ACOUSTIC ANALYSIS OF INFANT CRY

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DEDICATED TO

MY PARENTS, HUSBAND & IN LAWS

CERTIFICATE

This is to certify that the dissertation entitled **"ACOUSTIC ANALYSIS OF INFANT CRY"** is the bonafide work in part fulfillment for the degree of Master of Science (Speech and Hearing) of the student with **Register No. M9817.**

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This is to certify that this dissertation entitled: **"Acoustic Analysis of Infant** Cry", has been prepared, under my supervision and guidance.

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DECLARATION

This dissertation entitled **"ACOUSTIC ANALYSIS OF INFANT CRY",** is the result of my own study under the guidance of **Dr. N.P.Nataraja,** Professor and Head of the 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.

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INTRODUCTION

'Random', 'non expressive' and 'diffuse' and similar terms have been used to describe the utterances of babies (Gesell 1940, Osgood 1953; Spitz 1963). Crying is a behaviour, in fact, it is a sequence of behaviour patterns that is part of the larger behavioural repertoire of the infant which is the primary mode of expressing and communicating basic needs and events for the neonate and young infant, It is a social behaviour that has powerful effects on the parent-infant relationship, and it elicits strong emotions in parents. Crying is the beginning of vocalization and may have implications for the development of speech and language. In human vocalization and also in human vocalization and also in crying the entitled sound is a combination of a function of the brain, the larynx and the oral cavity (Espir and Rose, 1970; Perkins, 1971).

The general answer to why one should analyse infant cry, is one which according to Liberman (1971)is that the, ". . . . biological substrate of human speech involves an interplay between biological mechanism that have other vegetative functions and neural and anatomical mechanism that appear to have evolved primarily for their role in facilitating human communication".

 It is important to emphasize that crying is not just a reflection of only physiological state of infant. The cry is also an acoustical event that not only affects care givers but also contains information about the functioning of the infant's nervous system. Increasingly, a number of researchers are beginning to view crying and its perception as an interpersonal event (Boudkydis 1995). That is crying is considered as a social event and as a system of communication it may serve as a preverbal distress signal.

For clinical purpose, crying and other vocalisation are signals which can be used to evaluate neuro respiratory and phonatory functions of infants. It is this reason that there has been so much interest in cries of high risk new born with history of high risk factors.

Unusual cry is caused by some disturbances (or) abnormality some where in this complex chain of events. This disruption could be due to faulty neural control of respiration (or) phonation as might be produced in cri-du-Chat syndrome, Down syndrome (or) damage to recurrent laryngeal nerve etc. (or) it could be produced by some disarrangement in the airway itself. Reforming sophisticated analysis of the unusual cries (specifically acoustic analysis) it would be possible to detect and locate site of this disturbance. This is one of the real clinical purpose in pursuing infant cry analysis. That is, it is possible to differentially diagnose the difference between subglottal, periglottal and supraglottal sites of disturbances as well as detect the differences between airway and/or nervous system as the origin of abnormality. This is diagnostic significance of acoustic analysis of infant cries and vocalizations (Gopal and Gerber 1991). Cry analysis can thus be diagnostic and prognostic criterion of disease in neonatal period. Early diagnosis is very important because treatment when started early enough diminishes later defects (Maenpaa 1972). The objective techniques for analyzing infant cries are by volume unit graph (Fisichelli, Karelitz, Eichbar and Rosenfield, 1961) and computer analysis (Ostwald and Feltzman 1974). A number of investigators have employed acoustic analysis of various sorts of both normal and abnormal infants. For example, for over 30 years several Finish and Swedish researchers have used sound spectrograph and conducted systematic acoustic analysis of cries. They have provided large amount of acoustical data on cries of normal infant. This vast body of research has provided much of justification and inspiration for using acoustic analysis of cries as an additional

diagnostic tool in clinical paediatrics. Thus it can be concluded,that based on previous literature there is a need to differentiate between normal and abnormal infants.

The purpose of the present study is to analyse cries of normal and abnormal infants by both objective and subjective methods, objectively (Cry analysis using acoustic parameters extracted from MDVP) and also subjectively, 5 professionals and 5 mothers selected for perceptual analysis.

Brief plan of **the** study.

1. Administration of a list of high risk factors and collection of information from parents of normal and abnormal infants with history of high risk factors.

2. Collection of data from the infants (pain cries to be elicited from infants by flicking sole of infant's foot with index finger till they cry for atleast 30 seconds and to record the cries.

3. Analysis of recorded sample of cries to extract various parameters using multidimensional voice profile software

4. Perceptual analysis of recorded samples by professionals and mothers to identified normal and abnormal cries and relating them to acoustic parameters.

Need **and implication for the present study:**

-> Acoustic analysis of infant cry using multidimensional voice program is totally a non-invasive technique. Most other techniques employed in the diagnosis of sick babies are invasive (ex. endoscopy, blood test etc.). The process of administering some of these invasive tests and techniques themselves carry

varying amount of risk to the infant. Invasive techniques require waiting until infant is of appropriate age to some tests. However, with recording and analysis of birth cries, the moment of birth itself offers data for an evaluation of infant.

-> It will help to differentiate between normal and abnormal infants.

-> Infant cry analysis is a valuable tool in differential diagnosis of different abnormalities of infants.

-> Using for early identification of abnormalities and thus in early rehabilitation (or) treatment.

Sub-hypothesis:

-> No significance difference exist on various parameters derived using multidimensional voice programme between cries of normal infants and infants with history of septicema.

-> No significance difference exist on various parameters derived using multidimensional voice programme between cries of normal infants and infants with history of Jaundice.

-> No significance difference exist on various parameters derived using multidimensional voice programme between cries of normal infants and infants with history of birth asphyxia.

-> No significance difference exist on various parameters derived using multidimensional voice programme between cries of normal infants and infants with history of prematurity.

-> No significance difference exist on various parameters derived using multidimensional voice programme between cries of normal infants and infants with history of septic arthritis.

-> No significance difference exist on various parameters derived using multidimensional voice programme between cries of normal infants and infants with history of neonatal convulsions.

-> No significance difference exist on various parameters derived using multidimensional voice programme between cries of normal infants and infants with caessarian delivery with history of low birth weight, foetal distress and pregnancy induced hyper tension.

Limitations:

1. A small number of infants were included in each high risk category.

2. Equal number of samples (normals and abnormals) have not be obtained.

3. Among the abnormals, number of various abnormalities were not uniform.

4. All kinds of abnormalities could not be studied.

Thus acoustic analysis by MDVP is a powerful objective technique. Applying such powerful technique to infant cries and vocalization may hold a lot of promise in understanding infant cries of both normal and high risk infants. It is also economical and less time consuming compared to other techniques.

REVIEW OF LITERATURE

"Crying is one of the first way in which the infant is able to communicate with the world at large" (Ostwald and Petzmar, 1974). Crying is a behaviour, in fact, it is a sequence of behaviour patterns that is part of the larger behavioural repertoire of the infant and for the neonate and young infant, crying is the primary mode of expressing and communicating basic needs and events. It is a social behaviour that has powerful effects on the parents infant relationship, and it elicits strong emotions in parents. The cry is also an acoustical event that not only affects care givers but also contains information about the functioning of the infants nervous system. As a form of communication, crying is the beginning of vocalization and may have implications for the development of speech and language.

The function of the birth cry is said to be entirely physiological, having to do with establishment of normal respiration and the oxygenation of the blood. The first cry is said to have other physiological purposes, such as to remove foreign material (Reto), to improve pulmonary capacity in the first days of life (Tang and Hull, 1961), a defence mechanism to increase body temperature (Watson and Laurey, 1951).

According to Karelitz (1969), the cry probably starts with a startle reaction created by the first breath. "During infancy the child's only mode of communication is cry. The importance of early identification of problem and abnormalities in childhood is increased because of the concept of "critical period" (Lennerberg 1976).

Becker (1976) states that in addition to being desirable for child's development, early detection also helps parents to adjust more realistically to the

child's problem. As it would make rehabilitation economical, attempts have been made for early diagnosis of various problems. The implementation of "High Risk Register" and "infant screening programs" have made early identification possible.

"Screening" as accepted by world health organization is defined as the "the presumptive recognition of unrecognized disease or defects by the application of tests, examinations and other procedures which can be applied rapidly" (Roberts 1977). They are not intended to be diagnostic.

Any child who has a history (or) by its physical appearance suggests an abnormality is at risk and such a child is considered as a High Risk Infant. There are a list of conditions that place the infant at risk (Davis, 1978). There are a number of High Risk Programs like the National Joint Committee (NJC) on early identification, the Utah State infant H.R. hearing programme. The Colorado Infant Program, etc. In India, a high risk register for hearing loss in children was developed by Ashok, (1981). Questions have been included to collect information regarding the following factors:

1. Family history of hearing loss.

2. Consanguinous parentage, primarily involving uncle-niece marriages.

3. History of rashes, fever during pregnancy irrespective of the trimester.

4. Report of Rh blood group incompatibility.

5. Parental concern about their child's hearing.

APGAR Score is a scaling system developed to assess the condition of the children based on child's behaviour. The APGAR score is designed to determine

the physical condition or viability of the new born (60 seconds after birth) and it has established that there is a strong association between low scores and neonatal mortality.

Scoring method in evaluation condition of new born infant.

Sign	Score		
	0	1	2
1. Heart rate	Absent	Slow (100)	100
2. Respiratory effort	Absent	Weak cry hypoventilation	Good strong cry
3. Muscle tone	Limp	Well	
4. Reflex irritability (response to skin stimulation to feet)	No Response	Same motion	Cry
5. Colour	Blue Pale	Body Pink extremities blue	Completely Pink

Two of five parts of APGAR SCORE are concerned with crying. The segment on respiration is a response to environment stimulation i.e., change in the environment stimulates. When there is no crying it is scored zero. When it is a fair cry, it is scored one and when it is a good strong cry, it scored two. The second sign (reflex irritability) lists 'cry' in general.

According to Karelitz (1960) it is possible to identify the age of an infant by listening to the cry of that infant. Further he also states that it would be possible to use this process of identifying age, based on cry abnormalities in the child. Studies by Karelitz and Fisichelli (1962, 1963) show that there is difference in the latency and threshold of cries of normal and infants with brain damage.

With the development of the sound spectrograph by Porter et al. In 1940's objective analysis of cry sounds has become possible. Since then, many researchers have been doing studies on cry characteristics of normal and abnormal infants. The first cry in the infant is said to be very important. To achieve this, the infant takes the air into the lungs (or) inhalation takes place, which leads to the first cry. A delay in the cry would lead to the lack of oxygen in the body and thus the infant becomes blue. Blue infants are considered to be the high risk infants, showing a history of brain damage.

Crying is the result of the intense expulsion of air through tightened vocal cords into the pharynx and mouth as a resonating chamber. The character of the cry depends upon the intensity of air expulsion, the tension in the vocal cords and the shape and fixation of the resonating chamber. It reflects the capacity of the nervous system, to be activated and also the ability of the nervous system to inhibit or modulate this activation.

Bosma et al., (1965) suggest that neurological maturity is reflected in stability of laryngeal coordinations and the degree of mobility of vocal tract elements during crying. The source filter theory of speech production provides a theoretical basis for inferring the effects of these vocal apparatus on the infant's cry. According to this theory, the power of the speech sound spectrum (p) at a frequency (F) is the product of two approximately independently controlled factors, the source spectrum (s) and the transfer function (T), that is

$$P(f) = S(F) \times T(F)$$

As the neurological mechanism controlling the vocal apparatus mature, there is increased postural control of the vocal cords and the vocal tract, and as a result decreased variability in the functioning of these organs. Since there is

greater variability of vocal apparatus for premature than full term infants, it is hypothesized that the cry spectra of premature infants shows greater variability of (a) Fundamental frequency and (b) of formants than those of full term neonates. Thus one might say that a good cry is one that is obtained with a moderate amount of stimulation, has a duration proportional to the degree of stimulation but is readily terminated by central inhibition, and has some variability in total quality, implying lack of rigidity in the neurologic controlling mechanism. Therefore, detailed knowledge of the characteristic of crying sounds in various conditions may be expected to give considerable information about the nervous system (Parmlee, 1962).

PHYSIO ACOUSTIC MODEL:

The infant cry is the result of the complex interaction between many anatomic structures and physiologic mechanisms. These interactions involve the CNS, respiratory system, peripheral nervous system and a variety of muscles. A new approach model of infant cry production and a computer - based signal processing system that enable the observer to relate closely the acoustic properties of the cry to the infant producing the cry.

A simplified view of the cry production model was given by Golub (1979). The model divides cry production into four parts. The first part is the subglottal system that is responsible for developing the pressure below the glottis is necessary for driving the vocal fold. The second part is the sound source located at the larynx. The second source may be described mathematically, in the frequency domain, as either a periodic source or a turbulence noise source. These sources may operate alone, or more frequently, simultaneously. Both acoustic sources originate at the vocal folds. The periodic source results from the vibration of the folds. The turbulence noise is most likely produced by the turbulence created by

forcing air through a small opening left by the incomplete closure of the vocal folds. The third source of cry production is the vocal and nasal tracts located above the larynx. This part of the cry production system is an acoustic filter that has a transfer function whose characteristics change vvitli the shape and length of the vocal and nasal tracts and the degree of nasal coupling. The fourth part of the cry production system is the radiation characteristic that describes the filtering of the sound between the mouth of the infant and the microphone located some distance away.

The model assumes that muscle control is accomplished within three levels of central nervous system processing, i.e., upper, middle and lower processors. The upper processor is involved in choosing and modulating the state of action of the child. During the neonatal period, this higher processor may be relatively immature, and "conscious" control infrequent. As a result, at this stage of maturation, many activities occur in a "reflex like" manner.

It is assumed that all vegetative states such as swallowing, coughing, respiration, bowel movements and crying are within the middle processor. The stimuli that helps the upper processor to choose the appropriate vegetative state includes hunger, pain, hypoxemia, or hypercapnia and a full bladder. The neonatal cry is very much like other actions present at birth that are stimulated by survival pressures. The causes of crying are less complex for newborns than those for older infants. As the nervous system matures and the child's environment becomes more complicated, the cry may no longer be assumed to be "reflex like" but may often be the result of volitional activity.

Each of the three muscle groups upper, middle and lower processors important for cry production are controlled independently. Consequently, the parameters that each are responsible for are likely to vary independently.

Secondly, if one can pinpoint differences in the cry as caused by subglottal (respiratory), glottal (laryngeal) or supraglottal malfunctions, then one will be able to correlate the acoustic abnormality with specific physiological and anatomical abnormalities.

In summary, the mathematical formulation of the acoustic theory of speech production of Fant (1960) can be applied to infant cry production. Output = Source X Filter. Thus, it is apparent that there are basically two components to the model of cry production: an acoustical component that specifies how sound is generated at the larynx and in the airways above the larynx and a physiological component that specifies how the configuration and movements of the respiratory, laryngeal and supralaryngeal structures are controlled.

Acoustic component of the model:

Truby and Lind (1965) have described three cry types: Phonation = basic, cry hyperphonation = shift, and dysphonation = turbulence.

In phonation, the vocal folds vibrate fully at an Fo range of approximately 250-700 Hz. Hyperphonation results from a 'falsetto' like vibration pattern of the vocal folds with an Fo range of about 1000-2000 Hz. Finally, dysphonation contains both a periodic and aperiodic sound source and occurs when turbulence noise is generated at the glottis. These three modes of vibration can occur during the expiratory cry.

For a vocal tract length of about 8 cm. (Goldstein 1980) and for a roughly uniform vocal tract cross sectional area, acoustic theory predicts that formants occur at about 1100 Hz or 3300 Hz. If there is substantial velopharyngeal opening, then theoretical analysis predicts an additional spectral peak in the frequency range

of 2-3 KHz. If the pharyngeal region is narrowed, then acoustic theory predicts an upward shift of the formants. The fundamental frequency of vocal fold vibration and indeed the mode of operation of the vocal folds depend upon the subglottal pressure and the adjustment of the intrinsic laryngeal musculature. Increased subglottal pressure would be expected to result in a higher Fo. However Fo may also be influenced by contraction of the cricothyroid muscle (Vanden Berg, 1965).

Physiological Component of the Model

The physiological component of the model is based on the hypothesis that newborns tend to control the tension in their muscles in a continuous fashion.

The distinction between constant tension and constant control should be made, especially when describing the action of the larger muscle systems (e.g., respiratory system). For example, evidence from measurement made on the acoustics and subglottal pressure during the cry (Truby and Lind, 1965) indicates that the tensions of the larger respiratory muscles do indeed change somewhat continuously during the expiratory phase. In the case of these larger muscles, the continuous, relatively slow tension changes probably occur due to peripheral state changes of the muscles rather than continuous variation in the control of these muscles. The most important of these state changes can be described by the length-tension-loading aspects of the particular muscles of the system. The resulting muscle tensions are not only a function of higher level control, which is probably quantal in nature, but also of the particular length-tension-loading characteristics of the muscle at the onset of the control. The smaller laryngeal muscles have smaller peripheral state changes, and the tensions developed would not be expected to vary considerably during the course of any particular kind of phonation.

It is clear that the acoustical features one measures will vary with the particular mode of sound production. Meaningful cry analysis requires an assessment of what the mode of sound production was at the time of recording.

In summary, the model of cry production can provide guidance for the selection of the acoustical features that are most likely to reflect the anatomy and physiology of the infant accurately.

FACTORS THAT INFLUENCE CRY PRODUCTION:

Infant cry is a product of the respiratory and phonatory system whose output has been shown to have high degree of variability with regard to pitch and intensity. The respiratory system, which is undergoing rapid maturational changes, accounts for much of the variability. The breathing rate of an infant varies as a function of age, health, general activity varies as a function of age, health, general activity and the presence of vocalization. Initially as Fiscichelli et al., (1966) pointed out that there was inspiratory voicing in the neonatal cry. This inspiratory sound often makes it difficult to identify an expiratory cycle. As the infant matures, these vocalized cry becomes expiratory. By age of 1 year, infants acquire the quick inspiratory and long expiratory phases of respiration associated with adult speech and breathing. Shortly after birth, the infant adds to the abdominal movement of early cry by involving the thorax. After six months rib cage movements and the activity of the coastal cartilages allow for deeper breathing, leading to the reduced rates of ventilation.

Cry behaviour varies according to the cry evoking events or stimuli. The birth cry which is unique sequence of vocal beha\iors made within minutes after birth, may be partially pain related as well as hunger and environmentally related. Thus the birth cry is primarily a response to the infant's external stimulus.

Following the birth cry, the infant cries for several possible reasons: pain, hunger, discomfort (or) startle (shock). Early work by Sherman (1927) also considered anger and fear, however these states are difficult to verify.

Most of the literature describes pain and hunger cries as the two cry types used in the study of infant cry behaviour. A third type, startle cry, has been used in several recent investigations. Pain cry is considered as cry from suddenly inflicting a painful stimulus to the infant. Muller, Hollien and Murry (1974) stung the base of the foot with a rubber band. Others have recorded the cry coincident with taking a blood sample. Still others have used a pin prick on the heel of the foot to elicit the pain cry.

The hunger cry is usually defined as the cry produced by with holding food from the infant at the normal feeding time. In some instances, feeding is begun and then stopped, resulting in what is operationally defined as a hunger cry. The startle cry has been elicited in a number of ways, from a loud clap near the infant's head to suddenly dropping the child towards a table top.

In 1963, Warz Hockert, Valanne, Vuoren Koski, Michelsson and Sovijarvi (1963) reported on the acoustic patterns of birth, pain and hunger cries using sound spectrography. They described the rising or falling patterns in the birth cry but only qualitative differences between the pain and hunger cries. Sedlackova (1964) noted the birth cry to be a high frequency signal. Murry, Amundson and Hollien (1977) systematically examined the frequency characteristics of pain, hunger and startle cries of 4 male and 4 female infants. For all three types of cries the males produced a higher mean Fo than females. The cries were not only differentiated on the basis of sex but also according to cry type. Pain cries resulted in the highest Fo, followed by the hunger cry; the startle cries had the lowest mean Fo. However, the difference in Fo were not statistically significant and each infant

had a large standard deviation for at least one cry type. The consistent finding of higher Fo in males for all cry types varies. A trend reported by Sheppard and Lane (1968); that male infants have a higher Fo than females and also speculation by Hollien (1980) that male voice fundamental frequency is higher than the female voice during first 6 years.

The notion of cry as a meaningful mode of communication stems from early perceptual studies of infant vocalizations. In 1927, Sherman attempted to elicit distinctive emotional responses from neonates using four stimuli; restraint of the head, pricking with a needle, with holding feeding and suddenly dropping towards a table top. She found that both trained subjects (nurses, medical students and graduate psychology students) and untrained observers (college Freshman) were unable to match correctly the emotional responses with the cry evoking stimuli.

Wasz-Hockert, Partanen, Vuorenkoski, Valanne and Michelsson (1964) tested the notion that different types of infant vocalizations are perceptually distinguishable. Recordings of vocalizations 'typical' to the situations of birth, pain, hunger and pleasure were obtained from normal neonates. Eighty nurses, who were trained in the care of crying children, listened to the randomized cry recordings and were able to identify the type of vocalization 67% of the time. In a follow up study, Wasz-Hockert et al. (1964) used the same experimental method to examine the effect of training or the ability of the listener to identify the cry evoking stimulus. They found that the trained listeners were able to identify the types of cry - evoking stimuli better than the untrained listeners.

Muller et al (1974) reported on the perceptual responses of mothers to the cries of their children. In a carefully controlled experimental protocol, they elicited three types of cries i.e., pain, hunger and startle from four male and four female infants with age ranging from three to five months. All the children were

healthy and the samples were obtained in a quiet environment. After all recordings were made, first and third 15 second segments of each of the 24 recordings (eight infants by three stimulus condition) were extracted, randomized, and presented to two group of listeners. Group A consisted of the mothers of eight infants recorded in the study. They were asked to indicate on their answer sheets whether the stimuli that originally evoked the cry were of pain (P) hunger (h) (or) startle (S), and whether or not the sample was from their infant. Group B consisted of ten mothers of children whose ages were comparable with the infants recorded in the study but who had not previous contact with eight subjects. The results Indicated that, some of the hunger cry samples were correctly identified as hunger cries, a significant number of times by both groups of listeners and a number of other samples also were, incorrectly, identified as hunger cries, a significant percentage of time. Therefore it must be concluded that mothers incorrectly perceived an excessive number of samples as hunger cries and that those hunger samples that were correctly identified merely reflect this general bias. These results were similar for the samples of mothers judging only their own infant cries. Normal infants carry little perceptual information to the mother with respect to the cry evoking stimulation (Murry Hoit Dalgaard and Gracco 1983). It might be hypothesized, therefore that within the normal situation, the cry generally acts simply to alert the mother and that any of her suppositions concerning the situation that evoked the cry behaviour must be based upon additional cues from the environment (or) the context of the situation.

In further studies Murry, Hollien and Muller (1975) it was observed that mothers recognized their own children simply on the basis of a 15 second cry, despite the fact that they could not recognize the cry type. When it came to judging the sex of cries, mothers had difficulties with this task, except when judging their own children. After acoustically analyzing the cries, the investigators

(Murry et al., 1977) concluded that the perceptual cues relating the fundamental frequency and vocal tract that they utilized in judging the sex of adult voices are not evident in the voices of infants. Moreover, the finding of higher Fo values in males from infants to age 6 would be expected to lead judges to erroneous conclusions about sex, because Fo is so extensively used in perceptual judgement of speaker's sex (Sing, Murry, 1978).

TECHNICAL AND METHODOLOGICAL CONSIDERATIONS - STUDIES OF INFANT CRY:

Infant cry can be considered interms of its signal and sign properties. As signal, the sound is a complex wave form, requiring sophisticated acoustical devices for analysis. To avoid the problem of signal/noise interactions, the recording of crying is done at its source, that is, the infant's mouth. This approach skirts the perceptual issue, namely, what is the sound when it reaches the listener ? Ignoring the element of time, it's possible to describe certain features associated with the intrusive, alerting quality of these recorded sounds, specifically their intensity (83-85 dB) and the prominence of octave harmonics (Ostwald, 1972). Sound spectrography has the advantage of preserving the temporal configuration. This method also gives a fairly reliable "picture" of certain events that cannot be described by listeners.

Spectrography represents a most important technical innovation. However, when large samples have to be analyzed, spectrography becomes an overly time consuming procedure, and there is also some loss of accuracy in the temporal realm resulting from discontinuities between adjacent sonograms. For this reason, Poulter (1968) has used a continuous spectrography (a Rayscan apparatus designed at the Stanford Research Institute in Menlo Park, California). In one study, when it was necessary to process many cries produced by crainopagus twins, Peltznan et

al. (1970) have relied on computer averaged spectra to compare the two babies. Several cry studies using high speed digital computation have appeared since then (Lester and Zeskind, 1982, Tenold, Crowell, Jones. Daniel, McPherson, and Popper, 1974).

In terms of data collection, crucial decisions have to be made about the sign properties of infant sounds, under conditions of continuous bedside monitoring (Vuorenkoski, Lind, Wasz-Hockert, and Partanen, 1971). If spontaneous vocalizations are to be included in the analysis, it becomes difficult to know when to label a sound a cry as distinct from a noncry. And how is one to define the conditions causing a cry ? Gastric intubation (to measure contractile events presumably related to hunger), skin electrodes (to measure EEG or EMG correlates), and other required instruments tend to be seen as invasive and restrictive method. Today they are often unacceptable in terms of the ethics of human experimentation. To inflict pain deliberately is another objectionable technique, especially when the subjects cannot give informed consent. Efforts have been made to minimize these objections by recording the cries produced by so called routine procedures for example, blood sampling or circumcision. But such stimuli tend to be excessive and can produce exaggerated vocal responses. Also, the presence of ancillary personnel - lab technicians, nurses and the like -in the recording area adds unwanted noise and makes for a less than ideal experimental environment. In studies usually three cry types appear to emerge with a definable construct -birth cry, pain cry and hunger cry. Although the hunger cry may actually embody other cry characteristics such as distress, discomfort, and irritability, feeding tends to eliminate the cry behaviour and may therefore be operationally defined the hunger cry.

TECHNIQUES OF CRY ANALYSIS:

The infant cry has interested researchers of different disciplines for a long time and several methods have been utilized for cry analysis. Cry studies of infants have been done by auditory analysis, with musical notes, phonetic transcription, volume unit graphs and analysis by using electrolaryngograph, spectrograph and computer analysis.

AUDITORY ANALYSIS

The most readily available means for cry analysis is the human ear. Over years, various technological advances have increased our ability to assess the infant cry by listening. One of the first reports of the acoustic structure of infant cries was published in 1838 by William Gardiner. He described the cry calls of both humans and animals by means of musical signs. According to Gardiner, the tones of infant crying generally are between the notes of A & E in the middle of the piano key board. The initial expiratory component is usually the most prominent feature of the cry; it lasts about a second on an average and has an up and down melodic patterns. The inspiratory component of the cry is much shorter.

Flatau and Gutzmann (1906) used a graphophone to record infant vocalizations. They listened to the cry recordings of 30 neonates and noted three infants with higher pitched phonations. In 1936, Lewis used the international phonetic Alphabet (IPA) for the first time in an attempt to describe infant vocalizations. Fairbanks (19420 listened to gramophone records to study the frequency characteristics of the "hunger wails' of one infant over a period of 9 months.

Wasz-Hockert, Partanen, Vuoren Koski, Valanne (1964) have found tape recordings that hunger, pain, pleasure and birth cries can be identified auditorily. Valanne et al. (1967) found that mothers can recognize the vocalizations of their own infants. This finding was supported by the work of Formby (1967). Massengill (1968) found that speech clinicians were not able to recognize grade of nasality (or) type of crying of infants with cleft palate.

Partanen, Wasz-Hockert, Vuorenkoski, Theorell, Valanne and Lind (1967) demonstrated that the pain cries of healthy infants could be differentiated from cries of sick babies with one of the following diagnosis: Neonatal asphyxia neonatal brain damage, neonatal hyperbilirubinaemia and down's syndrome. It was shown that after a training period of approximately two hours, 82 pediatricians could diagnose normal and pathological cries very accurately and differently diagnose specific pathology, some what less accurately.

Hollien, Muller, Murry (1974) studied the ability of 18 mothers to perceptually differentiate cry samples elicited by 3 different stimulus conditions - Hunger, pain, and auditory stimulation. In some instances, the mothers were evaluating cries produced by infants with whom they were unfamiliar and in other cases they judged cries produced by their own infants. Results indicated that 18 mothers were unable to successfully match the cry samples with three cry evoking situations. The investigators hypothesize that within normal home situation, the cry generally acts simply to alert the mother and that any of her suppositions concerning the situation that evoked the crying behaviour must be based upon additional environmental cues.

Murry, Amundson and Hollien (1977) noticed that an infant's sex could be reliably identified on auditory basis. Auditory differences between the crying of sick infants and healthy ones have often been recognized by pediatricians.

Partanen et al. (1967) found that audible differences were recognizable when the cries of healthy newborn infants and those which asphyxia-brain damage, Jaundice/Down's syndrome were compared by 45 pediatricians.

It is clear that auditory analysis provides only a fraction of information contained in the cry signal, that more sophisticated techniques might give more significant diagnostic information.

TIME DOMAIN ANALYSIS:

Time domain information is obtained from devices that graph sound magnitude versus time on a paper strip chart. Fisichelli and Karelitz (1963), Fischelli, Karelitz, Eichbauer and Rosenfeld (1961) and Karelitz and Fisichelli (1962) used such a device to examine infant cries. They found that infants with diffuse brain damage require a greater stimulus to produce 1 minute of crying (1962) and that the mean latency period between pain stimulus and onset of crying was significantly longer for abnormal infants (2.6 sec) compared to healthy infants (1.6 sec) (1963).

A direct writing oscillogroph was a time domain device used by Lind, Wasz-Hockert, Vuoren Koski and Valanne (1965) to study the time course of the durations and latencies of different kinds of crying. They found that the initial phonation of a cry records were more irregular than those that appeared once the infant was fully aroused. After this arousal, a gradual reduction in time and intensity of the cry units occurs until the baby stopped crying.

Wolff (1967, 1969) measured in sanitary as well as expiratory phonation. His data also indicated that in pain produced cries, the cry units (one expiratory phonation) were longer in the beginning of the cry record than at the end. This

technique has the advantage of being relatively easy to operate and it is inexpensive, reliable and easy to inspect visually. However there are also many problems with this method of analysis. Signal distortion may occur, due to pen inertia and paper speed variations that results in poor frequency response. Manual measurement of features is open to human error and is rather a tedious process. Finally, the magnitude information shown is, in reality, an average measurement over a short time interval. This interval is fixed in writing of the apparatus is thus inflexible and liable to lose important information.

FREQUENCY DOMAIN ANALYSIS:

Devices performing frequency domain analysis allow one to obtain in coarse representation of the frequency spectrum characteristics of a sound. They utilize a bank of band pass filters. These filters allow only input of a specified frequency range, measure the average magnitude in that range and give a visual display of the relative magnitude. One can then compare the relative magnitude of a series of frequency ranges. The band pass filters are either one third or one half of an octave in width.

Ostwald, Freedman, and Kurtz (1962) used the half octave band analyzing the samples of cries of 32 twins. They determined that the variability in pitch measurements and temporal characteristics between the cries of twins could be explained by differences in 'weight, size, physical development and vigor of the children recorded". Ostwald et al. concluded that it was the "other factors" that determined the characteristics of the cries and that heredity did not play a major role. Later, Ostwald (1963) used half octave analysis to analyze the cry of a normal neonate and found the fundamental frequency to be between 425 and 600 Hz. As implied by the name, these devices only give information about the relative magnitude of various frequency ranges. They do not give timing information. In

addition, the band pass filters use a relatively large and inflexible bandwidth. **This** makes the frequency information obtained of limited value. However, as illustrated by the work of Ostwald, some useful information is obtained with this method of sound analysis.

4. SPECTROGRAPHIC ANALYSIS

The sound spectrograph produces a permanent visual record showing the distribution of energy in both frequency and time. It was originally developed at Bell Laboratories in the late 1940s. Its main goal was to aid the deaf by presenting a visual display of speech. It didn't achieve this goal because of the complexity of the speech signal as well as the limitations of the spectrograph itself. However, since it was presented in 1946, it has been a very useful and important device in many areas of signal processing. These areas include adult speech, animal and bird sounds, music and infant cries.

Over the past 20 years, most studies of the infant cry have utilized the sound spectrogram. Scandinavian research headed by Wasz-Hockert and Lind (1981) has particularly advanced the understanding of infant cry. They have defined spectrographically based cry parameters that can be grouped into two general categories: durational features and fundamental frequency features. A short description of these spectrographic features are as follows:

a) **Durational features:**

1) Latency period: The time between the pain stimulus applied to the child and the onset of cry sound. The onset of crying was defined as the first phonation lasting more than 0.5 seconds.

2) Duration: This feature is a measure of the time from the onset of the cry to the end of the signal and consists of the total vocalizations occurring during a single inspiration (or) expiration. The boundaries were determined by the point on the spectrogram where sound "seems" to end.

3) Second pause: The time interval between the **end** of the signal and the following inspiration.

b) Fundamental Frequency Features:

*** Maximum pitch:** The highest measurable point of the fundamental frequency seen on the spectrogram.

* **Minimum pitch:** The lowest measurable point in the Fo contour seen on the spectrogram.

* **Pitch of Shift:** Frequency after a rapid increase in the Fo seen on the spectrogram.

* **Glottal roll/vocal fry:** Unperiodic phonation of the vocal folds usually occurring at the end of an expiratory phonation when the signal becomes very weak and Fo becomes very low.

* **Vibrato:** Defined to occur when there are at least four rapid up and down movements of Fo.

* **Melody type:** Either falling, rising/falling, rising falling/rising or flat.

* **Continuity:** A measure of whether cry was entirely voiced, partly voiced, (or) voice less.

* **Double harmonic break:** A simultaneous parallel series of harmonics in between the harmonics of the fundamental frequency.

* **Biphonation:** An apparent double series of harmonics of two fundamental frequencies. Unlike double harmonic break, these two series seem to be independent of each other.

* **Gliding:** A very rapid up and down movement of Fo, usually of short duration.

* Noise **concentration:** High energy peak at 2000 - 2300 Hz, found both in voiced and voiceless signals, this attribute is clearly audible.

* **Furcation:** Term used to denote a 'split' in Fo where a relatively strong cry signal suddenly breaks into a series of weaker ones, each one of which has its own Fo contour. It is seen mainly in pathological cries.

* **Glottal plosives:** Sudden release of pressure at vocal folds producing an impulsive expiratory sound.

Many investigators have examined the correlation between abnormal ranges of spectrographically obtained cry features and particular medical problems.

Spectrographic studies were carried out for infants with oropharyngeal anomalies (Lind et al. 1965; Massengill 1968; Michelsson 1975); asphyxia neonatorum. (Michelsson 1971; Michelsson et al. (1977; Wasz-Hockert, Lind, Vuorenkoski, Partanen, V. Valanne, 1968), symptomless low birth weight (Michelsson, 1971); herpes encephalitis and congenital hypothyroidism (Michelsson, Sirvio, 1975, 1976); hyperbilirubinaemia (Wasz-Hockert et al., 1971), malnourished infants (Lester 1976); genetic defects (Fisichelli, Coxe, Rosenfeld, Haber, Davis, Karelitz, 1966; Lind, 1965; Lind et al., 1970;

Vourenkoski et al., 1966; Wasz-Hockert et al. 1968); Sudden infant death syndrome (Colton, Steinschneider, 1981; Stark and Nathanson, 1972); and mixed syndromes (Ostwald, Phibbs and Fox, 1968; Wasz-Hockert et al., 1968).

Obviously, the spectrogram has been a useful tool for the advancement of understanding infant cry analysis. It is relatively inexpensive and is a good way to "visualize" acoustic signals. However, it has several limitations. First there are physical limitations of the analysis. The spectrogram has a poor dynamic range and often inadequate frequency resolution. In addition, the spectrogram requires visual inspection of the output for interpretation. Extracting acoustical information spectrographically is a long and tedious process that requires much expertise. As a result, it's not possible to analyse a large sample of cries quickly and accurately.

5. COMPUTER BASED SIGNAL PROCESSING:

Computer analysis allows more accurate determination of the acoustical information and extractions of information that are otherwise unobtainable.

The analysis procedure consists of five major steps:

1) Recording of the cry
2) Obtaining the parameters of fundamental frequency, formants and amplitude Vs. time.
3) Sampling the complex Fo contours in order to facilitate the development of Fo features.
4) Developing a number of features from the parameters and samples by procedures that include averaging within cry modes and calculation of probability of being in any mode and any point in the cry.
5) Conglomerating relevant features into a set of "diagnostic tests".

The requirements for the tape recording system include a relatively flat (3dB 100-5000 Hz) frequency response, a dynamic range of 40 to 45 dB, and a signal to noise ratio of approximately 20 to 25 Hz.

The recordings are processed to obtain the parameters of amplitude, fundamental frequency and format frequencies. Regions in which the three laryngeal modes (phonation, hyperphonation and dysphonation) occur are marked as well as the occurrence of glottal stops and phonation on inspiration.

From the amplitude contours, formant tracks, and fundamental frequency contours, features are extracted at appropriate times in order to allow reconstruction of the contour or track with a minimum of lost information. Timing and amplitude data are obtained from each of the first eight cry units and detailed formant frequency and Fo data are extracted from first two cries in each sequence. These features specify certain attributes of the Fo contour for phonation, for hyperphonation, certain attributes of the formant contours and classification of phonation types in each cry. The final analysis stage utilizes 88 features to determine the outcome of specific cry types. This stage essentially entails the conglomeration of those features that best represent the specific test of interest. One can then assess each feature individually (or) group of features into appropriate type. Grouping of feature into type is based on model of cry production.

A computer based signal processing system is utilized for all data extraction. This system allows complete analysis of a cry in 5 to 10 minutes and is entirely automatic. The computer is able to control the tape recorder, so that one can merely insert a tape, tell the computer what time to start the analysis and then return later to examine the results.

CRY IN HEALTHY FULL TERM INFANTS

Analysis of pain cries from more that 300 healthy new born infants was analyzed by Michelsson, 1971; Wasz-Hockert et al., 1963, 1964, 1968). Study done by Thoden, Koivisto (1980) deals with a prospective analysis of cries of 38 infants from birth to 6 months of age and analyzed the first, second, third phonation after the pain stimulus. In all pain cry studies done, the mean maximum pitch of fundamental frequency without shift has been about 650 Hz and the mean minimum pitch about 400 Hz. In 80% of the samples, the pain cry had a falling or rising/falling melody type with a stable pitch and a duration of approximately 2.5 sec. Shifts with a higher pitch occurred roughly in every third cry. The mean maximum pitch of shift was about 1200 Hz. The mean maximum pitch of shift was about 1200 Hz. The mean maximum pitch of the whole cry was 800 Hz when the maximum pitch had been measured from highest part of either the main fundamental frequency or the shift. The signals were voiced and continuous in about two-thirds of the cries. The occurrence of glottal roll was quite common, mainly at the end of phonations. Vibrato occasionally proceeded the glottal roll part. Biphonation, glide, furcation and noise concentrations were extremely rare in normal infant cries (Michelsson 1971; Thoden and Koivisto 1980; Wasz-Hockert et al. (1968).

Thoden and Koivisto (1980) did a study on cries of 38 children. They found that the three first cry signals after the pinch did not differ much from each other. There was no significant difference in the maximum and minimum pitches of the fundamental frequency in the three signals analyzed. Shifts were, however, seen more often in the first cry signal, even if the difference were not statistically significant. Because of more frequent occurrence of shifts, the maximum pitch, including shift was some what higher in the first cry signal. The second and third

signals were significantly shorter and more often continuous than the first signal. Glottal roll and vibrato were more common in the first signal. The variation in the durational features in normal newborn infants is quite large. According to different investigators the latency period was from 0.6 to 3.6 seconds. This variation was attributed to measuring techniques and the infants wakefulness. But it may also be due to the fact that the latency period was not quite uniform in healthy neonates. The first latency was often longer than the latency of immediately repeated stimulation. Various reports have given different duration of phonation depending on the analyzing techniques used. The average is reported from 1.1 to 2.8 sees. (Sirvio and Michelsson, 1976).

According to Karelitz, Fisichelli (1969), when the rubber band snap was used as a means of stimulation to elicit the pain cry, there was a startle reaction followed by a period of breath holding. The arms and hands are extended, the facial expression is that of fright and loud burst of cry is followed by several bursts which are similar to the first. As the child continues to cry, the bursts tapers off to a stop. In the case of an older child, they might also sob for some time. Sobbing is not observed in severely brain damaged infants.

Birth, hunger and pleasure cries were analyzed by Wasz Hockert et al. (1968). hi 148 hunger cries, the mean maximum pitch was 550 Hz. and mean minimum pitch 390 Hz. The shift occurred in only 2% of the cries. The melody type was falling or rising/falling in 80%. Glottal roll occurred in 24%. In 77 first birth cries, the mean maximum pitch was 550 Hz. and mean minimum pitch 450 Hz. Shifts occurred in 18%. The cries were of shorter duration, mean 1.1. sec. Pleasure cries had a mean maximum pitch of 650 Hz and mean minimum pitch of 360 hz; shifts were seen in 19% glottal roll in 26%, flat signals were more common, occurring 46% of time.

Thoden and Koivisto (1980) made a prospective study of cries of infants at 1 and 5 days of age and at 3 and 6 months. The only significant differences in the first cry signals at age 1 day, 5 days, 3 months and 6 months were that the signals were less often continuous at age of 3 months and

that vibrato was less common at the age of 6 months. Results indicate that there are few changes in cry characteristics from one day of life up to the age of six months. The results showed, however, there were differences in cry characteristics, depending on whether/not one had analyzed first, second or third signal after the pain stimulus. The first signal was longer, more often interrupted and ended more often in glottal roll than second and third signals. The maximum pitch of shift and maximum pitch of cry signal when compared to third one at ages of 1 and 5 days. According to these differences, the number of cries in a cry sequence should be stated in cry analysis. In second and third cry signals, there were no significant differences in these cry characteristics.

CRY IN VARIOUS CONDITIONS AND DISEASES

When a child is sick and cry changes from normal to abnormal, it can be caused by disturbances in the larynx or in the oral cavity. It can however also reflect the function of the brain as the neural impulses to the larynx originate in the brain. Parmlee (1962) states that "crying reflects the capacity of the nervous system to be activated and also the ability of the nervous system of inhibit or modulate this activation. The difference in the ability and different nervous system to respond could be in the peripheral sensory receptors, but it seems more likely that the differences are in the more complex activating systems of the brain.

In order to evaluate the cry changes in various diseases in newborn and small infants, systematic studies have been done using the sound spectrographic

cry characteristics in infants with high risk factor. It has been found that it is not only the pitch but also other cry characteristics that change when child is sick and these changes are especially common in diseases in which the central system is affected.

CRY IN NEW BORN LOW BIRTH WEIGHT INFANTS:

Michelsson (1971) analyzed samples of 105 symptomless low birth weight infants. Results showed that there was no difference in the cry of low birth weight infants and 50 healthy full term infants. The mean of maximum fundamental frequency in the infants with low birth weight was 640 Hz. The premature infants were divided into 2 groups. Those born at 35-37 gestational weeks and those born at 34 gestational week or earlier. Results showed that the younger infants cried with a higher pitch. The fundamental frequency was highest in the youngest prematures with a mean of maximum pitch being 1360 Hz and a mean of minimum pitch being 570 Hz. The dominating melody type on all premature infants was falling or, rising/falling similar to the controls. Biphonation and gliding occurred in the cries of prematured in 5-14% of the time. No significant changes were seen in the continuity and voicing of signals and also in the occurrence of double harmonic break or in the second pause. As the premature infants grew older, their cry became similar to that of a healthy child born at full term.

Ternold et al. (1974) found a median fundamental frequency of 752 Hz for 5 premature infants and 518 Hz for 9 full term infants. Lester and Zeskind (1978) found that the cries of full term but underweight infant had a shorter duration (2.0 sec) and a higher fundamental frequency (740 Hz) than babies of normal birth weight (4.9 secs and 467 Hz. respectively).

CRY IN NEWBORN INFANTS WITH ASPHYXIA:

Michelsson (1971) collected cries from 250 asphyxiated infants during the first 3 days of life. All infants were born with APGAR score of 7 or less. These children were divided into groups depending on whether the child suffered from respiratory distress (Peripheral asphyxia) or had neurological symptoms in the new born period (central asphyxia). The cry characteristics were compared to the crying of 50 healthy fill-term and 75 premature infants, depending on whether the neonate with asphyxia was full term premature. In both, gestational age groups, cry was abnormal in 125 children with central asphyxia and in 80 children with peripheral asphyxia. The cry was, however different in both groups. The mean maximum pitch including shift was 1460 Hz. in full term neonates with central asphyxia, 1000 Hz in peripheral asphyxia and 650 Hz in controls (Michelsson and Wasz-Hockert, 1980). Prematures with central asphyxia had a mean maximum pitch of 1950 Hz. including shift, the mean in peripheral asphyxia was 1610 Hz. and in symptomless prematures, 1520 Hz. Michelsson 91971) showed that biphonation occurred more than 20% glide in more than 10% of the samples of infants with asphyxia. Rising and falling/rising types of melody occurred in more than 30% of the signals. These changes in the cry characteristics were more marked, the more severely the newborn had suffered from asphyxia.

Michelsson (1971) found that if the cries became normal in few days after asphyxia the child was more likely to recover without neurological sequelae than if the cry characteristics remained abnormal during the hospitalization period. The prognostic value of cry analysis in asphyxia was confirmed in a follow up study by Michelsson et al (1977). The results showed that infants who at later check up were found to be neurologically damaged had more abnormal cries in the newborn period.

Syutkina, Michelsson and Sirvio (1982) from an animal studies experientially confirmed that asphyxia produced changes in the sounds produced. The study analyzed the utterances of wistar rats in which asphyxia was experimentally caused by clamping the umbilical cord 2 to 4 days before birth. Antenatal hypoxia was found to produce a significant increase in maximum pitch and decrease in duration of phonations. The mean maximum pitch was 4140 Hz in 61 pain induced utterances of asphyxiated rats and 2890 Hz in 34 utterance of control rats.

CRY IN CLEFT PALATE INFANTS:

Messengill (1969) investigated to determine whether the speech clinicians who worked with cleft palate children could differentiate between cleft palate and cleft lip babies from the recordings of their cries. He also investigated to see if there was significant correlation between lengtli of cry and the judged nasality of the cry. 30 infants in the age range of 1-24 months were taken. The results indicated that judges were not able to find any differences in nasality between the cries of babies with cleft palate only, with cleft lip only and babies with both. Correlation between length of the cry point and judged nasality of the cry; and the age of the child and nasality of the cry were not statistically significant. Generally, the longer cries were from the older children.

Sound spectographic analysis of infants with cleft palate was reported by Michelsson et al (1975); 52 cries from 13 infants with cleft palate were analyzed. When compared to cries of healthy neonates of the same age, no differences were observed with respect to fundamental frequency. The mean maximum pitch was 710 Hz, the mean minimum pitch was 360 Hz. The melody type was falling or rising/falling in 88% of the cry samples, glide occurred in 10% of cleft palate infants. Biphonation was not seen. Several cry characteristics connected with disturbance of CNS were not seen in the cries of cleft palate infants. In studies by

Raes et al (1980), Raes, Michelsson, Dehacn, and Despontin (1982) these results were confirmed.

CRY IN INFANTS WITH HEARING IMPAIRMENT:

Collins (1954) in a symposium on the deaf child, has reported that deaf babies coo and gurgle in a normal fashion and that from 9 to 18 months they appear to be developing speech, saying 'mumum', 'data' but that no further progress in speech is then made. Tape-recordings of infants of congenitally deaf parents and of normal parents showed no difference. The vocalization and crying were identical and were regarded as developmental.

A comparative study of prelinguistic vocalization of deaf and normal hearing was done using spectrographic analysis by Stanley (1976). The infants ranged in age from 17-24 weeks. A significantly greater number of identifiable stops and greater voice lag time were found in the deaf infants vocalization patterns.

CRY IN CHROMOSOMAL ABNORMALITIES:

Study on cries of infants with chromosomal abnormalities Vuorenkoski et al (1966) analyzed the cries of infants with deletion of chromosome No. 5, the cri-du-chat syndrome. A general pitch of 860 Hz in 44 cries of 8 children was noted. Additionally it was found that a flat melody type occurred in 36% and rising melody type in 23% of the samples. Michelsson et al (1980) found approximately the same value of the Fo in 2 infants with cri-du-chat syndrome. Flat melody types were common. Michelson et al (1980) analyzed 135 cries of 14 infants aged 0.7 months, who exhibited various chromosomal abnormalities. The duration of the cries in the chromosomally abnormal infants have a wide range

from 0.3 to 18.7 secs. The cry in the cri-du-chat syndrome differed from the cries of other chromosomal abnormalities as it is more high pitched and have a flat monotonous melody type. Shifts occur in almost every second cry. Shift and flat melody type was less common in the cries of infants with anomaly of chromosome. The lack of shifts and the frequent occurrence of glottal roll in 13 and 18 trisomy accentuated the hoarse low pitched cry in these infants. The dominating melody type in trisomy 18 was falling/rising-falling and more flats signals occurred than in the controls. In trisomy 13, signals with flat melody type were also increased, when compared with the controls.

It was also found that the pitch characteristics in chromosomally abnormal infants were different from those in infants with other diseases affecting the brain, such as asphyxia, hyper bilirubinaemia, hypoglycaemia and meningitis, in which more high pitched cries occurred. In asphyxia and meningitis, an increased in rising and falling rising melody type and more frequent occurrence of biphonation and gliding have been observed. No biphonation had occurred in the cries of infants with trisomy 13 and 18. Gliding occurred in only one case. This was the only infant who had APGAR score of 5. The asphyxia might have affected the cry results in this case. The anatomic defects of physiological mechanism that changed the cry pattern in chromosome anomalies are known. (Michelson, Tuppurainen, Aula, 1980).

Fisichelli and Karelitz (1966) obtained samples of crying from four male mongloid infants, 6 months of age and four normal infants matched for age and sex and fed it into the Panoramic Sonic analyzer in order to survey the frequency content of the cries. Results showed that cries of normal infants were relatively homogeneous. The spectra of the mongloids showed greater variability within each spectrograms, more peaks and troughs were discriminable indicating that the

intensity variations were much greater for mongloids than they were for normals. The frequency content of the spectrograms of normal infants were much richer than that of spectrogram of Mongoloids. But the spectral range covered by the Mongoloids was same as that of the cry of normal infants.

Lind et al (1970) studied cry sample of 120 normal infants 0-8 month old and 30 infants with Down's syndrome (trisomy 21). The results have shown that when compared to the cries of 120 healthy infants of corresponding age, the cries in Down's syndrome had a long duration with a mean of 4.5 seconds. In addition they were low pitched with a mean of maximum pitch being 510 Hz and a mean of minimum pitch being 210 Hz. The melody was flat in 63% of the samples and biphonation occurred in 23%.

CRY IN INFANTS WITH MALNUTRITION

Malnutrition is a problem in most countries of the developing world. According to Stock and Smyth (1967), Marasmic malnutrition during the first year of life can cause irreversible intellectual impairment and organic brain dysfunction. Sound spectrographic investigation of the cries of 5 infants aged 7 months to 2 years, with severe malnutrition (One with Kwashirkar and four with Marasmus) were compared with cries of 15 healthy children of corresponding age. The mean maximum pitch was 1340 Hz, the mean minimum pitch was 730 Hz; biphonation occurred in 6 and 6 of the 26 cries had flat melody type. In Kwashiorkar the pitch was 290-460 Hz like the normal control cases (Juntunen et al., 1978). Easter (1976) analyzed the cries of 13 well nourished and 12 mal-nourished infants using real time analyzer. He found that crying of malnourished children had a higher pitch, lower amplitude, longer duration and longer latency to the next signal, compared to the normal subjects. The cries of the 12 malnourished infants were 2.66 versus 1.52 secs, for the controls. Cries of

children with severe malnutrition were studied by Juntunen, Sirvio, Michelsson (1976). In infant suffering from Kwashiorkar, cry characters did not differ from normal crying. The children often recover without sequlalae.

CRY IN INFANT WITH CENTRAL NERVOUS SYSTEM DISEASES:

The cry of 14 infants with bacterial meningitis was studied by Michelsson et al., (1977). The cries of the 0-6 month old infants were high pitched, with a mean maximum pitch of 750 Hz, in the 110 cries studies. The mean minimum pitch was 560 Hz. Rising and falling/rising melody type were more common (24%) than in control babies. Biphonation (49%) and glide (11%) occurred more frequently. Infant who at later check up had neurological sequelae and more abnormal cry characteristic at time of the disease. The results indicted that cry analysis had not only the diagnostic but also prognostic value when cries of infants with meningitis were analyzed.

In cries of infants with Herpes Simples virus encephalitis (Petty et al.. 1977), noise concentration occured at the frequency region of 2000-3000 Hz. The cries were more high pitched. Both biphonation and glide were more common than in healthy infants. Study on crying in children with hydrocephalus was done by Michelsson, Kaskinen, Aulanko, Rinne (1984). The cry analysis of 248 cries - 4 cries from each of 62 infants were analyzed. The mean maximum pitch without shift was 750 Hz. When the infants with hydrocephalus was separated into group according to etiology, the only significant difference in the maximum pitch when compared to controls was noted in infant who had congenital hydrocephalus present at birth. Flat types of melody were common regardless of the case of hydrocephalus. Biphonation occurred in 14% and glide in 8% in the whole material.

The cry results show that the cry is different from normal crying in diseases of CNS. Biphonation was more common in meningitis than in encephalitis and hydrocephalus. Noise concentration occurred in herpes encephalitis. All groups of children had more higher pitched cries than controls. In infants with congenital abnormalities such as down's syndrome (Wasz - Hockert et al., 1971), Hypothyroidism (Michelsson and Sirvio 1976) and congenital syphilis (Kittel and Hecht 1977), the cry was low pitched,. Thus it is obvious that the results of cry analysis are different in children with acquired and congenital disorder of the CNS.

Lind et al., (1965) reported a cry analysis of infant with brain damage from a birth injury. They found fundamental frequencies of 450-2070 Hz as compared to 280-900 Hz for group of 20 controls. Michelsson et al., (1980) analyzed the cry ir hydrocephalus. Cries with a mean of maximum pitch over 1000 Hz were noted in these infants who in addition to the hydrocephalus had congenital malformation of the brain (Rosemcephalus/Hydranencephalus). The cry changed to a more normal one after the shunt operation for hydrocephalus with the increased intra cranial pressure was normalized.

CRY IN INFANTS WITH METABOLIC DISTURBANCES:

The cry of infants with neonatal hyper bilirubinaemia was reported by Wasz-Hockert et al., (1971). The most abnormal cry signals were selected from 45 infants with hyper bilirubinaemia. Both the maximum and minimum pitch or the fundamental frequency were highly increased. The mean maximum pitch was 2120 Hz and the mean minimum pitch was 960 Hz. Biphonation was common in 49% of the samples as was furcation, in 42% of the samples. Furcation has been seen more commonly in cries of infants with hyperbilirubinaemia than cries of infants with any other disease.

Wasz-Hockert et al., (1971) noted also that the cries of some children with hyperbilirubinaemia changed already 1 to 2 days prior to increases in serum bilirubin values. The cry analysis method can thus enable early treatment with photo therapy or blood exchange. A cry score rating system that was developed by Vuorenkoski et al., (1971) has been used in analysing cries of 45 infants with hyperbilirubinaemia. Each of 13 cry features were assigned a weightage of 0 to 4 and the cry score was the sum of these ratings. A score of 0-3 was defined as normal and a score of 4-5 was defined as abnormal. A mean score of 4.4 was found in the case of infants with hyperbilirubinaemia as compared to a score of 1.4 in the group of control infants. Only one of the 45 infants with jaundice had a normal score.

A preliminary report on the crying of newborn infants with low blood sugar hypoglycemia was reported by Koivisto et al ., (1974). Hypoglycaemic infants with clinical symptoms are more likely to develop irreversible brain damage than those without symptoms (Koivisto, Blanco-sequeiros and Krause, (1972). Cry analysis can be one criterion in deciding which treatment in needed. In cries of 15 full term infant with hypoglycemia and clinical symptoms, a mean maximum pitch of 1000 Hz was noted with highest part of the fundamental most often at the beginning of the cry signals. Vibrato and biphonation were seen in about two thirds of the cries. Glides occurred in 3 of the 17 cries studied.

In analyzing cries of new bora infants of diabetic mothers, Thoden and Michelsson (1979) found higher fundamental frequency with a mean maximum pitch of 1180 Hz. The maximum pitch was still higher when the child in the neonatal period additionally had hypoglycemia (1520 Hz) or hyperbilirubinemia (1790 Hz) or both simultaneously (1980 Hz). The minimum pitch in cries of infants of diabetic mothers was 510 Hz. When the babies additionally had both

hypoglycemia and hyperbilirubinemia, the minimum pitch was 690 Hz. Thus the study clearly showed that the cry analysis was an indicator of the severity of the disease in the neonatal period.

The results of cry analysis of infant with hyperbilirubinemia were confirmed by Michelsson, Raes, Thoden and Wasz-Hockert (1982). These results showed that the cry characteristics changed whether child was born full term or premature.

CRY IN INFANTS WITH ENDOCRINE DISTURBANCES

The cry in congenital hyperthyroidism studied in 40 cries of 4 infants by Michelsson and Sirvio (1976) was of lower pitch than usually seen in cries of healthy infants. The mean maximum pitch was 470 Hz. and mean minimum pitch was 270 Hz. A low number of shifts, 7% and a frequent occurrence of glottal roll, 57% at the end of phonation accentuated the audible impression of a hoarse low pitched cry. The hoarse cry seems to persist for several months. Cry characteristics which occur in brain damaged infants such as the change in the melody type and occurrence of biphonation and gliding die not occur in hypothyroidism. Thus the change seen in brain damage seem to be more of a peripheral nature.

Perkins and Bamett (1972) had started that the hoarseness in hypothyroidism was due to odema in larynx. Vuoren Koski, Anttolainen (1973) showed that even at the age of 8 months a child who suffered from congential hypothyroidism did not had any cries with a pitch above l000Hz.

CRY IN TWIN PAIRS:

A study on cries in twins has been carried out by Michelsson and Rinne (1984). The results showed that cries in Twin pairs who were both healthy were more equal than the diseased. The study also confirmed previous results that cries are more abnormal than the more premature the infant is.

Michelsson, Raes and Thoden 1982, analyzed 90 cries from two pairs of Siamese twins. The results showed that cries of conjoined twins fell well within normal limits for crying. Cry feature of set of quadruplets was reported by Thoden, Raes Michelsson (1979).

CRY IN INFANTS WITH OTHER DISORDERS:

Blinick et al., (1971) have stated that 15% of 330 normal infants and 50% of 31 new born infants of narcotic addicted mothers showed abnormal birth cries with a higher fundamental frequency. Ostwald et al., (1968) determined the relationship between clinical diagnostic ratings and 2 acoustical characteristics pitch and duration. The subjects were 5 normal infants, 5 questionable impaired and 5 abnormal. Duration measurement showed no difference between the groups. The infants rated as impaired or abnormal had cries with a high frequency of 300-875 Hz. and the normal group had a frequency of 360-785Hz. A study of the cry of a 4 day old full term normal baby who at 6 months died suddenly showed that the cry in sudden infant death syndrome (SIDS) had a higher frequency or more shifts and more extreme frequency (Stark and Nathanson 1975).

Anderson - Huntingdon and Rosenblith (1976) also mentioned abnormal cries in their report of babies who died of SIDS. Tardy-Renucci and Appaxi (1978) found a mean fundamental frequency of 512 Hz in a group of 68 infants

with various neonatal disorders such as hyperbilirubinemia, malformation syndrome, anoxia and respiratory disorders. They have defined the cry as a "reflex motor action under the dependence of the nervous centres", further have states that cry" can be modified by diverse physiologic and pathologic processes". The highest mean fundamental frequency in infants with Jaundice was 630 Hz, 1 in 3 who had been resuscitated after birth had 613 Hz as the highest mean fundamental frequency. In 9 control infants it was 470 Hz.

Leaster and Zeskind (1978) found a mean pitch of 814 Hz in the cries of 24 healthy new bom infants with maternal risk factors when compared to 468 Hz for 24 healthy newborn infants without pre or perinatal complications. In infants with risk factors, cry was elicited after repeated snaps. The latency in infants with risk factors was 21.1 secs, and for those without risk factors it was 1.4 secs. In infants at risk cried less (13.7 secs.) than infants with no risk factors (21.3 secs.).

Thoden and Michelsson (1979) analyzed the cries of 3 infants with Krabbe's disease. They noted a mean of maximum pitch being 1120 Hz of a mean of minimum pitch being 590 Hz. in these infants. The control group had a mean maximum pitch of 520 Hz and a mean minimum pitch of 370 Hz. There was significantly less falling and rising-falling melody type in Krabbe group and these children also produced continuous signals less often.

Michelsson et al ., (1982) collected during a two moths period, the cries of all infants admitted to the ward for new born and small babies. The sound spectrographic cry analysis was performed blinding or without any knowledge of the infant with clinical diagnosis to confirm whether cry analysis is useful in neonatal diagnostics and especially if it can be additional means of estimating the conditions of CNS. The infants were divided into 4 groups and the results of the cry analysis, for the full term and the premature babies was considered separately

in each group. 4 groups were (1) observation group (2) Cardio pulmonary disorder group (3) Metabolic disturbances (4) Neurological symptom group. The control series consisted 110 pain cry signals from healthy, full term 0-3 months old infants. The results reported were as follows.

a) Fundamental Frequency

"The study confirms the previous investigations as the pitch was higher in the cries of infant with metabolic and neurological disturbances. In other two groups, there was no-significant increase in fundamental frequency. In the observation group, the highest pitch was found in an infant, delivered with the help of vacuum extraction which have affected CNS. In the cardio-pulmonary group, the highest fundamental frequency was noted in the infants with cyanotic congenital heart disease which can affect the brain strictures through maximum pitch was observed in a child with bacterial meningitis and lowest in those with microcephalus. This indicates that acute cerebral damage gives rise to more changes in cry characteristics than prenatally developed anomalies.

b) Melody type:

There was an increase in the rising and falling/rising types of melody in full term infant with metabolic disturbances and neurological symptoms. This indicates that change in melody is determined by CNS.

c) Biphonation and glide:

These are rare in cries of healthy infants and had occurred more often in all abnormal groups in the full term infants but the significant level was greater in the

cardio pulmonary metabolic and neurological groups than in the observation group.

d) Furcation:

This has previously been connected with hyperbilirubinaemia (Wasz-Hockert et al., 1971). In this study 2 to 5 cries with furcation were from infants with hyperbilirubinemia.

e) Noise concentration:

This was observed in 5 of cries. One of these infants had laryngo malacia and convulsions and one had virus infection of unknown etiology.

f) Durational feature:

The latency of the cries in all disorder group was longer than the latency of the controls. No differences in latency could be seen among the disorder groups.

The authors imply that their data provides a firm foundation for critical objective evaluation of the cry in sick infants especially when the cry is involved. Venugopal (1995) studied the developmental changes in infant cry. The study was carried out on normal infants 24 hours from birth to 3 months. The acoustic parameters of cry were studied using multidimensional voice programme. The results indicated following: The average fundamental frequency, Average pitch period, Highest Fo, Standard deviation of Fo, Amplitude tremor frequency, Fundamental frequency variation, Shimmer percent, Smoothened amplitude perturbation quotient, Peak amplitude variation, Degree of voice breaks, Degree of sub harmonic segment and Number of sub harmonics were found significantly different in older groups. But this was not consistent over period. Significant

difference was not observed for lowest Fo, Fo- Tremor frequency, Absolute Jitter, Jitter percent, Relative average perturbation, Shimmer in DB, Noise to harmonic ratio, Soft phonation index, Degree of voicelessness, Number of voice breaks, Fo-Tremor intensity index and Amplitude tremor intensity index.

Indira Nadyal (1982) analyzed cries of 13 normal full term infants and 28 infants belonging to the high risk category. The age range of infants were 10 hours to 3 months. Pain cries were elicited from these infants by flicking the sole of infant foot with index finger till they cried atleast for 30 seconds. The cries were recorded with cassette tape-recorder. The recordings were made at a constant intensity level with a microphone held approximately 5 cms to reduce background noise to a minimum. Cry samples from infants mouth were analyzed to obtain narrow band spectrogram. These specrtrogram were analyzed.

Based on analysis and interpretation of spectrogram by the various cry characteristics, following conclusions have been draw.

1. Significant difference exists between cries of normal and high risk infants in terms of some cry characteristics like fundamental frequency, duration of cry, double harmonic break, glottal plosive which are found more in cries of normal infants.

2. No significant differences were observed in both the normal and high risk infants in cry characteristic like shift, biphonation, glide and tonal pit.

3. Eight Categories of high risk infant were studies and it was found that each group exhibited cry characteristic which were distinctive to infant with that particular history or problem.

Vishalakshi (1997). Present study was to analyze cries of normal and abnormal infants by spectrographic analysis and to specify characters which will be distinctive to each abnormality.

The study was carried out in the following steps:

1. Construction of a list of high-risk factors for hearing loss and mental retardation.
2. Collection of data from normal and high-risk infants.
3. Spectrographic analysis.
4. Follow-up of the infants for hearing screening and to collect information about developmental milestones.

Cries of 28 normal full-term infants and 34 infants belonging to the high-risk category were recorded. The infants were from the age range of 16 hours to 1 1⁄2 months.

These spectrograms were analyzed to note the occurrence of the following cry characteristics -

1. Duration of the whole cry
2. Maximum fundamental frequency
3. Minimum fundamental frequency
4. Shift
5. Doubble harmonic break
6. Glide
7. Biphonation
8. Furcation
9. Noise concentration

10. Vibrato
11. Glottal plosives
12. Tonal pit
13. Melody type

A follow-up examination of the infants were carried out, 3-5 months after the recording.

Based on the analysis and interpretation of the spectograms for the various cry characteristics, the following conclusions have been drawn:

1. Significant difference existed between the cries of normal and high-risk infants in some cry characteristics like maximum fundamental frequency, second pause of cry, double harmonic break, vibrato, furcation, noise concentration, and shift.

2. No significant differences were observed in both the normal and high-risk infants in cry characteristics like minimum fundamental frequency, biphonation, glide, tonal pit, total duration of cry, glottal plosive and melody.

Thus the review shows that it is possible to identify the abnormality based on acoustic analysis of voice. Attempts have been made to analyse voice acoustically using different methods and techniques. Multi Dimensional Voice Prpgramme (MDVP) is one such programme.

MULTI DIMENSIONAL VOICE PROGRAMME (MDVP)

The Multi Dimensional Voice Programme (MDVP), software computes a set of 29 acoustic voice parameters in about 16 seconds and provides flexible routines for graphical representation of the results.

Anitha (1994) studied sixty normal subjects (30 males and 30 females) and 30 dysphonics (18 males and 12 males) to examine the relationship between various parameters of voice and voice disorders. Phonation of vowels /a/, *li/, /u/* and sentence (/allii/, /ga:di/ /ide/) was used to extract the acoustic parameters from multi dimensional voice program.

She found the following parameters to be useful in differentiating normals and dysphonics with an error ranging from 13 - 15% and wilks lambda as low as 0.03 to 0.04. The mean values for each parameter for the phonation of/a/, /i/, */u/* and sentence is listed in Appendix I for both normal and dysphonics.

1. Average fundamental frequency
2. Average pitch period
3. Lowest fundamental frequency
4. Phonatory Fo range
5. Amplitude tremor frequency
6. Absolute jitter
7. Relative average perturbation
8. Pitch perturbation quotient
9. Shimmer in dB
10. Shimmer percent
11. Smoothened amplitude perturbation quotient
12. Peak amplitude variation
13. Voice turbulence index
14. Soft phonation index
15. Amplitude tremor intensity index

16. Degree of voice breaks
17. Degree of sub-harmonics
18. Degree of voiceless
19. Number of sub harmonic segments
20. Number of segments computed

Brain (1995) studied children in the age range of 5-15 years to examine the changes in acoustic parameters as a function of age and sex. Phonation of the vowel /a/ was used to extract parameters from multi dimensional voice program.

a) A comparison of different age groups in the case of males showed that there was a consistent significant difference across the age groups in terms of the following parameters.

1. Average fundamental frequency (Fo)
2. Average pitch period (To)
3. Highest fundamental frequency (Fhi)
4. Lowest fundamental frequency (Flo)
5. Absolute jitter (Jita)
6. Jitterpercent (Jitt)
7. Relative average perturbation (Rap)
8. Shimmer in percent (Shim)
9. Soft phonation index (Spi)

b) A comparison of different age group in females showed that there was a consistent significant difference across the age groups in terms of the following parameters:

1. Average fundamental frequency (Fo)
2. Average pitch period (To)
3. Highest fundamental frequency (Fhi)
4. Lowest fundamental frequency (Flo)
5. Absolute jitter (Jita)
6. Relative average perturbation (Rap)
7. Pitch period perturbation quotient (PPQ)
8. Shimmer in dB (ShdB)
9. Average perturbation quotient (APQ)
10. Smoothened average perturbation quotient (SAPQ)
11. Peak amplitude variation (VAM)
12. Soft Phonation Index (SPI)
13. Degree of Sub-Harmonics (DSH)

c) A comparison between male and female across age groups showed that there was a significant difference across the age groups in terms of the following parameters:

1. Average fundamental frequency (Fo)
2. Average pitch period (To)
3. Highest fundamental frequency (Fhi)
4. Lowest fundamental frequency (Flo)
5. Amplitude Perturbation Quotient (APQ)

Gopal Krishna (1995) studied five normal subjects (4 males and I female) in the age range of 20-45 years to develop susceptibility criteria for vocal fatigue.

He determine the acoustic parameter before fatigue (pre fatigue condition) after half an hour and one hour of reading.

He found that the following parameters showing significant differences after 30 minutes of reading in males:

1. Fundamental frequency
2. Average pitch period
3. Highest fundamental frequency
4. Pitch perturbation quotient
5. Smoothened Average Perturbation Quotient
6. Frequency Tremor Intensity Index.

In Females:

1. Fundamental frequency
2. Average pitch period
3. Co-efficient of amplitude variation

After one hour of reading, the following parameters showed significant difference in males,

1. Average pitch period
2. Highest fundamental frequency
3. Co-efficient of amplitude variation
4. Fundamental frequency Tremor Intensity Index

hi Females:

1. Fundamental frequency
2. Average pitch period

3. Standard Deviation of Fundamental Frequency
4. Absolute Jitter
5. Jitter Percent
6. Relative average perturbation
7. Pitch perturbation quotient
8. Smoothened Average Perturbation Quotient
9. Co-efficient of Fo variation
10. Smoothened amplitude perturbation quotient
11. Co-efficient of amplitude variation
12. Noise to harmonic ratio
13. Voice turbulence index

Thus he concluded that Fo related parameters, short and long term frequency perturbation related measurements could be used to assess the fatiguability from multi-dimensional voice program.

Das (1996) studied 30 male dysphonics to examine the relationship between various parameters of voice and voice disorders. The parameters were extracted using multi dimensional voice program for the phonation of/a/, /i/, /*u*/and sentence (alli/ /ga.di/ /ide/).

He concluded that the following parameter are useful in differentiating normals from dysphonics.

1. Highest Fundamental Frequency (HFi)
2. Standard Deviation of Fundamental Frequency (STD)
3. Amplitude tremor frequency (Fatr)

4. Absolute Jitter (Jita)
5. Jitter Percent (Jitt)
6. Relative average perturbation (RAP)
7. Pitch period perturbation quotient (PPQ)
8. Smoothened Average Perturbation Quotient (SPPQ)
9. Fundamental Frequency Variation (vFo)
10. Shimmer in dB (ShdB)
11. Amplitude perturbation Quotient (APQ)
12. Smoothened amplitude perturbation quotient (sAPQ)
13. Peak amplitude variation (APQ)
14. Soft Phonation Index (SPI)
15. Frequency Tremor Intensity Index (FTRI)
16. Degree of voice breaks (DVB)
17. Degree of sub-harmonic breaks (DSH)
18. Degree of voiceless (DUV)
19. Number of sub-harmonic segments (NSH)
20. Number of unvoiced segments (NUV).

Aparna (1996), examined twelve hearing impaired children (6 males and 6 females) in the age of 5-9 years. Twelve subjects having normal hearing formed the control group. The study aimed at examining the various parameters of voice of hearing children using multi dimensional analysis of voice. Phonation of vowels /a/,/i/ and /u/ was considered for the purpose of analysis.

Significant difference was noted between normals and hearing impaired for the following parameters, in both males and females.

1. Mean fundamental frequency - normals showing lower fundamental frequency than the hearing impaired group.
2. Highest fundamental frequency - The hearing impaired showed larger maximum fundamental that the normal group.
3. The frequency range - greater means in hearing impaired than normals.
4. Amplitude perturbation quotient.

Parameter which showed significant difference between normal and hearing impaired, with respect to females only were;

1. Lowest fundamental frequency
2. Speed of fluctuations
3. The extent of fluctuations in intensity
4. Jitter ratio

Parameters which showed significant difference between males and females, with respect to both hearing impaired and normals were:

1. Directional perturbation factor
2. Relative amplitude perturbation
3. Shimmer
4. Directional perturbation of amplitude
5. Amplitude perturbation quotient.

Shameen,T. (1999). The present study was designed to objectively classify dysphonics from normals using the 29 acoustic parameters extracted from Multi Dimensional Voice program.

The normal group consisted of thirty males and thirty females in the age range 18-25 years. Among them five males and five females were assessed on five

sessions to find the stability of the parameters measured. The dysphonic group consisted of fifteen males and fifteen females in the age range of 20-45 years.

Most of the parameters were stable across sessions except,

1. Highest fundamental frequency
2. Shimmer in dB
3. Shimmer in percent
4. Number of unvoiced segments

The following parameters showed significant difference between normals and dysphonics:

1. Average fundamental frequency
2. Highest fundamental frequency
3. Standard deviation of Fo
4. Phonatory Fo. - range in semitones
5. Fo tremor frequency
6. Amplitude tremor frequency
7. Absolute jitter
8. Relative average perturbation
9. Pitch perturbation quotient
10. Smoothened pitch perturbation quotient
11. Fundamental frequency variation
12. Shimmer in dB
13. Shimmer in percent
14. Voice turbulence index
15. Soft phonation index
16. Degree of sub harmonics
17. Number of sub harmonics

18. Number of unvoiced segments

Parameters which showed significant difference between normals and dysphonics, in females were:

1. Average fundamental frequency
2. Lowest fundamental frequency
3. Standard deviation of Fo
4. Fo tremor frequency
6. Absolute jitter
7. Relative average perturbation
8. Pitch perturbation quotient
9. Fundamental frequency variation
10. Shimmer in percent
11. Amplitude perturbation quotient
12. Smoothened amplitude perturbation quotient
13. Voice turbulence index
14. Soft phonation index
15. Fo tremor intensity index
16. Amplitude tremor intensity index

These studies have shown that it is possible to differentiate the abnormal voice from normal. Therefore present study has been planned to study normal and abnormal cries to identify the parameters which would differentiate the two, so that the software can be used for further clinical aspects.

METHODOLOGY

The aim of this study was to find out the differences between the normal and the abnormal infant cries by using acoustic parameters extracted from multi dimensiorial voice profiles and perceptual analysis i.e. by both objective and subjective methods.

The study was carried out in the following steps.

1) Administration of the questionnaire regarding the high risk factors to the parents/grand parents of the infants.

2) Collection of data i.e. cry samples of normal and high risk infants.

3) Cry analysis using acoustic parameters extracted from multi dimensional voice programme (MDVP).

4) Perceptual analysis by professionals and mothers.

a) **Administration** of **Questionnaire:**

Questionnaire which consisted of questions regarding high risk factors, along with other prenatal, perinatal and postnatal history like prematurity, asphyxia, jaundice etc. were administered to the mother of the infants. The case history was drawn up with all the factors taken into considerations. Questinnaire given in Appendix A & B.

b) Data Collection

Infant cries of 23 normal full term infants and 29 infants considered to be with positive history of high risk factors according to the case history were recorded. Infants were from neonatal and sick baby wards of Cheluvamba Hospital.

GROUP-1

In this group pain cries of 23 normal infants from neonatal wards were recorded. The age range was from ½ hours to 7 days. These infants had no peri, pre (or), post natal factors to place them in high risk category. They were born after 37 weeks of gestation and their birth cries and birtli weights were considered normal. This was confirmed after enquiring the mothers and from the information collected from hospital records.

The pain was elicited by flicking the sole of infant's foot with index finger. When infant didnot cry immediately, it was stimulated again, till it cried for atleast more than 30 seconds. However, if infant cried for longer period and if especially the infant had some serious high risk factors, recording was stopped even before infant stopped crying.

The cries were recorded using digital tape deck with microphone attached to it. Sony, Portable mini disc recorder (M2-R30) was used to record the cry sample. All recordings were made at constant intensity level. The mic was held 5 cms away from infants mouth to reduce distortion.

Table 1: Gives Histories of Normal Infants

NORMALS

SI. No.	**Father's/Mother's Name**	Age	Sex	B.W.	P.D.
1.	Kumar	6 Hours	M	2.6 Kg	
2.	Mahesh	4 Days	F	3.75 Kg	Caessarian delivery
3.	Lakshman	5 Days	F	2.75 Kg	Caessarian
4.	Aziz Khan	1 Day	F	2.6 Kg	
5.	Shivanna	1 Day	M	2.8 Kg	
6.	Kalegowda	9hrs.	M	3 Kg	
7.	Azizzamugh	7 Days	M	3.1 Kg	
8.	Umesh	1 Day	F	3 Kg	
9.	Prakash	1 Day	M	3 Kg	
10.	Muhina Begum	3 Days	F	3.2 Kg	
11.	Abib	3 Days	F	2.5 Kg	
12.	Santha	1/2 hr.	M	2.5 Kg	
13.	Kumar	2 Days	F	3.5 Kg	
14.	Mahadeva	1 Day	M	3 Kg	
15.	Siddegowda	1 Day	M	2.5 Kg	
16.	Saleem	1 Day	M	3 Kg	

17.	Ankaya	lhr.	M	3 Kg	
18.	Ananth	1 Day	F	3.5 Kg	
19.	Anjam Pasha	1 Day	F	4 Kg	
20.	Nagaraj	1 Day	M	3 Kg	
21.	Sridhar	12hrs.	M	3.5 Kg	
22.	Mahesha	2 Days	M	3 Kg	
23.	Madhesha	12hrs.	M	3 Kg	

GROUP- 2

In this group pain cries of 29 infants from sick ward who were considered to be with history of high risk factors were recorded. The procedure for eliciting pain cries and recordings were same as used in group 1. Information obtained from the mothers and hospital records revealed that these infants had one/more of high risk factors.

Table 2: Gives Histories of Abnormal Infants

ABNORMALS

SI. No.	**Father's/Mother's Name**	Age	Sex	B.W.	**P.D.**
1.	Suresh	14 Days	M	2 Kg	Septicema
2.	Kumara	6 Days	M	1.8 Kg	Septicema
3.	Mahadevappa	9 Days	F	2.2 Kg	Jaundice
4.	Nanjundappa	2 Days	M	1.6 Kg	Premature Baby
5.	Suresh	8 Days	F	1.3 Kg	Premature Baby
6.	Mahadeva	4 Days	M	1.8 Kg	Asphyxia
7.	Basavanna	5 Days	F	1.7 Kg	Birth Cry delayed for 5 minutes Premature baby
8.	Nanjagowda	16 Days	F	1Kg	Premature
9.	Aziz Ula Khan	40 Days	F	2 Kg	Diarrhaea
10.	Mahadeva	18 Days	F	1.25 Kg	Pre-term Child
11.	Syed	21 Days	M	3 Kg	Septic Arthritis
12.	Gopal	8 Days	F	1.25 Kg	Premature
13.	Srinivas	15 Days	M	1-5 Kg	Pre-mature
14.	Ravikumar	50 Days	M	2.7 Kg	Premature, Septicema
15.	Mahadeva	12 Days	M	2 Kg	Hypercalcemia tetany / Neonatal convulsion

16.	Kyzar	4 Days	F	1.3 Kg	Pre-term
17.	Ravenappa	9 Days	M	3 Kg	Jaundice
18.	Kumara	15 Days	M	1.5 Kg	Premature
19.	Sridhar	20 Days	F	2 Kg	Premature
20.	Kumara	21 Days	M	2.25 Kg	Premature
21.	Pankaja	8 Days	M	3 Kg	Hyperbilirubinemia
22.	Jayamma	9 Days	M	3 Kg	Hyperbilirubinemia
23.	Ramu	1 Day	M	3.8 Kg	Birth Cry Delayed Equipment Delivery
24.	Kumar Swamy	1 1/2 Day	F	3.3 Kg	Peri-natal - PIH
25.	Shankara	4 Days	M	1.4 Kg	Caesarian Low Birth Weight
26.	Nanjunda	1 Day	M	3.2 Kg	Caesarian Foetal Distress
27.	Mariswamy	6 Days	M	3 Kg	Caesarian
28.	Somanna	8 Days	M	3.5 Kg	Caesarian
29.	Marigowda	6 Days	M	3 Kg	Caesarian

c) Multi Dimensional Voice Profile Analysis (MDVP):

Objective analysis was done by using the acoustic parameters extracted from Multidimensional Voice Program (MDVP) developed by kay elemetrics Inc., N.J.

Parameters measured:

The following acoustic parameters were extracted using MDVP.

1. Frequency parameters

1. Average Fundamental Frequency (Fo)
2. Highest Fundamental Frequency (Fhi)
3. Lowest Fundamental Frequency (Flo)
4. Standard deviation of Fo (STD)
5. Average Pitch Period (TO)
6. Fo tremor frequency (Fftr)
7. Absolute Jitter (Jita)
8. Jitter percent (Jitt)
9. Relative perturbation quotient (RAP)
10. Pitch perturbation quotient (PPQ)
11. Smoothened pitch perturbation quotient (SPPQ)
12. Fundamental frequency variation (vFO)
13. Fo - Tremor intensity index (FTRI).

II. Intensity parameters

14. Amplitude tremor frequency (Fatr)

15. Shimmer in dB (ShdB)

16. Shimmer percent (Shim)

17. Amplitude perturbation quotient (APQ)

18. Smoothened amplitude perturbation quotient (SAPQ)

19. Peak amplitude variation (VAM)

20. Amplitude tremor intensity index (ARTI).

III. Other parameters

21. Noise to harmonic ratio (NHR)

22. Voice turbulence index (VTI)

23. Soft phonation index (SPI)

24. Degree of voice breaks (DVB)

25. Degree of sub-harmonics (NSH)

26. Degree of voiceless (DUV)

27. Number of Voice Breaks (NVB)

28. Number of sub-harmonic segments (NSH)

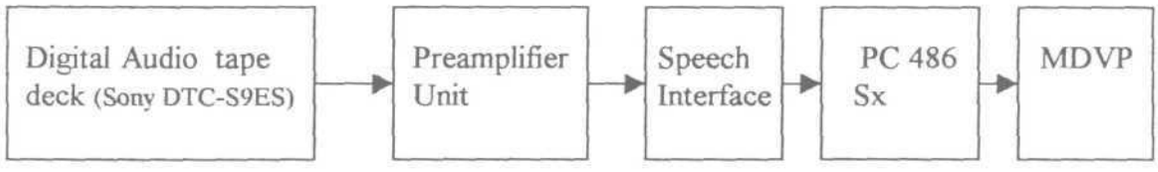
29. Number of unvoiced segments (NUV)

Defimtion of these parameters are given in appendix C. These definition have been used in the software to measure these parameters according to the developer (Kay elemetrics)

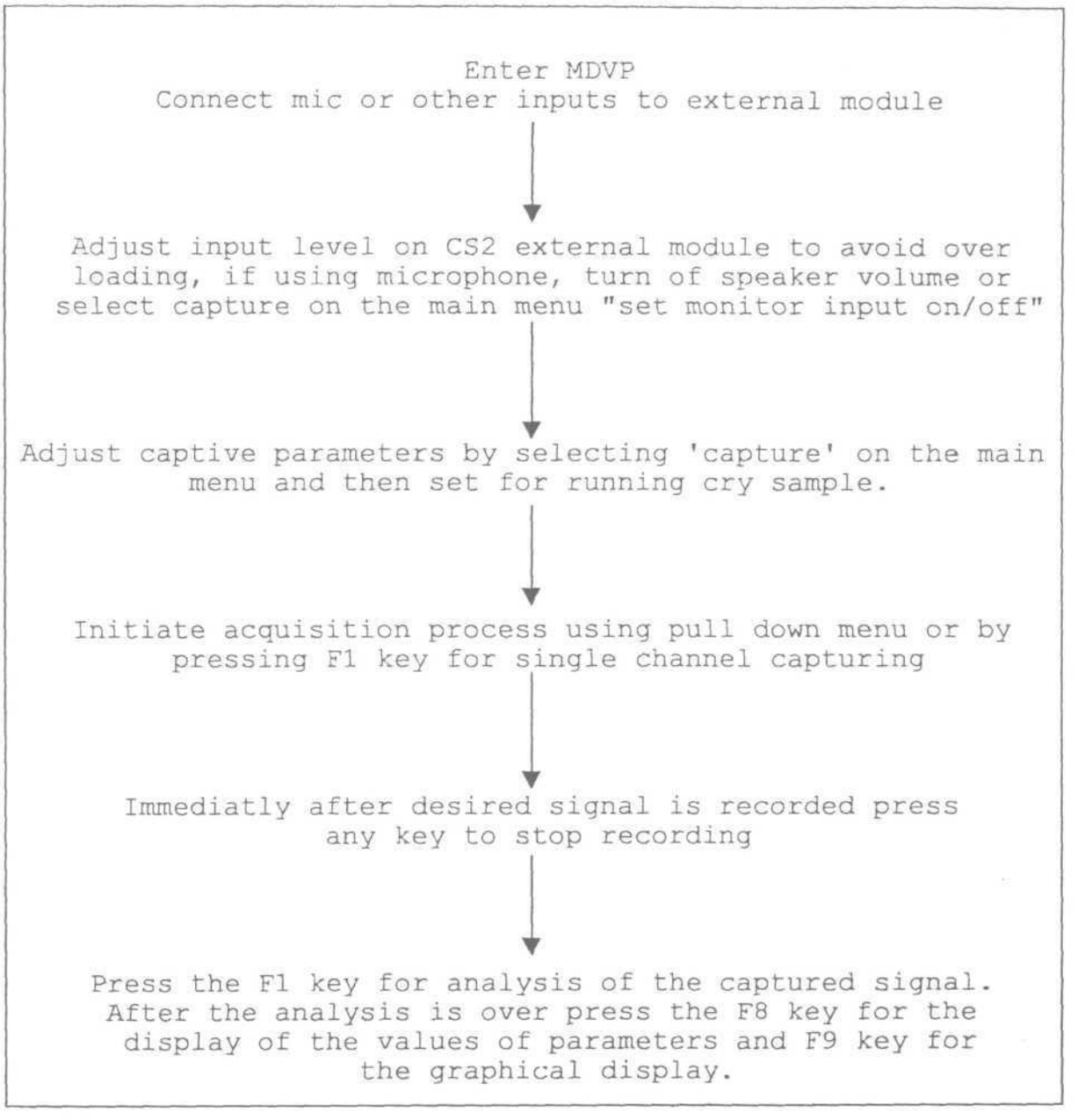
Instrumentation

The following instruments were used for acoustical analysis of voice.

1. CSL speech interface unit-model 4300B
2. Computer with Pentium.
3. 486 Sx with C.S.L 50 hardware card.
4. MDVP software.
5. Digital audio tape deck (Sony DTC - 59ES)
6. Audio mixer (Sony MU XOSI)
7. Digital audio Tape - 3M, 4 mm data tape, DDS-90
8. Microphone (Unidirectional, sony).
9. Connecting Jack. To connect the output of the digital audio tape deck to the input of the speech interface unit.



FLOW CHART



The cry recorded in the digital audio tape was fed into the speech interface unit. The duration of each cry sample used for analysis was 2-3 secs. The sample was digitized at a rate of 50,000 Hz. Time taken for each sample was around 5-7 mins. The cries were analysed for all the acoustic parameters. Output was

obtained in the form of statistical values and graphical display. Further these statistical values were fed into the SPSS software as two groups - normals and abnormals. Descriptive and discriminant analysis was carried out. Independent sample T-test was also done to know the significant difference between the groups across the different parameters. Bar graph was plotted from the results of descriptive statistics.

d) Perceptual analysis:

Twenty nine abnormal samples and ten normal samples were randomized and recorded on an analog tape (Meltrack). Five mothers and five professionals were selected for this study. The tape was played to both the groups. Forced choice analysis was carried out. They were asked to note down whether the cry was that of a normal infant or abnormal infant. Comparison between the results of the two groups was made, to indicate whether mothers / professionals can identify the abnormal cries better.

RESULTS AND DISCUSSION

The purpose of the present study was to differentiate between normal and abnormal infants by their cry samples using the acoustic parameters extracted from multidimensional voice programme (MDVP) developed by Kay Elemetrics Inc., N.J.

The cries of 23 healthy infants and 29 infants with various high risk factors like prematurity, birth asphyxia, jaundice, septicemia, neonatal convulsions, septic arthritis diarrhoea and caessarian babies with histories such as PIH (pregnancy induced hypertension), foetal distress etc.

The following acoustic parameters were extracted using MDVP.

I. Frequency Parameters:

1. Average fundamental frequency
2. Highest fundamental frequency
3. Lowest fundamental frequency
4. Standard deviation of F
5. Average pitch period
6. F tremor frequency
7. Absolute Jitter
8. Jitter percent
9. Relative perturbation quotient
10. Pitch perturbation quotient
11. Smoothened pitch perturbation quotient

12. Fundamental frequency variation
13. Fo - Tremor intensity index

II. Intensity **Parameters:**

14. Amplitude tremor frequency
15. Shimmer in dB
16. Shimmer percent
17. Amplitude perturbation quotient
18. Smoothened Amplitude perturbation quotient
19. Peak amplitude variation
20. Amplitude tremor intensity index

III. Other parameters

21. Noise to harmonic ratio
22. Voice turbulence index
23. Soft phonation index
24. Degree of voice breaks
25. Degree of sub-harmonics
26. Degree of voiceless
27. Number of voice breaks
28. Number of sub-harmonic segments
29. Number of unvoiced segments.

This study intended to check whether these acoustic parameters varied between normal and abnormal infants and also among the abnormals.

1. Average Fundamental Frequency (F):

Average fundamental frequency was measured for the cry samples of both normal as well as infants with high risk history. The mean, standard deviation (SD) and range for average Fo for normal infants (NOR), abnormal group (AN) and among them infants with various abnormalities like Prematurity (PREMATU), Septicema (SEPTI), Jaundice (JAUN), Birth asphyxia (BA), Septic arthritis (SA), Neonatal Convulsions (NC), Diarrhoea (DIA) and caessarian babies with histories (CAE) are presented in Table I and the mean values of each category are shown in Graph 1.

Table 1: Table showing mean, standard deviation (SD) and range for average fundamental frequency.

Groups	**Mean**	S.D.	**Range**
NOR	461.89	46.81	181.23
AN	456.07	59.74	245.88
PREMATU	467.08	68.98	245.88
SEPTI	405.24	15.62	30.81
JAUN	430.71	37.77	68.71
B.A.	531.50	-	-
S.A.	391.22	-	-
N.C.	397.26	-	-
DIA	543.41	-	-
CAE	469.46	47.72	151.58

Table 1 shows that infants with diarrhoea had significantly higher average Fo than for other groups. S.D. and range for infants with birth asphyxia, septic

arthritis and diarrhoea could not be obtained as the number of infants under each of these categories was only one.

Based on her study Indra Nandyal (1982) has reported that the fundamental frequency was higher in the high risk infants than in infants of the normal category. Studies done by Michelsson (1971) on 75 premature infants had revealed that fundamental frequency was highest in prematures.

Wasz Hockert et al. (1971) reported a mean of maximum fundamental of 2120 Hz in 45 infants with Jaundice. Michels son (1971) compared cries of 205 infants with asphyxia with 50 healthy full term and 75 premature infants. The pitch of infants with asphyxia was reported to be higher than that of normal infants. The results of the present study correlates with the results of other studies reported. Vishalakshi (1997) found that, Fo was higher in high risk infants than the infants in the normal category. The results of the present study are consonance, correlates only partly with results of Vishalakshi's study i.e., only for high risk infants i.e. infants with premature birth, birth asphyxia, diarrhoea and caessarian births showed Fo higher than normal infants, whereas infants with septicema, jaundice, septic arthritis and neonatal convulsions show Fo lower than normal infants.

The greater range and standard deviation obtained for premature infants could be due to heterogeneity in terms of age, sex, birth weight etc.

Table 1.1.: Table showing significance difference between the normal and abnormal group for Fo

Group	Significance
NOR Vs AN	+

(+) indicates presence of significant difference at 0.05 significance level.

Test of significance revealed that there is a significant difference between the cries of normal and abnormal group for average Fo. This T' test could not be carried out between normal and different abnormal group as the infants with various abnormalities were very few in number.

Thus the hypothesis stating that there is no significant difference between normal and abnormal infants, as **a** group, in terms of the parameter Fo is rejected.

2. Highest fundamental frequency : (FHi)

The mean, S.D. and range for FHi in normals as well as of infants of different abnormal groups and the average values of all abnormal groups are presented in table 2. The mean values of all the groups are presented in graph **1.**

Table 2: Table showing Mean, S.D. and Range for FHi.

Groups	Mean	S.D.	Range
NOR	622.80	39.37	159.05
AN	620.94	43.62	169.20
PREMATU	631.61	35.20	112.97
SEPTI	639.19	8.17	16.34
JAUN	567.31	66.84	158.43
BA	660.939	-	-
SA	567.86	-	-
NC	581.40	-	-
DIA	644.75	-	-
CAE	631.11	32.49	89.73

From Table 2 it can be seen that infants with birth asphyxia exhibited highest FHi. Infants with history of prematurity, sepricema, birth asphyxia, Ceasarrian birth and diarrhoea had FHi higher than normal infants, but infants with history of jaundice, septic arthritis and neonatal convulsions showed FHi lower than that of normals. The lower range and S.D. seen in infants with septicema could be due to small group size and also homogeneity among the groups.

According to Indra Nandyal (1982), Fo was higher in high risk group than normals. Among the high risk infants, premature infants had been found to have highest maximum fundamental frequency. Greater variations were reported in the cries of high risk infants. Vishalakshi (1998), reported that premature and asphyxiated infants had highest maximum Fo. Ternold et al. (1974) found that premature infants had highest maximum fundamental frequency.

Table 2.1: Table showing presence or absence of significance for FHi.

Group	Significance
NOR Vs AN	+

Table 2.1. Shows that there is a significant difference between the two groups for FHi parameter.

3. Lowest Fundamental Frequency (FLO):

When this parameter was subjected to statistical analysis the following results were obtained for normals, abnormals and subgroups of abnormals and the mean values for these groups are also shown in Graph 1.

Table 3: Table showing mean, S.D. and range for FLO

Groups	Mean	S.D.	Range
NOR	287.02	68.21	348.19
AN	275.70	70.55	266.23
PREMATU	302.95	60.52	203.10
SEPTI	252.84	47.78	95.55
JAUN	260.35	98.35	236.17
BA	332.34	-	-
SA	274.35	-	-
NC	263.99	-	-
DIA	303.49	-	-
CAE	241.24	87.62	255.01

From Table 3, it can be seen that the mean value for the abnormal group is almost same as the mean for normals. Infants with prematurity, birth asphyxia and diarrhoea had values a little higher than the normal mean values and others had mean values a little lower than the mean values of normals. The range and SD were less for infants with septicema, this could be due to the small group size. Higher range were seen in normals, this could be due to the large group size and heterogeneity in terms of age, sex, birth weight etc.

Vishalakshi (1998) reported that infants with neonatal jaundice had lowest minimum frequency and infants with history of low birth weight had lowest maximum frequency.

Table 3.1. Shows the significant difference between the groups

Group	Significance
NOR Vs AN	+

Table 3.1. it is seen that there is a significant difference between the normal and abnormal groups for the FLO parameter.

Thus the hypothesis stating that there is no significant difference between normal and abnormal infants was rejected.

4. Standard Deviation of Fo (STD):

The mean, Standard Deviation and range for STD are shown in Table 4. and the mean values are also represented in Graph 1.

Table 4: Showing mean, S.D. and range for STD

Groups	Mean	S.D.	Range
NOR	72.54	52.72	275.27
AN	74.36	32.15	170.90
PREMATU	72.49	17.74	64.76
SEPTI	63.79	15.33	29.49
JAUN	61.33	32.57	71.09
BA	51.07	-	-
SA	44.89	-	-
NC	37.55	-	-
DIA	80.71	-	-
CAE	101.17	46.98	156.07

GRAPH-1: MEAN OF AVERAGE FUNDAMENTAL FREQUENCY (Fo). HIGHEST FUNDAMENTAL FREQUENCY (Fhi), LOWEST FUNDAMENTAL FREQUENCY (FLo) AND STANDARD DEVIATION OF Fo (STD)

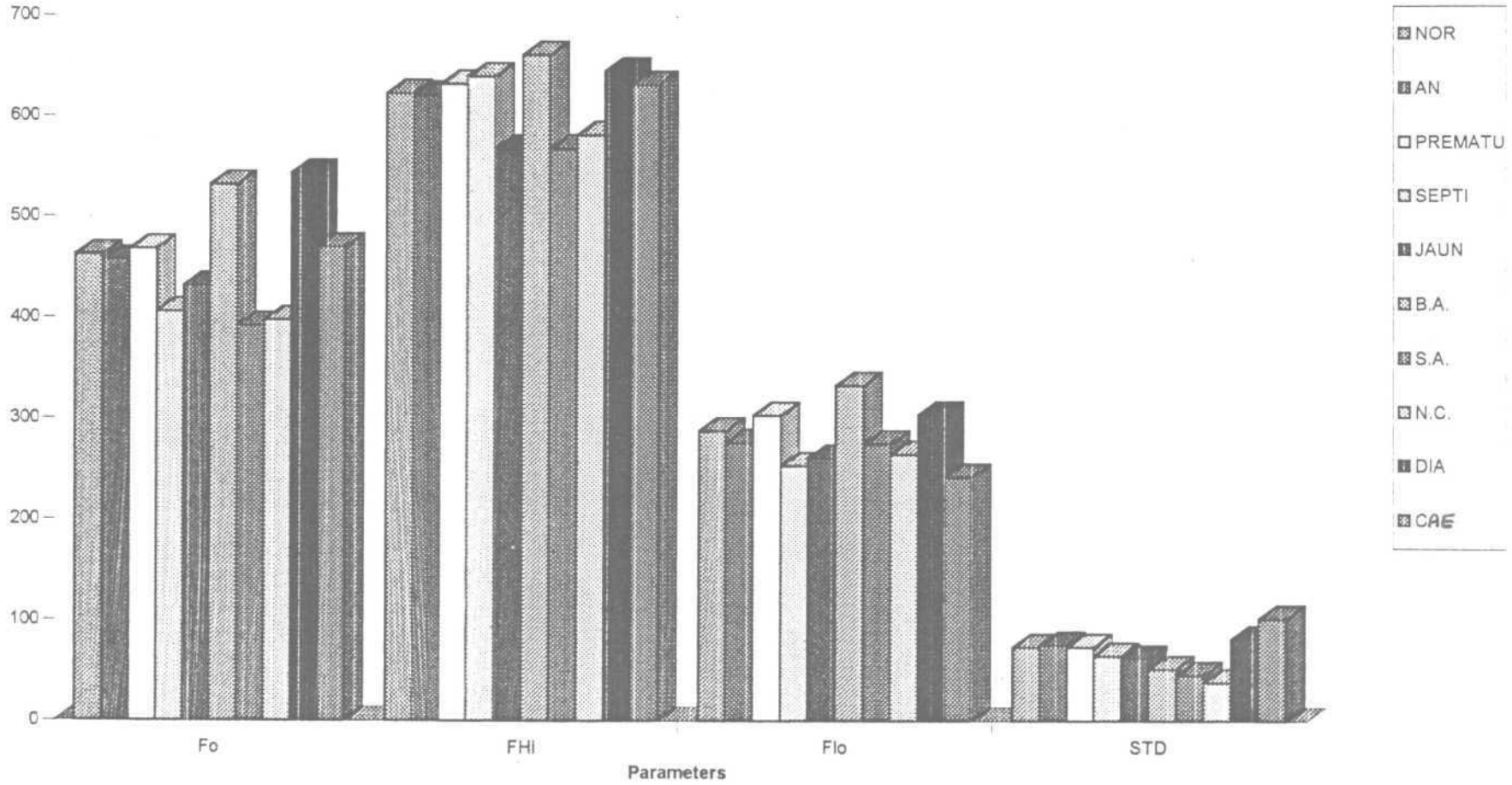


Table 4 indicates that premature infants had mean values almost same as that of normal mean. Caesarian babies with history of pregnancy induced hypertension and low birth weight and infants with diarrhoea exhibited mean values which were slightly higher than that of normal values. Other groups mean values were below the values of normal group.

The SD and range were greater for the normal infants. No studies relating to the STD parameters for infant cries are available in the literature.

Table 4.1. Shows the significant difference between the normal and abnormal group.

Group	Significance
NOR Vs AN	+

Table 4.1 indicates that no significance difference exist between the groups.

The hypothesis stating that there is no significant difference between normals and abnormals as a group is rejected.

5. **Average Pitch Period (To):**

The mean To for normals, abnormals and subgroups of abnormals is shown in Table 5 and graph 2. Table 5 also shows S.D. and range of To.

Table 5. Table showing mean, S.D. and range

Groups	Mean	**S.D.**	Range
NOR	2.25	0.2953	1.27
AN	2.30	0.3561	1.65
PREMATU	2.26	0.4631	1.65
SEPTI	2.53	0.1150	0.23
JAUN	2.39	0.2247	0.42
BA	1.90	-	-
SA	2.59	-	-
NC	2.54	-	-
DIA	1.88	-	-
CAE	2.24	0.2908	0.86

From Table 5 it is seen that the mean value SD and range for the abnormal group is slightly higher than the normal mean. Infants with history of birth asphyxia and diarrhoea exhibited mean values below the normal mean. Among the abnormal group infants with history of septic arthritis showed highest mean value and infants with prematurity exhibited greater SD and range.

No studies relating to the To parameter for differentiating normal and abnormal infant cries are available in the literature.

Table 5.1. Shows the significant difference between the groups

Group	**Significance**
NOR **Vs AN**	

Table 5.1 shows that there exist no significant difference between the normal and abnormal groups.

The hypothesis stating that there is no significant difference between normal and abnormal infants is rejected.

6. **Fo Tremor Frequency (Fftr):**

The results regarding this parameter are summarized in Table 6 and the mean values are shown in Graph 2.

Table 6. Table showing mean, S.D. and range.

Groups	**Mean**	S.D.	**Range**
NOR	4.25	4.01	11.34
AN	2.48	1.50	5.41
PREMATU	2.83	1.98	5.41
SEPTI	2.45	0.7588	1.50
JAUN	2.98	2.30	4.38
BA	1.44	-	-
SA	2.96	-	-
NC	**1.081**	-	-
DIA	1.067	-	-
CAE	2.31	0.9005	2.14

It is seen from Table 6, that greater mean, S.D. and range values were obtained for the normal group than for the abnormal group. In the review of

literature no studies relating to Fftr parameter for differentiating normal and abnormal cries are available to the present investigator.

Table 6.1. Shows the significant difference between the two groups

Group	Significance
NOR Vs AN	+

A significant difference exist between the two groups as seen in Table 6.1.

Thus the hypothesis stating that no significant difference exist between abnormal and normal cries in terms of Fftr parameter is rejected.

7. **Absolute Jitter (Jita):**

The result of statistical analysis for normals, abnormals and subgroups of abnormals are shown in Table 7. The mean values are represented in Graph 2.

Table 7. Table showing mean, S.D. and range **for Jita.**

Groups	**Mean**	S.D.	Range
NOR	57.79	43.09	119.54
AN	68.51	35.11	145.35
PREMATU	73.02	25.31	98.20
SEPTI	103.31	35.50	62.35
JAUN	41.05	16.95	37.37
BA	85.42	-	-
SA	108.14	-	-
NC	51.10	- -	-
DIA	37.92	-	-
CAE	60.98	48.02	137.65

From Table 7 it can be noticed that the mean values for infants with history of jaundice, neonatal convulsions and diarrhoea were lower than that of mean values of normals. Mean values of other groups are higher than mean values of normal group. Higher S.D. and range were observed for normal group.

Studies relating to this parameter for infant cries are not available in the literature, to the present investigator.

Table 7.1. Shows the significant difference between the groups

Group	**Significance**
NOR Vs AN	**+**

GRAPH-2: MEAN OF AVERAGE PITCH PERIOD(To), Fo TREMOR FREQUENCY (Ftr) AND ABSOLUTE JITTER (JITTA)

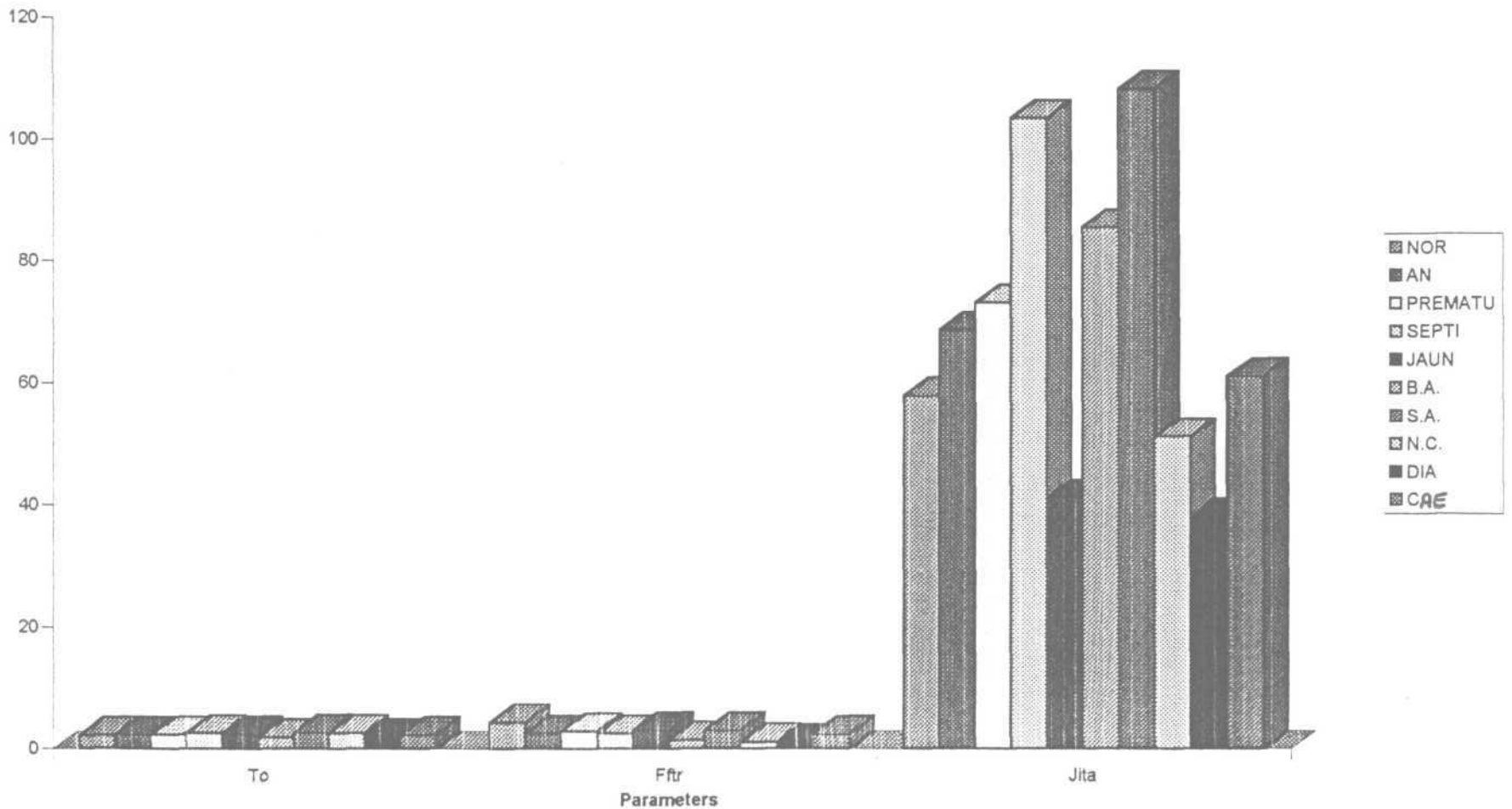


Table 7.1. indicates that a significant difference exists for the parameter absolute Jitter.

Thus the hypothesis stating that no significant difference exists between abnormal and normal infant cries for Jita parameter is rejected.

8. Jitter Percent (Jitt):

The mean, S.D. and range for Jitt are shown in Table 8 and the mean is represented in graph 3.

Table 8. Table showing mean, S.D. and range for Jitt

Groups	**Mean**	**S.D.**	Range
NOR	2.58	1.90	8.78
AN	3.04	1.69	7.42
PREMATU	3.33	1.44	5.38
SEPTI	4.09	1.42	2.62
JAUN	1.69	0.569	1.27
BA	4.50	-	-
SA	4.18	-	-
NC	2.01	-	-
DIA	2.02	-	-
cAe	2.81	2.48	7.08

Table 8 shows that the mean values were higher in infants with H/o asphyxia at birth. Among abnormal infants, few groups have mean values above the normal value and few groups i.e. infants with H/o jaundice, neonatal

convulsions and diarrhoea have values below the normal mean. Higher range were found in the normal group. S.D. was found high in infants with cesarian births. This may be due to their varying histories.

No studies was available in the literature pertaining to this parameter for infant cries.

Table 8.1. Shows the significant difference between the groups

Group	Significance
NOR Vs AN	-

Table 8.1. shows that there is no significant difference between the normal and abnormal groups for the parameter Jitter percent.

Thus the hypothesis stating that no significant difference exists among the groups with reference to Jitt percent is accepted.

9. Relative Perturbation Quotient (RAP):

The results of statistical analysis of this parameter are summarized in Table 9. The mean is represented in Graph 3 and 3.1.

Table 9. Table showing mean, S.D. and range for RAP

Groups	Mean	S.D.	Range
NOR	1.44	1.08	4.85
AN	1.70	0.990	4.43
PREMATU	1.86	0.795	2.95
SEPTI	2.27	0.938	1.82
JAUN	0.943	0.273	0.63
BA	2.75	-	-
SA	2.15	-	-
NC	1.03	-	-
DIA	1.23	-	-
cAE	1.59	1.50	4.26

Table 9 shows that the mean values of normal group and infants with history of prematurity, neonatal convulsion, diarrhoea and ceassarian births are almost same. Mean values of cry analysis of infants with history of birth asphyxia, septic arthritis and septicema were higher than that of normal infants. S.D. and range were higher for both normal group as well as group of infants with H/o ceassarian delivery. Studies relating to this parameter in cry analysis are not available to the present investigator.

Table 9.1. Shows the significant difference between the groups

Group	Significance
NOR **Vs AN**	-

The hypothesis stating that no significant difference exist between the normal and abnormal group is accepted as seen in table 9.1 it can be noticed that a significant difference does not exist between the two groups.

10. Pitch Perturbation Quotient (PPQ):

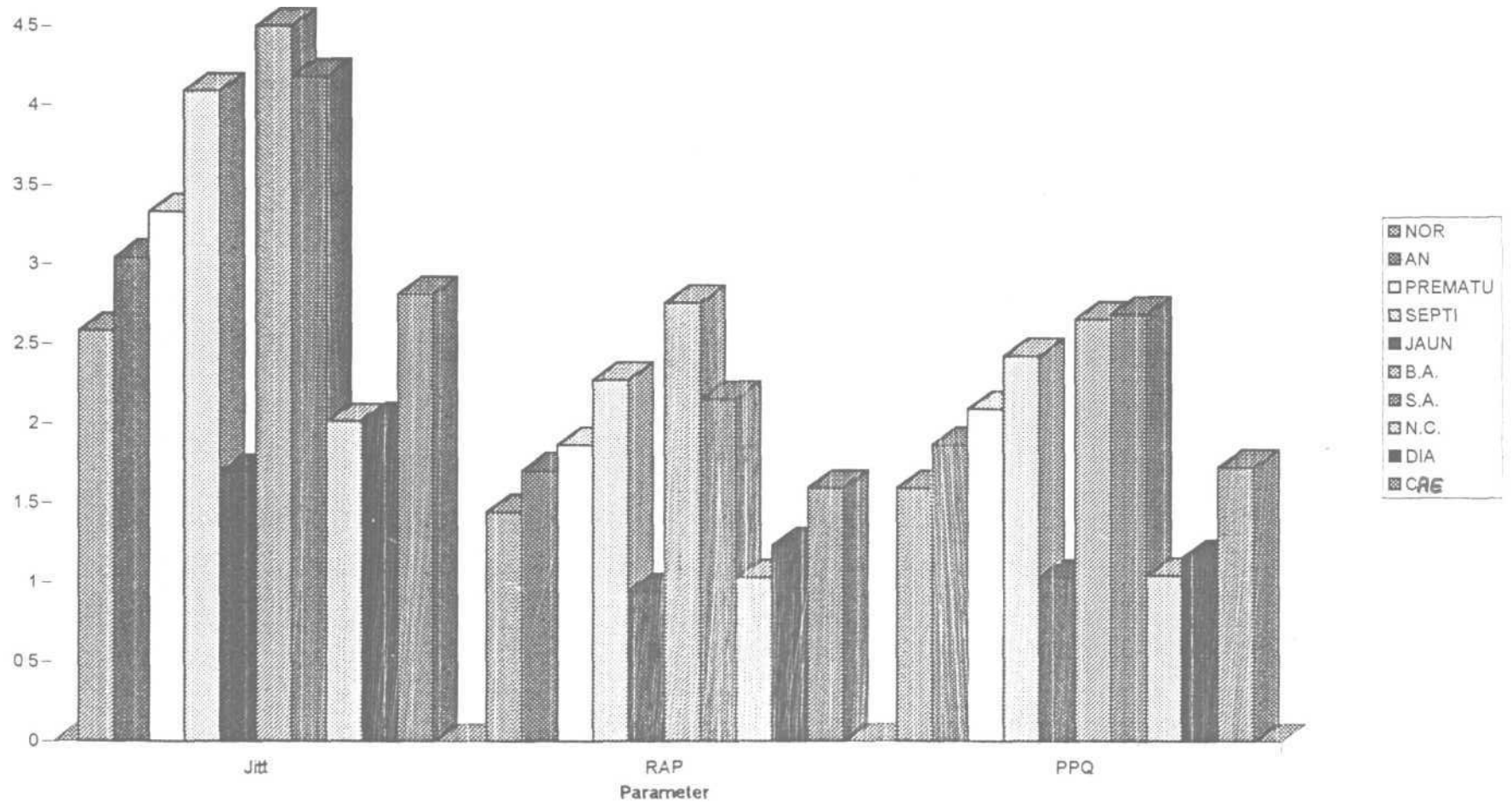
The mean, S.D. and range are shown in Table 10. The mean is represented in Graph 3.

Table 10. Table showing mean, S.D. and range for PPQ

Groups	Mean	S.D.	Range
NOR	1.59	1.15	5.20
AN	1.86	1.05	4.35
PREMATU	2.09	0.925	3.52
SEPTI	2.42	0.844	1.61
JAUN	1.03	0.380	0.80
BA	2.65	-	-
SA	2.68	-	-
NC	1.04	-	-
DIA	1.15	-	-
CAE	1.72	1.50	4.27

Table 10 shows that the mean values of infants with history of prematurity, septicema, birth asphyxia and septic arthritis were higher than the values of normals. The values of other abnormal groups were closer to that of normal group. S.D. and range were higher for normal and infants with H/o Caessarian births and lower for infants with history of jaundice.

GRAPH-3: MEAN OF JITTER PERCENTAGE (JITT), RELATIVE AVERAGE PERTURBATION (RAP) AND PITCH PERTURBATION QUOTIENT (PPQ)



The hypothesis stating that no significant difference exist among the group is accepted for the abnormal groups which has mean value almost same as that of normal group and rejected for groups which has mean values higher than the normal mean.

Table 10.1. Shows the significant difference between the groups

Group	Significance
NOR Vs AN	--

Thus the hypothesis staring that no significant difference exist between the normal and abnormal groups is accepted as shown in Table 10.1**.**

11. Smoothened Pitch Perturbation Quotient (SPPQ):

The results of statistical analysis of this parameter are summarised in Table 11 and mean is represented in graph 4.

Groups	Mean	S.D.	Range
NOR	3.28	3.45	16.84
AN	4.22	2.13	7.78
PREMATU	5.04	2.06	6.76
SEPTI	4.22	1.46	2.90
JAUN	2.50	1.79	4.16
BA	3.60	-	-
SA	4.45	-	-
NC	4.50	--	-
D1A	1.60	--	-
CAE	4.31	2.73	6.12

From Table 11 it is observed that infants with history of prematurity exhibits greater mean smoothened pitch perturbation quotient. Infants with history of jaundice and diarrhoea show mean values which were below the value of normal mean. Higher S.D. and range were for the normal group and lower S.D and range value noticed in infants with history of septicema.

Table 11.1. Shows the significant difference between the two groups

Group	Significance
NOR Vs AN	+

Thus the hypothesis stating that no significant difference exist among the groups is rejected with reference to the Table 11.1**.**

12. Coefficient of Fo variation (VFo):

The result of statistical analysis for this parameter are summarized in Table 12 and the mean is shown in graph 4.

Groups	Mean	S.D.	**Range**
NOR	16.11	13.31	67.71
AN	16.54	7.37	37.03
PREMATU	15.90	4.79	18.73
SEPTI	15.82	4.26	7.90
JAUN	14.47	7.86	18.40
BA	9.61	-	-
SA	11.48	-	-
NC	9.45	-	-
DIA	14.85	-	
CAE	22.01	10.89	34.27

Table 12 shows higher mean values for caesarian babies. Values of all other groups were below the mean Coefficient of Fo variation of normal group. Higher S.D and range obtained for normal group.

Related studies for infant cries are not available in the literature to the present investigator.

Table 12.1. Shows the significant difference between the normal and abnormal groups

Group	Significance
NOR Vs AN	--

Hypothesis stating that no significant difference exist among the diiferent groups and also between the normal and abnormal group is accepted with reference to table 12.

13. Fo **Tremorlntensity Index (FTRI):**

The mean, S.D. and range for FTRI parameter is shown in Table 13. Mean values are represented in Graph 4.

Table 13: Showing Mean, S.D. and Range.

Groups	Mean	S.D.	Range
NOR	4.23	3.13	10.72
AN	3.76	1.99	6.97
PREMATU	6.25	3.78	2.28
SEPTI	4.22	2.87	5.25
JAUN	1.37	1.17	1.66
BA	3.24	-	-
SA	2.65	-	-
NC	4.69	-	-
DIA	7.16	-	-
CAE	3.86	0.98	2.22

Table 13 shows that infants with history of prematurity and diarrhoea exhibit mean Fo Tremor intensity index, values higher than mean values of infants with history of septicema and neonatal convulsions show mean values closer to normal values and other groups show values below the normal group. S.D. were higher for premature infants and higher range obtained for normal infants. In the review of literature studies relating to this parameter for infant cries are not available.

Thus the hypothesis stating that no significant difference exist among the groups is accepted for the groups with septicema and neonatal convulsions and rejected for other groups.

GRAPH-4: MEAN OF SMOOTHENED PITCH PERTURBATION QUOTIENT (SPPQR), FUNDAMENTAL FREQUENCY VARIATION (vFo) AND Fo - TREMOR INTENSITY INDEX (FTRI)

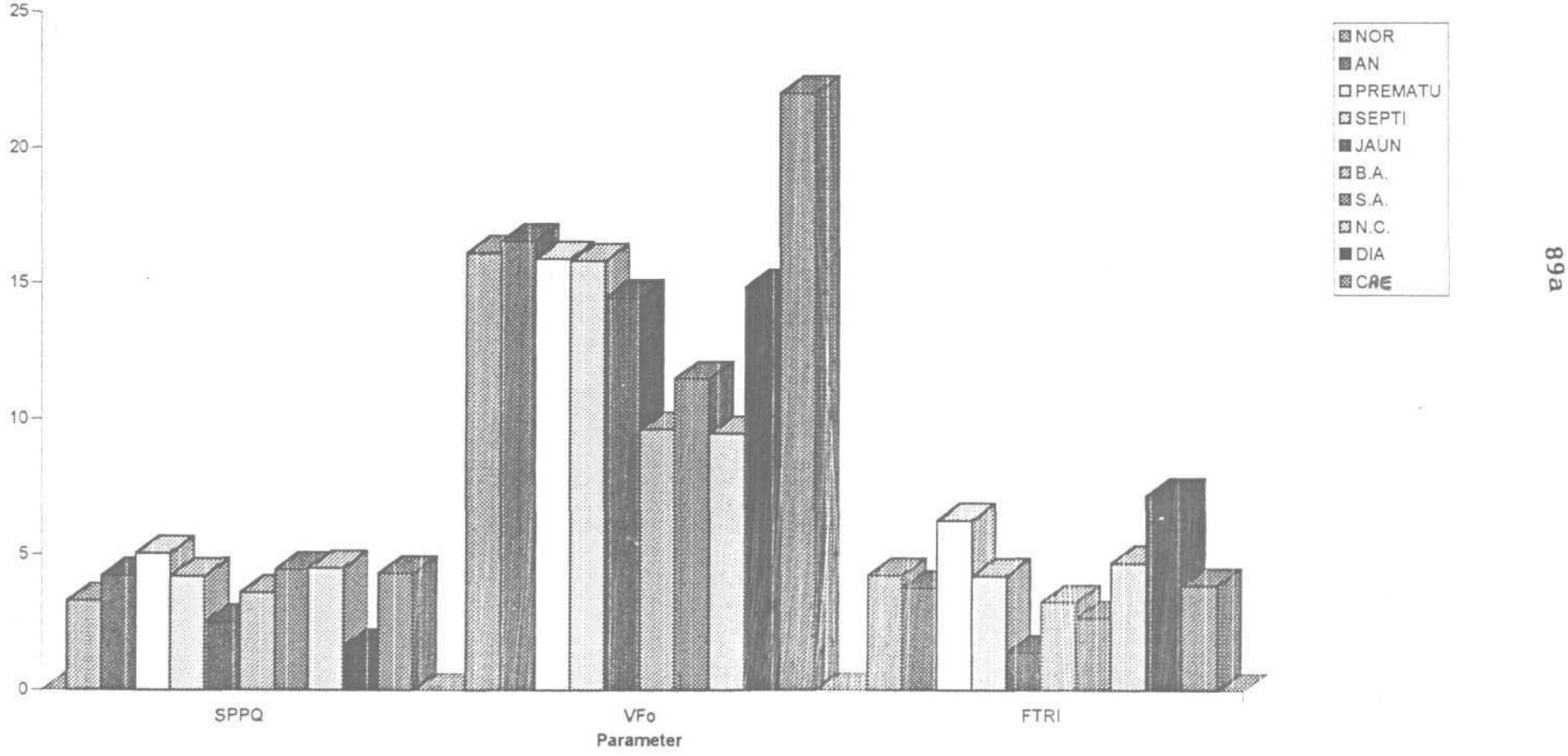


Table 13.1. Shows the significant difference **between the two groups**

Group	Significance
NOR Vs AN	+

The hypothesis stating that no significant difference exist between the normal and abnormal groups is rejected, as the Table 13.1 indicates **a** significant difference between the groups.

14. Amplitude Tremor Frequency (Fatr):

The results of the statistical analysis is presented in Table 14. Mean values are also represented in Graph 5.

Groups	Mean	S.D.	Range
NOR	3.76	3.22	11.87
AN	3.52	3.55	14.92
PREMATU	3.90	**3.49**	11.42
SEPTI	6.24	**8.46**	14.77
JAUN	**3.68**	**1.64**	3.03
BA	**1.14**	-	-
SA	-	-	-
NC	**3.571**	-	
D1A	**1.39**	-	
CAE	2.38	**1.52**	3.50

It is seen from Table 14 that higher mean value is found for infants with septicema, whereas infants with prematurity, jaundice and neonatal convulsions have values almost similar to that of normal group. Other abnormal groups show values below that of mean values of normal group. Greater S.D. range vaJues obtained for infants with H/o septicema.

Table 14.1. Shows the significant difference between the normal and abnormal groups

Group	Significance
NOR Vs AN	

Thus the hypothesis stating that no significant difference exists between two groups in terms of this parameter.

15. Shimmer in dB (ShdB):

The resultant Mean values, SD and Range for normal, abnormal and subgroups of abnormal are presented in Table 15. Mean values were also shown in Graph 5.

Groups	Mean	S.D.	Range
NOR	1.01	0.37	1.43
AN	1.08	0.34	1.47
PREMATU	1.14	**1.41**	1.47
SEPTI	1.16	0.13	0.24
JAUN	0.17	0.80	0.38
BA	1.22	-	-
SA	1.22	-	-
NC	1.07	-	-
DIA	1.04	-	-
CAE	1.07	0.39	1.18

Table 15 shows that mean values for all the groups were similar to the mean values of normal group except for infants with jaundice whose mean value is lower than the normal mean. Higher SD obtained for infants with H/o jaundice and greater range for premature infants. Studies related to this parameter for these subjects is not available.

Table 15.1. Shows the significant difference between the two groups

Group	**Significance**
NOR Vs AN	

As seen in Table 15.1 no significant difference exist between the normal and abnormal groups, thus the hypothesis stating that no significant difference exist between the two groups wes accepted.

16. Shimmer Percent **(SHIM):**

The mean, S.D. and range for parameter SHIM detailed out in Table 16. Mean is shown in Graph 5.

Groups	Mean	S.D.	Range
NOR	10.18	3.47	12.98
AN	11.46	3.56	14.57
PREMATU	11.98	4.43	14.57
SEPTI	12.21	1.58	3.16
JAUN	8.71	1.86	4.18
BA	12.38	-	-
SA	12.85	-	-
NC	12.22	-	-
DIA	10.13	-	-
CAE	11.64	4.13	12.15

Table 16 shows mean values lower in infants with jaundice and diarrhoea compared to normal group and higher values were found in other abnormal groups than normal group.

Table 16.1. Shows the significant difference between the two groups

Group	**Significance**
NOR Vs AN	+

Thus the hypothesis stating that no significant difference exist between normal and abnormal infant groups is rejected as inferred from Table 16.

17. Amplitude Perturbation Quotient (APQ):

The results of statistical analysis regarding Amplitude Pertubation Quotient are shown in Table 17 and the mean values of normal, abnormal and sub-groups of abnormal are also represented in Graph 5.

Groups	Mean	S.D.	Range
NOR	8.10	4.03	16.21
AN	9.08	3.12	14.27
PREMATU	9.87	4.02	14.27
SEPTI	8.88	0.86	1.66
JAUN	6.92	1.66	3.62
BA	8.92	-	-
SA	8.41	-	-
NC	14.35	-	-
DIA	8.23	-	-
CAE	8.62	2.73	8.22

Table 17 shows higher mean values for infants with NC and lower mean values for infants with jaundice. Infants with prematurity show higher mean values than that of normals. Mean values of all other groups were similar to that of normal group. Higher SD and range are found for normal and premature groups. Studies pertaining to this parameter with reference to infant cry are not available in literature.

GRAPH - 5: MEAN OF AMPLITUDE - TREMOR FREQUENCY (Fatr), SHIMMER IN PERCENAGE (Shim), AMPLITUDE PERTURBATION QUOTIENT (APQ) AND SHIMMER IN dB (ShdB)

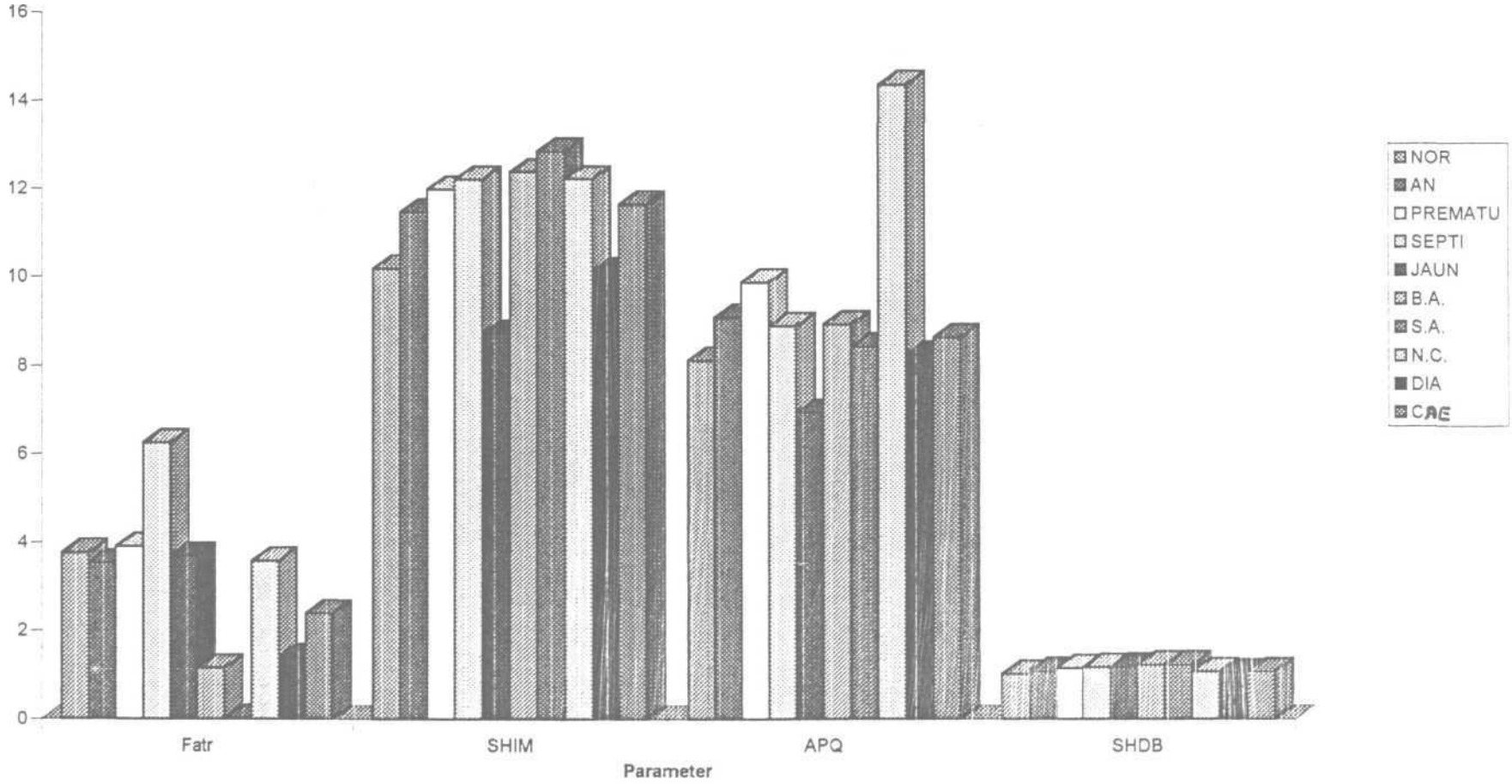


Table 17.1. Shows the significant difference between the normal and abnormal groups

Group	Significance
NOR Vs **AN**	+

Thus the hypothesis stating that no significant difference exists among the group is rejected as shown in Table **1**7.1.

18. Smoothened Amplitude Perturbation Quotient (SAPQ)

The Mean, SD and Range of Smoothened Amplitude Perturbation Quotient **for** normal, abnormal and subgroups of abnormal are shown in Table 18 and Mean values are also presented in graph 6.

Table 18: Showing Mean, SD and range for SAPQ

Groups	Mean	S.D.	**Range**
NOR	11.89	6.49	23.16
AN	12.32	4.03	17.53
PREMATU	13.71	5.11	17.53
SEPTI	10.98	0.84	1.69
JAUN	9.84	3.02	6.86
BA	14.47	-	
SA	15.68	-	
NC	9.95	-	
DIA	9.95	-	
CAE	12.03	3.75	8.92

It is seen from table 18, that four abnormal groups i.e. infants with H/o prematurity, birth asphyxia, septic arthritis and ceassarian delivery show higher mean expand values than normal group and the other four groups i.e. infants with H/o septicemia, jaundice, neonatal convulsions and diarrhoea show lower mean values than normal mean. Higher SD and range obtained for normal group.

Table 18.1. Shows the significant difference between the two groups

Group	Significance
NOR Vs AN	+

Thus the hypothesis stating that no significant difference exist between normal and abnormal cries is rejected as noticed in Table 18.1 with reference to parameter SAPQ.

19. Peak Amplitude Variation (VAM)

The results of statistical analysis of data regarding Peak Amplitude Variation as seen in normal, abnormal and groups of infants with H/o high risk factors are summarized in Table 19. Mean values of these groups are shown in graph 6.

Groups	Mean	S.D.	Range
NOR	32.72	12.26	50.60
AN	29.50	8.52	38.61
PREMATU	30.80	9.33	28.34
SEPTI	22.38	7.11	12.67
JAUN	28.81	5.66	**11.41**
BA	26.84	-	-
SA	29.73	-	-
NC	24.86	-	-
DIA	37.19	-	-
CAE	30.83	10.73	32.12

Table 19 shows higher mean values for infants with history of diarrhoea. Mean values found for all other groups were lower than the normal mean. Higher SD and range were obtained for infants in normal group. Studies related to this parameter for infant cries are not available to the present investigator.

Table 19.1. Shows the significant difference between the normal and abnormal groups

Group	**Significance**
NOR Vs AN	+

From Table 19.1 it is observed that there exist **a** significant difference between the normal and abnormal groups.

Thus the hypothesis stating that no significant difference exist between the groups is rejected with reference to the parameter peak amplitude variation.

20. Amplitude Tremor Intensity Index (ATRI)

The mean, SD and range for ATRI parameter for normals; abnormals and subgroups of abnormals are shown in Table 20.

Groups	**Mean**	S.D.	Range
NOR	9.61	4.39	14.94
AN	10.36	**5.39**	21.38
PREMATU	9,01	**3.02**	11.19
SEPTI	11.54	11.14	20.00
JAUN	11.11	6.11	11.31
BA	16.95	-	-
SA	-	-	-
NC	14.36	-	-
DIA	9.21	-	-
CAE	10.11	6.26	18.61

Table 20 shows that mean ATRI value for normal, premature and diarrhoea groups were almost same. Higher mean values then the normal group is obtained for the other groups. Higher SD and range obtained for infants with septicema. No studies are available in literature pertaining to this parameter for infant cry.

GRAPH-6 : MEAN OF SMOOTHENED AMPLITUDE PERTURBATION QUOTIENT (SAPQ), PEAK AMPLITUDE VARIATION (vAm) AND AMPLITUDE TREMOR INTENSITY INDEX (ATRI)

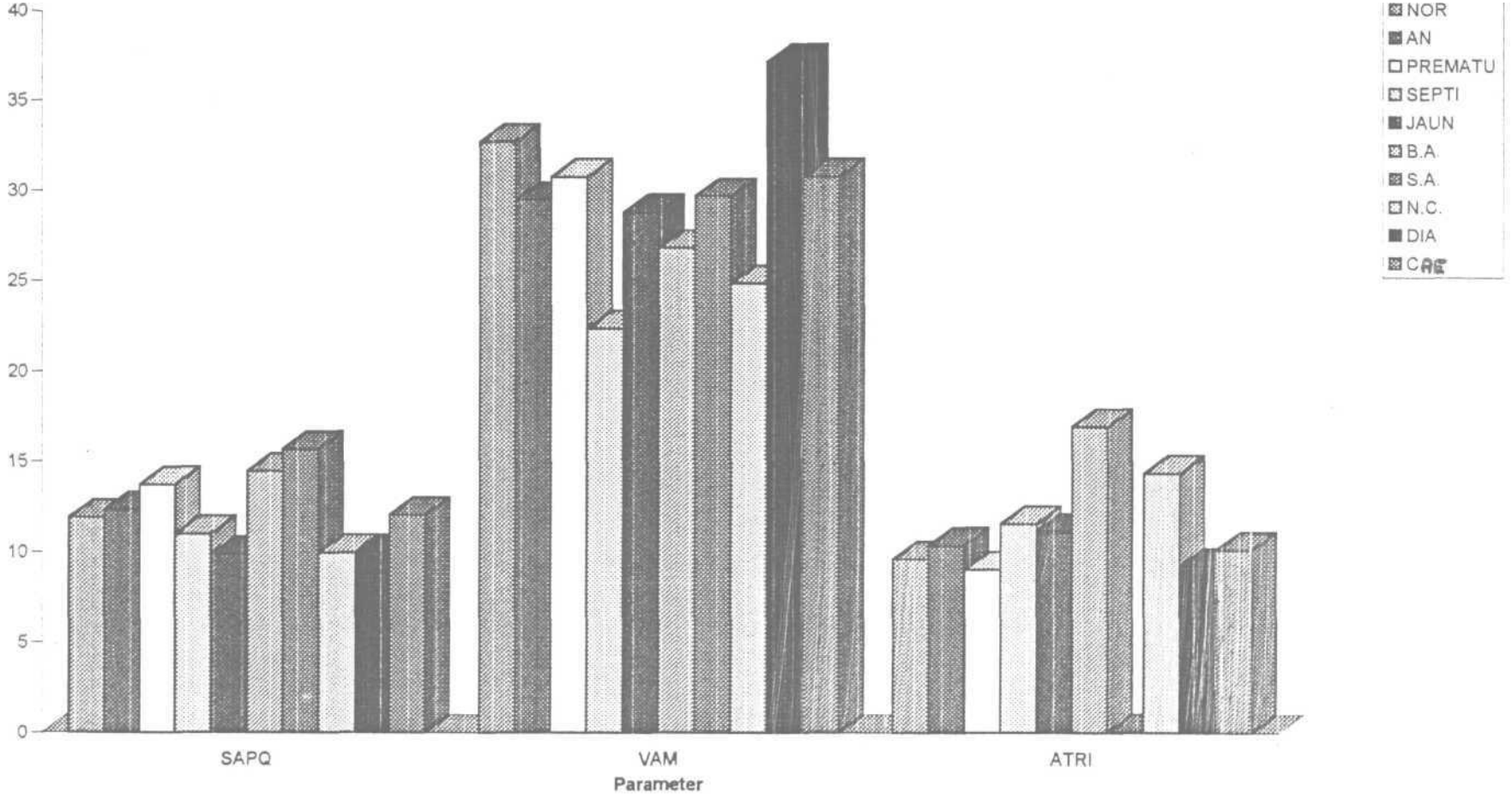


Table 20.1. Shows the significant difference between the normal and abnormal group

Group	Significance
NOR Vs AN	+

It is observed from Table 20.1 that significant difference exist between the two groups.

Thus hypothesis stating that no significant difference exist between the normal and abnormal group is rejected.

21. Noise to Harmonic Ratio (NHR)

The results of statistical analysis are summarized in Table 21. Mean of normal and subgroups shown in Graph 7 and mean of normals and abnormal groups are shown in graph 7.1.

Groups	Mean	S.D.	Range
NOR	0.70	0.25	**1.18**
AN	0.70	0.23	0.82
PREMATU	**0.80**	0.23	0.76
SEPTI	0.63	0.21	**0.41**
JAUN	**0.49**	0.17	0.40
BA	0.79	-	-
SA	**0.87**	-	-
NC	1.07	-	-
DIA	**0.44**	-	-
CAE	**0.64**	**0.18**	**0.51**

Table 21 shows higher mean values for infants with history of neonatal convulsions. No much significant difference exist among all other groups for their mean values obtained. Higher SD and range obtained for normal group. Studies pertaining to this are not available in the literature to the present investigator.

Table 21.1. Shows the significant difference between the two groups

Group	Significance
NOR Vs AN	

From Table 21.1 it is inferred that no significant difference exist between the two groups.

Hypothesis stating that no significant difference exist between the two group is accepted with reference to noise to harmonic ratio.

22. Voice Turbulence Index (VTI)

The Mean, SD and range for parameter voice turbulence index for normal, abnormal and subgroups of abnormals are shown in Table 22 and mean values for all these groups are represented in Graph 7.

Groups	Mean	S.D.	Range
NOR	0.91	0.83	2.60
AN	0.69	0.60	2.69
PREMATU	0.89	0.78	2.69
SEPTI	0.64	0.51	0.91
JAUN	0.45	0.15	0.37
BA	1.31	-	-
SA	0.35	-	-
NC	0.45	-	-
DIA	0.17	-	-
CAE	0.64	0.58	1.45

Table 22 shows higher mean voice turbulence index for infants with birth asphyxia. Mean values of all other groups showed no much significant difference. Higher SD and range obtained for normals and infants with H/o prematurity. No studies are available in the literature for infant cries relating to this parameter to the present investigator.

Table 22.1. Shows the significant difference between the normal and abnormal groups

Group	**Significance**
NOR Vs AN	

It is observed from Table 22.1, that no significant difference exist between the two groups.

Thus the hypothesis stating that no significant difference exist between the two group is accepted with reference to voice turbulence index parameter.

23. Soft Phonation Index (SPI)

The results of mean, SD and range for soft phonation index parameter for normals, abnormals and sub-groups of abnormals are presented in Table 23 and mean for these groups is shown in graph 7.

Table showing Mean, SD and range.

Groups	Mean	S.D.	Range
NOR	1.02	0.98	3.75
AN	1.14	0.97	3.42
PREMATU	1.38	1.23	3.28
SEPTI	2.13	0.21	0.42
JAUN	0.53	0.29	0.70
BA	0.74	-	-
SA	0.22	-	-
NC	0.71	-	-
DIA	0.96	-	-
CAE	0.93	0.85	2.38

Table 23 shows higher mean soft phonation index for infants with septicema. Obtained mean value for normal and premature groups were almost same. For all other groups', the obtained mean values were lower than normal mean. Higher range obtained for normal group and higher SD for premature group. No studies are available in literature to the present investigator for infant cries relating to this parameter.

GRAPH-7: MEAN OF NOISE TO HARMONIC RATIO(NHR), VOICE TURBULENCE INDEX(VTI) AND SOFT PHONATION INDEX(SPI)

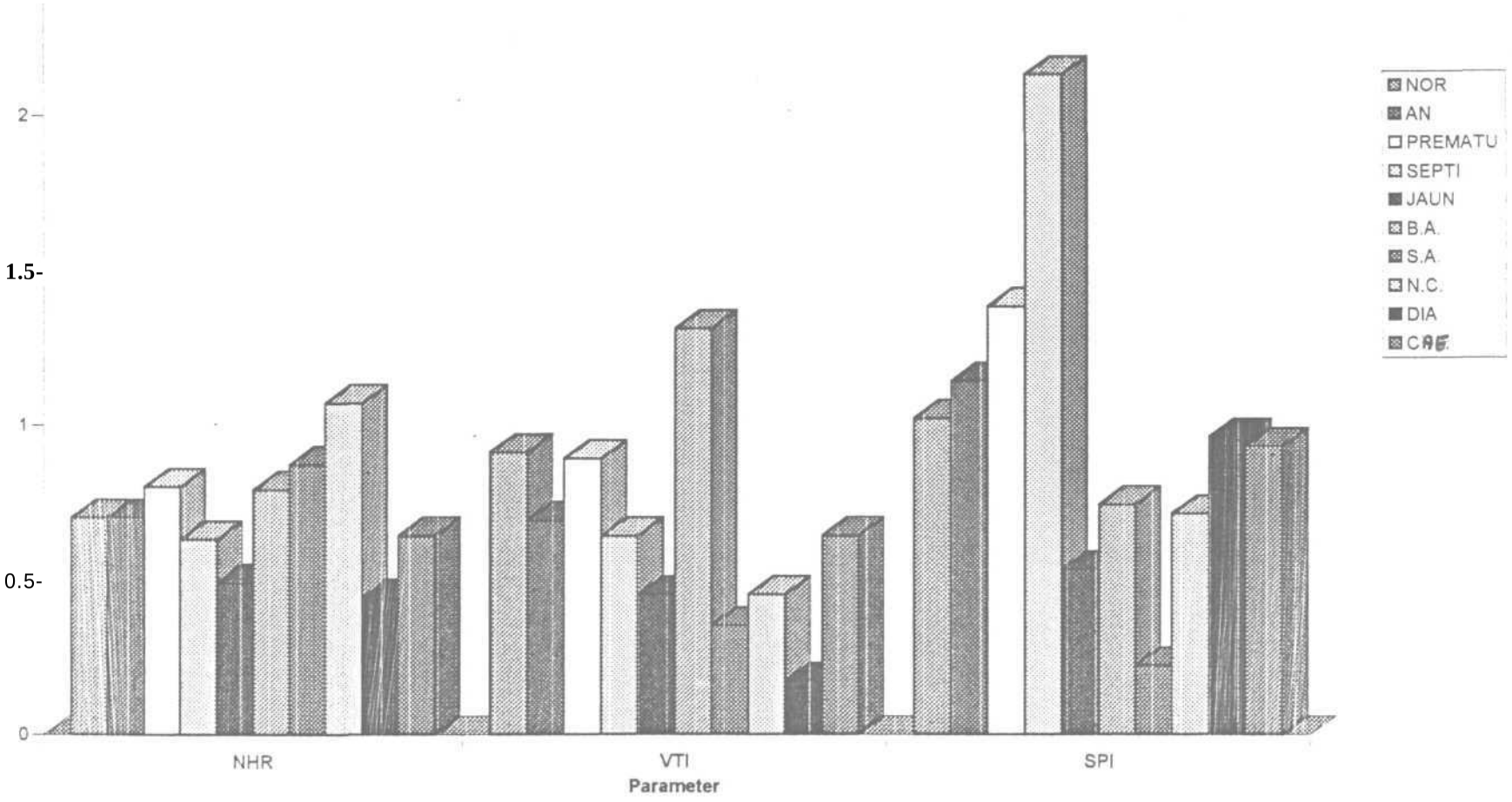


Table 23.1. Shows the significant difference between the two groups

Group	Significance
NOR Vs AN	

No significant difference exist between the normal and abnormal groups as seen in the Table 23.1.

Thus the hypothesis stating that no significant difference exist between the normal and abnormal group is accepted with reference to soft phonation index parameter.

24. Degree of Voice Breaks (DVB)

The results of statistical analysis for the parameter degree of voice break for normals, abnormals and subgroups of abnormals are summarized in Table 24 and mean for all these group is represented in Graph 8.

Table 24: Showing Mean, SD and Range.

Groups	Mean	S.D.	Range
NOR	30.16	29.30	90.95
AN	30.32	26.71	83.53
PREMATU	44.17	28.13	83.53
SEPTI	36.99	18.10	35.21
JAUN	9.27	14.98	31.48
BA	57.78	-	-
SA	0.00	-	-
NC	10.07	-	-
DIA	25.41	-	-
CAE	21.72	26.13	74.52

Table 24 shows higher mean values for infants with birth asphyxia and infants H/o jaundice exhibited lower mean value. Higher SD and range obtained for normal group. Studies pertaining to this parameter for infant cries are not available in literature to the present investigator.

Table 24.1. Shows the significant difference between the normal and abnormal groups

Group	Significance
NOR Vs AN	

As seen in Table 24.1, there is no significant difference between the two groups.

Thus the hypothesis stating that no significant difference exist between the normal and abnormal groups is accepted.

25. Degree of **Sub-Harmonics (DSH)**

The results of statistical analysis for normals, abnormals and subgroups of abnormals are shown in Table 25 and mean for these groups are represented in graph 8.

Table 25: Showing Mean, SD and Range.

Groups	Mean	S.D.	Range
NOR	0.16	0.74	3.57
AN	0.55	2.05	8.33
PREMATU	0.00	0.00	0.00
SEPTI	0.00	0.00	0.00
JAUN	0.00	0.00	0.00
BA	0.00	-	-
SA	0.00	-	-
NC	0.00	-	-
DIA	0.00	-	-
CAE	2.27	3.88	8.33

Table 25 shows higher mean, SD and range for infants with cessarian delivery with H/o pregnancy induced hypertension and low birth weight. All other abnormal groups showed 0 values and normal group exhibited lower values. No studies are available in literature for infant cries for this parameter to the present investigator.

Table 25.1. Shows the significant difference between the normal and abnormal groups

Group	Significance
NOR Vs AN	

No significant difference exist between the normal and abnormal groups as seen in the Table 25.1. Thus the hypothesis stating that no significant difference exist between the two groups is accepted with reference to the degree of sub-harmonic parameter.

26. Degree of Voiceless (DUV)

Mean, SD and range for normals, abnormals and subgroups of abnormals are shown in Table 26 and mean value for these groups are represented in graph 8.

Table 26: Showing Mean, SD and Range for DUV

Groups	**Mean**	S.D.	**Range**
NOR	53.31	21.51	80.46
AN	53.07	23.36	80.46
PREMATU	63.93	24.66	78.16
SEPTI	50.19	6.73	12.64
JAUN	48.28	27.44	59.77
BA	51.81	-	-
SA	78.16	-	-
NC	71.26	-	-
DIA	28.74	-	-
CAE	37.44	**19.01**	57.47

GRAPH-8: MEAN OF DEGREE OF VOICE BREAKS (DVB), DEGREE OF SUB HARMONICS(DSH) AND DEGREE OF VOICELESSPUV)

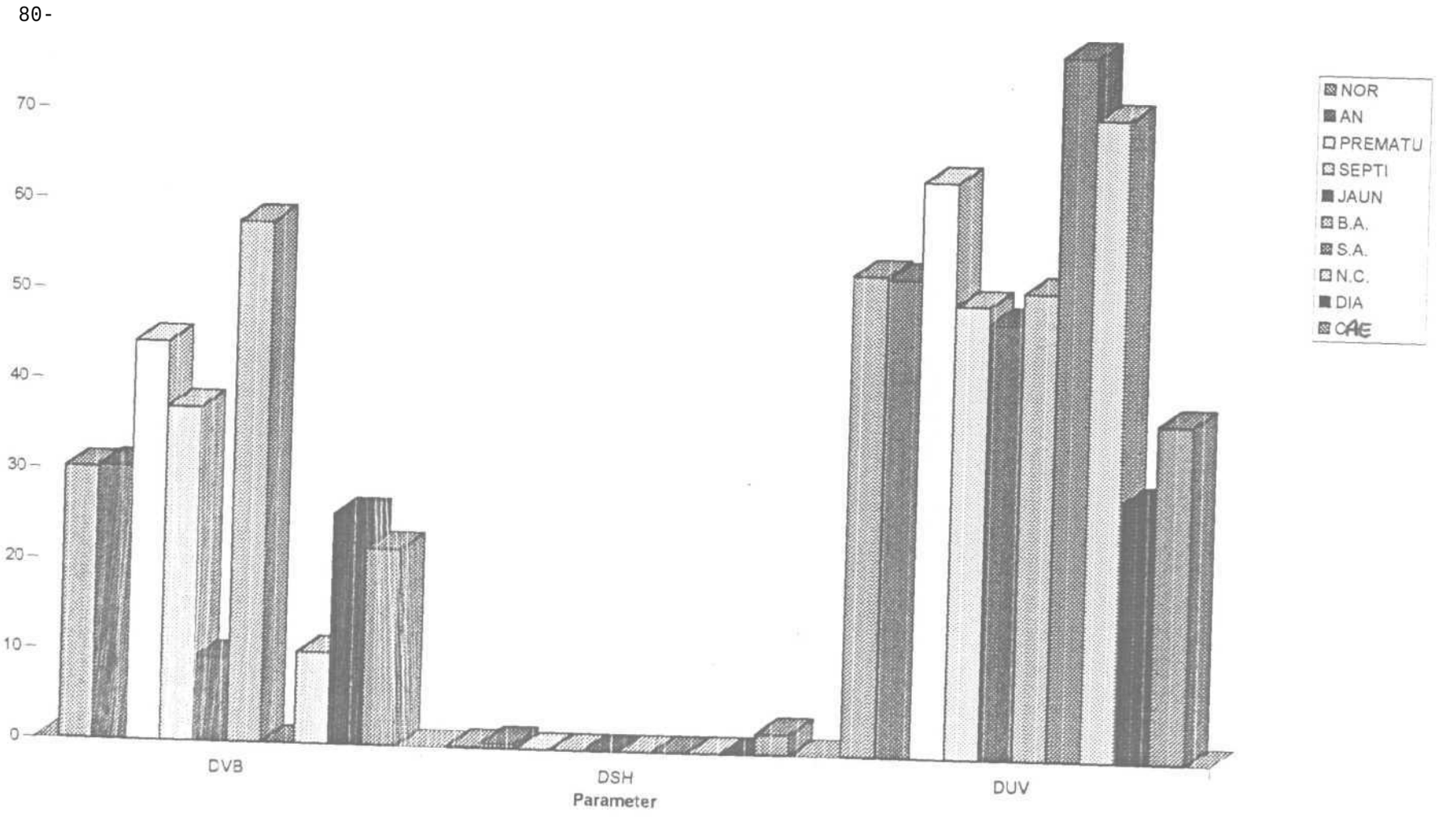


Table 26 shows that obtained mean values for infants with prematurity, septic arthritis and neonatal convulsions were higher than normal mean and the mean for infants of other groups were lower than mean of normal group. Higher SD obtained for infants with H/o jaundice and higher range for normal group.

Studies related to infant cries for this parameter is not available in the literature to the present investigator.

Table 26.1: Shows significant difference between the normal and abnormal group

Group	Significance
NOR Vs **AN**	

It is inferred from Table 26.1, that no significant difference exist, thus the hypothesis stating that no significant difference exist between the normal and abnormal group is accepted.

27. **Number of Voice Breaks (NVB)**

The results of statistical analysis for normals, abnormals and subgroups **of** abnormals for parameter Number of Voice Breaks are shown in Table 27 and mean value for these groups are represented in graph 9.

Groups	Mean	S.D.	Range
NOR	4.61	4.93	19.00
AN	5.24	5.22	18.00
PREMATU	6.82	6.42	18.00
SEPTI	7.33	3.51	7.00
JAUN	1.25	1.26	3.00
BA	13.00	-	-
SA	0.00	-	-
NC	1.00	-	-
DIA	4.00	-	-
CAE	4.57	4.24	11.00

Table 27 shows higher mean values for infants birth asphyxia. Infants with diarrhoea and ceassarian delivery exhibited almost same mean values as that of normal mean. Infants with septicema, birth asphyxia and prematurity exhibited higher mean than normals and other groups showed lower mean values. Higher range obtained for normals and higher SD for infants with prematurity. No studies are available in literature for infant cries for this parameter to the present investigator.

Table 27.1. Shows the significant difference between the normal and abnormal groups

Group	Significance
NOR **Vs AN**	+

It is inferred from Table 27.1 that there exist a significant difference between the two groups.

Thus the hypothesis stating that no significant difference exist between the two group is rejected.

28. Number of Sub-Harmonic Segments (NSH)

The mean SD and range for normals, abnormals and subgroups of abnormals are shown in Table 28 and mean value for these groups are represented in Graph 9.

Table 28: Showing mean, SD and Range.

Groups	Mean	S.D.	Range
NOR	8.70	0.42	2.00
AN	0.21	0.82	4.00
PREMATU	0.00	0.00	0.00
SEPT1	0.00	0.00	0.00
JAUN	0.00	0.00	0.00
BA	0.00	-	-
SA	0.00	-	-
NC	0.00	0.00	0.00
DIA	0.00	0.00	0.00
CAE	0.86	1.57	4.00

Table 28 shows higher mean value for infants in normal group than for other groups. Higher SD and range were observed for infants with ceassarian delivery. Values of mean, SD and range for infants of other abnormal groups were

zero. In the review of literature no studies are available regarding this parameter for infant cries to the present investigator.

Table 28.1. Shows the significant difference between the normal and abnormal groups

Group	Significance
NOR Vs AN	+

As seen in Table 28.1, there is a significant difference between the normal and abnormal groups. Thus the hypothesis stating that no significant difference exist between the two groups is rejected.

29. Number of Unvoiced Segments (NUV)

The results of statistical analysis for normals, abnormals and subgroups of abnormals are shown in Table 29. Mean of all these groups are represented in graph 9.

Table 29: Showing Mean, SD and Range number of unvoiced segments.

Groups	Mean	S.D.	**Range**
NOR	46.35	18.68	70.00
AN	46.00	20.26	68.00
PREMATU	55.36	21.39	68.00
SEPTI	43.67	5.86	11.00
JAUN	42.00	23.87	52.00
BA	43.00	-	-
SA	68.00	-	-
NC	62.00	-	-
DIA	25.00	-	-
CAE	32.57	**16.54**	50.00

GRAPH-9 : MEAN OF NUMBER OF VOICE BREAKS (NVB), NUMBER OF SUB-HARMONIC SEGMENTS (NSH) AND NUMBER OF UNVOICED SEGMENTS(NUV)

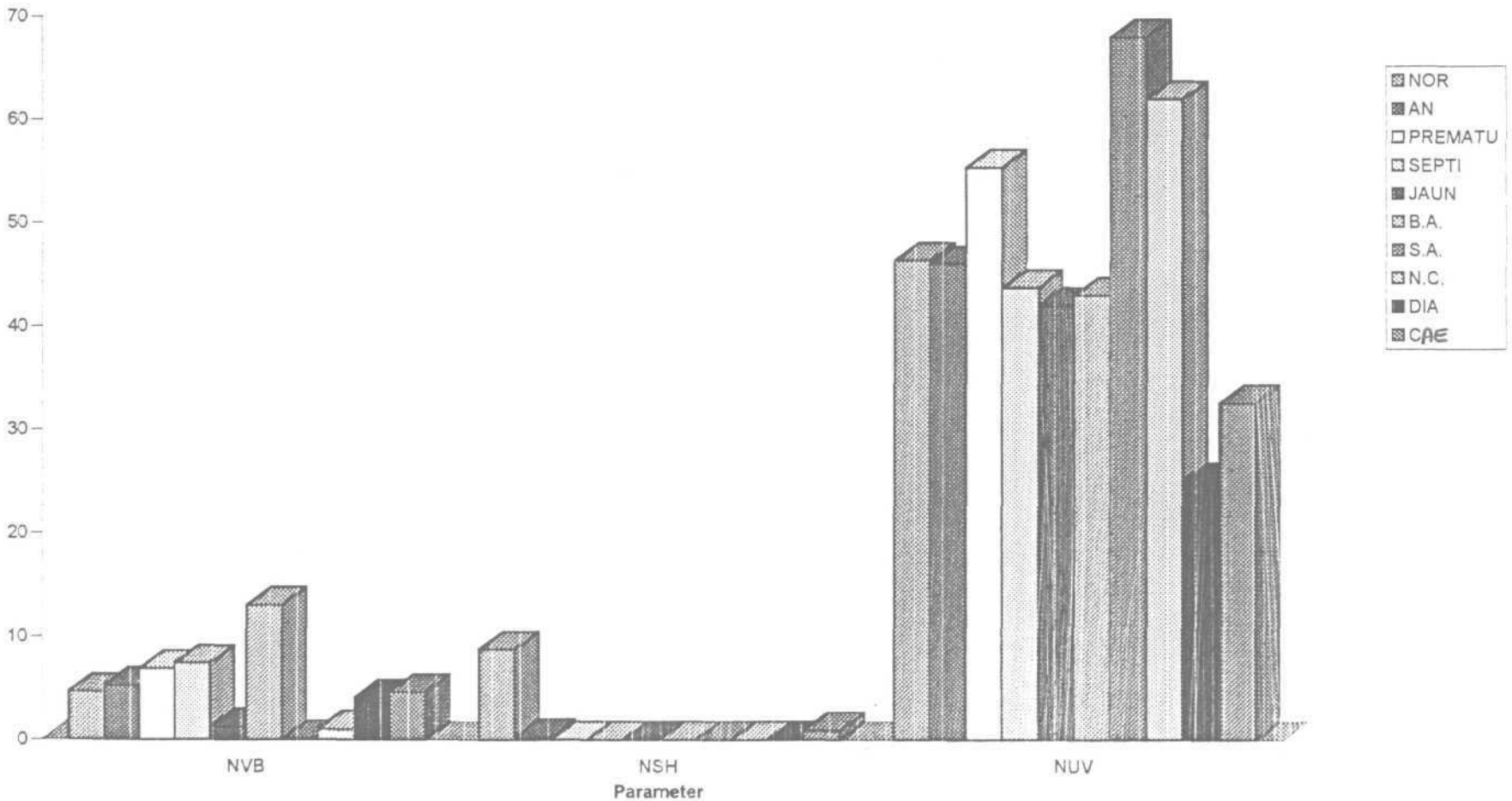


Table 29 shows that mean values of infants with history of prematurity, septic arthritis and neonatal convulsion were higher than normal mean and the mean values for infants of other groups i.e., infants with history of sepricema. jaundice birth asphyxia, diarrhoea and ceassarian births were lower than nonnal mean. Higher SD observed for infants with H/o jaundice and higher range were observed for normal group. Studies related to this parameter for infants cries is not available in the literature to the present investigator.

Table 29.1. Shows the significant difference between the normal and abnormal groups

Group	Significance
NOR Vs AN	

Table 29.1 shows that there is no significant difference between the normal and abnormal groups.

Thus hypothesis stating that no significant difference exist between the two groups is accepted with reference to the parameter number of unvoiced segments.

In general, it can be concluded that some parameters are helpful in differentiating the normal and abnormal cries, while others which could not differentiate, may be due to various contributing factors. Such as small sample size, sex, birth weight and also instrumental default.

Discriminant Analysis

The data was fed into the software as two groups. Group I, normal infants and group II, abnormal infants. Discriminant analysis was carried out using SPSS. The results obtained are shown in Table 30.

Table 30: Classification table

PD CODE	Group I	II	Total
	14	9	**23**
	0	29	**29**
%	60.09	34.01	100
	0	100	100

As can be seen from Table 30, 82.7% of the original classification was correctly identified for all the abnormal infants. But among the normal group only 14 infants are identified correctly as normals, whereas 9 infants among them were identified as abnormal who might have exhibited some abnormal values on certain parameters.

Infants of the normal group were classified as normals because no pre, peri and post-natal history was reported. No abnormal family history was presented by these subjects. There can be chances of abnormality among them as most of the informants were grandmothers or relatives and the age was mostly within one day.

However, it must be noted that it is no harm in having false positives and follow up such infants would always help in identifying any possible abnormality in future rather than missing real abnormal cases. Thus the purpose of identifying and differentiating the abnormalities in infants using the cry analysis has been

achieved. The acoustic analysis of infant cry using MDVP has been found to provide a tool for differentiating abnormal infants from normal infants.

Perceptual Analysis

Aim: 1) Whether perceptual analysis can differentiate normal and abnormal cries.

2) And if so, who were the better perceivers - mothers or professionals ?

Procedure:

Five mothers and five professionals were selected for this part of the analysis.

- Ten normal cry samples and twenty abnormal cry samples were recorded on an analog tape recorder from the digital tape.
- The tape was played to each of the ten subjects individually.
- The responses were obtained using the Yes or No responses i.e.. the judges were instructed to indicate whether the cry sample that tbey heard was considered as normal or abnormal.

Scoring: The number of correct responses were averaged for both the groups (mothers and professionals) and was converted into percentage.

Results:

Mother's obtained a score of 67.33% i.e. they could detect 67.33% of the abnormal cries correctly.

Where as, professionals obtained a score of 66.33% i.e. they could detect 66.33% of the abnormal cries correctly.

Though both the groups identified the cry samples almost to the same percent, still mother's stand a chance slightly higher than professionals.

- This could be because all the mothers selected were mother's of abnormal children.
- This can not be generalized as the number of cry samples in both groups were small in number.

Thus it was concluded that both the professionals and the mothers were equally capable of identifying the normal and abnormal cries.

SUMMARY AND CONCLUSION

The present study was designed to find out the possibilities of differentiating cries of normal and abnormal infants by both objective and subjective methods, i.e. objectively by using 29 acoustic parameters extracted using Multi Dimensional Voice Program and subjectively by perceptual evaluation by mothers and professionals.

The parameters that were studied include:

I. FREQUENCY PARAMETERS

1. Average fundamental frequency
2. Highest fundamental frequency
3. Lowest fundamental frequency
4. Standard deviation of Fo
5. Average pitch period
6. Fo tremor frequency
7. Absolute Jitter
8. Jitter percent
9. Relative perturbation quotient
10. Pitch perturbation quotient
11. Smoothened pitch perturbation quotient
12. Fundamental frequency variation
13. Fo Tremor intensity index.

II. INTENSITY PARAMETERS

14. Amplitude Tremor frequency
15. Shimmer in dB
16. Shimmer percent
17. Amplitude perturbation quotient
18. Smoothened Amplitude perturbation quotient
19. Peak amplitude variation
20. Amplitude tremor intensity index

III. OTHER PARAMETERS

21. Noise to harmonic ratio
22. Voice turbulence index
23. Soft phonation index
24. Degree of voice breaks
25. Degree of sub-harmonics
26. Degree of voiceless
27. Number of voice breaks
28. Number of sub-harmonic segments
29. Number of unvoiced segments.

The normal group consisted of 23 infants in the age range of 1/2 hr. - 7 days from birth. The abnormal group consisted of 29 infants in the age range of 2 to 50 days after birth.

The pain cry samples of the infants of both the groups were analyzed using MDVP software and statistically analysed further to find out the parameters which were useful in differentiating the two groups.

1. Average fundamental frequency (Fo)
2. Highest fundamental frequency (FHi)
3. Lowest fundamental frequency (FLo)
4. Standard deviation of Fo (STD)
5. Fo tremor frequency (Fftr)
6. Absolute Jitter (Jita)
7. Smoothened pitch perturbation quotient (SPPQ)
8. Fo tremor intensity index (FTRJ)
9. Shimmer percent (SHIM)
10. Amplitude perturbation quotient (APQ)
11. Smoothened amplitude perturbation quotient (SAPQ)
12. Peak amplitude variation (VAM)
13. Amplitude tremor intensity index (ATRI)
14. Number of voice breaks (NVB)
15. Number of sub-harmonic segments (NSH).

The results of Discriminant analysis indicated that 100% of abnormal group was identified correctly. Around 82.7% of the original classification i.e., both normal and abnormal infants was correctly identified and this was because only 60% of the subjects of normal group were identified correctly and remaining 40% of the normals were identified as abnormals. The perceptual evaluation by mothers and professionals showed that both of them could identify only 67% of the abnormal cries as abnormal

CONCLUSIONS

1. Most of the acoustic parameters extracted from MDVP could differentiate normal and abnormal cries.

2. Even perceptual analysis can be used for detecting normal and abnormal cries.

3. For reliable results for perceptual analysis, trained professionals and literate mothers should be selected.

Thus the aim of the present study to objectively and subjectively classify normal and abnormal infant cries was achieved.

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APPENDIX - A

List of High-Risk Factors

Father's Name: Age:

Mother's Name: Age:

Address:

Age of Child: Sex:

Questionnaire:

1) Has any of your close relative had a hearing loss since birth ? Yes/No
2) How is he or she related to this child ?
3) Do you know when and how he/she became deaf ?
4) Have you married your maternal uncle ? Yes/No
5) During your pregnancy did you have a rash with fever ? Yes/No
6) Did anybody tell you that you and your husband's Rh or blood groups do not match ? Yes/No
7) Prenatal during the 1st trimester of pregnancy, was the mother's health seriously affected as the result of injury or emotional trauma ?

Nausia - Anemia — Accidents

Vomiting - Bleeding — Nutritional difficiency

Toxemia - X-ray — Virus infection

Drugs

8) Was there any history of miscarriages or still birth ?

Yes/No

9) Perinatal:

a) Duration of labour

b) Labour induced Yes/No

c) Delivery - Normal/caesarian/Forceps/Breech

d) Barbituates given to mother Yes/No

10) Condition of body

a) Birth cut. -

b) Jaundice -

c) Blueness - Asphyxiated

d) Full-term/Premature/Postmature

e) Birth cry - Present/absent/delayed

f) Convulsions/twitching/drowsiness/listlessness

g) Administration of oxygen

h) Incubator care - Ye3/No

APPENDIX - B

DEPARTMENT OF SPEECH SCIENCES

ALL INDIA INSTITUTE OF SPEECH AND HEARING; MYSORE -570006

PROFORMA FOR INFANT CRY ANALYSIS

Reg. No: Date:

Father's Name: Age: Education:

Address:
Permanent: Occupation:

Local: TeleDhone:

Mother's Name: Age: Education:

Habits: Tobacco/Pan Occupation:

Birth at:

Hospital / Nursing Home / Home Reg. No:

Sex of child: Male / Female Age . . . . days

Siblings:

Consanguinity: Yes / No Relationship:

Family background:

History of	
1. Speech problems 2. Hearing impairment 3. Mental Retardation 4. Neurological Disorders: (a) Epilepsy (b) Cerebral Palsy (c) (d) 5. Other Congenital defects 6. Physical defects (specify) 7. Others	

Prenatal History:

1) History of Diabetes
Yes / No 2) History or Blood pressure
Yes / No

3) Any illness of complication and treatment decribe

[Viral . . . . . Infectious disease . . . . . .

Deficiency. . '. . . . . Tropical disease . , ...

Malnutrition . . . . . .

4) Threatened Abortion:
(Bleeding in 1st trimester)

5) Abortions if any:
When:

6) History of Toxaemia of Pregnenacy

7) Medication given:

a) Aminoglycocites

b) Quinine

c) Chloroquine

d) Others

8) Exposure to Radiation:

When:

9) Blood Group:

i) A B 0

ii) Rh (+) (-)

iii) Rh incompatibility Yes

iv) VDRL (+) (-)

10) Other relevant findings:

Natal History:

From Parents and Medical Records:

1. Full term:
2. Premature: (a) months . . . . . days,
3. Post term: (b) months . . . . . days.
4. Normal Labour Pain / Induced Labour Pair.
5. Normal Delivery:
6. Breach Delivery:
7. Instrumental Delivery:
8. Prolonged labour:
9. Caesarian Section: (a) Elective
   (b) Emergency
10. General Anaesthesia
11. Meconium stained amneotic fluid:
12. Birth cry: Normal / Delayed
    i) How long
    ii) Procedure to elicit cry:
    iii)
13. Birth Weight . . . . . .
14. as the child kept in the Incubator
15. Hypoxia:
16. APGAR Score: (a) Immediate
    (b) After 5 mts.
17. Any congenital abnormality:
18. Any other findings:

Obstetrician's opinion:

Postnatal care:

1. Was the child given any medication:

   (i) How: IM / IV
  (ii) Why ?
 (iii) What drug ?
       Dosage:

2. Did the child have Jaundice on

    (i) First day
   (ii) Later
  (iii) is progressives

  Treatment given: (a) Phototherapy
                   (b) Exchange transfusion
                   (c) Transfusion

3. Did the child suffer from convulsions:

   A. (a) 1st day (b) later

   B. Duration of convulsion

4. Congenital abnormality:

    a) Cranio facial anomolies
    b) Cleft Palate - sub mucus overt

    c) Morphological abnormality of pinna

5. Do you suspect hearing loss:

6. Any investigations or procedures done:

   (a) Ultrasound (b) L.P

   (c) C.T. Scan (C) Subdural tap

7. Any other findings:

Paediatrician's opinion:

Appendix -*C*

MDVP option acquires, analyzes and displays 29 voice parameters **from** a single vocalization. This program uses the computerized speech lab hardware system (CSL) for signal acquisition, analysis and play back. The 29 parameters are available as a numerical file or can be displayed graphically in comparison, to a data base. This data base of extracted voicing parameters is used **for** comparison **and** the user can add his own finding to this database. The advantage of MDVP extraction is that different parameters are important for the analysis of different vocal pathologies. The MDVP extracts 29 parameters in about 16 seconds. The definition of the 29 parameters as given in the MDVP manual are as follows :

1. Amplitude perturbation quotient (APQ)/%/

Relative evaluation of the period-to-period variation, variability of the peak-to-peak amplitude within the analyzed voice sample at smoothing of 11 periods. Voice break areas are excluded.

$$APQ = \frac{\frac{1}{N-4}\sum_{i=1}^{N-4}\left|\frac{1}{5}\sum_{r=0}^{4} A^{(i+r)} - A^{(i+2)}\right|}{\frac{1}{N}\sum_{i=1}^{N} A^{(i)}}$$

where $A^{(0}$, i= 1,2……N extracted peak to peak amplitude data.

N = Number of extracted impulses.

APQ measures the short term (cycle-to-cycle with smoothing factor of 11 periods) irregularity of the peak-to-peak amplitude of the voice. The smoothing reduces the sensitivity of APQ to pitch extraction errors while it is less sensitive to the period-to-period amplitude variations, it still describes the short term amplitude perturbation of the voice very well. Breathy and hoarse voice usually have an increased APQ. APQ should be regarded as the preferred measurement for shimmer in the MDVP.

2. Amplitude Ttfemor Intensity Index (ATRI)/%/

Average ratio of the amplitude of the most intense low-frequency amplitude modulating component (amplitude tremor) to the total amplitude of the analyzed voice signal.

The method for computation is same as FTRI except that here the peak to peak amplitude data has been taken into consideration instead of fo data.

3. Degree of **subharmonic components** (DSH)/%/

Estimated relative evaluation of sub-harmonic to Fo components in the voice sample.

4. Degree of Voice Less (DUV)/%/

Estimated relative evaluation of nonharmonic areas (where Fo cannot be detected) in the voice samples.

5. Degree of Voice Breaks (DVB)/%/

Ratio of the total length of the areas representing voice breaks to the time of the complete voice sample. DVB is computed as the ratio of the sum of all voice break length to the length of the complete voice same T sam (Voice command) as :

$$DVB = \frac{t_1 + t_2 + t_3 \ldots + t_n}{T_{sam}}$$

where t_1, t_2 ....t_n - lengths of the 1st, 2nd ... voice break.

T_{sam} - length of analyzed voice data samples.

DVB does not reflect the pauses before the 1st and after the last voiced areas of the recording. It measure the ability of the voice to sustain uninterrupted voicing. The normative threshold is "O" because a normal voice, during the task of sustaining voice, should not have any voice break areas. In cases of phonation with pauses (such as running speech, voice breaks, delayed start or earlier and of sustained phonation). DVB evaluates only the pauses between the voiced areas.

6. Amplitude tremor frequency (FATR)/Hz/

The frequency of the most intensive low frequency amplitude modulating component in the specified amplitude tremor analysis range. If the corresponding ATRI value is below the specified threeshold, the Fatr value is zero.

7. Fo - Tremor frequency (FFTR)/Hz/

The number of semi-tones frequencies found in the range **Flo** to Fhi consists of PFR.

The frequency of the most intensive low frequency **Fo** modu tating component in the specified Fo - tremor analysis range. If the corresponding FTRI values is below the specified threshold, the Fftr value is zero.

8. Highest Fundamental Frequency (FHI)/Hz/

The greatest of all extracted period to period fundamental frequency values. Voice break areas are excluded. Fhi is the highest fundamental frequency from the extracted period to period pitch data (Voice command). It is computed as

$Fhi = \max [Fo^{(i)}]$ i = 1,2.....N.

where $Fo^{(I)} = \frac{1}{To(^{i)}}$ period to period fundamental frequency values

To (i), i = 1,2,.....N - extracted pitch period data.

N - Number of extracted pitch periods

9. Lowest Fundamental Frequency (FLO)/Hz/

The lowest of all extracted period to period fundamental frequency values. Voice break areas are excluded, Flo is the lowest fundamental frequency from the extracted period - to - period pitch data (Voice command).

It is computed as

FlO = min [$Fo^{(i)}$, i = 1,2.....N.

Where $Fo^{(1)}$ = period-to-period fundamental frequency values

$To^{(i)}$

To (i) = i = 1,2.....N- extracted pitch period data.N- Number of extracted pitch period.

10. Average Fundamental Frequency (Fo)/Hz/

Average value of all extracted period to period fundamental frequency values. Voice break areas are excluded.

Fo is computed from the extracted period to period pitch data as :

$$Fo = \frac{1}{N} \sum_{i=1}^{N} Fo^{(i)}$$

Where Fo (i) = $\frac{1}{To^{(i)}}$ = Period to period fundamental frequency.

To (i), i = 1,2.....N - extracted pitch period data, N = PER - number of extracted pitch periods.

11. Frequency Tremor Intensity Index (FTRI)/%/

Average ratio of the frequency magnitude of the most intensive low-frequency modulating component (Fo tremor) to the total frequency magnitude of the analyzed voice signal.

12. Absolute Jitter (JITA)/usec/

An evaluation of the period to period variability of the pitch period within the analyzed voice sample. Voice break areas are excluded.

Jita is computed from the extracted period-to-period pitch data (voice command) as :

$$\text{Jita} = \frac{1}{N-1} \sum_{i=1}^{N-1} \left| To^{(i)} - To^{(i+1)} \right|$$

where $To^{(i)}$, i = 1,2,.....N - extracted pitch period data.

N = PER - number of extracted pitch periods

Absolute Jitter measures the very of the pitch short term (cycle-to-cycle) irregularity of the pitch periods in the voice sample. This measure is widely used in the research literature on voice perturbation (Iwata and vonLeden 1970). It is very sensitive to the pitch variations occurring between consecutive pitch periods. However, pitch extraction errors may affect absolute jitter significantly.

The pitch of the voice can vary for a number of reasons cycle-to-cycle irregularity can be associated with the inability of the vocal cords to support a periodic vibration for a defined period. Usually this type of variation is random. They are typically associated with hoarse voices. MDVP also provides the jitter the research literature contains normative data for three four parameter. The MDVP customer is generally advised to use RAP or PPQ instead of Jita and Jitt for determining jitter present in the voice.

Both Jita and Jitt represent evaluations of the same type of pitch pertubation. Jita is an absolute measure and shows the result in micro-seconds which makes it dependent on the average fundamental frequency of voice. For this reason, the normative values of Jita for men and women differ significantly. Higher pitch results into lower Jita. That's why, the Jita values of two subjects with different pitch are difficult to compare. Jitt is a relative measure and the influence of the average fundamental frequency of the subject is significantly reduced.

13. Jitter Percent (JITT)/%/

Relative evaluation of the period -to-period (every short term) variability of the pitch within the analyzed voice sample voice break areas are excluded. **Jiit** is computed from the extracted period to period pitch data (voice commana) as :

$$Jitt = \frac{\frac{1}{N-1}\sum_{i=1}^{N-1}\left|To^{(i)} - To^{(i+1)}\right|}{\frac{1}{N}\sum_{i=1}^{N}To^{(i)}}$$

where $To^{(i)}$, i = 1,2.....N-extracted pitch period data. N = PER - number of extracted pitch periods.

Jitter percent measures the very short term (cycle-to-cycle) irregularity of the pitch period of the voice. Jitt is a relative measure and the influence of the average fundamental frequency of the subject is significantly reduced.

14. Noise to Harmonic Ratio (NHR)

Average ratio of the inharmonic spectral energy in the frequency range 1500-4500 Hz to the harmonic spectral energy in the frequency range 70-4500 Hz. This is general evaluation of noise present in the analyzed signal.

15. Number of subharmonic segments (NSH)

Number of autocorrelation segments where the pitch was found to be **a** sub-harmonic of Fo.

16. Number of unvoiced segments (NUV)

Number of unvoiced segments detected during the autocorrelation analysis.

17. Number of Voice Breaks (NVB)

Number of times the fundamental period was interrupted during the voice sample (measured from the first detected period to the last period).

18. Phonotory fundamental frequency range in semitones (PFR)

It is the range between-£he highest Fo (HFi) and lowest F_o (FLo) expressed in the number of semi -tones. PFR is computed by accounting the number of semi-tones in the frequency range FLO **to** Fhi. The ratio of the two consequentive semi tones (ki) is equal to 12th root of 2.

First are the frequency of semitones $Fst^{(k)} = f,a^k$, K = 1, 2, 3.....n are computed within the frequency range 55 Hz - 1055 Hz where a = 12... $\sqrt{2}$.

$f_1 = 55$ Hz, $f_2 = 1055$ Hz,

$f_1 \leq fst(K) \leq f_2$

.19. Pitch period perturbation quotient (PPQ)/%/

Relative evaluation of the period-to-period variability of the pitch within the analyzed voice sample with a smoothing factor of 5 periods. Voice break areas are excluded. PPQ is computed as,

$$PPQ = \frac{\frac{1}{N-4}\sum_{i=1}^{N-4}\left|\frac{1}{5}\sum_{r=0}^{4} To^{(i+r)} - To^{(i+2)}\right|}{\frac{1}{N}\sum_{i=1}^{N} To^{(i)}}$$

where $To^{(i)}$, **i** = 1,2,.....N - extracted pitch period data, N = PER - number of extracted pitch periods.

PPQ measures the short term (cycle-to-cycle with a smoothing factors of 5 periods) irregulatrity of the pitch period of the voice. The smoothing reduces the sensitivity of PPQ to pitch-extraction errors while it is less sensitive to period-to-period variations, it describes the short-term pitch perturbation of the voice very well. Hoarse and/or breathy voices may have an increased PPQ.

20. Relative average perturbation (RAP)/%/

Relative evaluation of the period-to-period variability of the pitch within the analyzed voice sample with smoothing factor of 3 periods. Voice breaks areas are excluded. It is computed as :

$$RAP = \frac{\frac{1}{N-2}\sum_{i=2}^{N-1}\left|\frac{To^{(i-1)} + To^{(i)} + To^{(i+1)}}{3} - To^{(i)}\right|}{\frac{1}{N}\sum_{i=1}^{N} To^{(i)}}$$

where $To^{(0}$ = i = 1, 2.....N - extracted pitch period data. N = PER - number of extracted pitch periods.

Relative Average perturbation measures **the short term** (cycle-to-cycle with smoothing factor of 3 periods) irregularity of the pitch period of the voice. The smoothing reduces the sensitivity of RAP to pitch extraction errors. However, it is less sensitive to the very short term period-to-period variations, but describes the short **term** pitch perturbation of the voice very well.

The pitch of the voice can vary for a number of reasons, cycle-to-cycle irregularity can be associated with the inability of the vocal cords to support a periodic vibration with a defined period. Hoarse and/or breathy voices may have an increased RAP. MDVP also provides the jitter parameters PPQ, Jitta and Jita because the research literature contains normative data .for these parameters the MDVP customer is advised to use RAP or PPQ instead of Jita and Jitt as an indication of jitter in the voice.

21. Smoothed amplitude perturbation quotient (SAPQ)/%/

Relative evaluation of the short or long term variability of the pitch period within the analysed voice sample at smoothing factor defined by the user. The factory setup for the smoothing factor is 55 periods, voice break areas are excluded.

$$SAPQ = \frac{\frac{1}{N-sf+1}\sum_{i=1}^{N-sf+1}\left|\frac{1}{sf}\sum_{r=0}^{sf-1}A^{(i+r)} - A^{(i+m)}\right|}{\frac{1}{N}\sum_{i=1}^{N}A^{(i)}}$$

where $A^{(I)}$,i= 1,2……N extracted peak to peak N = Number of extracted impulses amplitude data.

Sf = smoothing factor defined by voice. Smooth SAPQ allows the experimenter to define his own amplitude perturbation measure by changing the smoothing factor from 1 to 199 periods. This flexibility is desirable because in the scientific literature researchers use amplitude perturbation measures with different smoothing factors or without smoothing.

With a small smoothing factors, SAPQ is sensitive mostly to the short-term amplitude variation of the voice impulses.

With a smoothing factor of 1 (no smoothing), SAPQ is identitical to Jitter variations occurring between consecutive pitch periods. Usually this type of variation is random. It is typical for hoarse voices. However.pitch extraction errors may object Jitter percent significantly.

22. Shimmer in dB (shdb)/db/:

Evaluation is dB of the period-to-period (very short term) variability of the peak-to-peak amplitude within the analyzed voice sample voice break areas are excluded.

$$shdB = \frac{1}{N-1} \sum_{i=1}^{N-1} \left| 20 \log \left(A^{(i+1)}/A^{(i)}\right) \right|$$

where $A^{(0}$, i = 1,2.....N - extracted peak to peak amplitude data.
N - number of extracted impulses.

Shimmer in dB measure the very short term (cycle-to-cycle) irregulatiry to peak-peak amplitude of the voice. This measure is widely used in the research literature on voice perturbation(lwata & vonLeden 1970). It is very

sensitive to the amplitude variation occurring between consecutive pitch periods. However pitch extraction errors may affect shimmer percent significantly.

The amplitude of the voice can vary for a number of reasons. Cycle-to-cycle irregularity of amplitude can be associated with the inability of the vocal folds to support a periodic vibration for a defined period and with the presence of turbulent noise in the voice signal, usually this type of variation is random. It is typically associated with hoarse and breathy voices. MDVP also provides the shimmer parameters APQ and Shim. APQ because the research literature contains normative data for these three parameters preferred measurement for shimmer because it is less sensitive to pitch extraction errors while still providing a reliable indication of short-term amplitude variability in the voice.

Both shim and shdB are relative evaluations of the same type of amplitude perturbation but they use different measures for the result percent and **dB.**

23. Shimmer Percent (SHIM)/%/

Relative evaluation of the period-to-period (very short term) variation of the peak-to-peak amplitude within the analyzed voice sample voice break means are excluded. Shim is computed from the extracted peak-to-peak amplitude data (voice command) as :

$$\text{shim} = \frac{\frac{1}{N-1}\sum_{i=1}^{N-1}\left|A^{(i)} - A^{(i+1)}\right|}{\frac{1}{N}\sum_{i=1}^{N}A^{(i)}}$$

where $A^{(1)}$, **i** = 1,2,…….N - extracted peak to peak amplitude N = Number of extracted impulses.

Shimmer percent measure the very short term (cycle-to-cycle) Irregularity of the peak-to-peak amplitude of the voice.

24. Soft Phonation Index (SPI)

Average ratio of the lower frequency harmonic energy in the range 70-1600 Hz to the higher frequency harmonic energy in the range 1600-**4500 Hz.**

25. Smoothed Pitch Period Perturbation Quotient (sPPQ)/%/

Relative evaluation of the short or long-term variability of the pitch period within the analyzed voice sampl e at smoothing factor defined by the user. The factory setup for the smoothing factor is 55 periods. Voice break areas are excluded.

sPPQ is computed from the extracted period-to-period pitch data as:

$$sPPQ = \frac{\frac{1}{N-sf+1}\sum_{i=1}^{N-sf+1}\frac{1}{sf}\sum_{r=0}^{sf-1}To^{(i+r)} - To^{(i+m)}}{\frac{1}{N}\sum_{i=1}^{N}To^{(i)}}$$

where : $To^{(1)}$, i = 1.2...N - extracted pitch period data, N=PER-number of extracted pitch periods, sf-smoothing factor defined by VOICE.SMOOTH.SPPQ.

26. Standard deviation of fundamental frequency (STD)/Hz/

Standard deviation of all extracted using the voice command period to period fundamental frequency values. Voice break areas are excluded.

STD is computed as standard deviation of the extracted period-to-period fundamental frequency data (Voice command) as

$$STD = \sigma = \sqrt{\frac{1}{N} \sum_{i=i}^{N} (Fo\ (i)\ )^2}$$

where $Fo = \frac{1}{N} \sum_{i=1}^{N} Fo^{(i)} = \frac{1}{To^{(i)}}$ - period to period fundamental frequency values.

$To^{(i)}$ = 1,2,……N - extracted pitch period data.

N = Number of extracted pitch period data.

27. Voice Turbulence Index (VTI)

Average ratio of the spectral inharmonic high frequency energy in the range 2800-5800 Hz to the spectral harmonic energy in the range 70-4500 Hz in areas of the signal where the influence of the frequency and amplitude variations, voice breaks and sub-harmonic components are minimal. VTI measures the relative energy levels of **a** high frequency noise .

28. Co-efficient of Fo variation (VFO)/%/

Relative standard deviation of the fundamental frequency. It reflects, in general, the variation of Fo (short term to long term), within the analyzed voice sample. Voice break areas are excluded.

$$vFO = \frac{\sigma}{Fo} = \frac{\frac{1}{N}\sum_{i=1}^{N}\left(\frac{1}{N}\sum_{j=1}^{N} Fo^{(i)} - Fo^{(i)}\right)^2}{\frac{1}{N}\sum_{i=1}^{N} Fo^{(i)}}$$

$$\text{where } Fo = \frac{1}{N}\sum_{i=1}^{N} Fo^{(i)}$$

$Fo^{(i)} = \frac{1}{To^{(i)}}$ - period to period Fo values

To (1), i = 1,2. . . . .N, extracted pitch period data.

N = number of extracted pitch periods.

vFO reveals the variations in the fundamental frequency. The vFO value increases regardless of the type of pitch variation. Either random or regular short term or long term variations increase the value of VFO. Because the sustained phonation normative thresholds assume that the Fundamental frequency should not change, any variations in the fundamental frequency are reflected in vFO. These changes could be frequency tremors (i.e., periodic modulation of the voice) or non periodic changes, very high jitter or simply rising or falling pitch over the analysis length.

29. Co-efficient of amplitude variation (vAM)/%/

Relative standard deviation of peak-to-peak amplitude. It reflects in general to peak-to-peak amplitude variations (short **term** to long term) within **the analyzed** voice sample. Voice break areas are excluded.

vAM is computed as ratio of **the** standard deviation to the average value of **the** extracted peak-to-peak amplitude data (voice command) as :

$$VAM = \frac{\frac{1}{N}\sum_{i=1}^{N}\left(\frac{1}{N}\sum_{i=1}^{N} A^{(i)} - A^{(i)}\right)^2}{\frac{1}{N}\sum_{i=1}^{N} A^{(i)}}$$

where $A^{(i)}$, i=1,2.....N - extracted peak to peak amplitude data.
N - number of extracted impulses.

vAM reveals the variations in **the** cycle-to-cycle amplitude of the voice. The **vAM** value increases regardless of the type of amplitude variation. Either random or regular short term or long term variation increase the value of vAM.