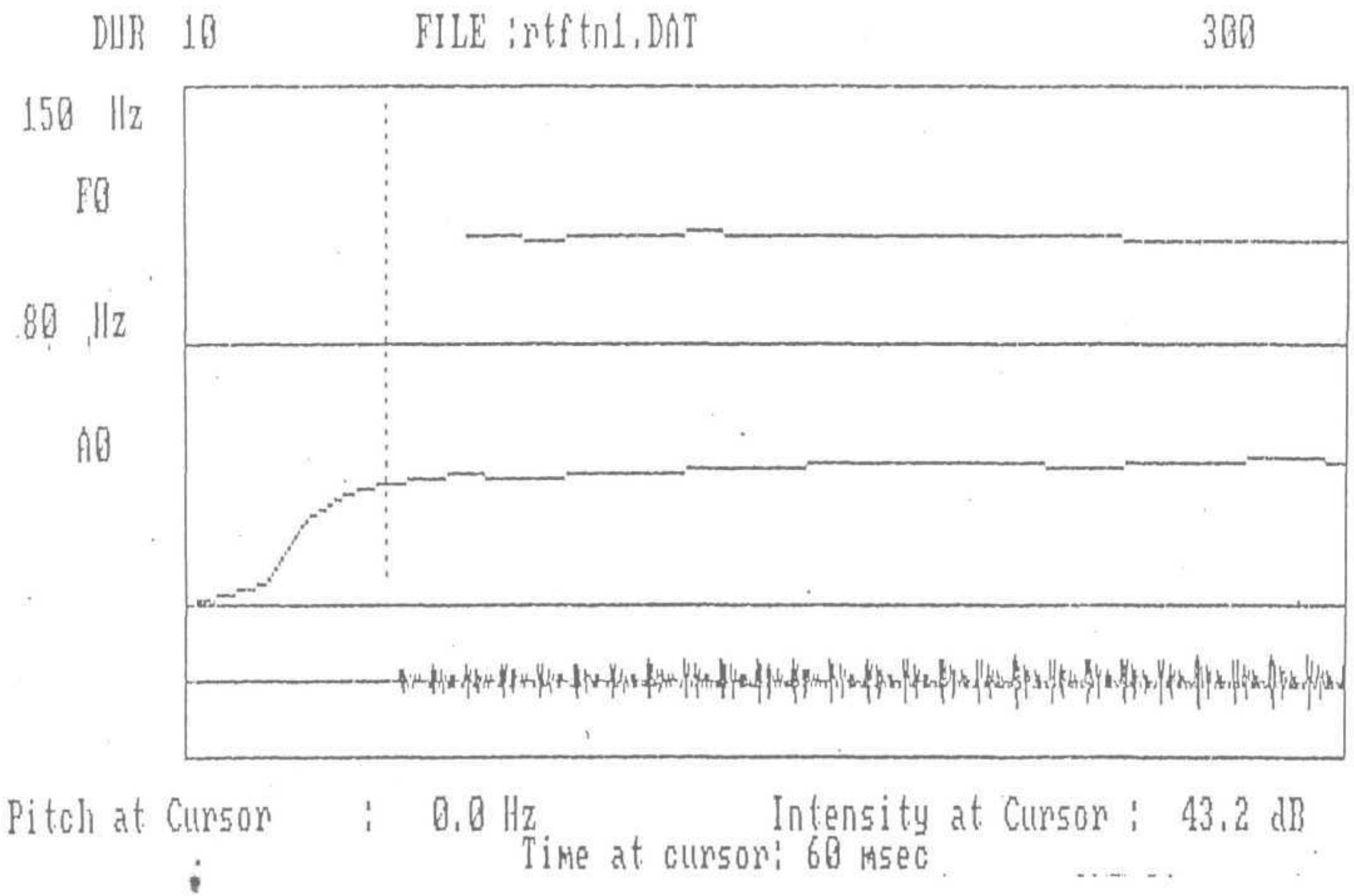


Fig-2 : Measurement of rising time in phonation in a normal subject

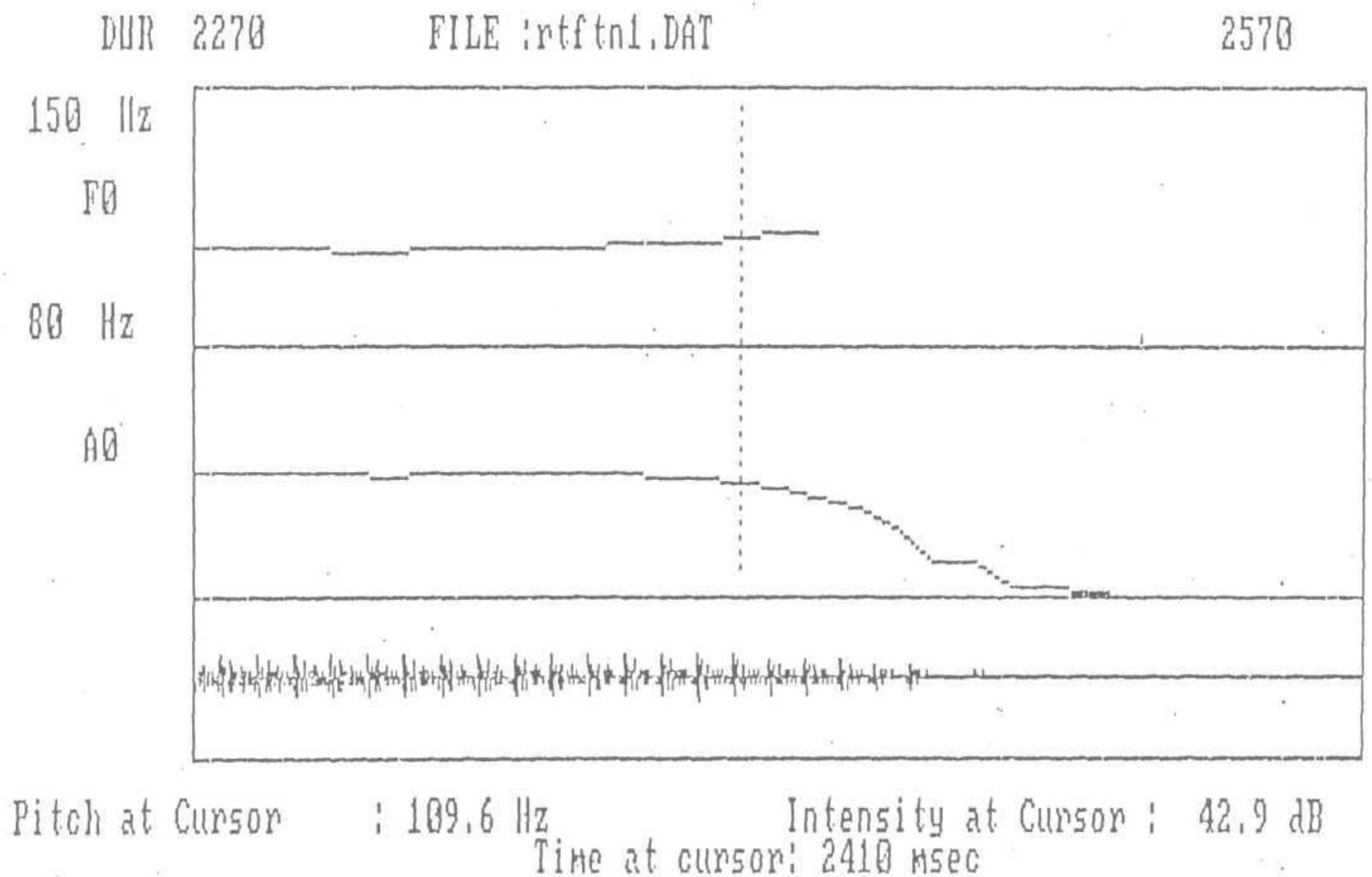


Fig- 3 : Measurement of falling time in phonation in a normal subject

RESULTS AND DISCUSSIONS

The purpose of the study was to find out the variations in acoustic and aerodynamic parameters in cerebral palsied children in the age range 3-10 years.

Therefore it was necessary to

* Find out the means, standard deviations and range of parameters constituting each group
* Compare the values obtained by normal male and female subjects with cerebral palsied subjects.
* Compare the values obtained by normal male and female subjects with three types of cerebral palsied subjects that is spastic diplegic, athetoid quadriplegic and spastic quadriplegic, that were available for study.
* Compare the values between each subtype of cerebral palsied subjects.

The significance of difference between groups have been determined using Mann-whitney 'U' test.

A total of 13 parametes were obtained by analyzing a total of 57 subjects belonging to two groups, normal (42 subjects) and cerebral palsied (15 subjects).

MAXIMUM PHONATION DURATION

Maximum phonation time was defined as the maximum time an individual could sustain phonation after a deep inhalation.

The mean values, range and standard deviation values of maximum phonation duration in both normal subjects and Cerebral palsied subjects are shown in the Tables la and lb and Graph I.

It was seen that (Table la) mean MPD scores in the normal group (12.82) were higher than the Cerebral palsied group (3.32) across each age groups. The range and S.D. values were also found to be higher in the normal group.

On comparison of means of scores obtained by males and females within the normal group,females were observed to have higher MPD than males. A gradual increase in MPD values was seen as the age progressed.

Inspection of mean values obtained by Cerebral palsied as a group on MPD reveraled that sex difference across each age group was not significant. The range and SD values were lower compared to normals.

Mann-Whitney 'U' test was applied to study the significance of difference between the groups. In the present study, in both males and females, the maximum phonation duration was different significantly when normal subject were compared with Cerebral palsied subjects (U - 0.0 Significant at 0.05 level)

		NORMALS			CEREBRAL PALSIED		
AGE IN YEAR	SEX	MEAN	S.D.	RANGE	MEAN	S.D.	RANGE
3-4	Male	10.89	2.37	7	3.33	2.06	7.0
	Female	12.56	1.74	5	3.72	1.86	5.0
4-5	Male	12.11	1.17	4.0	3.0	2.0	4.0
	Female	12.22	1.09	3	2.33	0.58	1.0
5-6	Male	12.0	1.41	4	5.0	0.894	2.0
	Female	12.89	2.80	9	2.42	0.49	1.0
6-7	Male	13.78	1.72	5	2.0	0.0	0
	Female	13.00	1.00	3	3.30	1.96	2.71
7-8	Male	13.44	1.24	4	3.0	0	0
	Female	13.89	2.20	6	2.0	0	0
8-9	Male	11.33	1.80	4.00	3.0	0.0	0.0
	Female	13.33	1.00	3.00	4.33	0.58	1.0
9-10	Male	13.33	2.29	7.00	6.0	1.0	2.0
	Female	14.73	1.30	4.00	3.0	0	0

Table la : The range, mean and S.D. values of average maximum phonation duration (In Sec's) for sustained phonation of /a/, /i/ and J/u/ shown by males and females of normal and cerebral palsied groups.

t.1

		SPASTIC DIPLEGIC			ATHETOID QUADRIPLEGIC			SPASTIC QUADRIPLEGIC		
AGE IN YEAR	SEX	MEAN	S.D.	RANGE	MEAN	S.D.	RANGE	MEAN	S.D.	RANGE
3-4	Male	3.86	2.11	6.00	(-)	(-)	(-)	2.33	0.65	2.0
	Female	(-)	(-)	(-)	(-)	(-)	(-)	3.72	1.86	5.0
4-5	Male	4.83	3.25	7.0	(-)	(-)	(-)	(-)	(-)	(-)
	Female	(-)	(-)	(-)	(-)	(-)	(-)	2.33	0.58	1.0
5-6	Male	(-)	(-)	(-)	(-)	(-)	(-)	65.0	0.89	2.0
	Female	2.42	0.59	1.00	(-)	(-)	(-)	(-)	(-)	(-)
6-7	Male	2	0	0	(-)	(-)	(-)	2.0	0	0
	Female	(-)	(-)	(-)	(-)	(-)	(-)	3.30	1.96	2.71
7-8	Male	3.0	0	0	(-)	(-)	(-)	(-)	(-)	(-)
	Female	(-)	(-)	(-)	(-)	(-)	(-)	2.0	0	0
8-9	Male	(-)	(-)	(-)	3.0	0	0.0	(-)	(-)	(-)
	Female	(-)	(-)	(-)	(-)	(-)	(-)	4.33	0.58	1.0
9-10	Male	(-)	(-)	(-)	0.0	1.0	2.0	(-)	(-)	(-)
	Female	3.0	0	0	(-)	(-)	(-)	(-)	(-)	(-)

(-) -> No Subjects for comparison

Table 1b : The range, mean and S.n. values of average maximum phonation duration (In Sec's) for sustained phonation of (a), (i) and (u) shown by males and females of spastic diplegic, athetoid quadriplegic and spastic quadriplegic group.

Hence the hypothesis stating that there is no significant difference between Cerebral palsied subjects and normal subjects in maximum phonation duration is rejected.

The difference was also statistically significant when the scores of subjects of normal group (both males and females) were compared to spastic diplegic Cerebral palsied subjects (U=0.0) athetoid quadriplegic (U=0.0) and spastic quadriplegic cerebral palsied (U=0.0 significant at 0.05 level).

Hence the null hypothesis stating that there is no significant difference between spastic diplegic spastic quadriplegic and athetoid quadriplegic when maximum phonation duration was compared with normal subjects is rejected.

Comparison of mean values of maximum phonation duration between spastic diplegic and athetoid quadriplegic Cerebral palsied (U=0.125) between spastic diplegic and spastic quadriplegic (U=0.926) and between athetoid quadriplegic and spastic quadriplegic (U=0.077) show that significant difference does not exist between three sub types of cerebral palsied subjects in terms of maximum phonation duration as the subjects of all the three subgroups had performed similarly.

The result of the present study in terms of maximum phonation duration, both in normal males and females are in consonance with earlier reports (Rashmi, 1985; Tharmar, 1991). Therefore the measurements made in the present study are valid.

Hence the null hypothesis stating that there is no significant difference between three types of Cerebral palsied subjects; spastic diplegic, spastic quadriplegic and athetoid quadriplegic in maximum phonation duration is accepted.

Results of this study are similar to reports by Westlake Rutherford (1961), Warnass (1993) and Wit et al (1993). The reduced phonation duration reflects poor control of the individual over phonation and laryngeal valving mechanism. Natraja (1986) found MPD as a useful parameter in differentiating between normal and dysphonics and also for differential diagnosis of various types of dysphonias. In the present study also maximum phonation duration seems to be a useful parameter in differentiating normal group from cerebral palsied group, as the normal group had higher values than cerebral palsied group.

FUNDAMENTAL FREQUENCY IN PHONATION

The fundamental frequency in phonation for all the three vowels was analyzed as described in chapter III.

The results of the measurement are presented in table 2a, 2b and graph 2.

Table 2a depicts the mean, SD and range of average fundamental frequency in phonation as shown by normals and cerebral palsied group.

The values of mean fundamental frequency in phonation in females (278.13) were higher than in males (259.60) in the normal group. Across age group, in both sexes significant difference was not seen.

Inspection of mean values obtained by cerebral palsied group on average fundamental frequency revealed that females had higher values than males. The SD and range were found to be higher than in normal group.

When the scores obtained by normal males and females were compared to the cerebral palsied group across each age group, significant difference was not seen (0.697 significant at 0.05 level).

Hence the null hypothesis stating that there is no significant difference between cerebral palsied subject and normal subjects in fundamental frequency in phonation is accepted.

Statistically significant difference was not observed when the scores of subjects of normal group (both males an females) were compared to spastic diplegic (U=0.415)

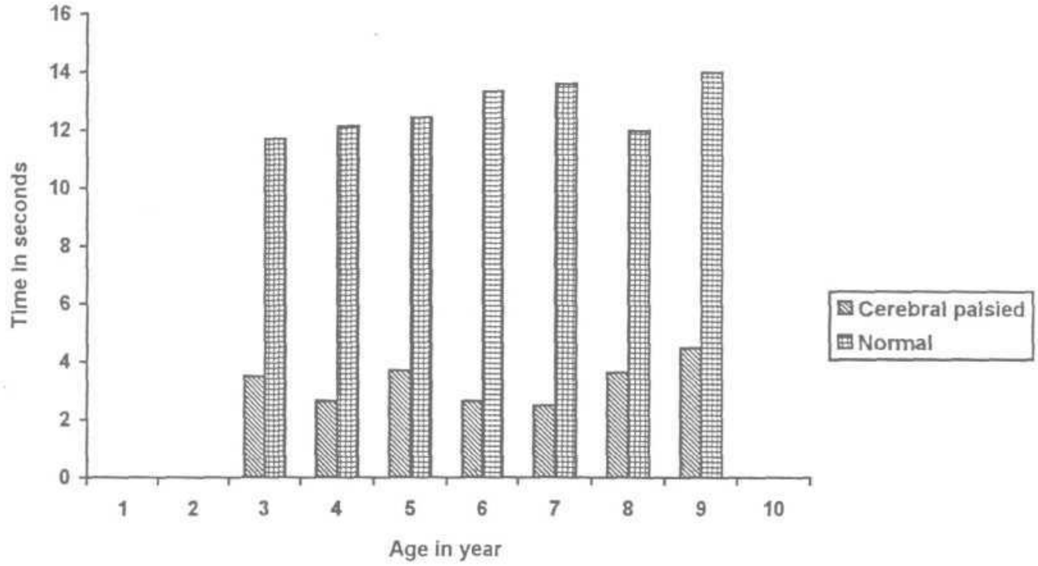
		NORMALS			CEREBRAL PALSIED		
AGE IN YEAR	SEX	MEAN	S.D.	RANGE	MEAN	S.D.	RANGE
3-4	Male	287.42	19.72	62.42	264.83	63.40	234.45
	Female	299.23	46.08	133.85	272.21	48.20	121.67
4-5	Male	288.15	25.09	80.0	257.87	44.15	102.63
	Female	291.90	22.82	68.60	265.51	28.70	50.05
5-6	Male	280.17	32.15	89.36	220.86	16.46	47.84
	Female	282.29	36.84	113.49	240.18	24.61	62.89
6-7	Male	248.55	10.02	32.15	336.46	23.92	45.3
	Female	262.71	7.38	22.51	320.18	24.21	58.16
7-8	Male	218.17	89.66	198.40	290.62	48.66	112.61
	Female	274.56	10.70	34.0	300.24	38.34	89.19
8-9	Male	279.49	23.00	71.65	345.42	108.99	189.25
	Female	250.61	54.60	180.05	224.77	13.29	26.21
9-10	Male	245.28	23.09	79.40	295.03	30.83	61.31
	Female	315.61	24.43	73.86	292.66	29.82	50.24

Table 2a : The mean, S.D, range values of average fundemental frequency in phonation (in Hz.) shown by males and females in the normal and Cerebral palsied group

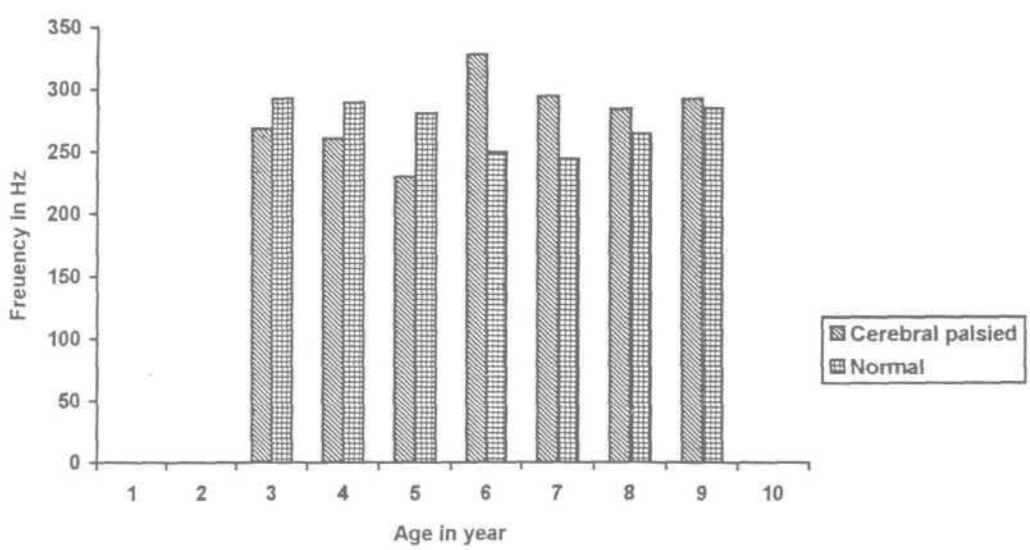
AGE IN YEAR	SEX	SPASTIC DIPLEGIC MEAN	SPASTIC DIPLEGIC S.D.	SPASTIC DIPLEGIC RANGE	ATHETOID QUADRIPLEGIC MEAN	ATHETOID QUADRIPLEGIC S.D.	ATHETOID QUADRIPLEGIC RANGE	SPASTIC QUADRTPLEGIC MEAN	SPASTIC QUADRTPLEGIC S.D.	SPASTIC QUADRTPLEGIC RANGE
3-4	Male	225.53	95.39	227.70	-		-	280.55	27.28	96.38
	Female					-		272.21	48.20	121.67
4-5	Male	275.83	44.13	116.15	-	-				
	Female						-	265.51	28.70	50.05
5-6	Male							220.86	16.46	47.84
	Female	240.18	29.61	62.89	-	-	-			
6-7	Male	336.46	23.92	45.3	-	-	-			
	Female							320.18	24.21	58.16
7-8	Male	296.62	48.66	112.61	-		-			
	Female					_		300.24	38.34	89.19
8-9	Male	-	-	-	345.42	108.99	189.25			
	Female							224.77	13.29	26.21
9-10	Male				295.03	30.83	61.31			-
	Female	292.66	29.82	50.24				-	-	

(-) -> No Subjects for comparison

Table 2b : The mean, S.D, range values of average foundamental frequency in phonation (In Sec's) shown by males and females of spastic diplegic, athetoid quadriplegic and spastic quadriplegic group.



Graph I : Mean values of maximum ponation duration for normal and cerebral palsied groups.



Graph II. : Mean values of fundamental frequency of phonation of normal and cerebral palsied groups.

athetoid quadriplegic (U=0.116) and spastic quadriplegic (U=0.053).

Hence the null hypothesis stating that there is no significant difference between spastic diplegic, spastic quadriplegic and athetoid quadriplegic when fundamental frequency in phonation was compared to normal subjects is accepted.

Comparison of mean values of fundamental frequency in phonation between spastic diplegic and athetoid quadriplegic cerebral palsied (U=0.243) between spastic diplegic and spastic quadriplegic (U=0.204) and between athetoid quadriplegic and spastic quadriplegic (U=0.055) showed that significant difference does not exist between three types of cerebral palsied subjects in terms of average fundamental frequency in phonation.

Hence the null hypothesis stating that there is no significant difference between three types of cerebral palsied subjects, spastic diplegic, athetoid quadriplegic and spastic quadriplegic in fundamental frequency in phonation is accepted.

The results of earlier studies (Rashmi, 1985 and Tharmar, 1991) have shown the same results in normal males and females. So the measurements made in the present study are valid.

Review of literature shows no study on cerebral palsied population in terms of fundamental frequency. Hence the present study could not be compared with others. When compared to nomral subjects it could be seen that there was no significant difference between normal subjects and cerebral palsied subject in terms of average fundamental frequency in phonation.

FREQUENCY RANGE IN PHONATION

Tables 3a, 3b and graph 3 presents the results of analysis of phonation in terms of frequency range that is the difference between maximum and minimum fundamental frequency seen during the phonation of /a/, /i/ and /u/.

The inspection of Table 3 a and graph 3 show that mean values of frequency range in phonation obtained by females of normal group (21.28) were higher than males (19.57) across all age group. As the age increased, a gradual decrease in the frequency range also seen. The SD and range values were higher for females than in males.

Study of the mean values obtained by cerebral palsied group showed extreme variability within and across age groups. The SD and range values were also higher compared to normals.

AGE IN YEAR	SEX	NORMALS MEAN	NORMALS S.D.	NORMALS RANGE	CEREBRAL PALSIED MEAN	CEREBRAL PALSIED S.D.	CEREBRAL PALSIED RANGE
3-4	Male	25.29	3.25	11.00	304.55	93.31	375.85
	Female	28.60	5.70	19.02	314.66	82.96	215.92
4-5	Male	22.28	4.08	11.98	319.82	151.74	369.47
	Female	23.32	4.12	10.97	99.70	127.60	224.19
5-6	Male	22.69	3.66	10.65	126.50	56.96	160.66
	Female	22.82	4.95	13.89	298.61	59.63	124.84
6-7	Male	22.44	2.90	8.24	312.72	30.60	60.68
	Female	23.18	3.76 .	9.65	321.82	46.21	56.46
7-8	Male	18.98	6.04	17.64	186.67	56.67	56.46
	Female	16.22	3 .00	11.08	142.88	66.24	32.98
8-9	Male	11.08	2.19	6.32	334.41	196.09	378.10
	Female	18.40	5.89	18.00	192.01	42.82	79.56
9-10	Male	14.37	4.94	14.97	277.53	4.33	8.66
	Female	16.40	5.53	16.29	124.62	28.62	29.88

Table 3a : The mean, S.D, range values of fundemental frequency range (in Hz.) in phonation of vowel (a) (i) and (u) shown by males and females in the normal and Cerebral palsied group.

AGE IN YEAR	SEX	SPASTIC DIPLEGIC MEAN	SPASTIC DIPLEGIC S.D.	SPASTIC DIPLEGIC RANGE	ATHETOID QUADRIPLEGIC MEAN	ATHETOID QUADRIPLEGIC S.D.	ATHETOID QUADRIPLEGIC RANGE	SPASTIC QUADRIPLEGIC MEAN	SPASTIC QUADRIPLEGIC S.D.	SPASTIC QUADRIPLEGIC RANGE
3-4	Male	311.29	113.92	375.85	-		-	287.52	71.44	257.52
	Female					—		314.66	82.96	275.92
4-5	Male	306.25	119.45	369.47	-	-	-			
	Female							99.70	127.60	224.19
5-6	Male					-		126.50	56.96	160.66
	Female	298.61	30.60	60.68	-		-			
6-7	Male	312.72	30.60	60.68		-	-			
	Female				-			321.82	46.21	56.46
7-8	Male	186.67	56.62	48.66	-		-			
	Female					-		142.88	66.21	32.98
8-9	Male	-	-		334.41	196.09	378.10			
	Female			-				192.01	42.82	79.56
9-10	Male				277.53	4.33	8.66			
	Female	124.62	28.62	29.88				-	-	-

(-) -> No Subjects for comparison

Table 3b : The mean, S.D, range values of fundemental frequency range (in Hz.) in phonation of vowel (a) (i) and (u) shown by males and females in spastic diplegic, athetoid quadriplegic and spastic quadriplegic group.

On comparison of mean values obtained by males and females in the two groups, mean frequency range value of cerebral palsied subjects was higher (239.75) than the normal subjects (20.43). The SD and range values were also greater for cerebral palsied subject acorss all age groups.

Administration of Mann-Whitney 'U' test to find out the significance of difference revealed significant difference (U=0.0) when normal subjects were compared to cerebral palsied subjects. Hence the null hypothesis stating that there is no significant difference between cerebral palsied subjects and normal subjects in frequency range in phonation is rejected.

The difference was also statistically significant when the scores of subjects of normal group (both males and females) were compared to spastic diplegic (U=0.0) athetoid quadriplegic (U=0.0) and spastic quadriplegic (U=0.0) significant at 0.05 level). Thus the null hypothesis stating that there is no significant difference between spastic diplegic, athetoid quadriplegic and spastic quadriplegic when frequency range in phonation was compared to normal subjects is rejected.

Comparison of mean values of frequency range in phonation between spastic diplegic and athetoid quadriplegic (U=0.640) and between athetoid quadriplegic and spastic quadriplegic (U=0.120) did not show significant difference across age groups. Significant difference was seen between spastic diplegic and spastic quadriplegic cerebral palsied subjects (U=0.007) when their mean values of frequency range in phonation were compared.

Thus the null hypothesis stating that there is no significant difference between three types of cerebral palsied subjects : spastic diplegic, athetoid quadriplegic and spastic quadriplegic in frequency range of phonation is partly accepted and partly rejected.

Measures of fundamental frequency range in normal subjects in Indian population were attempted by Sreedevi (1987) who found the values as 16.29 and 24.33 Hz for male and females respectively. The present study showed that cerebral palsied subjects had an increased frequency range and this could be attributed to innacurate laryngeal adjustment during phonation in cerebral palsy subjects. These results are in agreement with results obtained by earlier investigators. Natraja (1986) in his study found frequency range to be an important parameter for differentiating between normals and dysphonies and also for the differential diagnosis of different types of dysphonias. In the present study frequency range was found to be useful in differentiating between the two groups, i.e. cerebral palsy and normals.

INTENSITY RANGE IN PHONATION

The intensity range in phonation was defined as the difference between the maximum and minimum intensities in phonation of a vowel.

From Table 4a and graph 4, it was seen that mean values of intensity range in phonation in cerebral palsied subjects (18.30) were higher than that of the normal subjects (9.70). The SD and range values were also higher for cerebral palsied subjects across all age groups. From the above table it was also seen that females of normal group had higher mean, SD and range values than males.

There was statistically significant difference between the intensity values shown by normal group and cerebral palsy group (U = 0.0) (both male and female subjects). Thus the null hypothesis stating that there is no significant difference between cerebral palsied subjects and normal subjects in terms of intensity range in phonation is rejected.

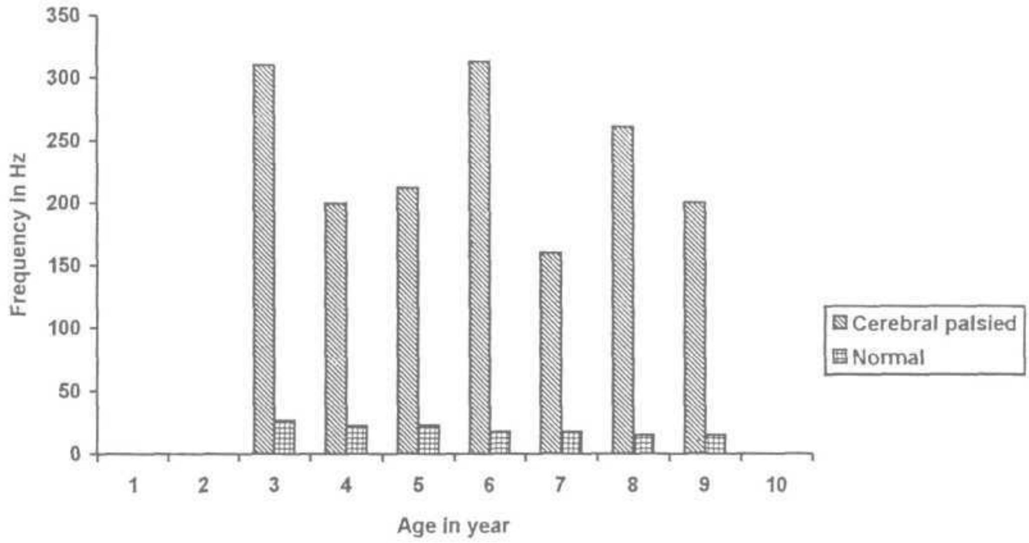
The difference was also statistically significant when the scores of subjects of normal group (both males

		NORMALS			CEREBRAL PALSIED		
AGE IN YEAR	SEX	MEAN	S.D.	RANGE	MEAN	S.D.	RANGE
3-4	Male	9.80	2.09	6.97	15.69	6.16	22.40
	Female	12.26	2.46	5.95	14.66	6.02	16.24
4-5	Male	8.241	1.19	3.37	15.22	6.49	13.85
	Female	10.79	4.16	12.85	15.25	3.61	6.92
5-6	Male	8.15	2.28	6.12	15.06	11.01	23.42
	Female	7.68	3.65	,11.92	14.24	8 .42	18.46
6-7	Male	9.08	1.15	3.42	20.88	9.13	18.23
	Female	10.13	3.64	11.02	22.92	6.28	12.92
7-8	Male	7.89	6.31	18.12	16.82	6.66	13.86
	Female	19.61	11.45	30.43	14.96	4.89	11.81
8-9	Male	6.54	2.44	5.85	25.68	21.64	4.12
	Female	11.22	5.41	16.50	10.92	6.17	12.07
9-10	Male	7.0	2.14	6.10	27.29	8.24	15.11
	Female	7.37	3.00	9 .28	26.66	6.46	13.86

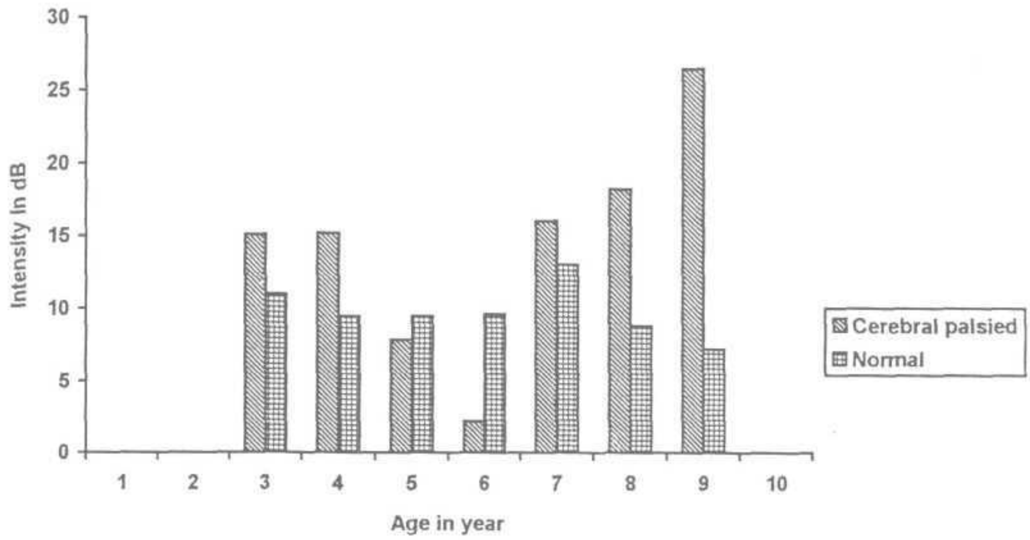
Table 4a : The mean, S.D, range values of intensity range (in dB) in phonation of vowel (a),(i) and (u) shown by males and females in the normal and Cerebral palsied group.

AGE IN YEAR	SEX	SPASTIC DIPLEGIC			ATHETOID QUADRIPLEGIC			SPASTIC QUADRIPLEGIC		
		MEAN	S.D.	RANGE	MEAN	S.D.	RANGE	MEAN	S.D.	RANGE
3-4	Male	15.50	8.4006	21.33			-	16.19	5.28	16.86
	Female				-	-		14.66	6.02	16.24
4-5	Male	13.02	6.17	13.85			-			
	Female				-	-		15.25	3.61	6.92
5-6	Male							15.06	11.01	23.40
	Female	14.24	8.42	18.46	—	-	—			
6-7	Male	20.88	9.13	18.23	-	-				
	Female						-	22.92	6.28	12.92
7-8	Male	16.82	6.66	13.96	-		-			
	Female					-		14.96	4.89	11.81
8-9	Male	-	-	-	25.68	21.64	4.12			
	Female	-	-	-				10.92	6.17	12.07
9-10	Male				27.29	8.24	15.11	-	-	
	Female	26.66	6.46	13.86						-

Table 4b : The mean, S.D, range values of intensity range (in dB) in phonation of vowel (a) (i) and (u) shown by males and females in spastic diplegic, athetoid quadriplegic and spastic quadriplegic cerebral palsied subjects.



Graph III : Mean value of frequency range in phonation of normal and cerebral palsied groups.



Graph IV : Mean value of intensity range in phonation of normal and cerebral palsied groups.

and females) were compared with spastic diplegic(U=0.01) athetoid quadriplegic (U=0.0) and spastic quadriplegic cerebral palsied subjects (U=0.0). Hence the null hypothesis stating that there is no significant difference between spastic diplegic, athetoid quadriplegic and spastic quadriplegic when intensity range value were compared to normal subjects is rejected.

Comparison of mean values of intensity range in phonation between spastic diplegic and athetoid quadriplegic (U=0.013) and between athetoid quadriplegic and spastic quadriplegic (U=0.002) showed that statistically significant difference existed between these three groups. However, statisticaly significant difference was not observed when mean values of spastic diplegic and spastic quadriplegic were compared (U=0.686). Thus the null hypothesis stating that there is no significant difference between three types of cerebral palsied subjects: spastic diplegic, athetoid quadriplegic and spastic quadriplegic in intensity range in phonation is partly accepted and partly rejected.

The result of present study in terms of intensity range in phonation in normal males and females are in consonance with earlier investigations (Rashmi, 1985 and Tharmar, 1991). So the measurements made in the present study are valid.

There is no study regarding the intensity range in cerebral palsied individual. Comparison of cerebral palsied subject to the normal subjects of same age group in this study revealed that the intensity range in cerebral palsied were greater (18.30) when compared to normal (9.7). This reflects the inablity of the individual to control the voice production system. This proved that subjects of normal group could maintain a steady phonation better than cerebral palsied group.

FUNDAMENTAL FREQUENCY IN SPEECH

The fundamental frequency in speech for all the three sentences were analyzed and results are presented in the Tables 5a and 5b and Graph 5.

It was seen that (Table 5a) mean fundamental frequency in speech of females (288.54) was greater than in males (270.60) of the normal group across at all ages. On comparison between the two groups, it was seen that mean values of frequency in speech of normal subjects (280.57) were greater than that of cerebral palsied subjects (256.54). The SD and range values was greater for cerebral palsied.

Mann-Whitney "U" test revealed a statistically significant difference between the normal group and cerebral palsied group (U=0.0). Thus the null hypothesis

AGE IN YEAR	SEX	NORMALS MEAN	NORMALS S.D.	NORMALS RANGE	CEREBRAL PALSIED MEAN	CEREBRAL PALSIED S.D.	CEREBRAL PALSIED RANGE
3-4	Male	317.23	22.67	67.89	241.47	39.17	137.43
	Female	316.54	39.95	124.70	252.68	14.66	124.62
4-5	Male	307.13	16.17	44.66	240.50	44.16	93.19
	Female	314.59	12.96	37.19	240.53	14.12	27.95
5-6	Male	311.91	25.44	86.07	201.19	57.82	160.95
	Female	312.91	34.00	93.79	242.56	39.28	101.61
6-7	Male	285.25	22.93	69.35	267.11	19.57	26.33
	Female	288.82	14.76	36.29	269.666	22.62	48.98
7-8	Male	193.41	36.53	104.94	260.16	26.62	58.24
	Female	296.04	12.74	88.58	272.24	14.62	19.66
8-9	Male	255.66	38.18	103.58	275.43	21.13	37.21
	Female	220.09	74.02	216.66	231.14	8.56	16.08
9-10	Male	237.68	48.73	125.13	300.86	36.34	72.68
	Female	270.94	44.10	108.96	296.44	21.81	56.16

Table 5a : The mean, S.D and range values of fundamental frequency in speech (in Hz) shown by males and females in normal and cerebral palsied group.

AGE IN YEAR	SEX	SPASTIC DIPLEGIC			ATHETOID QUADRIPLEGIC			SPASTIC QUADRIPLEGIC		
		MEAN	S.D.	RANGE	MEAN	S.D.	RANGE	MEAN	S.D.	RANGE
3-4	Male	235.64	16.95	58.06	-	-	-	249.96	48.58	137.43
	Female	—	—	—	—	—	—	252.68	14.66	124.62
4-5	Male	234.01	36.77	99.14	-	-	—	—	—	—
	Female	—	—	—	—	—	—	290.53	14.12	27.98
5-6	Male	—	—	—	—	—	—	201.19	57.82	160.95
	Female	242.56	39.28	101.61	—	—	—	—	—	-
6-7	Male	267.11	19.57	26.33	—		—	—	—	—
	Female	—	—	—	—	—	—	269.66	22.62	48.98
7-8	Male	260.16	26.62	28.24	—		—	—	—	—
	Female	-	—	—	—	-	—	272.24	14.62	19.56
8-9	Male	—	—	—	275.43	21.13	37.21	—	—	—
	Female	—	—	—	—	—	—	231.14	8.56	16.08
9-10	Male	—	—	-	300.86	36.34	72.68	-	-	-
	Female	296.49	21.81	56.16	—	—	—	—	—	—

(-) -> No Subjects for comparison

Table 5b : The mean, S.D, and range values of fundamental frequency in speech (in Hz) shown by males and female in spastic diplegic, athetoid quadriplegic and spastic quadriplegic cerebral palsied subjects.

stating that there is no significant difference between cerebral palsied subjects and normal subjects in fundamental frequency in speech is rejected.

Statistically significant difference was seen when normal subjects were compared with spastic diplegic (U=0.001) and spastic quadriplegic cerebral palsied subjects. The difference was not statistically significant when mean fundamental frequency in speech of normal were compared to athetoid quadriplegic (U=0.861). Hence the null hypothesis stating that there is no significant difference between spastic diplegic, athetoid quadriplegic and spastic quadriplegic when fundamental frequency in speech were compared to normal is partly accepted and partly rejected.

When mean values of fundamental frequency in speech were comapred between spastic diplegic and athetoid quadriplegic and spastic quadriplegic, a statistically significant difference was observed (U=0.010 and U=0.010). Comparison of mean values between spastic diplegic and spastic quadriplegic showed absence of statistically significant difference between these two groups (U=0.525). Thus the null hypothesis stating that there is no statistically significant difference between three types of cerebral palsy in terms of fundamental frequency in speech is partly rejected and partly accepted.

Results of previous investigations have shown the same results in normal males and females in fundamental frequency in speech. (Rashmi, 1985 and Tharmar, 1991). So the present study is valid.

The review of literature on fundamental frequency in speech shows no study in cerebral palsy population. Hence the present study could not becompared with others. However when compared to normal population, cerebral palsied group showed a difference which help in differentiating between the two group.

FREQUENCY RANGE IN SPEECH

Frequency range in speech was analyzed using three sentences. The mean, SD and range of frequency range in speech for each age group in both males and females across two groups that is normal and cerebral palsied groups are provided in Tables 6a, 6b and Graph 6.

Table 6a showed that the values of frequency range in speech in males (133.62) were lower than those obtained by females (126.43) in the normal group. The SD and range values were also higher for normal female subjects.

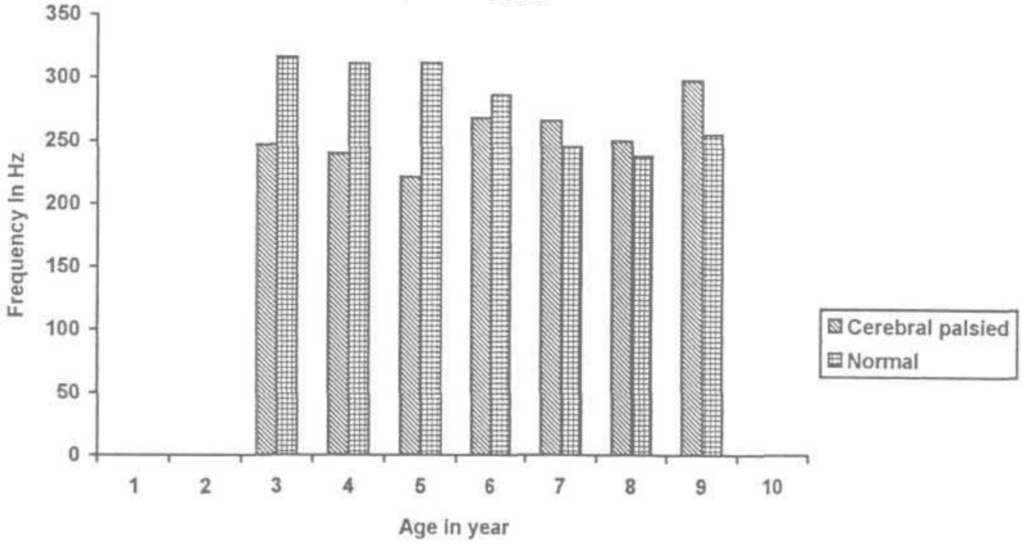
AGE IN YEAR	SEX	NORMALS MEAN	NORMALS S.D.	NORMALS RANGE	CEREBRAL PALSIED MEAN	CEREBRAL PALSIED S.D.	CEREBRAL PALSIED RANGE
3-4	Male	109.09	9.57	21.78	256.61	70.50	369.09
	Female	81.25	21.96	71.33	296.82	67.32	121.62
4-5	Male	97.39	10.68	34.00	330.22	72.06	149.47
	Female	105.59	12.07	37.77	252.69	66.11	129.84
5-6	Male	87.62	12.37	37.72	174.67	29.17	114.52
	Female	88.94	15.60	46.77	210.66	52.26	104.14
6-7	Male	189.45	26.59	83.98	207.48	19.57	38.68
	Female	195.24	55.38	183.72	270.24	15.64	32.14
7-8	Male	192.44	37.79	109.88	220.13	128.43	113.62
	Female	153.16	74.60	202.60	189.24	28.62	104.21
8-9	Male	153.70	15.57	55.33	277.79	71.69	142.33
	Female	139.54	49.70	145.69	162.36	30.66	54.28
9-10	Male	135.78	28.79	76.18	266.60	58.50	116.89
	Female	161.28	79.37	232.25	270.18	48.24	99.63

Table 6a : The mean, S.D and range values of frequency range in speech (in Hz) shown by males and females in normal and cerebral palsied group.

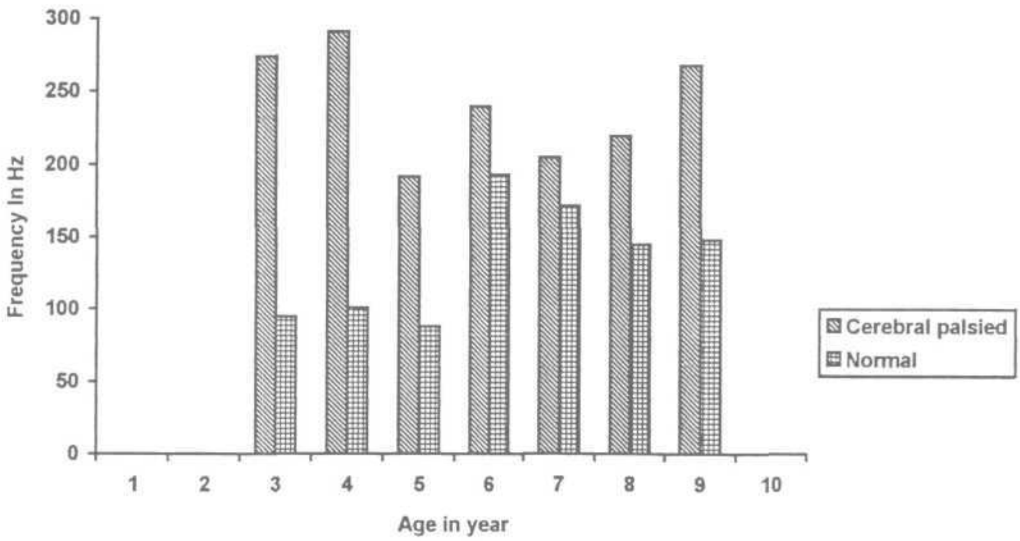
		SPASTIC DIPLEGIC			ATHETOID QUADRIPLEGIC			!SPASTIC QUADRIPLEGIC		
AGE IN YEAR	SEX	MEAN	S.D.	RANGE	MEAN	S.D.	RANGE	MEAN	S.D.	RANGE
3-4	Male	265.07	16.95	57.87	-	-	-	251.25	92.59	369.09
	Female	-	-	-	-	-	-	296.82	67.32	121.62
4-5	Male	297.71	75.37	213.73	-	-	-	-	-	-
	Female	-	-	-	-	-	-	252.69	66.11	129.84
5-6	Male	-	-	-	-	-	-	174.67	39.17	114.52
	Female	210.66	56.26	104.14	-	-	-	-	-	-
6-7	Male	267.48	17.87	38.68	-	-	-	-	-	-
	Female	-	-	-	-	-	-	210.24	18.54	82.14
7-8	Male	220.13	28.43	113.62	-	-	-	-	-	-
	Female	-	-	-	-	-	-	189.24	28.62	104.21
8-9	Male	-	-	-	277.79	71.69	142.33	-	-	-
	Female	-	-	-	-	-	-	162.36	30.66	54.28
9-10	Male	-	-	-	266.60	58.50	116.89	-	-	-
	Female	270.24	48.24	99.63	-	-	-	-	-	-

(-) -> No Subjects for comparison

Table 6b : The mean, S.D, and range values of frequency range in speech (in Hz) shown by males and female of spastic diplegic, athetoid quadriplegic and spastic quadriplegic cerebral palsied subjects.



GraphV : Mean value of fundamental frequency in speech of normal and cerebral palsied groups.



GraphVI : Mean value of frequency range in speech of normal and cerebral palsied groups.

Mean values obtained by female cerebral palsied subjects were higher than that of male subjects. On comparison of mean values of frequency range in speech across two groups, it was observed that cerebral palsied group had higher mean values than normal group. The SD and range of values also were higher in cerebral palsied. Mean values of female cerebral palsied subjects were higher than males.

On comparison of values obtained by normal subjects and Cerebral palsied subject, it was found that the difference between them were statistically significant (U=0.0). so the null hypothesis stating that there is no statistically significant difference between Cerebral palsied subjects and normal subjects in frequency range in speech is rejected.

Statistically significant difference was seen when normal subjects were compared with spastic diplegic (U=0.0) athetoid quadriplegic (U=0.0) and Spastic quadriplegic (U=0.0). Thus the hypothesis stating that, there is no difference between spastic diplegic, athetoid quadriplegic and spestic quadriplegic when frequency range in speech were compared to normal is rejected.

Comparison of mean values of frequency range in speech between spastic diplegic and athetoid quadriplegic

(U=1.0) and between athetoid quadriplegic and spastic quadriplegic (U=0.120) showed no significant difference. Between spastic diplegic and spastic quadriplegic, the difference was statistically significant. (U = 0.021).

Hence the null hypothesis status that there is no significant difference between three types of cerebral palsied groups is partly accepted and partly rejected.

Result of the present study is in consonance with earlier study (Tharmar, 1991) in normal male and female subjects.

The review of literature on frequency range in speech shows no study in cerebral palsied population. Hence comparison of present study with others could not be done.

However when compared to normal population Cerebral palsied subjects showed a large difference due to wide variation in frequency in each individual production. This shows that there was a lack of laryngeal control in this population which presents due to adequate neuromuscular control for the production of voice.

INTENSITY RANGE IN SPEECH

The intensity range in speech for all the three sentences were analyzed and results are presented in the Tables 7a, 7b and Graph 7.

		NORMALS			CEREBRAL PALSIED		
AGE IN YEAR	SEX	MEAN	S.D.	RANGE	MEAN	S.D.	RANGE
3-4	Male	25.65	4.59	13.59	20.22	9.17	38.03
	Female	25.70	5.34	14.51	18.26	8.24	8.66
4-5	Male	27.75	5.37	15.01	15.06	3.44	7.70
	Female	18.90	4.71	17.35	21.17	4.46	8.00
5-6	Male	32.58	2.93	8.71	26.15	5.33	14.52
	Female	28.75	6.56	19.83	16.28	6.20	9.60
6-7	Male	23.83	7.46	21.44	15.54	5 .20	10.37
	Female	17.28	3.22	10.46	17.28	4 .82	7.62
7-8	Male	23.68	8.38	22.59	21.68	4.82	7.98
	Female	26.80	7.55	17.01	20.29	5.20	6.16
8-9	Male	23.14	2.57	7.10	21.38	4.26	7.53
	Female	26.99	8.45	21.21	17.46	6.19	12.00
9-10	Male	27.93	10.39	28.10	29.57	3.06	6.11
	Female	37.16	15.39	51.26	24.26	4.32	7.89

Table 7a : The mean, S.D and range values of intensity range in speech (in dB) shown by males and females in normal and cerebral palsied group.

AGE IN YEAR	SEX	SPASTIC DIPLEGIC MEAN	SPASTIC DIPLEGIC S.D.	SPASTIC DIPLEGIC RANGE	ATHETOID QUADRIPLEGIC MEAN	ATHETOID QUADRIPLEGIC S.D.	ATHETOID QUADRIPLEGIC RANGE	SPASTIC QUADRIPLEGIC MEAN	SPASTIC QUADRIPLEGIC S.D.	SPASTIC QUADRIPLEGIC RANGE
3-4	Male	20.66	10.08	28.28	-	-	-	20.08	9.85	38.0
	Female	-	-	-	-	-	-	18.26	8.24	8.66
4-5	Male	15.92	3.62	10.42	-	-	-	-	-	-
	Female	-	-	-	-	-	-	21.17	4.46	8.00
5-6	Male	-	-	-	-	-	-	26.15	5.33	14.52
	Female	16.28	6.20	9.60	-	-	-	-	-	-
6-7	Male	15.54	5.20	10.37	-	-	-	-	-	-
	Female	-	-	-	-	-	-	17.28	4.82	7.62
7-8	Male	21.68	4.82	7.98	-	-	-	-	-	-
	Female	-	-	-	-	-	-	20.29	5.20	6.16
8-9	Male	-	-	-	21.38	4.26	7.53	-	-	-
	Female	-	-	-	-	-	-	17.46	6.19	12.0
9-10	Male	-	-	-	29.57	3.06	6.11	-	-	-
	Female	24.26	4.32	7.89	-	-	-	-	-	-

(-) -> No Subjects for comparison

Table 7b : The mean, S.D, and range values of intensity range in speech (in dB) shown by males and female of spastic diplegic, athetoid quadriplegic and spastic quadriplegic cerebral palsied subjects.

From Table 7a it was seen that mean value of intensity range in speech did not show sex difference across both groups. Comparison of mean values of Cerebral palsied group and normal group showed a greater mean value for Cerebral palsied group. The S.D. and range values also showed a greater value for Cerebral palsied group.

Statistically significant difference was seen when the mean value of intensity range of speech of Cerebral palsied children were compared to normal group. (U=0.0). Thus the null hypothesis stating that there is no statistically significant difference between Cerebral palsied subjects and normal subjects in intensity range in speech is rejected, both in caseof males and females.

There was statistically significant difference between the intensity range values shown by both male and female subjects of normal and spastic diplegic (U=0.0) and between normal and spastic quadriplegic Cerebral palsied subjects (U=0.011) statistically significant difference was not observed when athetoid quadriplegic subjects compared with normal subjects.

Thus the null hypothesis stating that there is no significant difference between spastic diplegic, athetoid quadriplegic and spastic quadriplegic when intensity range in speech were compared to normal is partly rejected and partly accepted, i.e.

Comparison of mean values of intensity range in speech between spastic diplegic and athetoid quadriplegic showed a statistically significant difference (U=0.029). statistically significant difference was not seen when spastic diplegic were compared to spastic quadriplegic (U=0.145) and on comparison of athetoid quadriplegic to spastic quadriplegic (U=0.147).

Hence the null hypothesis stating that there is no significant difference between three types of Cerebral palsied group is partly accepted and partly rejected.

Result of the present study in terms of intensity range in speech, both in males and females are in consonance with earlier studies (Rashmi, 1985 and Tharmar, 1991). So the measurements made in the present study are valid.

There is no similar study regarding the intensity range in speech in Cerebral palsied individual, comparison of Cerebral palsied subjects with normal groups in the present study revealed that Cerebral palsied group had higher intensity range value indicating their inability to control the voice production system and to maintain a steady phonation.

Thus this parameter seems to be a useful parameter in differentiating normals from Cerebral palsied group.

EXTENT OF FLUCTUATION IN FREQUENCY OF PHONATION

The extent of fluctuation in frequency of phonation for all three vowels was analyzed as described in Chapter 3. The results of the measurement are presented in the Table 8a, 8b and Graph 8.

From the inspection of Table 8a it was evident that females of the normal group (8.08) had higher mean values than the males (7.33). The S.D. and range value were higher for females. A gradual increase in the mean value of extent of fluctuation in frequency was seen as the age increased.

Comparison of mean values obtained by Cerebral palsied group with that of normal group revealed that the mean value of Cerebral palsied group was greater then that of normal group. Individual variation was found to be wider in case of Cerebral palsied group when compared to normal. The S.D. range values were also greater.

Significant difference was seen between normal group and Cerebral palsied group when mean value of extent of

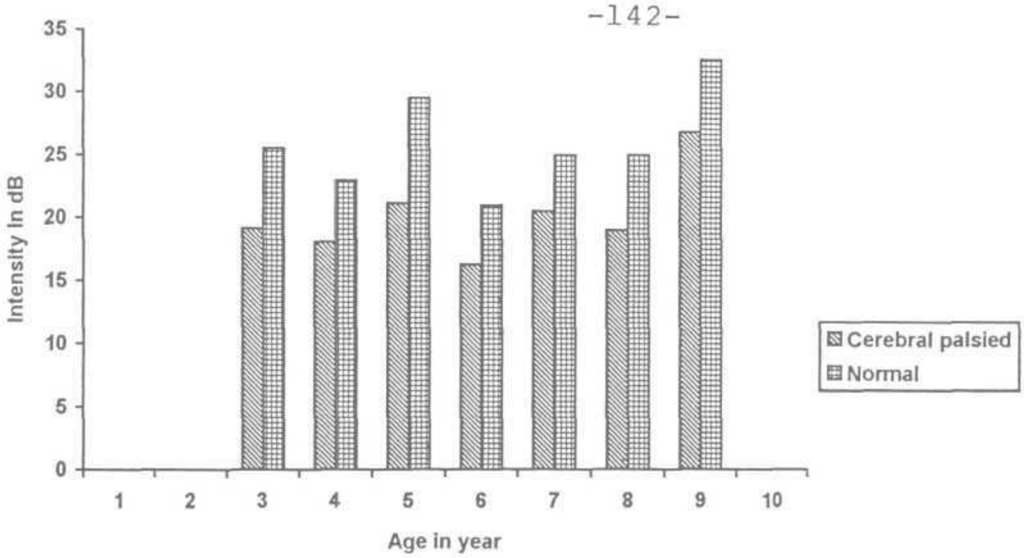
		NORMALS			CEREBRAL PALSIED		
AGE IN YEAR	SEX	MEAN	S.D.	RANGE	MEAN	S.D.	RANGE
3-4	Male	5.52	1.10	2.93	60.75	29.14	98.61
	Female	5.92	1.58	4.23	52.82	18.64	46.29
4-5	Male	6.58	1.12	3.69	67.74	34.39	81.11
	Female	5.42	0.69	2.01	22.55	23.35	44.68
5-6	Male	6.61	1.94	5.41	31.94	20.54	52.17
	Female	6.68	1.95	5.73	42.86	14.92	31.66
6-7	Male	5.79	1.55	4.59	47.40	13.72	25.81
	Female	10.47	6.46	17.37	46.62	12.48	29.24
7-8	Male	16.06	9.97	24.51	35.43	11.90	23.76
	Female	8.16	5.09	12.33	21.26	14.91	32.62
8-9	Male	4.03	0.59	1.67	29.46	33.12	60.26
	Female	8.04	4.40	15.06	75.82	15.47	27.11
9-10	Male	6.74	3.42	10.81	19.60	3.88	7.47
	Female	11.92	12.30	17.35	26.32	13.21	28.62

Table 8a : The mean, S.D and range values of extent of fluctuation in frequency (in Hz) for phonation of vowels (a), (i) and (u), shown by males and females in normal and cerebral palsied group.

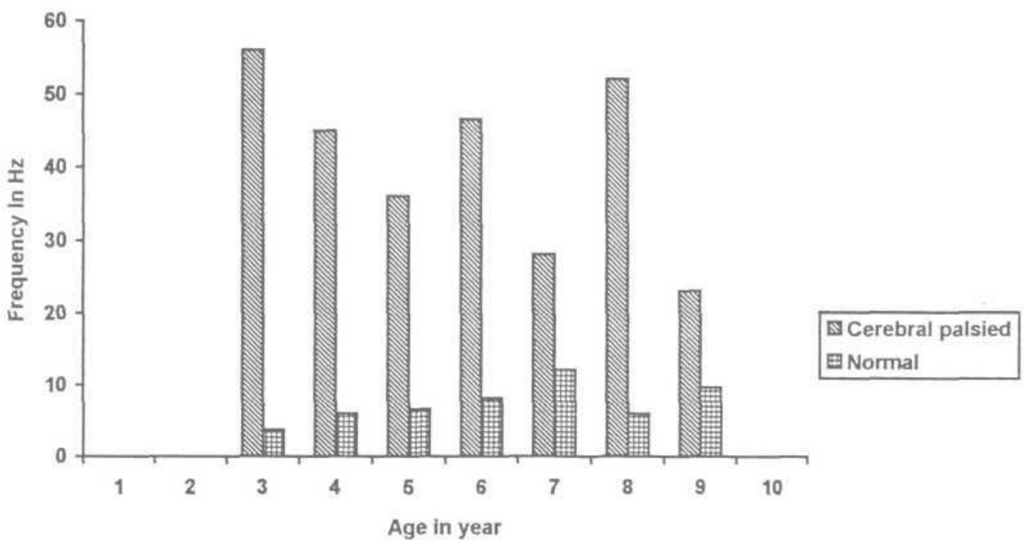
		SPASTIC DIPLEGIC			ATHETOID QUADRIPLEGIC			SPASTIC QUADRIPL,EGIC		
AGE IN YEAR	SEX	MEAN	S.D.	RANGE	MEAN	S.D.	RANGE	MEAN	S.D.	RANGE
3-4	Male	69.00	36.57	98.61	—	—	—	53.97	26.14	79.21
	Female	—	—	—	—	—	—	52.82	18.64	46.29
4-5	Male	68.34	26.88	81.11	-	-	-	-	-	
	Female	-	-	-	-	-	-	22.55	23.35	44.68
5-6	Male	—	-	-	—			31.94	20.54	52.17
	Female	42.86	14.92	31.66	-	-	-	-	-	-
6-7	Male	47.40	13.72	25.81	—	—	—	—	—	—
	Female	—	-	-	-	-	—	46.62	12.48	29.24
7-8	Male	35.43	11.90	23.76	—	—		—	—	—
	Female	—	—	—	-	-	—	21.26	14.91	32.62
8-9	Male	-	-	-	29.46	33.12	60.26	—	—	—
	Female	-	-	-	—	-	-	75.82	15.47	27.11
9-10	Male	-	-	-	19.60	3.88	7.47	-	-	—
	Female	11.97	12.30	37.35	-	-	—	-	-	-

(-) -> No Subjects for comparison

Table 8b : The mean, S.D, and range values of extent of fluctuation in frequency (in Hz) for phonation of vowels (a), (i) and (u), shown by males and female of spastic diplegic, athetoid quadriplegic and spastic quadriplegic group.



GraphVII : Mean value of intensity range in speech of normal and cerebral palsied groups.



GraphVIII : Mean value of the extent of fluctuation in frequency of phonation of normal and cerebral palsied group.

fluctuation in frequency were compared (U=0.0). Thus the null hypothesis stating that there is no significant difference between Cerebral palsied subjects and normal subjects (both males and females) in extent of fluctuation in frequency is rejected.

The difference was also statistically significant when the scores of subjects of normal group (both males and females) were compared to spastic diplegia (U=0.0), athetoid quadriplegic (U=0.001) and Spastic quadriplegia (U=0.0).

Thus the null hypothesis stating that there is no significant difference between spastic diplegia, athetoid quadriplegic and spastic quadriplegia when extent of fluctuation in frequency was compared to normal subjects is rejected.

Comparison of mean values of extent of fluctuation in frequency between spastic diplegia and athetoid quadriplegia (U=0.02) showed a statistically significant difference. Comparison of mean values between spastic diplegia and spastic quadriplegia and between athetoid quadriplegia and spastic quadriplegia showed absence of statistically significant difference between these groups, both in case of males as well as females.

So the null hypothesis stating that there is no difference between three types of Cerebral palsied group is partially accepted and partially rejected.

Rashmi (1985) reported the same results in extent of fluctuation in both male and female subjects. So the measurements made in the present study are valid.

The analysis of extent of fluctuation in frequency is helpful in differentiating the normal and dysphonics (Natraja, 1988 and Kim, 1982). There is no similar study in Cerebral palsied population to compare the data obtained here. However when compared to normal subjects of some age group, wide variability in the score in Cerebral palsied population is seen, indicating the lack of ability of the subject to control voice.

SPEED OF FLUCTUATION IN FREQUENCY OF PHONATION

This parameter has been considered as a gross measure of jitter (Nataraj, 1987). The analysis of speed of fluctuation in frequency of phonation has been found to be helpful in differential diagnosis of normal and dysphonics (Kim, 1982 and Natraja, 1988)

The mean, S.D. and range values of this parameter are shown in Tables 9a, 9b and Graph 9. 9a.

Study of Table 9a showed that the mean value of of fluctuation in frequency of phonation in normal

		NORMALS			CEREBRAL PALSIED		
AGE IN YEAR	SEX	MEAN	S.D.	RANGE	MEAN	S.D.	RANGE
3-4	Male	6.84	2.18	7.05	41.14	18.39	67.17
	Female	5.75	1.79	5.55	24.28	6.48	19.84
4-5	Male	3.35	1.18	3.35	52.15	11.73	27.78
	Female	5.00	1.74	5.00	18.97	6.65	12.86
5-6	Male	6.58	1.91	6.58	22.28	8.58	25.62
	Female	11.67	4.49	11.67	32.61	8.92	16.29
6-7	Male	7.39	2.02	7.39	34.53	11.90	23.76
	Female	4.73	1.95	4.73	28.26	10.82	18.66
7-8	Male	17.27	6.14	11.27	34.63	9.41	19.62
	Female	12.34	3.25	12.34	18.61	7 .02	13.16
8-9	Male	5.05	1.82	5.05	58.22	3.15	6.29
	Female	13.64	4.41	13.64	26.65	3.97	7.06
9-10	Male	15.97	5.35	15.97	40.27	15.79	31.55
	Female	25.25	7.63	25.25	38.62	10.86	23.29

Table 9a: The mean, SD, range values of speed of fluctuation (in fluc, /sce) for sustained phonation of (a), (i), (u) shown by males and females in the and normal Cerebral palsied group.

AGE IN YEAR	SEX	SPASTIC DIPLEGIC MEAN	SPASTIC DIPLEGIC S.D.	SPASTIC DIPLEGIC RANGE	ATHETOID QUADRIPLEGIC MEAN	ATHETOID QUADRIPLEGIC S.D.	ATHETOID QUADRIPLEGIC RANGE	SPASTIC QUADRIPLEGIC MEAN	SPASTIC QUADRIPLEGIC S.D.	SPASTIC QUADRIPLEGIC RANGE
3-4	Male	35.03	17.144	46.97	-	-	-	46.10	19.61	62.15
	Female	-	-	-	-	-	-	24.28	6.48	19.84
4-5	Male	41.31	19.61	54.04		-		-	-	-
	Female	-	-	-	-	-	-	18.97	6.65	12.86
5-6	Male	-	-	-	-	-	-	22.28	8.55	25.62
	Female	32.61	8.92	16.29	-	-	-	-	-	-
6-7	Male	34.53	11.90	23.76	-	-	-	-	-	-
	Female	-	-	-	-	-	-	28.26	10.86	18.66
7-8	Male	34.63	9.41	19.62	-			-	-	-
	Female	-	-	-	-	-	-	18.61	7.02	13.16
8-9	Male	-	-	-	58.22	3.15	6.29	-	-	-
	Female	-	-	-	-	-	-	26.65	3.97	7.06
9-10	Male	-	-	-	40.27	15.79	31.55	-	-	-
	Female	38.62	10.86	23.29	-	-	-	-	-	-

Table 9b : The mean, S.D, range values of speed of fluctuation in frequency in (in fluc. /sce) for sustained phonation of (a), (i), (u) shown by males and females in the specific dyplyic, athetoid guadriplyic and specific quadriplyic group.

females (11.20) were greater than males (8.87) across each age group S.D. values were greater in males were as range value was greater in females. Across the Cerebral palsied group mean values showed wide individual variability. The mean values of Cerebral palsied subjects were considerably greater than that seen in normal subjects. The S.D. and range values were also greater in Cerebral palsied group. The values of speed of fluctuation in frequency in females were higher than males in Cerebral palsied group.

On comparison of means of the scores obtained by males and females of normal group and Cerebral palsied group, a statistically significant difference was observed (U=0.0). Thus the null hypothesis stating that, there is no significant difference between Cerebral palsied subjects and normal subjects (males and females) in speed of fluctuation in frequency is rejected.

The difference was also statistically significant, when the scores of subjects of normal group were compared spastic diplegia (U=0.0), athetoid quadriplegia (U=0.0) and spastic quadriplegia (U=0.0).

Hence the null hypothesis stating that there is no significant difference between spastic diplegia, athetoid quadriplegia and spastic quadriplegia when speed of fluctuation of frequency in phonation was compared to normal subjects is rejected, in both males and females.

Statistically significant difference was not observed between spastic diplegia and athetoid quadriplegia (U=0.129), between athetoid quadriplegia and spastic quadriplegia (U=0.062) and between spastic diplegia and spastic quadriplegia.

So the null hypothesis stating that there is no significant difference between three types of Cerebral palsied groups is accepted.

Nataraja (1986) studied normal and dysphonics on several parameters of which speed of fluctuation in frequency of phonation was one. He reported that this parameter was able to differentiate normal and dysphonic in both males and females.

Result of the present study in terms of speed of fluctuation, both in normal males and females are in consonance with earlier reports (Rashmi, 1985). So the measurements made in present study are valid.

Review of literature on speed of fluctuation in frequency shows no study in Cerebral palsied population. When the Cerebral palsied subjects were compared to normal group of some age range a large difference is seen. This speed of fluctuation in frequency of phonation is found to be an important parameter in differentiating normal from Cerebral palsied group.

EXTENT OF FLUCTUATION IN INTENSITY OF PHONATION

The mean, S.D. and range value of extent of fluctuation in intensity for phonation of (a), (i) and (u) are shown in Tables 10a, 10b and Graph 10.

From the study of Table 10a, it was revealed, that the mean values of extent of fluctuation in intensity for phonation (a), (i) and (u) observed is females (3.52) were higher than that of males (3.47) of normal group. The S.D. values were higher for females.

Comparison of mean of scores obtained by members of Cerebral palsied group and normal group, it was seen that normal group had a lower mean values than the Cerebral palsied group. Statistically significant difference was seen between normal group and Cerebral palsied group across the different age group (U=0.0).

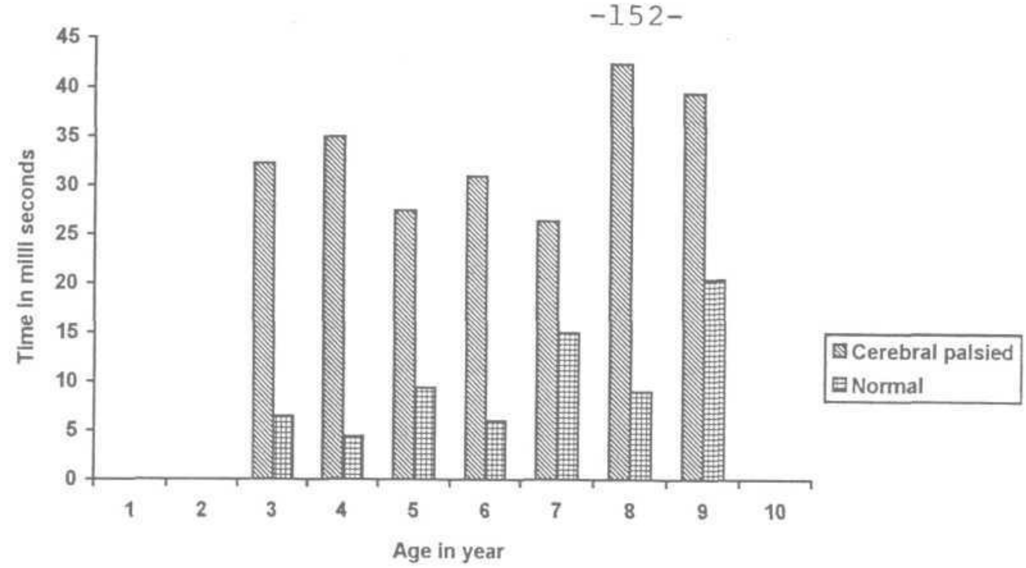
Hence the null hypothesis stating that there is no significant difference between Cerebral palsied subjects and normal subject, both males and females, in extent of fluctuation of intensity in phonation is rejected.

AGE IN YEAR	SEX	NORMALS MEAN	S.D.	RANGE	CEREBRAL PALSIED MEAN	S.D.	RANGE
3-4	Male	3.52	0.30	0.82	3.55	0.34	1.20
	Female	3.59	0.43	1.41	4.62	0.42	0.21
4-5	Male	3.68	0.47	1.35	3.61	0.24	0.49
	Female	3.48	0.57	1.47	3.97	0.63	1.23
5-6	Male	2.98	0.55	1.60	2.93	1.47	1.96
	Female	3.08	0.44	1.59	3.86	1.21	1.26
6-7	Male	3.09	1.87	6.30	3.62	0.40	0.79
	Female	3.16	0.89	2.92	3.28	0.64	1.23
7-8	Male	2.90	2.00	6.61	4.11	0.62	0.98
	Female	3.37	2.45.	6.96	4.24	0.49	0 .86
8-9	Male	1.52	1.37	3.21	3.92	9.16	0.18
	Female	3.66	0 .65	1.72	3.49	0 .34	0.6 3
9-10	Male	3.10	1.74	6.11	3.74	0.49	0.96
	Female	2.90	1.11	3.84	3.28	0.84	0.18

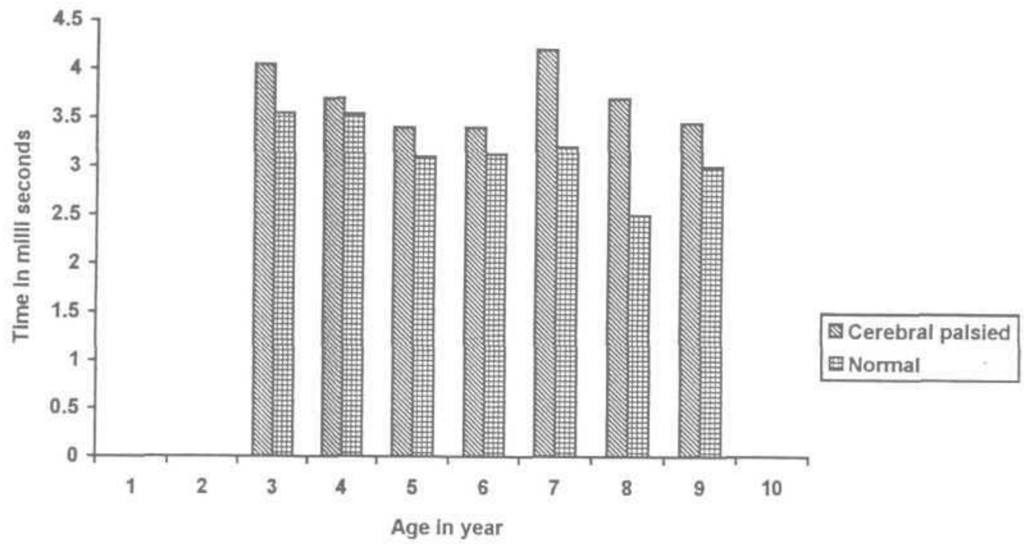
Table 10a: The Mean, S.D, & range values of extent of fluctuation in intensity in (in dB) for phonation of (a), (i) & (u) (shown by males and females in the normal and Cerebral palsied group.

AGE IN YEAR	SEX	SPASTIC DIPLEGIC MEAN	SPASTIC DIPLEGIC S.D.	SPASTIC DIPLEGIC RANGE	ATHETOID QUADRIPLEGIC MEAN	ATHETOID QUADRIPLEGIC S.D.	ATHETOID QUADRIPLEGIC RANGE	SPASTIC QUADRIPLEGIC MEAN	SPASTIC QUADRIPLEGIC S.D.	SPASTIC QUADRIPLEGIC RANGE
3-4	Male	3.59	0.39	1.08	—	—	—	3.53	0.34	1.0
	Female	—	—	—	—	—	—	4.62	0.42	0.21
4-5	Male	3.48	0.27	0.65	—	—	—	—	—	—
	Female	-	-	-	-	-	-	3.97	0.63	1.23
5-6	Male	—	—	—	—	—	—	2.93	1.47	3.96
	Female	3.86	1.21	1.26	-	-	-	-	-	-
6-7	Male	3.62	0.40	0.79		—	—	—	—	—
	Female	-	-	-	-	-	-	3.28	0.64	1.23
7-8	Male	4.11	0.62	0.98	—	—	—	—	—	—
	Female	—	—	—	—	—	—	4.24	0.49	0.86
8-9	Male	—	—	—	3.92	9.16	0.18	—	—	—
	Female	—	—	—	—	—	—	3.49	0.34	0.63
9-10	Male	—	—	—	3.74	0.49	0.96	—	—	—
	Female	3.28	0.84	0.18	-	-	-	-	-	-

Table 10b : The mean, S.D, & range values of extent of fluctuation in intensity in (in dB) for phonation of (a), (i), (u) shown by males and females in the specific dyplyic, athetoid guadriplyic and specific quadriplyic group.



Graph IX : Mean value of speed of fluctuation in frequency of phonation of normal and cerebral palsied groups.



Graph X : Mean value of extent of fluctuation in intensity of phonation of normal and cerebral palsied groups.

The difference were also statistically significant when normal subject were compared with spastic diplegia (U=0.02) athetoid quadriplegia (U=0.039) and spastic quadriplegia (U=0.042). Thus the null hypothesis stating that there is no significant difference between spastic diplegia, athetoid quadriplegia and spastic quadriplegia when extent of fluctuation of intensity in phonation were compared to normal is rejected in males as well as females.

Comparison of mean values of extent of fluctuation of intensity in phonation between spastic diplegia and athetoid quadriplegia (U=0.087) between spastic diplegia and athetoid quadriplegia (U=0.628) and between athetoid quadriplegia and spastic quadriplegia (U=0.087) showed the absence of statistically significant difference between these groups, both males and females.

So the null hypothesis stating that there is no significant difference between three types of Cerebral palsied in extent of fluctuation of intensity in phonation is accepted.

The results of earlier study (Rashmi, 1985) has shown similar results in normal males and females.

This parameter with a similar definition has not been studied in children and in Cerebral palsied palsied

The difference were also statistically significant when normal subject were compared with spastic diplegia (U=0.02) athetoid quadriplegia (U=0.039) and spastic quadriplegia (U=0.042). Thus the null hypothesis stating that there is no significant difference between spastic diplegia, athetoid quadriplegia and spastic quadriplegia when extent of fluctuation of intensity in phonation were compared to normal is rejected in males as well as females.

Comparison of mean values of extent of fluctuation of intensity in phonation between spastic diplegia and athetoid quadriplegia (U=0.087) between spastic diplegia and athetoid quadriplegia (U=0.628) and between athetoid quadriplegia and spastic quadriplegia (U=0.087) showed the absence of statistically significant difference between these groups, both males and females.

So the null hypothesis stating that there is no significant difference between three types of Cerebral palsied in extent of fluctuation of intensity in phonation is accepted.

The results of earlier study (Rashmi, 1985) has shown similar results in normal males and females.

This parameter with a similar definition has not been studied in children and in Cerebral palsied palsied population. Natraja (1986) found extent of fluctuation in intensity to be a valid parameter for differential diagnosis of dysphonias and for differentiating between normal and pathological cases. The present study also found extent of fluctuation in intensity as an important parameter differentiating between normal and Cerebral palsied groups. The present finding that extent of fluctuation in intensity was high in case of Cerebral palsied group reflect the inability of the individual to control voice production systems. Therefore it was considered that extent of fluctuation in intensity would be a useful measures in assessing voice.

SPEED OF FLUCTUATION IN INTENSITY OF PHONATION

The speed of fluctuation in intensity of phonation for three vowels (a), (i) and (u) was analyzed and the results are presented in the table 11a, 11b and graph 11.

It could be seen from the table lla that among the subjects of normal group, males has higher mean values (1.67) than females (1.39). The S.D. and range values were higher for females across each age group. Mean values of Cerebral palsied group showed greater variability across age groups.

On comparison of mean values of speed of fluctuation in intensity of phonation between normal group and

		NORMALS			CEREBRAL PALSIED		
AGE IN YEAR	SEX	MEAN	S.D.	RANGE	MEAN	S.D.	RANGE
3-4	Male	2.60	0.72	2.11	5.59	2.39	8.69
	Female	3.23	1.21	4.45	6.24	2.16	3.42
4-5	Male	2.11	0.45	1.28	4.98	2.70	6.08
	Female	1.91	0.93	1.63	3.38	1.15	2.27
5-6	Male	1.68	0.51	1.32	4.20	4.33	11.62
	Female	1.54	0.81	2 .28	5.28	1.28	2 .21
6-7	Male	1.59	0.74	1.95	7.42	1.49	2.97
	Female	1.13	1.08	2.59	6.99	2.86	6.08
7-8	Male	1.47	1.2 7	4.04	6.26	2.62	2.18
	Female	1.43	2.22	6.29	8.24	2.92	5.62
8-9	Male	0.69	0.59	1.56	11.43	1.97	3.69
	Female	2.03	0.77	2.53	1.72	0.67	1.33
9-10	Male	1.57	0.84	3.03	7.60	4.58	9.06
	Female	1.36	1.82	3.56	6.68	2.04	4.86

Table lla : The mean, S.D, range values of speed of fluctuation in intensity in (in fluc, /sce) shown by males and females in the normal and Cerebral palsied group.

AGE IN YEAR	SEX	SPASTIC DIPLEGIC MEAN	S.D.	RANGE	ATHETOID QUADRIPLEGIC MEAN	S.D.	RANGE	SPASTIC QUADRIPLEGIC MEAN	S.D.	RANGE
3-4	Male	6.11	3.27	8.69	—	—	—	5.59	1.94	5.93
	Female	-	—	—	-	-	-	6.24	2.16	3.42
4-5	Male	4.41	2.31	6.08	-	—	—	—	-	—
	Female	—	—	—	—	—	—	3.38	1.15	2.27
5-6	Male	-	—	—	-	—	-	4.19	4.34	11.62
	Female	5.28	1.28	2.21	—	—	—	—	—	—
6-7	Male	7.42	1.49	2.97	-	-	-	-	-	-
	Female	—	—	—	—	—	—	6.99	2.86	6.05
7-8	Male	6.26	2.62	2.18	-	-	-	-	-	-
	Female	—	—	—	—	—	—	8.24	2.92	5.62
8-9	Male	—	—	—	11.43	1.97	3.69	—	—	—
	Female	—	-	-	-	-	-	1.72	0.67	1.33
9-10	Male	—	—	—	7.60	4.58	9.06	—	—	—
	Female	6.68	2.04	4.86	-	—	—	—	—	-

Table l1b : The mean, S.D, range values of speed of fluctuation in intensity in (in fluc./sce) shown by males and females in specific dyplyic, athetoid guadriplyic and specific quadriplyic ceretral palsied groups.

Cerebral palsied group, it was seen that Cerebral palsied group has higher values, the S.D. and range values were also higher for Cerebral palsied group. Statistically significant difference was seen between these groups (U=0.0).

Thus the null hypothesis stating that there is no siginificant difference between Cerebral palsied subjects and normal subjects is speed of fluctuation in intensity in phonation is rejected, both with regard to males and females.

Statistically significant difference was seen when normal subjects were compared with spastic diplegia (U=0.0) athetoid quadriplegia (U.00) and spastic quadriplegia (U=0.0) Cerebral palsied subjects. so the null hypothesis stating that there is no significant difference between spastic diplegia, athetoid quadriplegia and spastic quadriplegia when speed of fluctuation in intensity in phonation were compared to normal is rejected.

When mean values of speed of fluctuation in intensity in phonation were compared between spastic diplegia and athetoid quadriplegia (U=0.029) and between athetoid quadriplegia and spastic quadriplegia (U=0.007), a statistically significant difference was observed. Statistically significant difference was not seen when mean values of spastic diplegia where compared with spastic quadriplegia Cerebral palsied subjects.

Hence the null hypothesis stating that there is no statistically significant difference between three types of Cerebral palsied subjects of both the sexes in speed of fluctuation in intensity in phonation is partly rejected and partly accepted.

The results of the present study in terms of speed of fluctuation in intensity in phonation. So the in normal males and females are in consonance with earlier reports (Rashmi, 1985; Nataraja, 1986; Tharmar, 1991). Therefore measurements made in the present study are valid.

No investigation with similar definition has been carried out to study variation in Cerebral palsied population. Natraja (1988) had carried out a study to differentiate normal and dysphonics. This parameter shows change with age indicating neuromuscular activity of the laryngeal system.

Comparison of Cerebral palsied population with normal group in the present study showed a higher value for Cerebral palsied group. This parameter shows control exercised by subject in his/her voice and thus helping in differentiating between normal and Cerebral palsied group.

RISE TIME IN PHONATION

The rise time in phonation for three vowels (a), (i) and (u) were analysed and the results are presented in Tables 12a, 12b and Graph 12.

From Table 12a, it was seen that mean values of rise time in phonation in Cerebral palsied subjects wre lower (71.37 msec) than that of normal subjects (99.17 msec). The S.D. and range values of Cerebral palsied subjects were greater than normal group. Greater individual variability was seen across age groups in Cerebral palsied subjects. A statistically significant difference was seen when Cerebral palsied subjects were compared to normal subjects to same age group (U=0.0). Thus the null hypothesis stating that there is no significant difference between Cerebral palsied subjects and normal subjects both males and females in rise time in phonation is rejected.

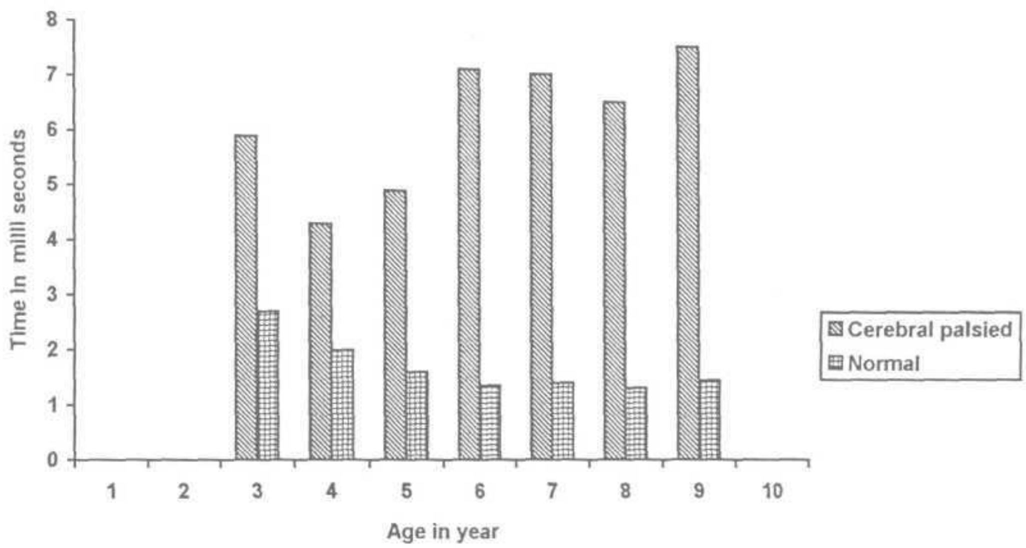
Statistically significant difference was also seen when scores of subjects of normal group were compared to spastic diplegic (U=0.0), athetoid quadriplegia (U=0.001) and spastic quadriplegia cerebral palsied group (U=0.0).

AGE IN YEAR	SEX	NORMALS MEAN	S.D.	RANGE	CEREBRAL PALSIED MEAN	S.D.	RANGE
3-4	Male	100.85	6.72	19.4	75.79	17.46	58.30
	Female	103.12	5.37	14.5	60.0	11.62	29.44
4-5	Male	95.58	9.80	25.2	75.0	13.64	33.40
	Female	90.98	6.35	17.4	74.34	1.13	1.97
5-6	Male	97.18	6.77	20.0	63.0	12.49	25.0
	Female	94.0	7.94	17.0	55.0	6.87	20.0
6-7	Male	97.09	4.85	15.0	90.0	13.22	25.0
	Female	98.7	2.05	5.0	66.67	18.24	23.69
7-8	Male	102.37	9.51	31.0	74.39	1.28	1.78
	Female	107.11	15.75	39.0	75.0	14.21	24.68
8-9	Male	103.51	4.35	10.0	66.67	14.43	25.0
	Female	96.47	8.14	28.7	74.23	1.33	2.30
9-10	Male	99.28	11.07	42.00	86.10	12.73	25.0
	Female	93.07	9.38	27.3	63.0	11.82	24.28

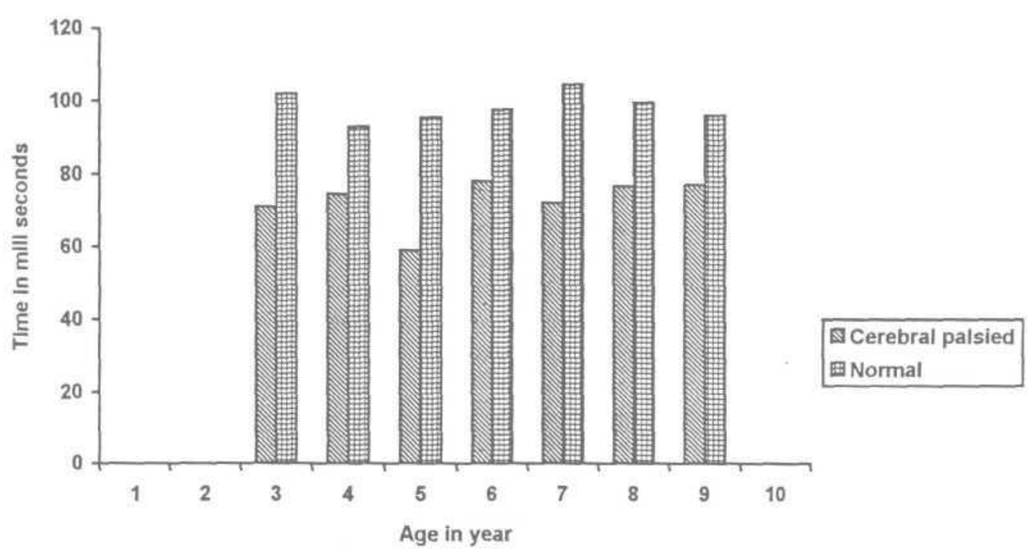
Table 12a : The mean, S.D, range values of speed of rese time in phonation in (in /sce) for inch (a), (i) & (u) shown by males and females in the normal and Cerebral palsied group.

AGE IN YEAR	SEX	SPASTIC DIPLEGIC MEAN	S.D.	RANGE	ATHETOID QUADRIPLEGIC MEAN	S.D.	RANGE	SPASTIC QUADRIPLEGIC MEAN	S.D.	RANGE
3-4	Male	77.39	19.66	58.3	-	-	-	72.92	16.71	50.0
	Female	-	-	-	-	-	-	60.0	11.62	29.44
4-5	Male	83.33	16.68	41.70	-	-	-	-	-	-
	Female	-	-	-	-	-	-	74.34	1.13	1.97
5-6	Male	-	-	-	-	-	-	63.0	12.49	25.0
	Female	94.0	7.94	17.0	-	-	-	-	-	-
6-7	Male	90.0	13.22	25.0	-		-			
	Female					-		66.67	18.24	23.69
7-8	Male	102.37	9.51	31.0	-	-	-	-	-	-
	Female	-	-	-	-	-	-	75.0	14.21	24.68
8-9	Male	-	-	-	66.67	14.43	25.09	-	-	-
	Female	-	-	-	-	-	-	74.23	1.33	2.30
9-10	Male	-	-	-	86.10	12.73	25.0	-	-	-
	Female	63.0	11.82	24.28	-	-	-	-	-	-

Table 12b : The mean, S.D, range values of rese time in phonation in (in /sce) for inch (a), (i) & (u) shown by males and females in specific dyplyic, athetoid guadriplyic and specific quadriplyic ceretral palsied groups.



Graph XI : Mean value of speed of fluctuation in intensity of phonation of normal and cerebral palsied groups.



Graph XII : Mean value of Rise time in phonation of normal and cerebral palsied groups.

So the null hypothesis stating that there is no significant difference between spastic diplegia, athetoid quadriplegia and spastic quadriplegia when rise time is phonation were compared to normal subjects is rejected.

Comparison of mean values of rise time in phonation between spastic diplegic and athetoid quadriplegic (U=0.648) and between athetoid quadriplegic and spastic quadriplegic (U=0.213) showed no significant difference comparison of mean values of spastic diplegic and spastic quadriplegic Cerebral palsied subjects showed statistically significant difference (U=0.028).

Hence the null hypothesis stating that there is no significant difference between three types of Cerebral palsied group both males and females in rise time in phonation is partly accepted and partly rejected.

Earlier investigation in normal male and female subjects (Rashmi, 1985; Tharmar, 1991) has reported the same results. So the measurements made in the present study are valid.

Review of literature on rise time is phonation shows no study in Cerebral palsied population. When scores were compared to normal population of same age group, Cerebral palsied subjects showed a lesser value. This may indicate the abrupt onset of phonation and inability to sustain phonation as is seen in Cerebral palsied population.

FALL TIME IN PHONATION

The mean, S.D. and range values of fall time in phonation for vowels (a), (i) and (u) are represented in Tables 13a, 13b and Graph 13.

Table 13a clearly shows that females of normal group had higher mean values in fall time in phonation across age groups. On comparison of Cerebral palsied group to normal group it was found that Cerebral palsied group had a lower mean values (74.57 msec) than normal group (93.85 msec). The S.D. and range values were more in Cerebral palsied group and greater variability of scores across age groups can be seen.

Significant difference was seen when mean values of fall time in phonation of Cerebral palsied subjects were compared with normal group (U=0.0) so the null hypothesis stating that there is no significant difference between Cerebral palsied subjects and normal subjects (both males and females) in fall time in phonation is rejected.

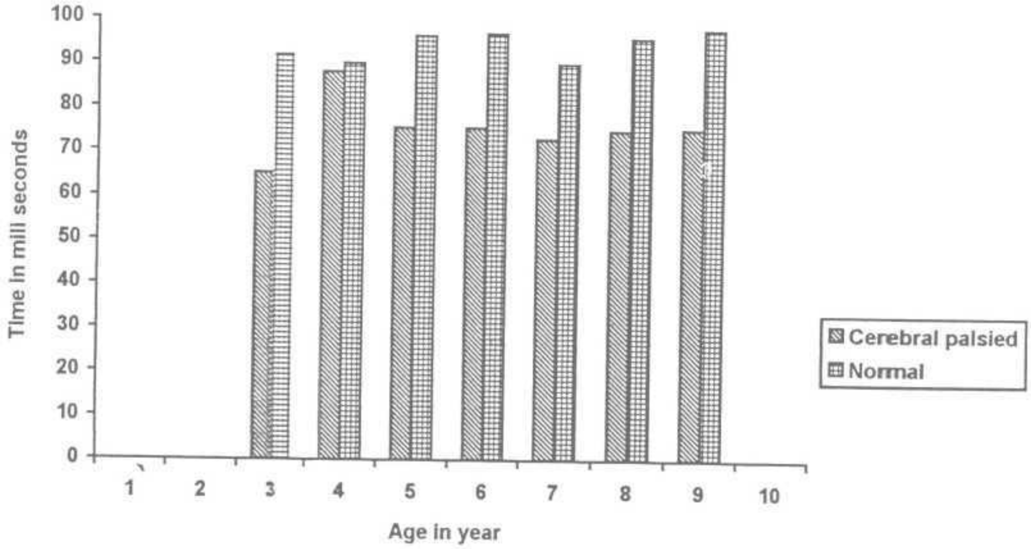
Statistically significant difference was seen when scores of subjects of normal group (both males and females) were compared to spastic diplegia (U=0.0) spastic quadriplegia (U=0.0) and athetoid quadriplegia (U=0.002) Cerebral palsied group.

		NORMALS			CEREBRAL PALSIED		
AGE IN YEAR	SEX	MEAN	S.D.	RANGE	MEAN	S.D.	RANGE
3-4	Male	86.79	31.73	28.10	70.24	13.06	50.00
	Female	96.94	4.85	14.40	60.84	12.86	23.28
4-5	Male	88.82	9.36	25.0	77.08	4.15	8.3
	Female	92.38	7.86	25.0	83.3	14.43	25.0
5-6	Male	95.90	9.97	28.3	76.28	3.41	7.70
	Female	97.59	11.36	33.3	75.0	3.96	1.84
6-7	Male	90.83	7.35	20.1	80.57	17.33	33.30
	Female	94.18	9.09	29.1	75.78	18.24	25.0
7-8	Male	97.84	8.76	28.0	66.7	19.28	27.64
	Female	82.50	40.47	10.0	78.26	4.92	8.54
8-9	Male	100.39	4.58	16.33	83.33	14.43	25.0
	Female	92.52	6.97	17.00	75.00	0.00	0.00
9-10	Male	94.48	8.76 .	27.70	58.33	14.43	25.00
	Female	102.69	12.02	35.20	83.3	18.64	29.28

Table 13a : The mean, S.D, range values of fall time in phonation (in m sce) shown by males and females in the normal and Cerebral palsied group.

AGE IN YEAR	SEX	SPASTIC DIPLEGIC MEAN	S.D.	RANGE	ATHETOID QUADRIPLEGIC MEAN	S.D.	RANGE	SPASTIC QUADRIPLEGIC MEAN	S.D.	RANGE
3-4	Male	71.42	17.25	50.0	-	-	-	68.75	11.31	25.0
	Female	-	-	-	-	-	-	60.84	12.86	23.28
4-5	Male	79.16	11.48	33.3	-	-	-	-		-
	Female	-	-	-	-	-	-	72.31	2.68	2.34
5-6	Male	-	-	-	-		-	76.28	3.14	7.70
	Female	75.0	3.96	9.84	-	-	-	-	-	-
6-7	Male	80.57	17.33	33.30	-	-	-	-	-	-
	Female	-	-	-	-	-	-	75.78	18.24	25.0
7-8	Male	66.7	19.28	22.64	-	-	-	-	-	-
	Female	-	-	-	-	-	-	78.26	4.92	8.54
8-9	Male	-	-	-	83.33	14.3	25.0	-	-	-
	Female	-	-	-	-	-	-	75.0	0.00	0.00
9-10	Male	-	-	-	58.33	14.43	25.00	-	-	-
	Female	102.69	12.02	35.20	-	-	-	-	-	-

Table 13b : The mean, S.D, range values of fall time in phonation (in m sce) shown by males and females in specific dyplyic, athetoid guadriplyic and athetoid quadriplyic cerebral palsied groups.



Graph XIII : Mean value of fall time in phonation of normal and cerebral palsied groups.

Hence the null hypothesis stating that there is no significant difference between spastic diplegic, athetoid quadriplegia and spastic quadriplegia when fall time in phonation was compared to normal subjects is rejected.

Comparison of mean values of fall time in phonation between spastic diplegic and athetoid quadriplegic (U=0.672), between spastic diplegic and spastic quadriplegic (U=0.972) and between athetoid quadriplegic and spastic quadriplegic (U=0.593) Cerebral palsied group showed no significant difference.

Hence the null hypothesis stating that there is no significant difference between three types of Cerebral palsied sujects in fall time in phonation is accepted.

Results of earlier studies on fall time in phonation (Rashmi, 1985; Tharmar, 1991) has shown the same results. So the measurements made in the present study are valid.

Review of literature on fall time in phonation shows no study in Cerebral palsied population. Hence the present study cannot be compared with others. However when compared to normal population, Cerebral palsied group showed a lesser value in fall time in phonation. so in the present study it was found that fall time in phonation is an important parameter in differentiating Cerebral palsied subjects from normal subjects.

Thus the findings of the present study indicated that, the following parameters like maximum duration of phonation, speaking fundamental frequency, frequency range in phonation and speech, intensity range in phonatino and speec, intensity range in phonation and speech, extent and speed of fluctuation in frequency and intensity rise time and full time in phonation will help in differentiating cerebral palsied children from normals.

SUMMARY AND CONCLUSION

Speech is a complex activity involving various muscles of respiration, phonation, articulation and resonation. The end product of this neuromuscular activity is an acoustic signal is speech. Voice is considered as multidimensional series of measurable events. Many have suggested various means of analyzing voice to note the factors that are responsible for creating an impression of a particular voice and to determine the underlying mechanism (Micheal and Wondahl, 1971; Jayaram 1975; Hanson and Laver 1981; Herano 1981; Kelness, 1981; Perkins, 1971; Emerick and Hattress, 1979).

The objective of the present study was to find out phonatory abilities of cerebral palsied children of both sexes across age groups (3-10 years).

In the present study the following thirteen parameters which were earlier recommended by investigators. (Herano, 1981; Michel and Wendahl, 1971; Imaizumi et al. 1980; Kim et al. 1982, Natraj, 1986:) were considered to find out the possibilities of differentiating cerebral palsied subjects from normal population.

1. The maximum phonation duration of vowels.
2. The fundamental frequency of phonation.
3. The speaking fundamental frequency.
4. Speech of fluctuation in frequency of phonation.
5. Extent of fluctuation in frequency of phonation
6. Frequency range in phonation
7. Frequency range in speech
8. Speed of fluctation in intensity of phonation
9. Extent of fluctuation in intensity of phonation.
10. Intensity range in phonation
11. Intensity range in speech
12. Rise time in phonation
13. Fall time in phonation

All the 13 parameters were measured in a group of 57 subjects: 42 normal subjects (21 males and 21 females) and 15 Cerebral palsied subjects (8 male and 7 female) consisting of 7 spastic quadriplegic (2 males and 5 females) 6 spastic diplegic (4 males and 2 females) and 2 athetoid quadriplegics (2 males) ranging in severity from mild to moderate.

Data on maximum duration (a), (i) and (u) along with repetition of three malayalam sentences "0:nam Vannu", "Oru ila" and "it eli a :n " were recorded.

The duration of vowels were measured using a stop watch, the longest of which was considered as the maximum phonation duration.

These samples were digitized by using ADC and fed to computer (PC-with 100 MHz pentium processor. INTON programme (VSS, Bangalore) in Vaghmi Software package was used to extract the parameters.

The results obtained were subjected to statistical analysis to determine the mean, S.D, range and significant of difference using the computer program SPSS for Windows (Version 6) Mann-whitney "U" test was applied to know the significance of differences.

Analysis of the results of both normal and Cerebral palsied group using SPSS programme indicated that the following twelve paramters differentiated Cerebral palsied from normal.

1. Maximum duration of phonation
2. Speaking fundamental frequency
3. Speed of fluctuation in frequency of phonation
4. Extent of fluctuation in frequency of phonation
5. Speed of fluctuation in intensity of phonation
6. Extent of fluctuation in intensity of phonation
7. Frequency range in phonation

8. Intensity range in phonation
9. Frequency range in speech
10. Intensity range in speech
11. Rise time in phonation
12. Fall time in phoantion.

CONCLUSION :

1. 12 parameters out of 13 studied were useful in differentiating between normal and Cerebral palsied group.
2. Normal and Cerebral palsied voice can be defined in terms of these parameters.
3. Across three types of Cerebral palsied subjects ie. spastic diplegia, spastic quadriplegia and athetoid quadriplegic large inter subject variability is seen.

RECOMMENDATION

1. Investigations involving more subjects of different types of cerebral palsies.

2. Investigations considering other parameters of voice, speech(segmental and supra segmental).

3. Attempt to use the present findings in providing therapy to cerebral palsy are recommended.

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APPENDIX-A

DEFINITIONS

1. **Maximum Phonation Duration (MPD):** Maximum phonation duration has been defined as the maximum duration for which an individual can sustain phonation.

2. **Fundamental Frequency in Phonation (PFF):** It is defined as the mean frequency of the steady portion of phonation as displayed on the pitch analyser.

3. **Fundamental Frequency in Speech (SFF):** Fundamental frequency in speech is defined as the mean frequency of speech stimuli displayed.

4. **Extent of fluctuation in fundamental frequency in phonation (PFx):** It is defined as the means of fluctuations in fundamental frequency in a phonation of one second.

   Fluctuation in frequency was defined as variation +/- and beyond in fundamental frequency.

5. **Speed of fluctuation in fundamental frequency in phonation (PFS):** The speed of fluctuation in frequency is defined as the number of fluctuations in fundamental frequency in fundamental frequency in a phonation of one second.

6. Extent of fluctuation in intensity in phonation (PIX): The extent of fluctuation in intensity was defined as the mean of fluctuations in intensity in a phonation of one second.

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

7. Speed of fluctuation in intensity in phonation (PIS): The speed of fluctuation in intensity was defined as the number of fluctuations in intensity in a phonation of one second.

8. Frequency range in phonation (PFR): The frequency range in phonation was defined as the difference between the maximum and minimum fundamental frequency in phonation.

9. Intensity range in phonation (PIR): The intensity range in phonation was defined as the difference between maximum and minimum intensities in phonation.

10. Frequency range in speech (SFR): The frequency range in speech was defined as the difference between the maximum and minimum fundamental frequency in speech.

11. Intensity range in speech (SIR): The intensity range in speech was defined as the difference between the maximum and minimum intensities in speech.

12. Rising time in phonation (PRT): The rising time in phonation was defined as the time required for an increase in intensity from 0 dB to the beginning of the steady level of the intensity in the initial portion of the phonation.

13. Falling time in phonation (PFT): The falling time in phonation was defined as the time required for the intensity to decrease from the steady level to 0 dB in the final portion of the phonation.