# DEVELOPMENTAL CHANGES IN INFANT CRY

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*Dedicated to the one,*

*Whose thoughts are always next to me.*

*your love & affection is an indelible part of my memories.*

*Wishing you happiness, life long............*

*&*

*Dear "Parents - I cherish your love*

*(Akka & Appaji)*

## C E R T I F I C A T E

This is to certify that the disseration entitled **"DEVELOPMENTAL CHANGES IN INFANT CRY"** is the bonafide work in part fulfilment for the degree of Master of Science (Speech and Hearing) of the student with Register No. M 9323.

MYSORE
MAY 1995

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# C E R T I F I C A T E

This is to certify that the dissertation entitled **"DEVELOPMENTAL CHANGES IN INFANT CRY"** has been prepared under my supervision and guidance.

MYSORE
MAY 1995

Dr.N.P. Nataraja
Guide

# D E C L A R A T I O N

This dissertation is the result of my own study undertaken under the guidance of Dr. N.P.Nataraja, Prof, and Head, Department of Speech Science, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any university for any other Diploma or Degree.

Reg. No.M 9323.

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MAY 1995

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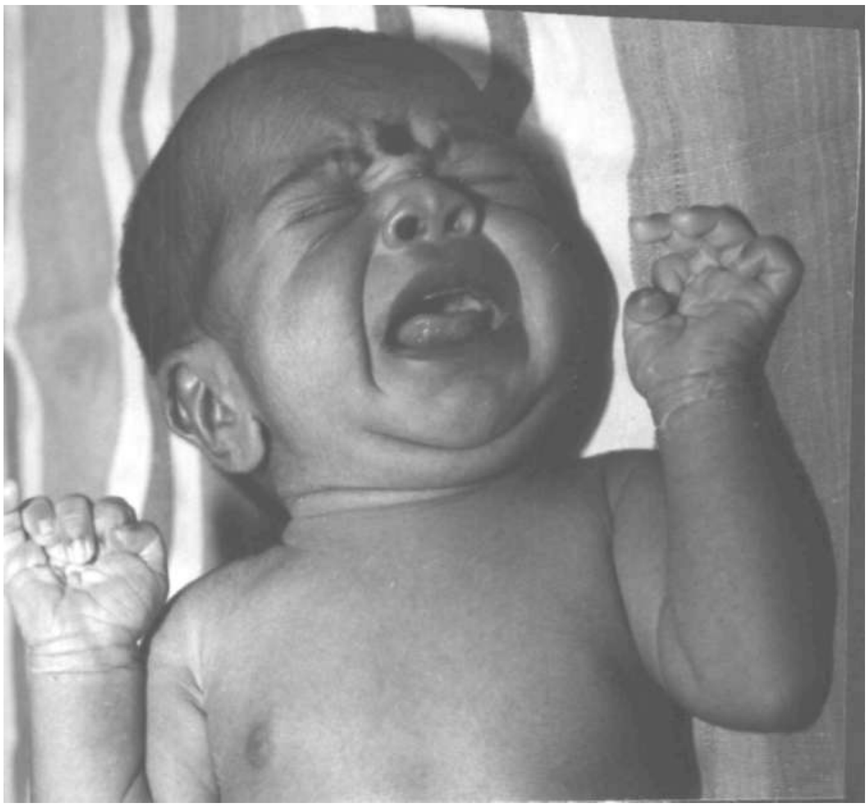

BABY GIVING A PAIN CRY

# INTRODUCTION

**But what am I ?**
**An infant crying in the night;**
**An infant crying for the light;**
**And with no language but a cry.**

**Alfred Lord Tennyson**
**(1809-1892)**

"During infancy, the child's only mode of communication is the cry, and we should listen to his vocalization and try to interpret it. When a baby is ill, the parents too are most eager and anxious to have some explanation of his prognosis and possible life-long defects. Any method which could provide further enlightenment should be thoroughly explored" (Sijruio and Michelson, 1976).

What do we know about normal infant cries and vocalizations? How would this information be useful in applying it to assess the cries of non-normal infants? Does it have other benefits besides its diagnostic value? Unfortunately, this is one area where there is a huge lack of data and research. Very little has been done in systematically documenting the changes in the cries and vocalizations of normal infants with the anatomical and maturational changes in the first few years of life. At the very least, we first need to examine the acoustics of vocalization in normal infants because our criterion for nonnormalcy is a comparative one with respect to the normal infants cries. Only with this knowledge we can know if the phonatory output of any infants is " normal" or not.

Hence the infant cry sounds has interested researchers of different disciplines for over a century. The general answer to why we should study infant cry is at least one which accords with view, stated by Liberman:

"......the biological substrate of human speech involves an interplay between biological mechanisms that have other vegetative functions and neural and anatomical mechanisms that appear to have evolved primarily for their role in facilitating human vocal communication".

Boukydis, considered crying "to be a gradation of a pre-verbal distress signal". His notion, evidently, is that crying and its perception constitute an interpersonal event. Although this is undoubtedly true, but it is not the primary reason why we should study infant cry or other vocalizations. As Hollien observed, cries relate to some physiological event or condition as well as to behavioral events or states. Crying in infants is a reflection of the integrity of the neurology, anatomy and physiology of the mechanisms involved in crying.

It is important to emphasize here that crying is not just a reflection of only the physiological state of the infant. Increasingly, a number of researchers are beginning to view crying and its perception as an interpersonal event (Boudkydis, 1955). That is, crying is considered as a social event, as a system of communication. It may serve as a pre-verbal distress signal. There is, now, an increasing body of research systematically documenting this aspect of crying and the consequences of its perception and response by the caregivers. For clinical purposes, crying and other vocalization are signals which can be used to evaluate the neurorespiratory and phonatory functions of the infant. It is this reason that there has been so much interest in the cries of high risk newborns.

Unusual cry is caused by some disturbance 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 by cri-du-chat syndrome, Down syndrome, or damage to the recurrent nerve, etc. Or, it could be produced by some disarrangement in the airway itself, For eg: laryngomalacia, tracheostenosis, or upper airway abnormality. Performing sophisticated analysis of these unusual cries ( specifically, acoustic analysis), we ought to be able to detect and locate the site of this disturbance. This is the real clinical purpose in pursuing infant cry analysis. That is, we ought to be able to differentially diagnose the difference between subglottal, periglottal and supraglottal sites of disturbance, as well as detect the difference between airway and nervous system origins of the abnormality. This is the diagnostic significance of acoustic analysis of infant cries and vocalizations (Gopal and Gerber 1992).

A number of investigators has employed acoustical analysis of various sorts of both normal and non-normal infants. For example: for over 30 years, several Finnish and Swedish researchers have used the sound spectrograph and conducted systematic acoustical analysis of cries. They have provided large amounts of acoustical data on cries of normal infants as well as on cries of several different type of non - normal infants. This vast body of research has provided much of the justification and inspiration for using acoustical analysis of cries as an additional diagnostic tool in clinical pediatrics.

More recently, sophisticated and automated computer analysis of cries have been under taken with the same objective in mind. For example: Golub and Corwin, employing sophisticated acoustical techniques, analyzed the cries of 87 infants. They extracted 88 acoustic features and by a grouping of some combination of these features, they designed a set of eight cry tests which was based on their model of cry production. They reported that a majority of the normal cries (about 82%) had none of the abnormal cry features. These newer, automated, sophisticated analysis provide increasing promise for cry analysis as a powerful non-invasive tool in the future. However, more studies are need to establish standardized procedures and templates for acoustical analyses of cries before the true potential of cry analysis may be evaluated and harnessed. Hence, we first need to examine the acoustics of vocalizations of normal infants in a systematic way. This will help us substantially in understanding the development of speech production as well as our attempts to use infant cry analysis for diagnostic purposes.

Hence the purpose of the present study was to systematically analyse the developmental changes of the infant cries by multi dimensional voice programmer (MDVP) and to note the specific changes in the cry over a period of 3 months. The research was designed to obtain normative data of newborn infants cries without any pathological symptoms to look for possible variation that takes place within 3 months.

**Need for the present study:**

Acoustic analysis of the infa'nt cry using MDVP is a totally non - invasive technique. Most other techniques employed in the diagnosis of sick babies are invasive (eg: Radiography, endoscopy, blood tests etc.,). The process of administering some of these invasive tests and techniques themselves carry varying amount of risk to the infant. Given comparable diagnostic utility of techniques clearly non-invasive procedure are the techniques of choice. Invasive techniques require waiting until the infant is of an appropriate age for some of the tests, with a recording and analysis of the birth cry, the moment of birth itself offers data for an evaluation of the infant. Early evaluation leads to possible early detection of non-normal or high risk infants which has enormous implication in diagnosis and remediation.

Acoustic analysis is also a powerful and objective technique. The past 20 years of research has witnessed an enormous progress in the understanding of the speech process with the application of digital signal processing to human speech analysis. Applying such powerful techniques to infant cries and vocalizations may hold a lot of promise in an understanding of infant cries both normal and non-norraal infants. Hence automated computerized acoustic analysis of infant cries may offer potential diagnostic benefit. Based on this the present study is planned to extract the developmental changes in the infant cry from 1st day to 3 months using the Multi-dimensional voice programmer.

**Hypothesis:**

Main hypothesis there is no significant differences between cry recording made from first day to three months in terms of parameters measured using Multi-dimensional voice programmer.

1. There is no significant difference between the cry recordings made from 1st day to 3 months in terms of Average Fundamental Frequency (Fo).
2. There is no significant difference between the cry recordings made from 1st day to 3 months in terms of Average Pitch Period (To).
3. There is no significant difference between the cry recordings made from 1st day to 3 months in terms of Highest Fundamental Frequency (Fhi).
4. There is no significant difference between the cry recordings made from 1st day to 3 months in terms of Lowest Fundamental Frequency (Flo).
5. There is no significant difference between the cry recordings made from 1st day to 3 months in terms of Standard Deviation of Fo (STD).

There is no significant difference between the cry recordings made from 1st day to 3 months in terms of Fo - Tremor Frequency (Fftr).

There is no significant difference between the cry recordings made from 1st day to 3 months in terms of Amplitude Tremor Frequency (Fatr).

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There is no significant difference between the cry recordings made from 1st day to 3 months in terms of Pitch Perturbation Quotient (PPQ).

There is no significant difference between the cry recordings made from 1st day to 3 months in terms of Smoothed Pitch Perturbation Quotient (sPPQ).

There is no significant difference between the cry recordings made from 1st day to 3 months in terms of Fundamental Frequency Variation (vFo).

There is no significant difference between the cry recordings made from 1st day to 3 months in terms of Shimmer in dB (ShdB).

There is no significant difference between the cry recordings made from 1st day to 3 months in terms of Shimmer Percent (Shim).

There is no significant difference between the cry recordings made from 1st day to 3 months in terms of Amplitude perturbation Quotient (Apq).

There is no significant difference between the cry recordings made from 1st day to 3 months in terms of Smoothed Amplitude Perturbation Quotient (sAPQ).

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There is no significant difference between the cry recordings made from 1st day to 3 months in terms of Noise to Harmonic Ratio (NHR).

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There is no significant difference between the cry recordings made from 1st day to 3 months in terms of Soft Phonation Index (SPI).

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**Limitations of the study:**

1. The sample size is very small. Hence a large data can be collected in order to confirm the present study.
2. This study concentrated only from 1st day to 3 months. But we need a longitudinal study to characterize the pattern of change in infant vocalization which will be diagnostically useful in the clinic but also important in understanding the link between preverbal vocalization and language development.

**Implication of this study:**

1. The present study imply on the correlation of the acoustical changes with the developmental anatomy, physiology and maturation factors.
2. The present data can be served as normative data. Based on this it can be possible to compare the cry of any infant to these prototypical templates in the hope to contribute to diagnosis and therefore to treatment.

# REVIEW OF LITERATURE

# REVIEW OF LITERATURE

'Random', 'non-expressive' & 'diffuse' & similar terms have been used to describe the utterances of babies (Gesell 1940, Osgood 1953, Spitz 1963). Writers such as Miller (1951), Sherman (1927) & Van Riper (1954) suggest that the cry of a baby has little, intent or meaning & that the nature of the discomfort that causes could not be identified by the type of vocalisation. The cries of infant have stimulated curiosity among scientists and physicians.

Crying is a behavior; in fact, it is a sequence of behavior patterns that is part of the larger behavioral 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 behavior that has powerful effects on the parent-infant relationship, and it elicits strong emotions in parents. The cry is, also an acoustical event that not only affects caregivers but also contains information about the functioning of the infant's nervous system. Finally, as a term of communication, crying is the beginning of vocalization and may have implications for the development of speech and language.

**The development of cry** :

Crying is an organized behavioral response that, unlike other reflexes such as rooting and sucking, occurs at birth without any previous functioning of the total operating behavioral system. Crying has its discrete beginning at birth because this is usually the first time that the maturational capabilities of the infant interact with an environmental condition that allows the potential crying behavior to be realized. Infant crying has great significance for many aspects of infant development and has this been studied with in a variety of contexts. In one context, crying is a salient social behavior of the newborn and young infant that influences the infant's interactions with the care giving environment.

Crying is one of the first ways in which the infant is able to communicate with the world at large (Ostwald and peltzman, 1924). Different authors have offered various explanations for the first cry emitted by the child. The function of the birth cry is said to be entirely physiological, having to do with the establishment of normal respiration and the oxygenation of the blood. It constitutes the first use of the delicate respiratory mechanisms which are to be involved in speech. It is also the first time that the child hears the sound of his own voice, and as such, has significance for language development (Mc Carthy 1954).

The first cry is said to have other physiological purposes, such as to remove foreign material (Peto), to improve pulmonary capacity in the first days of life (Long and Hull' 65) or being a defense 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. Hopefully, this cry is a good one, if not, a nurse or doctor in the delivery room tries to stimulate the infant to cry. It may be by tapping the infant on the foot, back side, back, or by one of several resuscitation techniques. The fact that the cry is an essential part of life, alone adds significance to the study of the infant's cry.

The first cry in the infant is said to be very important. The infant is no longer depending on the blood circulation from the mother, and this is oxygen supply to the body must be taken care of by the infant itself. 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 high risk infants, showing a history of brain damage. Therefore, whenever there is a delay in the first cry, the cry is elicited by using one of the several resuscitation techniques.

Crying is the results of the intense expulsion of air through tightened vocal cords into the pharynx and month as a resonating chamber. The character of the cry depends upon the intensity of air expulsion, the tension in the vocal cards and the shapes and fixation of the resonating chamber. Since crying is generally a maximal type of response, 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, the differences in the ability of different nervous system to respond could be in the peripheral sensory receptors, but it seems more complex that these differences are in the more complex activating system of the brain, in the brain stem and thalamus. Likewise, the character of the minor responses could be due to changes in the peripheral motor control of the expulsion of air, vocal cord tension and shape and tension in the supra glottal resonators. But it is more likely due to the effects of higher control centres in the brain, the act in a modulating or inhibiting fashion on the activating centres.

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 tonal 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).

Borma 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.

**Infant cry analysis**

In a traditionally separate context, infant crying has long been an integral part of standard newborn neurological examinations (prechtl and Beintema, 1964). Early studies of newborn and young infants showed that several measures of the threshold and production of crying (Fisichelli and Karelitz, 1963; Karelitz and Fisichelli, 1962) studied the spectral characteristics of the cry sound (Vuorenkoski, Lind, Partanen, Lejeune, Lafourcade, and Wasz-Hockert, 1966) and concluded that cry sound could be used to support the diagnosis of a wide range of central nervous system (CNS) disorders.

There have been substantial advances in the field during the past few years, due, in part to increased collaboration among investigators from different disciplines. The study of crying from a normal developmental perspective has had a number of implications for the understanding of normal and abnormal developmental processes Another major advance in cry research, also aided by a normal developmental perspective, has been the burgeoning and cry perception studies- how adults feel about and respond to different infant cry patterns. Cry perception studies provide an important adjunct to, and cross-validation of, acoustic analysis by showing the acoustical dimensions along adults differentiate with in the really of normal infant cries and between the cries of normal and abnormal infants. They actually help in the selection of acoustic variables.

The art of diagnostic listening was described in ancient times by Hippocrates. The art, however, was essentially ignored until 1855 when Charles Darwin treated the topic of infant crying and screening quite comprehensively, using photographs and drawings to illustrate various expressions and emotions. Flatan and Gutzmann (1906) used a gramophone to record infant vocalizations. They listened to the cry recordings of 30 neonates and noted 3 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. Fair banks (1942) listened to gramophone records to study the frequency characteristics of the "hunger wails" of one infant over a period of 9 months.

The infant cry sound has interested researches 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 electro-laryngograph, spectrograph and computer analysis.

The most readily available means for cry analysis is the human ear. Over the years, various technological advances have increased our ability to assess the infant cry by listening. It is instructive to review briefly the reports that have examined the value of diagnostic listening

Wasz-Kockert et. al., (1964) found that when typical pain, hunger and pleasure cries were played to 438 adults, those with more experience in child-care identified the cries more accurately than those who had no previous experience. Murry Amundson, and Hollien (1977) noticed that an infant's sex could not be reliably identified on auditory basis.

Oartanen et at, (1967) found audible differences between the cries of healthy new born infants and those with asphyxia, brain damage, jaundice, and Down's syndrome who recognizable by pediatricians and medical students.

The phonetic structure of cries, cry duration, stimulus intensity, cry latency, and cry threshold have been found to be useful parameters in differentiating between normal and abnormal infants cries. (Fisichelli et al, 1966, Rebelsicy and Black, 1972, Fisichelly and Karelitz, 1969, Ferichelli and Karelitz, 1963; Karelitz and Fisichelli, 1962).

Objective techniques for analyzing infant cries are by volume-unit graphs (Fisichelli, Kearelitz, Eichbarer, and Resenfield, 1961) and computer analysis (Ostwald and Peltzman, 1974).

**Auditory Investigation**

Earlier the studies on infant cry analysis used auditory investigations. Auditory investigations were carried out by William Gardiner (1838), charles Darwin (1855), Flatau and Gutzman (1906), Sherman (1927), Bayley (1932), FairBanks (1942) and Mc Carthy (1952), Wasz - Hockert et.al., (1964), Partanem et.al.,(1967) and they have found that infant cry analysis in helpful in differentiating normal and abnormal infants.

Spectrographic Analysis:

Over the past 20 years, most studies of the infant cry have utilized the sound spectrogram. The sound spectrograph produces a permanent visual record showing the distribution of energy in both frequency and time. It was originally developed at the Bell laboratories in the late 1840's.

With the development of the sound spectrograph by potter et. al., (1940) Objective analysis of any sounds has become possible. Since then, many researchers have been doing studies on cry characteristics of normal and abnormal infant cries. More than 20 different cry characteristics like latenecy, duration, continuity of the cries. Shift, Melody type, voice quality, fundamental frequency, the maximum and Minimum frequency have been measured. The occurence of double harmonic break, glottal roll, vibrato, bi-phonation, gliding, furcation, concetration, tonal pitch and glottal plosives have also been identified nand measured.

These studies have shown that cry analysis can be helpful in differentiating between normal and abnormal infants and thus it will become an additional valuable tool for arriving at the diagnosis and prognosis of newborn infants.

Tenold et. al., (1974) have attempted to find out the spectral variability in the cries of pre-mature and fullterm neonates. 9 full termed 5 pre-mature infants were taken for the study. There was no difference in variability of fundamental frequency between the 2 groups. But premature infants showed greater variability of cry spectram than did the full-term infants. Since formants are peaks in the sound spectrum, variability of formats will be reflected in spectral variability. Therefore, greater instability of cry spectra for premature infants may be interpreted as reflecting less postural stabilization based on the source theory of speech production.

Cullen et. al., (1968) have tried to study the development of auditory feedback monitoring in infants ranging from 24- 168 hours of age. 11 males and 9 females were studied. Vocal cry samples of these 30 normal newborn infants were recorded under 2 test conditions-synchronous auditory feedback and a 200 msec, delay in auditory feedback(DAF). Averages for cry duration, pause time and maximum sound pressure level were obtained for 16 of the 20 subjects. This study has demonstrated that a 200 msec, delay in the air conducted auditory feedback of the cry of a newborn infant is associated with a significant decrease in average cry duration. This result is at variance with the consistent observation that the average deviation of connected speech events for children and adults increases under DAF. The results, while not conclusive, indicate that cry behavior may be under closed loop auditory-feedback control.

Karelitz(1969) carried out a longitudinal study on the normal development of cry in a baby girl. The first recording was made at the age of 2 days shortly before the infant was fed. The cry response came immediately after a finger flick was applied to the infant's foot. The duration of each burst of cry lasted as long as the infant had exhaled and was followed by a sharp intake of breath. The rhythm was rapid but regular and the intensity was great. The cry diminished in frequency and intensity gradually until it stopped, this sequence was repeated with each painful stimulus.

The cry at 4 days was similar to but, a bit stronger than at 2 days. At one month the cry was still rapid and rhythmic and coughlike sounds could be heard. The cry at 2 months was still rhythmic, but this rhythm pattern was some what slowed by the lengthening of the inhalation and cry. Inflection variations and a plaintive quality were evident at 3 months. The repetitive rhythmic pattern which is evident in a younger infants's cry was no longer characteristic of the cry at 6 months. At 9 months the cry was inflected and distinct syllable, "ah-ha" occurred throughout. At 12 months the qualities of the 9 month cry were still present but somewhat intensified. Recognizable words were inter spersed throughout the crying at 18 months. At 2 years- the child communicated with words as well as with the cry.

Fundamental frequency characteristics of non-distress vocalizations produced by four infants during the first 24 weeks of life were examined by laufer and Haru (1977) period-by-Period Fo melody plots and descriptive statistics for each utterance were derived from computer analysis. Mean Fo centered around 335 Hz with little variation. Individual Fo fluctuations deviating from the mean were felt to be associated with the infant's state, activity levels and changing vocal repertoire.

Keating and Buhr(1978) studied the fundamental frequency in the speech of 6 children, ranging in age from 33-169 weeks. Utterances were divided into 3 registers: fry register, modal register and high register. The overall range of frequency in fry register was 30-250 Hz. Utterances containing modal register comprised the bulk of the samples for each child and the overall range of frequency in modal register was 150-700 Hz. In addition to these high modal values, the occurrence of a separate high register was also noted. The data for this sample of 6 children shows that both very low and high fundamental frequencies are common at all stages of language acquisition.

The course of crying activity was traced at successive intervals after birth: one minute, ten minutes, then 2, 4, 6, 6, 24, 48, 72 and 94 hours after birth, for 24 infants with Apgar scores from 8-10(High Apgar group) and 12 with Apgar scores from 4-6 (Low Apgar group). These 36 infants were studied 'cross-sectionally' (ten at each of seven time intervals corresponding to those in the longitudinal group). A cry index (C.Z) was devised incorporating cumulative time of crying, the number of bursts in the cry, and threshold. The findings indicate: (1) The curves describing cry activity show a drop at 4-6 hours for all three groups with subsequent recovery for all. (2) No differences were found between the 'Low' Apgar and the 'Cross sectional' groups in crying activity. (3) It is suggested that the depression in crying activity for the majority of infants between 2 and 6 hours after birth is traceable to 'fatigue'. The effort expended in the act of birth, the transition from placental to pulmonary breathing, the violent and sudden extension of the diaphragm, possible chilling in the immediate postnatal period, the type of delivery, perhaps even the sedative effects of drugs administered to the mother in labour, all may contribute to the depression found in these early hours of life (Fisichelli, Karelitz and Haber, 1969).

2.13

A similar study was carried out by Fisichelli et.al., (1974). 71 male and 87 female normal full term infants were taken and their crying activity in response to painful stimulation was recorded at successive ages from 5 hours through 52 weeks of age. They found that, although there is considerable variability in the crying response to stimulation which is painful, at any of the age levels specified in the study, reactivity is low at 5 hours of age, increases at 2 days of age, and then remains relatively stable upto 12 weeks. Thereafter, it diminishes markedly, or at the least, the overt cry reaction is suppressed.

Thus, it has been stated that the course of the cry reaction curve is primarily a function of age. This view has been supported by additional findings, which also rule out the major determinants, i.e., Systematic adaptation affects, sex differences, and gross differences in 10 levels within the group studied. The authors hypothesize that, this lack of cry reaction is a maturing response and that it may be related to the corresponding maturation of central nervous processes within the individual at 3 or 4 months of age.

Karelitz et. al.,(1964) explored the relation between the crying of infants four to ten days of age and intelligence as well as speech development level at 3 years of age. The cry samples were taken from 36 infants 4 to 7 days of age, one infants of age 8 days and another of age 10 days. 30 were given the Catell Infant Intelligence scale between 15 and 20 months of age. All 38 were retested at 3 years for intelligence with Form L of the Stanford-Binet. Also they were given a speech evaluation test, which was primarily an array of articulation, using a picture test. Crying scores showed a significant correlation (.45) with Stanford-Binet 10 at 3 years, a borderling correlation (.32) with Catell 10 to 15 to 20 months, and a non-significant trend with speech ratings at 3 years. Although no correlations were adequate for individual prediction, the authors consider that further investigation of infant crying as a possible indicator of intellectual potential should be done.

Lieberman et.al. (1971) studied the neonatal cry and compared it with vocalization of non-human primates. The spectrogram of the cry of a male infant during the 1st five minutes of life revealed a fundamental frequency of phonation of 400 Hz. Energy concentrations appeared approximately at 1.1, 3,3 and 5.8 KHz. The authors say that one can infer the configuration of the infant's supra-laryngeal vocal tract for this vocalization by making use of the acoustic theory of speech production (Fant, 1960). This theory allows one to infer that the supralaryngeal vocal tract configuration of this infant approximated a 7.5 ams long uniform tube open at one end. The formants of such a tube will occur at 1.1, 3.3 and 5.5 KHz., since it will have resonances at intervals of $\frac{(2K+1)C}{4L}$ where C=Velocity of sound, L=Length of tube and K is an integer 0.

Lieberman et. al.(1971) believe that the energy concentration at widely spaced regular intervals, reflect the formants of a supra-laryngeal vocal tract shape that resembles a uniform tube that has similar open boundary conditions at each end. Similar effects also appear to occur during the vocalization of non-human primates like apes and monkeys. It is also found that fundamental frequency of phonation, in general, was not stable during the neonatal cry.

Spectrographic analysis has several limitation. It has a poor dynamic range and limited frequency resolution. It requires expertise on the part of the investigator to read and interpret the spectrogram. From a practical standpoint, it is very time consuming and hence, may not be ideal for the analysis of a huge number of cries as would be required for screening purposes.

**Time domain analysis**

Time domain information is obtained from devices that graph sound magnitude versus time on a paperstrip chart.

Fisichelli and Karelitz (1963), Fisichelli, Karelitz, Eichbauer, and Rosenfeld (1961), and Karelitz and Fisichelli (1962) examine the infant cries and 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).

A direct writing oscillograph was a domain device used by Lind, Warz-Hockert, Virorenkoski, and Valanne (1965) to study the time course of the durations and latencies of different kinds of crying. They found that the initial phonations of a cry record are more irregular than those that appear once the infant is fully aroused. After this arousal, a gradual reduction in time and intensity of the cry units occurs until the baby stops crying.

Wolf (1967, 1969) measured inspiratory as well as expiratory phonations and revealed duration differences between "hungry, and pain-produced, and teased crying" in 4-day-old infants. His data also indicate that in pain produced cries, the cry units (one expiratory phonation) are longer is the beginning of the cry record than at the end.

**Frequency Domain Analysis**

Devices performing frequency domain analysis allow one to obtain a coarse representation of the frequency spectrum characteristics of a sound. They utilize a bank of band pass filters. These filters only allow input of a specified frequency range, measure the average magnitude is that range, and give a virtual 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-half or one-half of an octave in width.

Ostwald, freedman, and Kurtz (1962) used the half octave bank analyzer to examine the cries from 32 twins. They determined that the variability in pitch measurements and temporal characteristics between the cries of twins could be explained cry differences in "weight, size, physical development and vigor of the children recorded." Ostwald et. al., concluded that it was there "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 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 sound pass filters use a relatively large and inflexible band width. This makes the frequency information obtained of limited value. However, as illustrated by the work of ostwald, some useful information is obtainable with this method of sound analysis.

**Cry in healthy infants**

In healthy newborn infant, the features of the cry signals can be divided into two main groups, features related to the duration and features related to the fundamental frequency.

The fundamental frequency in crying of healthy infants varies between 350 Hz to 650 Hz. The cry in healthy infants often has falling or rising-falling melody type with a stable pitch. Shift with a higher pitched frequency occur mainly at the beginning of the signals and especially in pain cries in which almost every third cry has a shift part. Occurance of glottal roll is quite common at the end of the phonations, and vibrato sometimes precedes the glottal roll part. Bi-phonation and gliding are quite rare. The signals are voiced and continuous in about two-thirds of the cries.

The variations in the duration features in normal newborn infants is quite large. According to different authors, the latency period is from 0.6 to 3.6 seconds. This variation is attributed to measuring techniques and the infant's wakefulness. But it may also be due to the fact that the latency period is not quite uniform in healthy neonates. The first latency is often longer than the latency of immediately repeated stimulations. Various reports have given different durations of phonations depending on the analyzing technique used. The average reported is from 1.1 to 2.8 seconds (Siruio and Michelson, 1976).

Another characteristic response of the normal infant, a few days old has been reported by karelitz and 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, his facial expression is that of fright, and a loud burst of crying is followed by several bursts which are similar to the first. As the child continues to cry, the bursts taper off to a stop. In the case of an older child, he might rob for some time. Sobbing is not observed in severaly brain-damaged infants.

**Acoustical features of the cries studied**

The interpretation of the birth cry is complicated and some marked differences among signal type can be seen in this period. When considering the newborn situation during the birth process one might wonder if the birth cry was a pain signal. However the typical birth cry, when compared with the pain cry after birth, has distinctive features. It is similar in general pitch and tenseness, but birth signals differ from pain signals in length and type of melody and in their maximum and minimum pitch.

The pain cry, is the easiest to use as a clinical test as it is the easiest to standardize. Two different types of stimulation, pinching and vaccinataion, can be used to elicit pair cry. There was no significant difference between pain cries resulting from different forms of stimulation.

Pain Cry in healthy full-term infants

Analysis of pain cries from more than 300 healthy new born infants has been analysied by Michelsson, 1971; Wasz Hockert et.al., 1963, 1964a, 1968. In the pain cry of healthy full-term newborn infants, the mean maximum pitch of the 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 or falling melody type with a stable pitch and a duration of approximately 2.5 seconds. Shifts with a higher pitch occurred roughly in every third cry. The mean maximum pitch of the whole cry signal was about 800 Hz.

Michelsson (1971), Thoden and Koisto 1980, Wasz -Hockert et.al.,(1968), analysed the normal infant cries and reported that the occurrence of glottal roll was quite common mainly at the end of phonations. Vibrato occasionally preceded the glottal roll part, Bi-phonation, glide, furcation, and voice concentration were extremealy rare in normal infant crying.

Thoden and Koivisto (1980) did a study on cries of 38 normal children. They found that the 3 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 3 signals analyzed. Shifts were seen more often in the first cry signal even if the difference was not statistically significant. Because of the 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 then the first signal. Glottal roll and vibrato were more common in the first signal.

Wasz - Hockert et.at.,(1968) analysed the hunger, birth, and pleasure cries. In 148 hunger cries, the mean maximum pitch was 550 Hz and mean minimum pitch 390Hz . Shifts occurred in only 2% of the cries. The melody type was or rising/falling in 80% glottal roll occurred in 24%. In 77 first birth cries, the mean maximum pitch was 550Hz and mean minimum pitch 450 Hz. Shifts occurred in 18%. The cries were of short duration, mean 1.1 seconds. 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 the 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 the age of 1 day, 5 days, 3 months, and 6 months, were that the signals were less often continuous at the age of 3 months and that vibrato was less common at the age of 6 months.

The results indicates that there are few changes in the cry characteristics from 1 day of life up to the age of 6 months. The results showed, that there were differences in the cry characteristics of the 1st, the 2nd or the 3rd signal after the pain stimulus. The first signal was longer, more often interrupted, and ended more often in glottal roll than the second and the third signals. The maximum pitch of shifts and the maximum of the cry signal, including shift, were more high pitched in the 1st cry signal when compared to the 3rd one at the 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 the second and the third cry signals, there were no significant differences in these cry characteristics.

Indira Nandyal (1984) analysed the cries of 13 normal full term infants and 28 infants belonging to the high risk category. The age range of the infants was 16 hours to 3 months.

Pain cries were elicited from these infants by flicking the sole of the infants foot with the index finger, till they cried for at least 30 seconds. The cries were recorded using a cassette tape recorder. The recording were made at a constant intensity level with the microphone held approximately 5cms from the infant's mouth to reduce background noise to a minimum.

The cry samples were analysed to obtain narrow-band, bar-type spectrograms. These spectrograms were analyzed.

Based on the analysis and interpretation of the spectrograms for the various cry characteristics the following conclusions have been drawn.

(l) Significant differences exist between the cries of normal and high risk infants in some cry characteristics like fundamental frequency, duration of the cry, double harmonic break and glottal plosives which are found more in the cries of normal infants.

(2) No significant differences were observed in both the normal and hilgh-risk infants in cry characteristics like shifts, bi-phonation, glide and tonal pit.

(3) 8 categories of high-risk infants were studied and it was found that each group exhibited cry characteristics which were distinctive to infants with that particular problem or history.

Based on the above study, the present study was planned to anysise the acoustic parameters of normal infant cry and to extract the developmental changes in the infant cry using the Multi - dimensional voice programme (MDVP).

# METHODOLOGY

# Methodology

**Purpose of the study:**

The main object of the study was to determine the acoustic characteristics of the infant cry at various stages of development.

Therefore it was decided to collect cry samples of infants, five subjects on 7 different occasion. i.e., with in 24 hours, after 1st week, 2nd week, 3rd week, 4th week, 2nd month, and 3rd month.

For this purpose, the study was carried out in the following steps:

1. Selection of the normal infants was done by administering the "proforma for infant cry analysis".
2. Collection of cry samples of normal infants.
3. Follow up of the infants till 3 months to collect the cry samples at different intervals of time.
4. Acoustic analysis of the cries using MDVP.

Following 29 acoustical parameters of MDVP ( Multi Dimensional Voice Programme) developed and marketed by Kay elementrics were used.

**Parameters**

**1.** Average Fundamental Frequency (Fo)
2. Average Pitch Period (To)
3. Highest Fundamental Frequency (Fhi)
4. Lowest Fundamental Frequency (Flo)

5. Standard Deviation of Fo (STD)
6. FO - Tremor Frequency (Fftr)
7. Amplitude Tremor Frequency (Fatr)
8. Absolute Jitter (Jita)
9. Jitter Percent (Jitt)
10. Relative Average Perturbation (RAP)
11. Pitch Perturbation Quotient (PPQ)
12. Smoothed Pitch Perturbation Quotient (sPPQ)
13. Fundamental Frequency Variation (vFo)
14. Shimmer in dB (ShdB)
15. Shimmer percent (Shim)
16. Amplitude perturbation Quotient (Apq)
17. Smoothed Amplitude Perturbation Quotient (sAPQ)
18. Peak - Amplitude Variation (vAm)
19. Noise to Harmonic Ratio (NHR)
20. Voice Turbulence Index (VTI)
21. Soft Phonation Index (SPI)
22. Fo - Tremor Intensity Index (FTRI)
23. Amplitude Tremor Intensity Index (ATRI)
24. Degree of Voice Breaks (DVB)
25. Degree of Sub - harmonic segments (NSH)
26. Degree of Voice less (DUV)
27. Number of Voice Breaks (NVB)
28. Number of Sub-harmonic segments (NSH)
29. Number of Unvoice segments (NUV)

Definition of the parameters are given in Appendix - A.

**Subjects:**

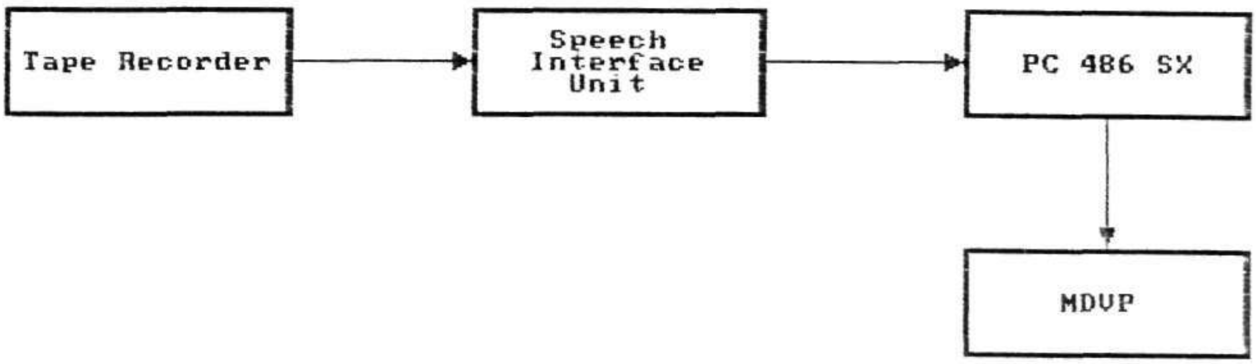
Five infants (2 males and 3 females) who had no prenatal, perinatal or postnatal factors to place them in high risk category were selected. They were born after 37 weeks of gestation and their birth cries were considered normal. They were born to healthy mothers, who had normal delivery. This was confirmed from the information collected from the medical history, Obsterician's and Paediatrician's opinion and mother. The babies were selected after administering the " proforma for infant cry analysis" to the mother (given in appendix - B).

All of them had 9 or 10 point score in the Apgar scale 1 and 5 minuets after birth. The birth weight varied between 2500 - 3500 gms. The weight of the children was noted at the time of each recording. All the babies included in this study were considered to be completely healthy and normal. All pathological cases were carefully excluded and all the infants were examined by a Paediatrician. Complete clinical data are available for all of the children.

**Instrumentation:**

The following instruments were used in the present study:

1. Tape Recorder (Fair mate-Stereo cassette recorder) used for recording the infant cry.
2. MDVP software (marketed by Kay elemintrics Inc., New Jersey), for acoustic analysis of the infant cry.




Block diagram showing the arrangement of the instruments for acoustic analysis

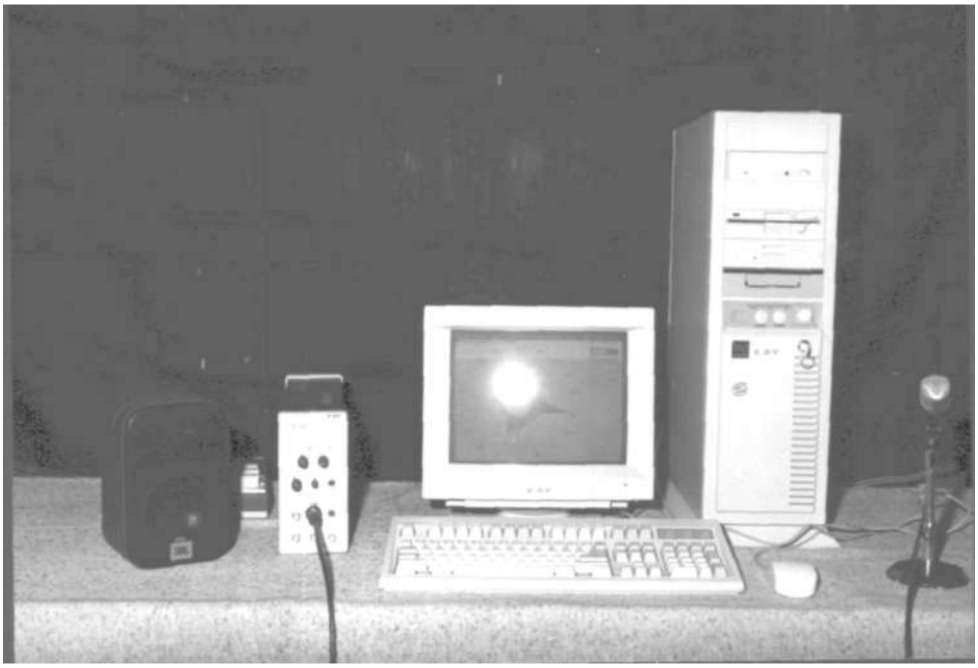


Photo Graph showing the arrangement of the instrument for acoustic analysis.

**Recording of the sample:**

The pain cry was elicited by flickring the sole of the infant's foot with the index finger. When the infant did not cry immediatly, it was stimulated again, till it cried for at least 20 seconds. The recording of the cries were carried out on each infants with respect to the following ages - with in 24 hours, 1st week, 2nd week, 3rd week, 4th week, 2 month and 3rd month.

The cry recordings were made at the private nursing home and during follow up the recordings were done at the respective home. Maximum care was taken to control the presence of the noise level in the recording room.

The cries were recorded using a Fairmate Stero Cassette Recorder. The tape recorder was battery operated. The cassette used was (Meltrack CR-X90). Everyday prior to recording, the voltage of the batteries were checked and voltage was maintained between 1.2v - 1.5v. All the recordings were made at a constant intensity level. The Microphone was held at approximately 5 to 10 cms from the infant's mouth to reduce back ground noise to a minimum. The cry sample were recorded at a tape speed of 1 7/8 ips.

For each infant cry samples were recorded on 1st day, after 1st week, 2nd week, 3rd week, 4th week, 2nd month and 3rd month.

## Acoustic analysis

The recorded samples were played back using the same tape recorder and digitized using Computerized Speech Lab (Kay Elemintrics) at a sampling rate of 50 kHz . The cry of one breath group was thus digitized and stored on computer. The cry samples were fed to the input of MDVP.

The wave form of the digitized acoustic signal of the cry sample produced by the infants were displayed on the computer screen, and subjected to acoustic analysis using Multi Dimensional Voice Programme by elementrics Inc., N.J.

All the cry samples were was subjected to analysis. Thus the cry samples of all the 5 infants were analysied. Further the data was subjected to statistical analysis using discripitive statistics and un-paried, Wilcoxin test. The results are presented in the following chapter.

# RESULTS & DISCUSSION

# RESULTS AND DISCUSSION

The objective of the present study were:

1. To study the acoustic parameters in infant cry at various developmental stages i.e., (from 1st day to 3 months) using Multi-dimentional Voice Program developed by Kay elemetrics Inc., N.J. (MDVP).

**I Frequency Parameters:**

1. Average Fundamental Frequency
2. Average Pitch Period
3. Highest Fundamental Frequency
4. Lowest Fundamental Frequency
5. Standard Deviation of Fo
6. Fo Tremor Frequency
7. Absolute Jitter
8. Jitter Percent
9. Relative Average Perturbation
10. Pitch Perturbation Quotient
11. Smoothed 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. Smoothed Amplitude Variation

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 Voice less
27. Number of Voice Breaks
28. Number of Sub-harmonic segments
29. Number of Unvoiced segments

**Average fundamental frequency (Fo); /Hz/**

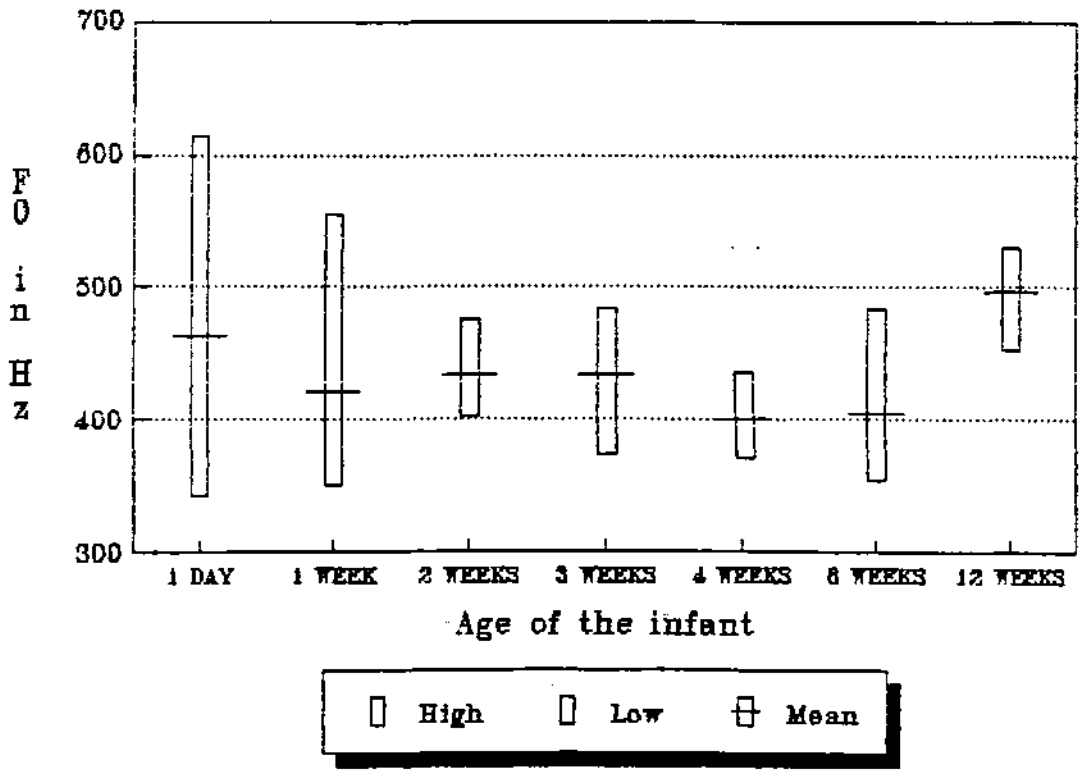
Average fundamental frequency was measured using MDVP software. The Mean, S.D & Range for average fundamental frequency of infant cry are presented in Tabel:l & Graph:1.

The average fundamental frequency varied from a minimum of 341.3 Hz to maximum of 614.9 Hz. The lowest frequency seen was 400 Hz on the 5th recording i.e., during 4th week.

Examination of table & graph showed that there is no consistent change in fundamental frequency across the recordings made from 1st day to 3 months and had shown a maximum of 497.2 Hz in the 7th cry recording.

Table:1 Showing Mean, S.D and Range for Average Fundamental Frequency (Fo) and its variations in the cry of infants during the 1st day (1), 1st week (2), 2nd week (3), 3rd week (4), 4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 463.1 | 103.0 | 341.3 - 614.9 |
| 2 | 422.2 | 78.5 | 351.7 - 556.9 |
| 3 | 434.6 | 26.5 | 403.9 - 475.5 |
| 4 | 436.9 | 47.1 | 374.5 - 483.0 |
| 5 | 400.7 | 31.0 | 372.3 - 435.5 |
| 6 | 405.6 | 55.0 | 355.3 - 485.2 |
| 7 | 497.2 | 39.4 | 453.3 - 529.4 |




Graph:1 Average Fundamental Frequency (Fo) and its variations in the cry of infants at different ages

The subjects showed maximum variation in the 1st recording i.e., 103 Hz and minimum variation on 3rd recording i.e., 26.5 Hz.

Further the administration of wilcoxin test confirmed the observation made earlier, based on study of table & Graph i.e., no significant change had occurred over the period of study i.e., 1st day to 3 months. However, a significant difference between 5th and 6th recording with 7th recording (3rd month) was noticed.

The average fundamental frequency had varied significantly after 5th recording. It may be because subjects had shown 400 Hz as the mean fundamental frequency on 5th recording and it increased to 497 Hz on 7th cry recording.

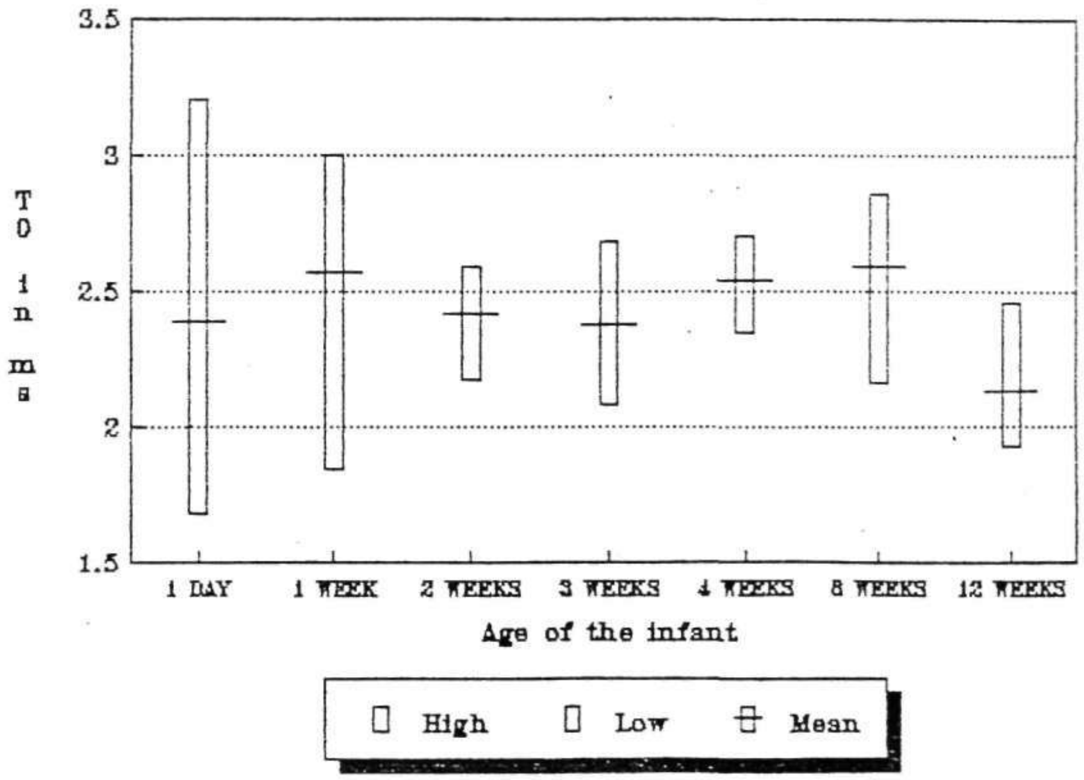
However, since no systematic change in fundamental frequency is observed over the period. Hypothesis:1 stating that there is no significant difference between recordings (1st day to 3rd month) in terms of average fundamental frequency was accepted, except for 5th & 6th recording when compared to 7th recording. Therefore it was concluded that no systematic variation in average fundamental frequency was found from age 1st day to 3 months and no significant was noticed.

**Average pitch period ( To ) ¢m sec¢**

The Mean, S.D and Range for Average pitch period of infant cry presented in Table:2 and Graph:2.

Table:2 Showing Mean, S.D and Range for Average Pitch Period and its variations in the cry ofinfants during the 1st day (1), 1st week (2), 2nd week (3), 3rd week (4), 4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 2.3 | 0.58 | 1.6 - 3.2 |
| 2 | 2.5 | 0.43 | 1.8 - 3.0 |
| 3 | 2.4 | 0.15 | 2.1 - 2.5 |
| 4 | 2.3 | 0.24 | 2.0 - 2.6 |
| 5 | 2.5 | 0.17 | 2.3 - 2.7 |
| 6 | 2.5 | 0.28 | 2.1 - 2.8 |
| 7 | 2.1 | 0.28 | 1.9 - 2.4 |




Graph:2 Average Pitch Period (To) and its variations in the cry of infants at different ages

The average pitch period varied from a minimum of 1.68 msec to a maximum 3.2 msce. The lowest seen was 2.13 msec on the 7th recording i.e., during 3rd month.

Examination of table and graph showed that there was no consistent change in average pitch period across the recordings made from 1st day to 3rd month. A maximum of 2.58 msec was seen in the 6th recording i.e., 2nd month.

The subjects showed maximum variation in the 1st recording i.e., 0.58 msce and a minimum variation was noticed in the 3rd recording i.e., 0.15 msce.

Further the administration of wilcoxin test confirmed the observation made earlier i.e., no significant change occurred over a period of 1st day to 3 months. However, a significant difference between the 2nd recording and the 6th recording (2nd month) was noticed.

However, since no systematic change in average pitch period was observed over the period. Hypothesis: 2 stating that there is no significant difference in the cry at different period of age (1st day to 3rd month) was accepted. Therefore average pitch period was concluded that no systematic variation in average pitch period was found from age 1st day to 3 months in the cry of infants.

**Highest fundamental frequency (Fri) ¢Hz¢**

Highest fundamental frequency was measured using MDVP software. The Mean, S.D and Range for highest fundamental frequency of infant cry samples over a period of three months are presented in Table: 3 and Graph: 3.

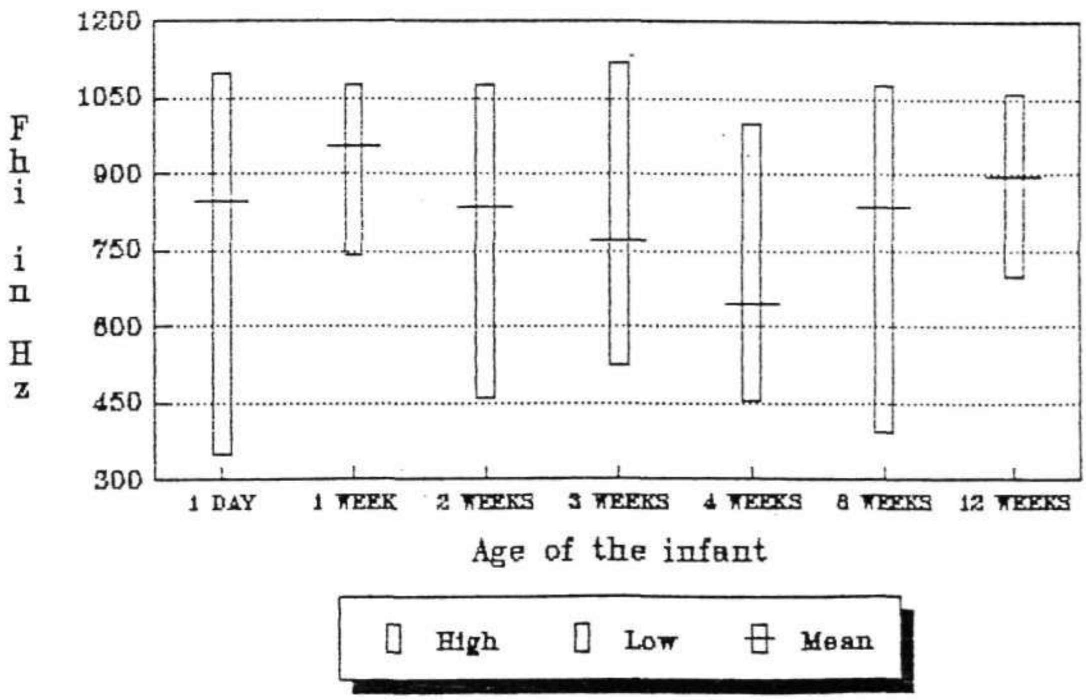
The study of table and graph showed that the highest fundamental frequency varied from a minimum of 350 Hz to a maximum of 1121 Hz. The lowest frequency seen was 641 Hz in the 5th recording i.e., 4th week.

Further examination of table and graph showed that there is no consistent change in highest fundamental frequency in cry samples recording was made from 1st day to 3 months, and had shown a maximum of 956.2 Hz in the 1st week i.e., 2nd recording. Subjects had shown maximum variation in the 1st cry recording i.e., 333 Hz and minimum variation on 2nd recording i.e., 152.7 Hz.

Further the administration of wilcoxin test confirmed the observations made earlier. Based on the study of table and graph i.e., no significant change had occurred over the period of time 1st day to 3 months. However, a significant difference between the 2nd recording and the 5th recording (i.e., 4th week) was noticed. However, since no systematic change in highest fundamental frequency was observed over the period it was concluded that to accept, hypothesis: 3 stating that there is no significant difference between recording in terms of highest fundamental frequency. Thus it was concluded that no systematic variation in highest fundamental frequency was found from age 1st day to 3 months.

Table:3 Showing Mean, S.D and Range for highest Fundamental Frequency and its variations in the cry of infants during the lstday (1), 1st week (2), 2nd week (3), 3rd week (4), 4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 848.4 | 333.0 | 350.3 - 1096.4 |
| 2 | 956.3 | 152.7 | 704.2 - 1077.5 |
| 3 | 837.0 | 270.8 | 458.2 - 1077.8 |
| 4 | 767.4 | 242.5 | 523.5 - 1121.0 |
| 5 | 641.4 | 218.2 | 454.5 - 998.0 |
| 6 | 833.1 | 279.1 | 391.6 - 1072.9 |
| 7 | 896.2 | 182.3 | 699.3 - 1059.3 |




Graph:3 Highest Fundamental Frequency (Fhi) and its variations in the cry of infants at different ages

**Lowest fundamental frequency. (Flo) /Hz/**

The Mean, S.D and Range for Lowest fundamental frequency of infant cry are presented in Table:4 and Graph:4.

The Lowest fundamental frequency varied from a minimum of 188.9 Hz to a maximum of 394 Hz. The lowest frequency seen was (222Hz in the 2nd recording i.e., 1st week).

Examination of table and graph showed that there was no consistent change in lowest fundamental frequency across the cry recordings made from 1st day to 3 months and had shown a maximum of 293.2 Hz in the 7th recording. Subjects had shown maximum variation in the 7th recording i.e., 100.6 Hz and a minimum variation in 2nd cry recording i.e., 29.9 Hz.

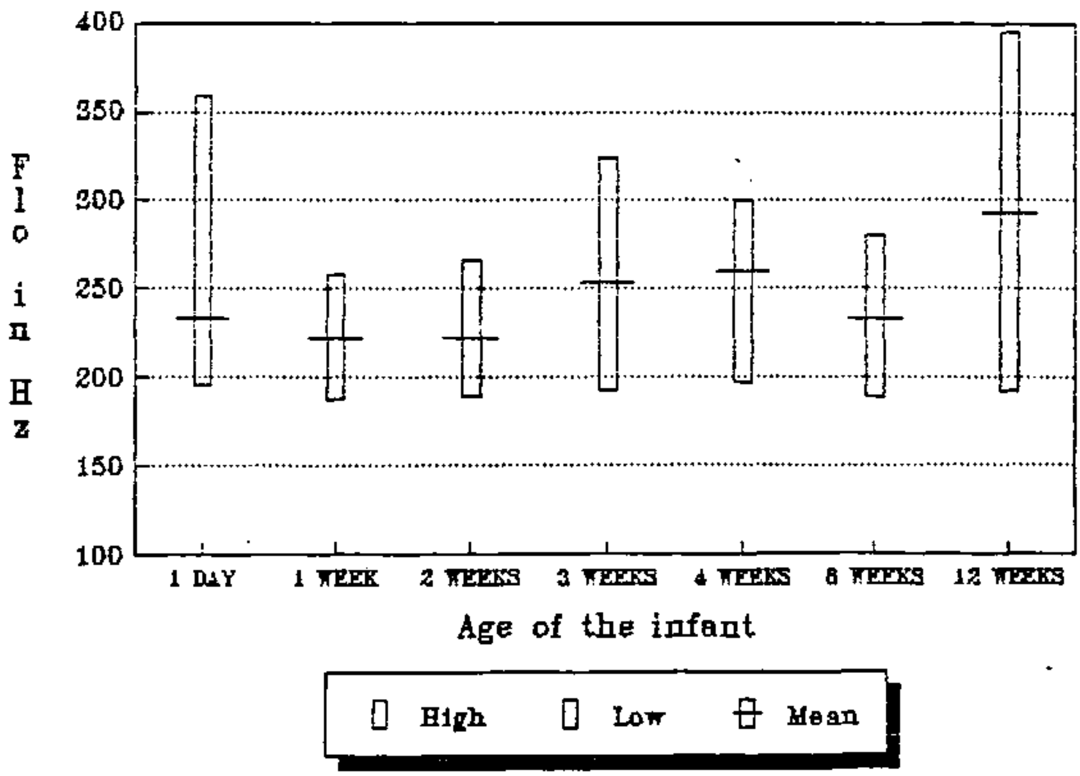
Further the administration of wilcoxin test confirmed the observation made from earlier examination i.e., no significant change had occurred over a period of three months.

The lowest fundamental frequency had varied significantly in the 2nd recording, when compared to the remaining recordings i.e., it had shown 222 Hz as mean Lowest fundamental frequency in 2nd cry recording and it had increased to 293.3 Hz in the 7th cry recording.

However, since no systematic change in lowest fundamental frequency was observed over the period of three months i.e., (1st day to 3 months). It was decided to

Table:4 Showing Mean, S.D and Range for Lowest Fundamental Frequency and its variations in the cry of infants during the 1st day (1), 1st week (2), 2nd week (3), 3rd week (4), 4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 233.8 | 69.8 | 195.2 - 358.6 |
| 2 | 222.0 | 29.9 | 188.9 - 259.3 |
| 3 | 223.5 | 31.3 | 189.4 - 266.0 |
| 4 | 254.6 | 54.9 | 192.9 - 325.9 |
| 5 | 260.2 | 39.0 | 198.5 - 300.7 |
| 6 | 234.1 | 43.7 | 190.1 - 281.9 |
| 7 | 293.3 | 100.6 | 192.7 - 394.0 |




Graph:4 Lowest Fundamental Frequency (Flo) and its variations in the cry of infants at different ages accept, hypothesis: 4 stating that there is no significant difference between cry recordings in terms of lowest fundamental frequency during first three months. Thus it was concluded that no systematic variation in lowest fundamental frequency was found from age 1st day to 3 months, in the cry of infants.

**Standard deviation of fundamental frequency (STD) /Hz/**

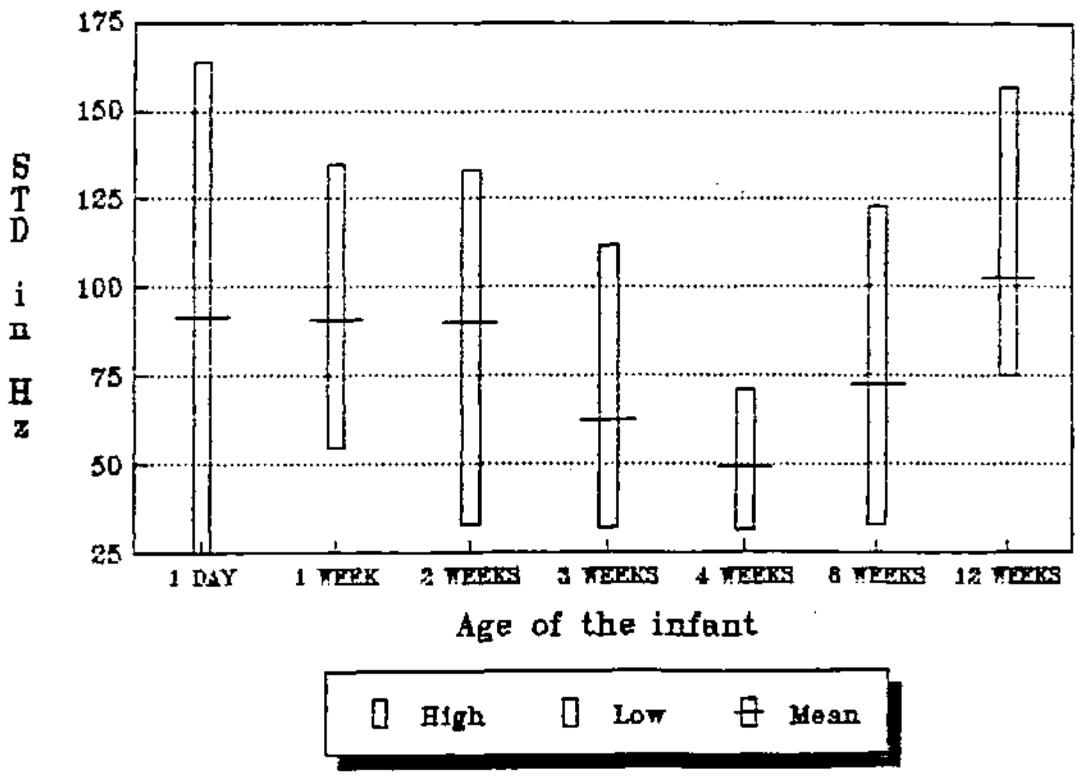
Standard deviation of fundamental frequency is one of the measures that MDVP provides. This reflects the variation that occur in fundamental frequency during phonation. The Mean, S.D and Range for standard deviation of fundamental frequency of infant cry are presented in Table: 5 & Graph: 5. The standard deviation of fundamental frequency varied from a minimum 25.9 Hz to a maximum of 164.1 Hz. The lowest standard deviation of fundamental frequency was 49.2 Hz in the 5th cry recording i.e., 4th week.

Examination of table and graph showed that there was no consistent change in standard deviation of fundamental frequency across the cry recording made from 1st day to 3rd month, and had shown a maximum 103.1 Hz in the 7th cry recording. The subjects showed maximum variation in the 1st recording i.e., 56.9 Hz and minimum variation on 5th recording i.e., 17.5 Hz.

Further the administration of wilcoxin test confirmed observation made earlier based on study of table and graph

Table:5 Showing Mean, S.D and Range for Standard Deviation of Fo and its variations in the cry ofinfants during the 1st day (1), 1st week (2), 2nd week (3), 3rd week (4),4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 92.8 | 56.9 | 25.9 - 164.1 |
| 2 | 91.1 | 31.4 | 55.2 - 135.2 |
| 3 | 90.4 | 37.1 | 33.7 - 133.0 |
| 4 | 63.4 | 33.3 | 32.1 - 112.9 |
| 5 | 49.2 | 17.5 | 31.0 - 71.9 |
| 6 | 73.3 | 36.7 | 33.1 - 123.1 |
| 7 | 103.1 | 47.4 | 75.0 - 157.8 |




Graph:5 Standard Deviation of Fo (STB) and its variations in the cry of infants at different ages i.e., no significant change had occurred over the period of study i.e., 1st day to 3 months. However, a significant difference between 2nd and 3rd recording with 5th recording (4th week) was noticed.

The standard deviation of fundamental frequency had varied significantly after 5th recording. It may be because the subjects had shown 49.2 Hz as the mean standard deviation of fundamental frequency on 5th recording and it had increased to 103.1 Hz on 7th recording.

However, since no systematic change in standard deviation of fundamental frequency was observed over the period, hypothesis: 5 stating that there is no significant difference between cry recordings (1st day to 3 months) in terms of standard deviation of fundamental frequency was accepted. Therefore it was concluded that no systematic variation in standard deviation of fundamental frequency was found from age 1st day to 3 months and no significant difference was noticed.

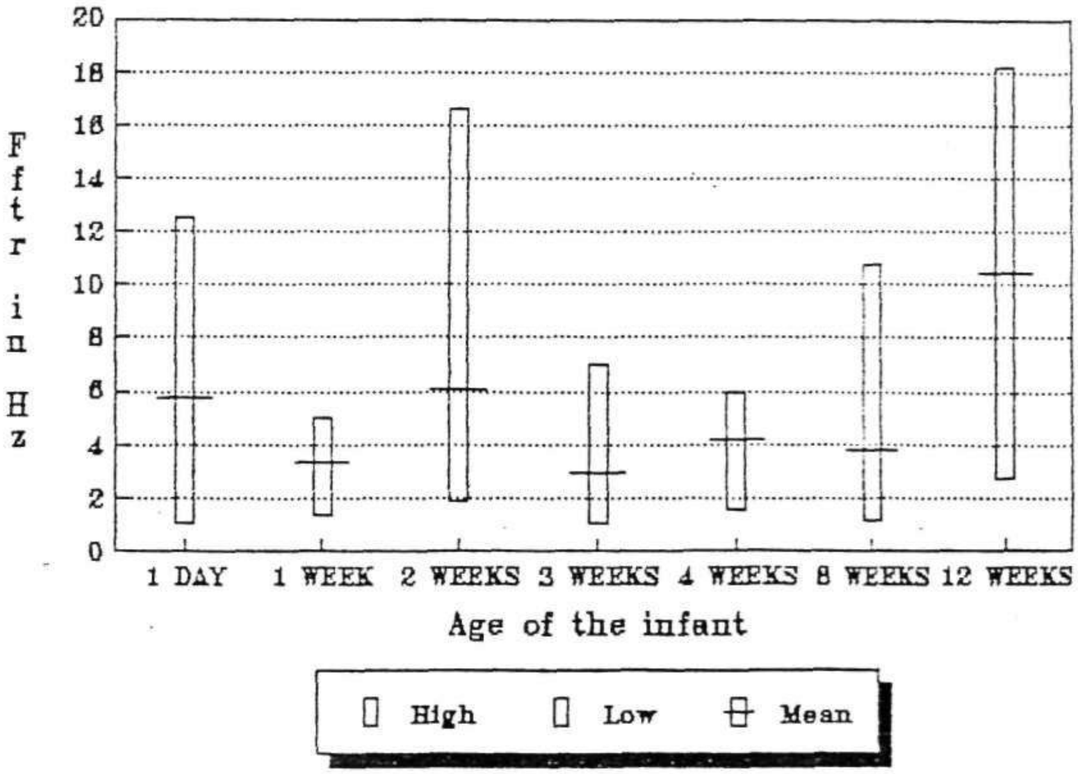
**Fo - Tremor frequency (FFTR) /Hz/**

It is defined as the frequency of the most intensive low frequency Fo modulating component in the specified Fo-Tremor analysis range. The Mean, S.D and Range for Fo-tremor frequency of infant cry presented in Table:6 and Graph:6.

The Fo - Tremor frequency varied from a minimum of 1.01 Hz to maximum of 18.1Hz. The lowest frequency seen (2.96 Hz

Table:6 Showing Mean, S.D and Range for Fo - Tremo Frequency and its variations in the cry ofinfant during the 1st day (1), 1st week (2), 2nd week (3) 3rd week (4), 4th week (5), 2nd month (6) and 3r month (7).

| | Mean | S.D | Rarige |
|---|---|---|---|
| 1 | 5.7 | 4.7 | 1.0 - 12.5 |
| 2 | *3.3* | 1.6 | 1.3 - 5 |
| 3 | 6.0 | 6.0 | 1.8 - 16.6 |
| 4 | 2.9 | 2.7 | 1.0 - 7.0 |
| 5 | 4.2 | 2.3 | 1.5 - 5.9 |
| 6 | 3.7 | 4.0 | 1.2 - 10.8 |
| 7 | 10.4 | 10.9 | 2.7 - 18.1 |




Graph:6 FO - Tremor Frequency (Fftr) and its variations ir the cry of infants at different ages

**Amplitude Tremor frequency (Fatr) /Hz/:**

The Mean, S.D and Range for amplitude tremor frequency of infant any are presented in Table:7 and Graph:7.

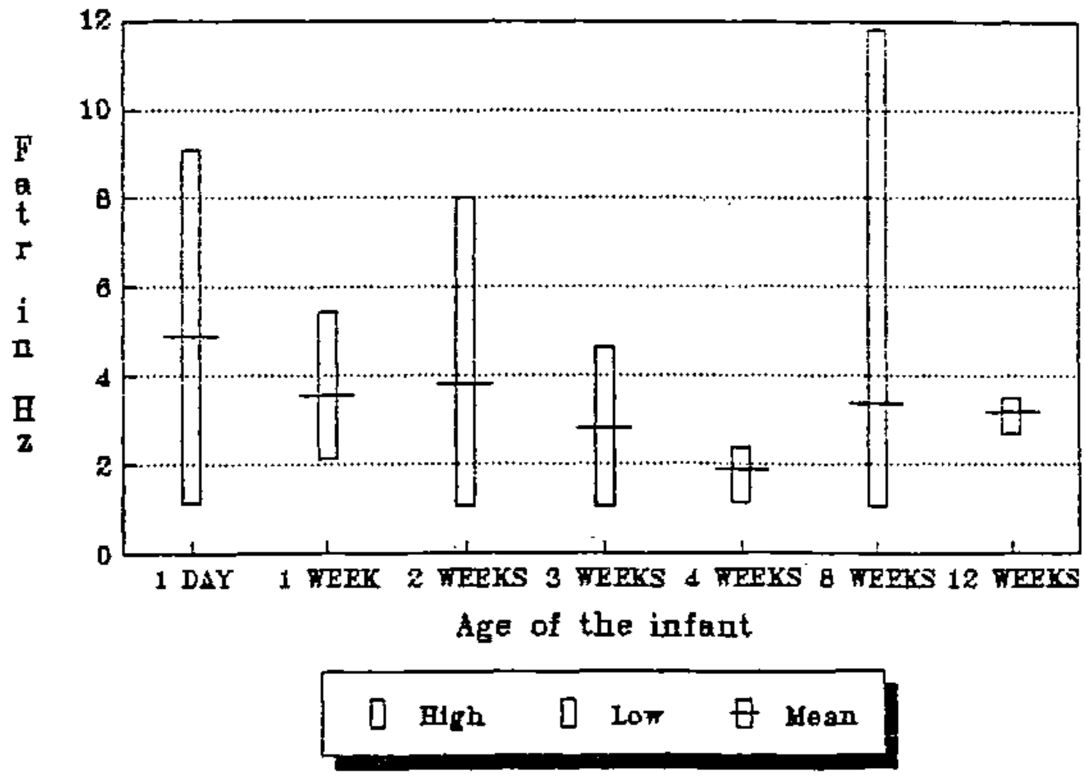
The study of table and graph showed that the amplitude tremor frequency varied from a minimum of 1.06 Hz to a maximum of 11.7 Hz. The lowest frequency seen was 1.6 Hz in the 6th recording i.e., 2nd month.

Further examination of table and graph showed that there was no consistent change in amplitude tremor frequency in cry sample recordings that were made from 1st day to 3 months. It had shown a maximum 4.8 Hz in the 1st recording i.e., 1st day cry recording. Subjects had shown maximum variation in the 1st recording i.e., 3.0 Hz and minimum variation on 7th recording i.e., 0.4 Hz.

Further the administration of wilcoxin test confirmed the observation made earlier based on the study of table and graph i.e., no significant change occurred over the period of 3 months i.e., 1st day to 3 months. However, a significant difference between the 2nd cry recording and 5th cry recording was noticed. However, since no systematic change in amplitude tremor frequency was observed over the period thus hypothesis:7 stating that there is no significant difference between recording in terms of amplitude tremor frequency was accepted, hence it was concluded that no

**Table:7** Showing Mean, S.D and Range for Amplitude Tremo Frequency and its variations in the cry of infant during the 1st day (1), 1st week (2), 2nd week (3) 3rd week (4),4th week (5), 2nd month (6) and 3r month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 4.8 | 3.0 | 1.1 - 9.0 |
| 2 | 3.5 | 1.3 | 2.1 - 5.4 |
| 3 | 3.8 | 2.8 | 1.0 - 8 |
| 4 | 2.8 | 1.4 | 1.0 - 4.6 |
| 5 | 1.9 | 0.5 | 1.1 - 2.4 |
| 6 | *3.3* | 4.6 | 1.0 - 11.7 |
| 7 | 3.1 | 0.4 | 2.7 - 3.5 |




Graph:7 Amplitude Tremor Frequency (Fatr) and its variations in the cry of infants at different ages systematic variation in amplitude tremor frequency was found from age 1st day to 3 months.

**Absolute Jitter (Jita) /usec/**

It is an evaluation of the period to period variability of the pitch period with in the analyzed voice sample. The Mean, S.D and Range for absolute jitter of infant cry are presented in Table 8 and graph 8.

Study of table and graph showed that the absolute jitter varied from a minimum of 14.5 usec to a maximum of 117.3 usec. The lowest seen was 38.9 usec in the 5th recording i.e., 4th week.

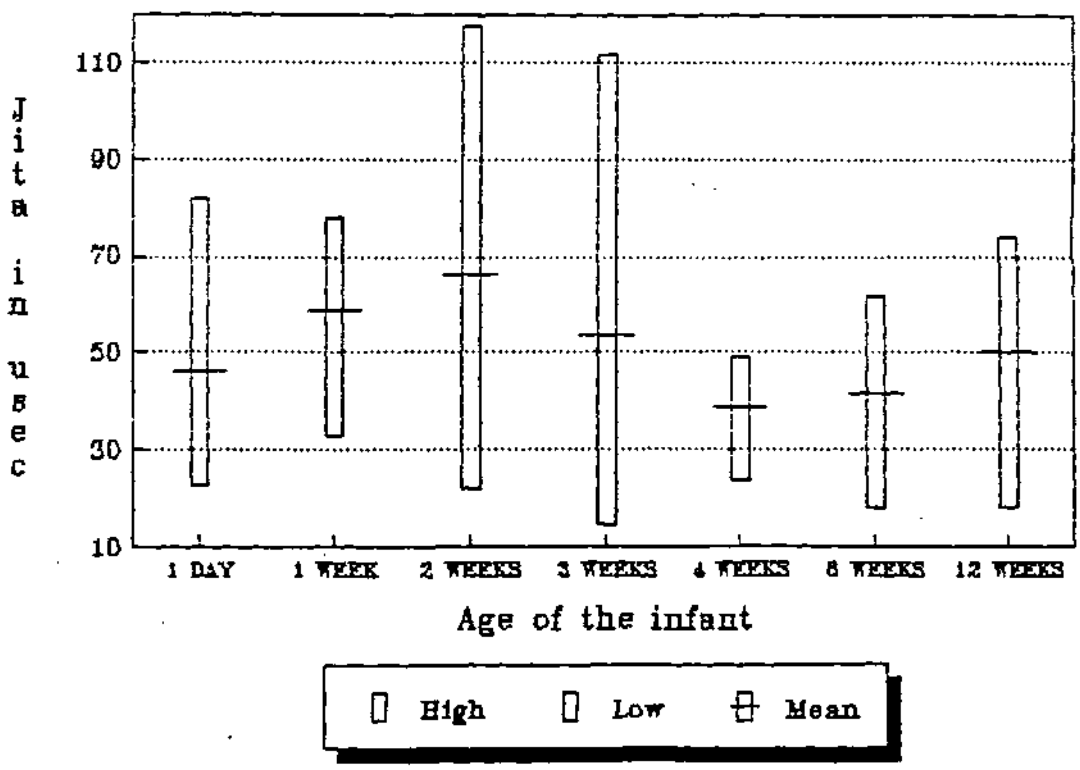
Further the examination of table and graph showed that there was no consistent change in absolute jitter in cry samples recorded from 1st day to 3 months. The table had shown a maximum of 66.1 usec in the 3rd cry recording i.e., recording of 2nd week. Subjects had shown maximum variation in the 3rd recording i.e., 1.7 usee and minimum variation on 5th cry recording i.e., 0.4 usec.

Further the administration of wilcoxin test confirmed the observations made earlier, based on the study of table and graph i.e., no significant change occurred over the period of 3 month i.e., 1st day to 3 months.

The absolute jitter had varied significantly in the 3rd recording, when compared to the remaining recording i.e., it

**Table:8** Showing Mean, S.D and Range for Absolute Jitte and its variations in the cry ofinfants during th 1stday (1), 1st week (2), 2nd week (3), 3rd week (4) 4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 46.0 | 23.2 | 22.8 - 81.8 |
| 2 | 58.9 | 23.3 | 33.3 - 77.9 |
| 3 | 66.1 | 44.3 | 21.8 - 117.3 |
| 4 | 53.9 | 40.2 | 14.5 - 111.6 |
| 5 | 38.9 | 10.6 | 23.7 - 49.3 |
| 6 | 41.8 | 19.4 | 18.1 - 61.6 |
| 7 | 50.1 | 28.9 | 17.8 - 73.3 |




**Graph:8** Absolute Jitter (Jita) and its variations in the cry of infants at different ages had shown 66.1 usec as the mean of absolute jitter in 3rd cry recording and had decreased to 38.9 usec in the 6th recording.

However, since no systematic change in absolute jitter was observed over the period of three months i.e., 1st day 3 month. It was decide to accept, hypothesis:8 stating that there is no significant difference between cry recording in terms of absolute jitter during first three months, thus it was concluded that no systematic variation in absolute jitter was found from age 1st day to 3 months, in the cry of infants.

**Jitter percent (Jita)** /%/

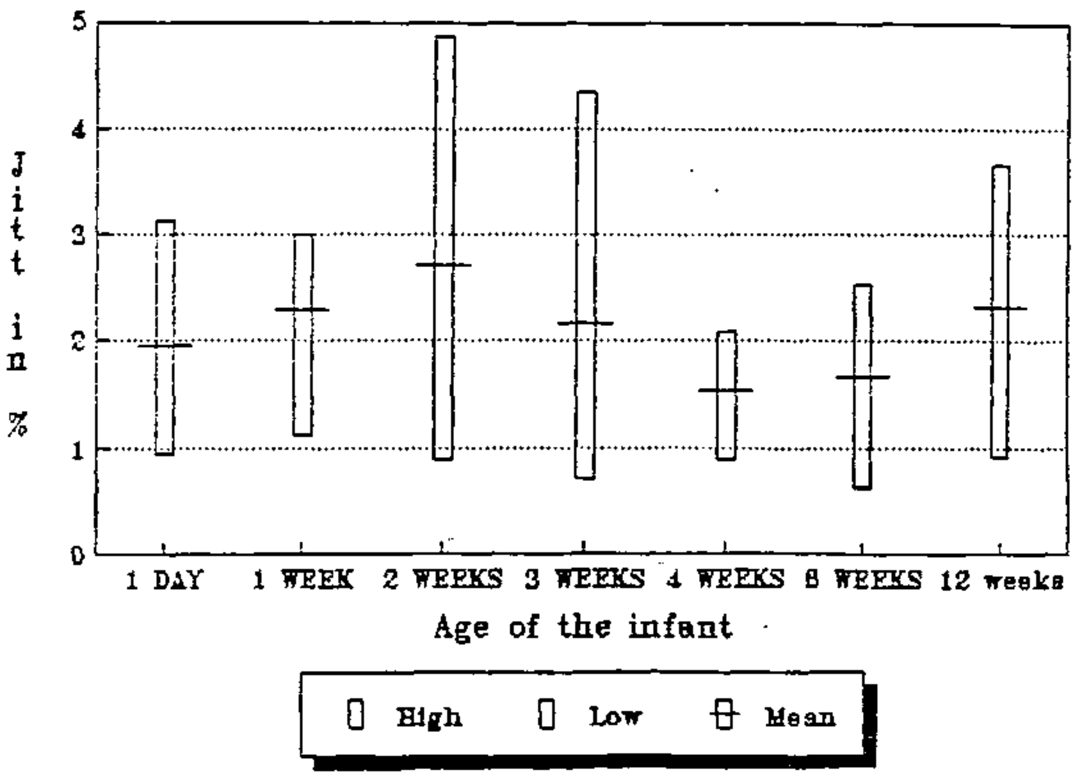
The Mean, S.D and Range for jitter percent of infant cry are presented in Table:9 and Graph:9.

The Jitter percent varied from a minimum of 0.6% to a maximum of 4.8%. The lowest percent seen was 1.6% in the 6th recording i.e., 2nd month.

Examination of table and graph showed that there was no consistent change in jitter percent across the cry recording made from 1st day to 3 months and had shown maximum of 2.7% in the 3rd recording. Subjects had shown maximum variation in the 3rd cry recording i.e., 1.7% and a minimum variation in 5th cry recording i.e., 0.4%.

Table:9 Showing Mean, S.D and Range for Jitter Percent and its variations in the cry of infants during the 1st day (1), 1st week (2), 2nd week (3), 3rd week (4),4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 1.9 | 0.9 | 0.9 - 3.1 |
| 2 | 2.2 | 0.8 | 1.1 - 2.9 |
| 3 | 2.7 | 1.7 | 0.8 - 4.8 |
| 4 | 2.1 | 1.4 | 0.6 - 4.3 |
| 5 | 1.5 | 0.4 | 0.8 - 2.0 |
| 6 | 1.6 | 0.8 | 0.6 - 2.5 |
| 7 | 2.3 | 1.3 | 0.9 - 3.6 |




Graph:9 Jitter Percent (Jitt) and its variations in the cry of infants at different ages

Further the administration of wilcoxin test confirmed the observation made from earlier examination i.e., no significant change had occurred over a period of three months.

The Jitter percent had varied significantly in the 3rd recording. When compared to the remaining recordings i.e., it had shown 2.7% as mean Jitter percent in 3rd cry recording and it had decreased to 1.6% in the 6th cry recording.

However, since no systematic change in Jitter percent was observed over the period of three months i.e., (1st day to 3 months). It was decided to accept, hypothesis: 9 stating that there is no significant difference between cry recordings in terms of jitter percent during first three months. Thus it was concluded that no systematic variation in jitter percent was found from age 1st day to 3 months, in the cry of infants.

**Relative Average perturbation (RAP)** /%/

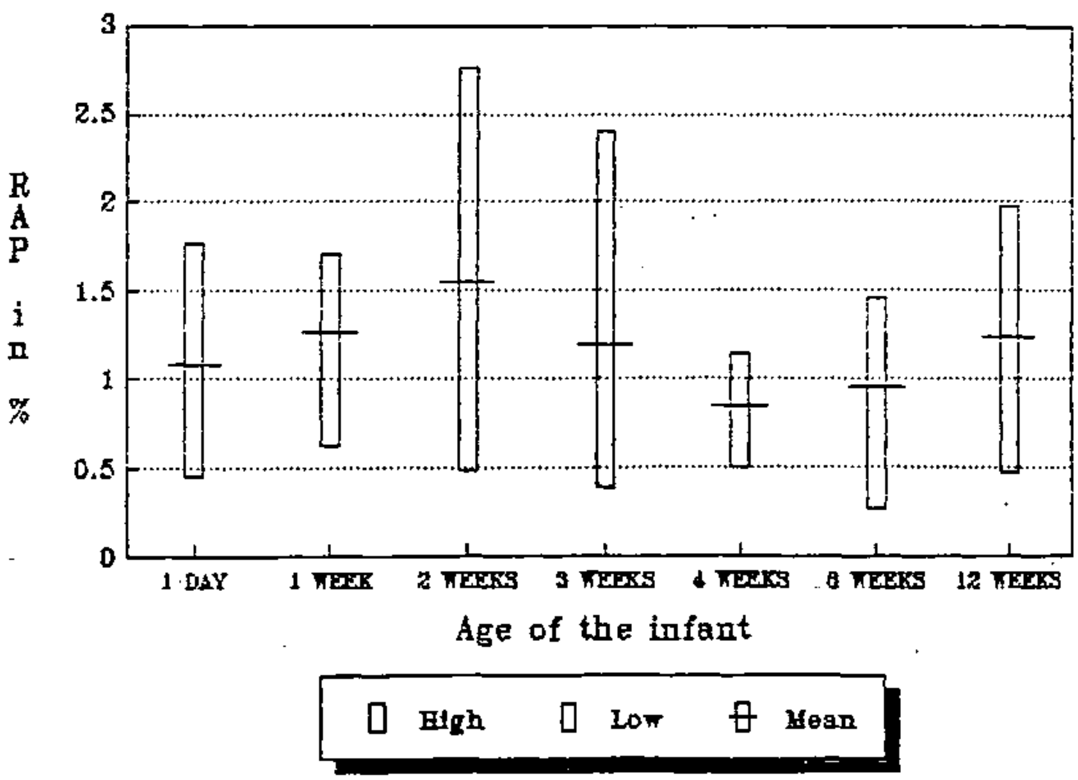
Table: 10 and graph: 10 present the Mean, S.D and Range for relative average perturbation of infant cry.

The relative average perturbation varied from a minimum of 0.2% to maximum 2.7%. The lowest percent 0.8% on the 5th recording i.e., during 4th week was seen.

Table and graph from examination showed that there was no consistent change in relative average perturbation across

**Table:10** Showing Mean, S.D and Range for Relative Average Perturbation and its variations in the cry of infants during the 1st day (1), 1st week (2), 2nd week (3), 3rd week (4),4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 1.0 | 0.5 | 0.4 - 1.7 |
| 2 | 1.2 | 0.4 | 0.6 - 1.7 |
| 3 | 1.5 | 0.9 | 0.4 - 2.7 |
| 4 | 1.1 | 0.8 | 0.3 - 2.4 |
| 5 | 0.8 | 0.2 | 0.5 - 1.1 |
| 6 | 0.9 | 0.5 | 0.2 - 1.4 |
| 7 | 1.2 | 0.7 | 0.4 - 1.9 |




**Graph:10** Relative Average Perturbation (RAP) and its variations in the cry of infants at different ages the recordings made from 1st day to 3rd month, A maximum of 1.5% was seen in the 3rd recording. The subjects showed maximum variation in 3rd cry recording i.e., 1.11% and minimum variation on 5th cry recording i.e., 0.3%.

Further the administration of wilcoxin test confirmed the observation made earlier based on study of table and Graph i.e., no significant change had occurred over the period of study i.e., 1st day to 3 months.

The relative average perturbation had varied significantly in the 2nd recording, when compared to the remaining recordings i.e., it had shown 1.2% as mean relative average perturbation in 2nd cry recording and had decreased to 0.8% in the 5th cry recording i.e., by 4th week.

However, since no systematic change in relative average perturbation was observed over the period of three months, i.e., (1st day to 3 months). It was decided to accept hypothesis: 10 stating that there is no significant difference between cry recordings in terms of relative average perturbation during first-three months. Thus it was concluded that no systematic variation in relative average perturbation during first three months, was found from age 1st day to 3 months, in the cry of infants.

**Pitch perturbation Quotient (PPQ)** /%/

The Mean, S.D and Range for pitch perturbation quotient of infant cry are presented in Table: 11 and Graph: 11.

The pitch perturbation quotient varied from a minimum of 0.3% to maximum 3%. The lowest percent seen was (1.01% on the 5th cry recording i.e., during 4th week).

No consistent change in pitch perturbation quotient across the recordings made from 1st day to 3 months, and a maximum of 1.8% in the 3rd recording were found from the examination of table and graph. Subjects showed maximum variation in 3rd recording i.e., 1.11% and minimum variation on 5th recording i.e., 0.34%

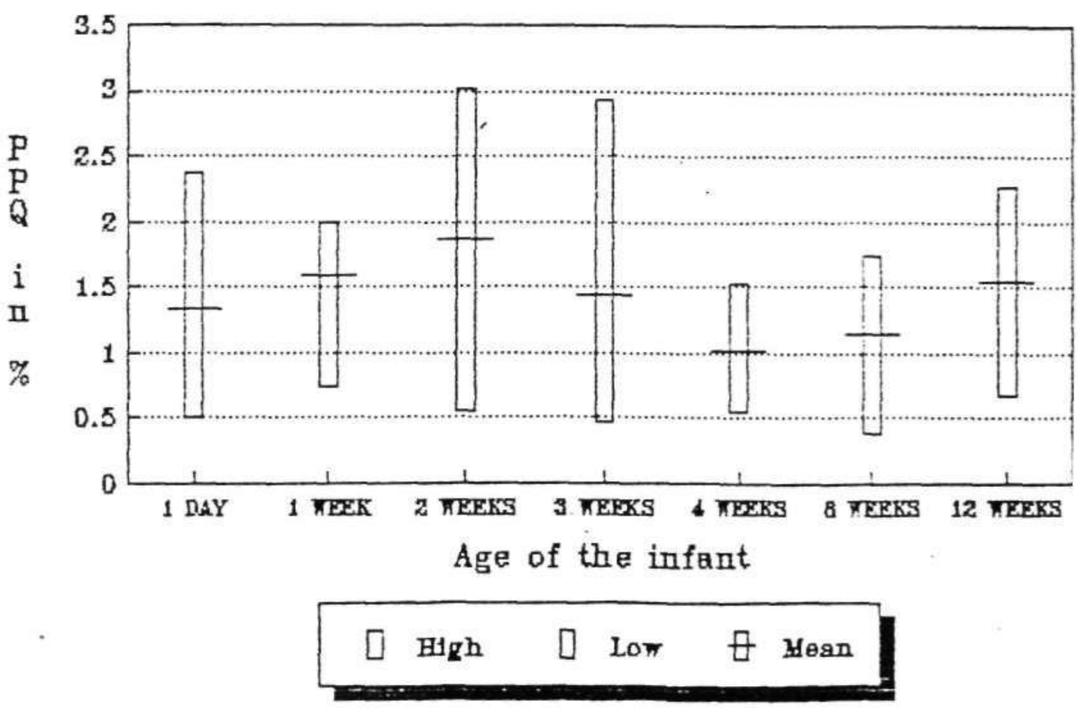
Further the administration of wilcoxin test confirmed the observation made earlier based on the study of table and graph i.e., no significant change had occurred over the period of study i.e., 1st day to 3 months.

The pitch perturbation quotient had varied significantly in the 3rd recording, when compared to other cry recordings i.e., it had shown 1.8% as mean pitch perturbation quotient in 3rd cry recording and had deceased to 1.0% in the 5th recording.

However, since no systematic change in pitch perturbation quotient was observed over the period of three months i.e., (1st day to 3 months). It was decided to accept, hypothesis: 11 stating that there is no significant difference between cry recordings in terms of pitch perturbation quotient during first three months. Thus it was concluded that no systematic variation in pitch perturbation

**Table:ll** Showing Mean, S.D and Range for Pitch Perturbatior Quotient and its variations in the cry of infants during the 1st day (1), 1st week (2), 2nd week (3), 3rd week (4),4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 1.3 | 0.7 | 0.5 - 2.3 |
| 2 | 1.5 | 0.5 | 0.7 - 1.9 |
| 3 | 1.8 | 1.1 | 0.5 - 3.0 |
| 4 | 1.4 | 1.0 | 0.4 - 2.9 |
| 5 | 1.0 | 0.3 | 0.5 - 1.5 |
| 6 | 1.1 | 0.6 | 0.3 - 1.7 |
| 7 | 1.5 | 0.7 | 0.6 - 2.2 |




**Graph:il** Pitch Perturbation Quotient (PPQ) and in variations in the cry of infants at different age quotient was found from age 1st day to 3 months, in the cry of infants.

**Smoothed pitch perturbation quotient (SPPQ)** / % / :

Table:12 and Graph:12 depict the Mean, S.D and Range for smoothed pitch perturbation quotient of infant cry.

The smoothed pitch perturbation quotient varied from a minimum of 0.9 % to a maximum 11.3%. The lowest percent seen was 2.3 on the 5th recording i.e., during 4th week.

Examination of table and graph showed that there was no consistent change in smoothed pitch perturbation quotient across the recordings made from 1st day to 3 month. A maximum of 6.6% was seen in the 2nd recording i.e., 1st week.

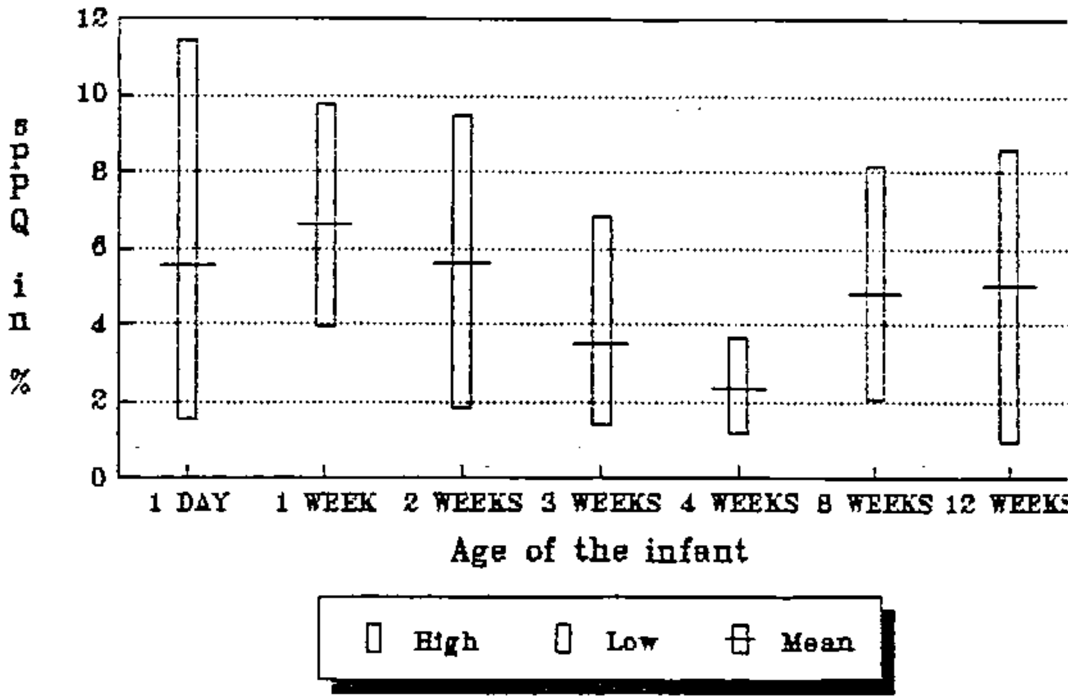
Subjects showed maximum variation in the 1st recording i.e., 4.3% and minimum variation was noticed in the 5th recording i.e., 0.9%.

Further the administration of wilcoxin test confirmed the observation made earlier i.e., no significant change occurred over a period of 1st day to 3 months. However, a significant difference between 2nd and 3rd recording with 5th cry recording (4th week) was noticed.

The smoothed pitch perturbation quotient had varied significantly after 2nd cry recording. It may be because subjects had shown 6.6% as mean smoothed pitch perturbation

Table:12 Showing Mean, S.D and Range for Smoothed Pitch Perturbation Auotient and its variations in the cry of infants during the 1st day (l), 1st week (2), 2nd week (3), 3rd week (4),4th week (5), 2nd month (6} and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 5.5 | 4.3 | 1.5 - 11.3 |
| 2 | 6.6 | 2.6 | 3.9 - 9.7 |
| 3 | 5.6 | 2.7 | 1.8 - 9.4 |
| 4 | 3.5 | 2.1 | 1.3 - 6.8 |
| 5 | 2.3 | 0.9 | 1.1 - 3.6 |
| 6 | 4.8 | -2.4 | 2.0 - 8.1 |
| 7 | 5.0 | 3.8 | 0.9 - 8.5 |




Graph:12 Smoothed Pitch Perturbation Quotient (sPPQ) and it variations in the cry of infants at different age quotient on 2nd recording and it has decreased to 2.3% on 5th cry recording.

However, as no systematic change in smoothed pitch perturbation quotient was observed over the period, Hypothesis: 12 stating that there is no significant difference between recordings (1st day to 3 months) in terms of smoothed pitch perturbation quotient was accepted, except for 2nd and 3rd cry recording when compared to 5th recording. Therefore it was concluded that no systematic variation in smoothed pitch perturbation quotient was found from age 1st day to 3 months and no significant changes was noticed.

**Fundamental frequency variation (VFo)** /%/:

The Mean, S.D and Range for fundamental frequency variation of infant cry presented in Table:13 and Graph:13.

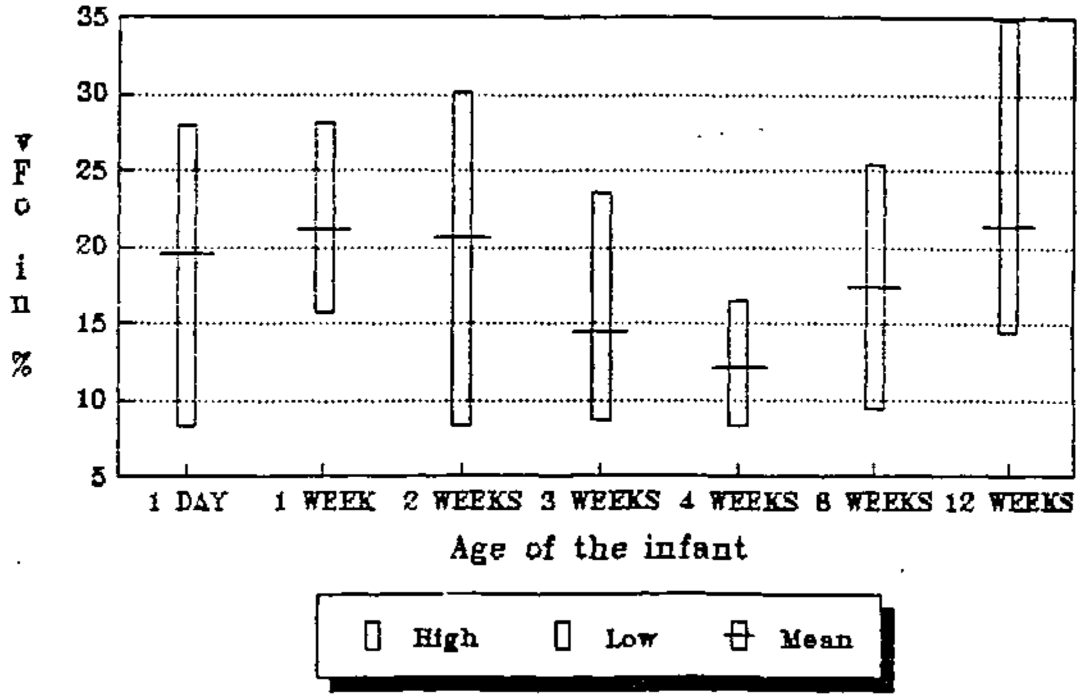
The fundamental frequency variation varied from a minimum of 8.2% to a maximum 34.8%. The lowest percent seen was 12.0% on the 5th cry recording i.e., during 4th week.

Examination of table and graph showed that there was no consistent change in fundamental frequency variation across the recordings made from 1st day to 3rd month. A maximum of 21.3% was seen in the 7th cry recording i.e., during 3rd month.

The subjects showed maximum variation in the 7th recording i.e., 11.6% and a minimum variation was noticed in the 5th recording i.e., 3.5%.

Table:13 Showing Mean, S.D and Range for Fundamental frequency Variation and its variations in the cry of infants during the 1st day (1), 1st week (2), 2nd week (3), 3rd week (4),4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 19.4 | 10.0 | 8.2 - 27.9 |
| 2 | 21.2 | 4.8 | 15.7 - 28.0 |
| 3 | 20.6 | 8.1 | 8.3 - 30.0 |
| 4 | 14.3 | 6.9 | 8.5 - 23.5 |
| 5 | 12.0 | 3.5 | 8.3 - 16.5 |
| 6 | 17.4 | 6.8 | 9.3 - 25.3 |
| 7 | 21.3 | 11.6 | 14.4 - 34.8 |




Graph:13 Fundamental Frequency Variation (vFo) and it: variations in the cry of infants at different ages

Further the administration of wilcoxin test confirmed the observation made earlier i.e., no significant change occurred over a period of 1st day to 3 months. However, a significant difference between the 2nd cry recording and the 5th recording (4th week) was noticed.

The fundamental frequency variation had varied significantly after 5th cry recording. It may be because subjects had shown 12.0% as the mean fundamental frequency variation on 5th recording and it had increased to 21.3 % in 7th cry recording (3rd month).

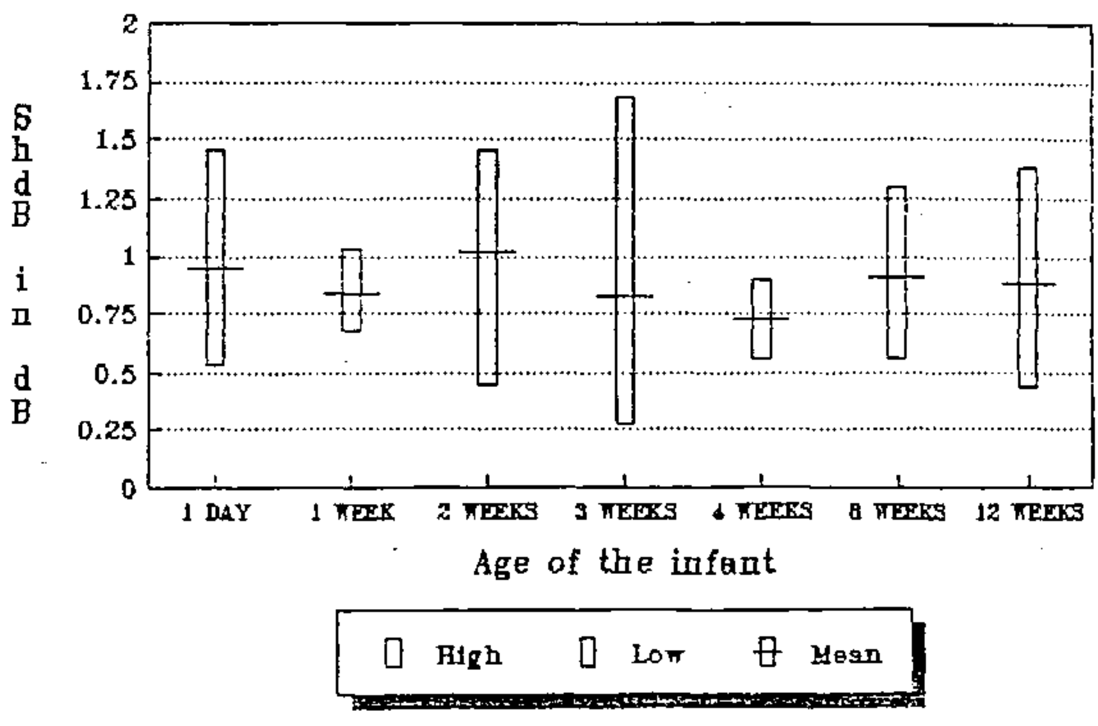
However, since no systematic change in fundamental frequency variation was observed over the period. Hypothesis: 13 stating that there is no significant difference between recordings (1st day to 3rd month) in terms of fundamental frequency variation was accepted, except for 2nd recording with compared to 5th recording. Therefore it was concluded that no systematic variation in fundamental frequency variation was found from age 1st day to 3 months and no significant was noticed.

**Shimmer in dB (ShdB) /dB/:**

Shimmer (in dB) was measured using MDVP software. The Mean, S.D and Range for shimmer in d3 of infant cry are presented in Table: 14 and Graph: 14.

Table:14 Showing Mean, S.D and Range for Shimmer in dB and its variations in the cry of infants during the 1st day (1), 1st week (2), 2nd week (3), 3rd week (4), 4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| i | 0.9 | 0.3 | 0.5 - 1.4 |
| 2 | 0.8 | 0.1 | 0.6 - 1.0 |
| 3 | 1.0 | 0.3 | 0.4 - 1.4 |
| 4 | 0.8 | 0.5 | 0.2 - 1.6 |
| 5 | 0.7 | 0.1 | 0.5 - 0.8 |
| 6 | 0.9 | 0.3 | 0.5 - 1.2 |
| 7 | 0.8 | . 0.4 | 0.4 - 1.3 |




Graph:14 Shimmer in dB (ShdB) and its variations in the cry of infants at different ages shimmer (in dB) varied from a minimum of 0.2dB to a maximum of 1.6 dB. The lowest intensity seen was (0.7 dB in the 5th cry recording i.e., 4th week)

Examination of table and graph showed that there was no consistent change in shimmer (in dB) variation across the cry recordings made from 1st day to 3 months and had shown a maximum of 1.0 dB in the 3rd recording. Subjects had shown maximum variation in the 4th cry recording i.e., 0.55 dB and a minimum variation in 5th cry recording i.e., 0.13 dB.

Further the administration of wilcoxin test confirmed the observation made from earlier examination i.e, no significant change had occurred over a period of three months.

shimmer (in dB) had varied significantly in 3rd recording, when compared to the remaining recordings i.e., it had shown 1.01 dB as mean shimmer (in dB) in 3rd cry recording and had decreased to 0.7 dB in the 5th recording.

However, since no systematic change in shimmer (in dB) variation was observed over the period of three months i.e., (1st day to 3 months). It was decided to accept, hypothesis: 14 stating that there was no significant difference between cry recordings in terms of shimmer (in dB) during first three months. Thus it was concluded that no systematic variation in shimmer (in dB) was found from age 1st day to 3 months, in the cry of infants.

**Shimmer percent (Shim)** /%/:

Shimmer percent was measured using MBVP software. The Mean, S.D and Range for shimmer percent of infant cry are presented in Table: 15 and Graph: 15.

The shimmer percent varied from a minimum of 2.8% to a maximum 17%. The lowest percent seen was (6.9% on the 5th recording i.e., during 4th week).

Examination of table and graph showed that there was no consistent change in Shimmer percent across the recordings made from 1st day to 3 months, and had shown a maximum of 9.8% in the 3rd recording.

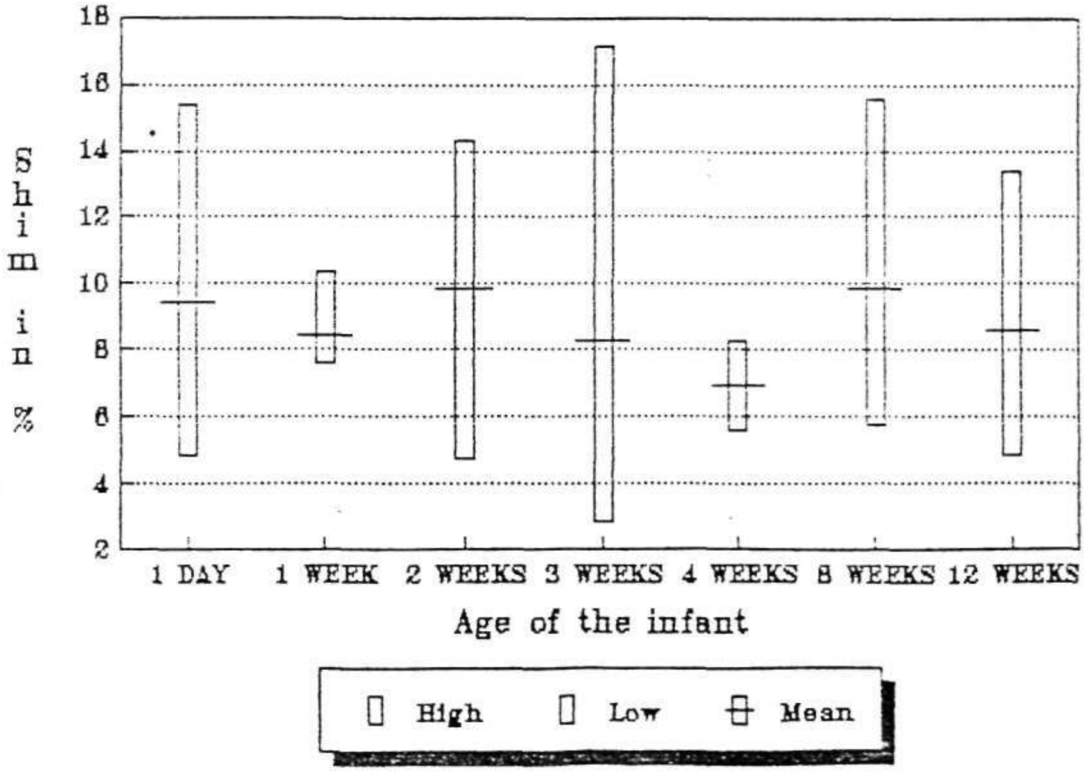
The subjects showed maximum variation in the 4th recording i.e., 5.5% and minimum variation on 2nd recording i.e., 1.0%.

Further the administration of wilcoxin test confirmed the observation made earlier based on study of table and graph i.e., no significant change had occurred over the period of study i.e., 1st day to 3 months. However, a significant difference between the 2nd and 5th recording (4th week) was noticed.

However, since no systematic change in shimmer percent was observed over the period. Hypothesis: 15 stating that there is no significant in the cry at different period of age (1st day to 3rd month) was accepted. Therefore Shimmer percent, was concluded that no systematic variation in

**Table:15** Showing Mean, S.D and Range for Shimmer Percent and its variations in the cry of infants during the 1st day (1), 1st week (2), 2nd week (3), 3rd week (4), 4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 9.4 | 4.7 | 4.8 - 15.4 |
| 2 | 8.4 | 1.0 | 7.5 - 10.3 |
| 3 | 9.8 | 3.7 | 4.8 - 14.3 |
| 4 | 8.2 | 5.5 | 2.8 - 17.0 |
| 5 | 6.9 | 1.0 | 5.5 - 8.2 |
| 6 | 9.8 | 3.8 | 5.7 - 15.5 |
| 7 | 8.6 | 4.3 | 4.8 - 13.3 |




**Graph:15** Shimmer percent (Shim) and its variations in the cry of infants at different ages shimmer percent was found from age 1st day to 3 months in the cry of infants.

**Amplitude perturbation Quotient (APQ)** /%/:

The Mean, S.D and Range for amplitude perturbation quotient of infant cry presented in Table: 16 and Graph: 16.

The study of table and graph showed that the amplitude perturbation quotient varied from a minimum of 2.5% to a maximum of 14.1. The lowest percent seen was 5.5% in the 5th recording i.e., 4th week.

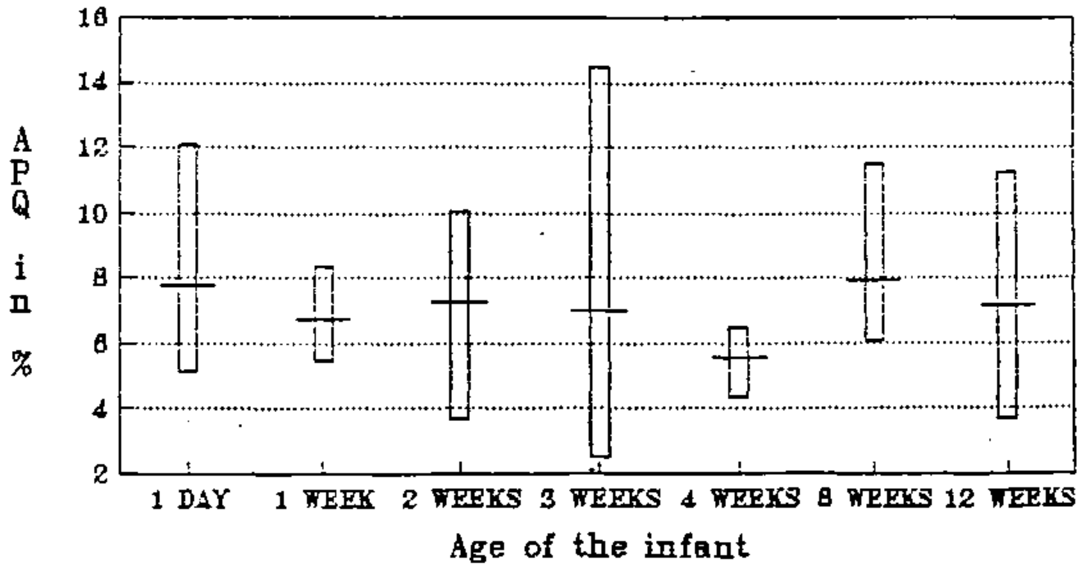
Further examination of table and graph showed that there is no consistent change in amplitude perturbation quotient in cry samples recording was made from 1st day to 3 months, and had shown a maximum of 7.9% in the 4th week i.e., 5th cry recording. Subjects had shown maximum variation in the 4th cry recording. i.e., 4.7% and minimum variation on 5th cry recording i.e., 0.9%.

Further the administration of wilcoxin test confirmed the observations made earlier based on the study of table and graph i.e., no significant change occurred over the period of 3 months i.e., 1st day to 3 months.

The amplitude perturbation quotient had varied significantly in the 5th recording, when compared to the remaining recordings i.e., it had shown 5.5% as mean

**Table:16** Showing Mean, S.D and Range for Amplitude perturbation Quotient and its variations in the cry of infants during the 1st day (1), 1st week (2), 2nd week (3), 3rd week (4),4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 7.7 | 3.2 | 5.1 - 12.1 |
| 2 | 6.7 | 1.1 | 5.4 - 8.4 |
| 3 | 7.2 | 2.4 | 3.6 - 10.0 |
| 4 | 7.0 | 4.7 | 2.5 - 14.4 |
| 5 | 5.5 | 0.9 | 4.4 - 6.4 |
| 6 | 7.9 | 2.4 | 6.0 - 11.5 |
| 7 | 7.1 | 3.8 | 3.7 - 11.2 |




Graph:16 Amplitude perturbation Quotient (Apq) and its variations in the cry of infants at different ages amplitude perturbation quotient in 5th cry recording and it had increased to 7.9% in the 6th cry recording.

However, since no systematic change in amplitude perturbation quotient was observed over the period of three months. i.e., (1st day to 3 months). It was decided to accept, hypothesis: 16 stating that there is no significant difference between cry recordings in terms of amplitude perturbation quotient during first there months. Thus it was concluded that no systematic variation in amplitude perturbation quotient was found from age 1st day to 3 months, in the cry of infants.

**Smoothed pitch perturbation quotient (SAPQ)** /%/

The Mean, SD and Range for smoothed pitch perturbation quotient of infant cry are presented in Table: 17 and Graph: 17.

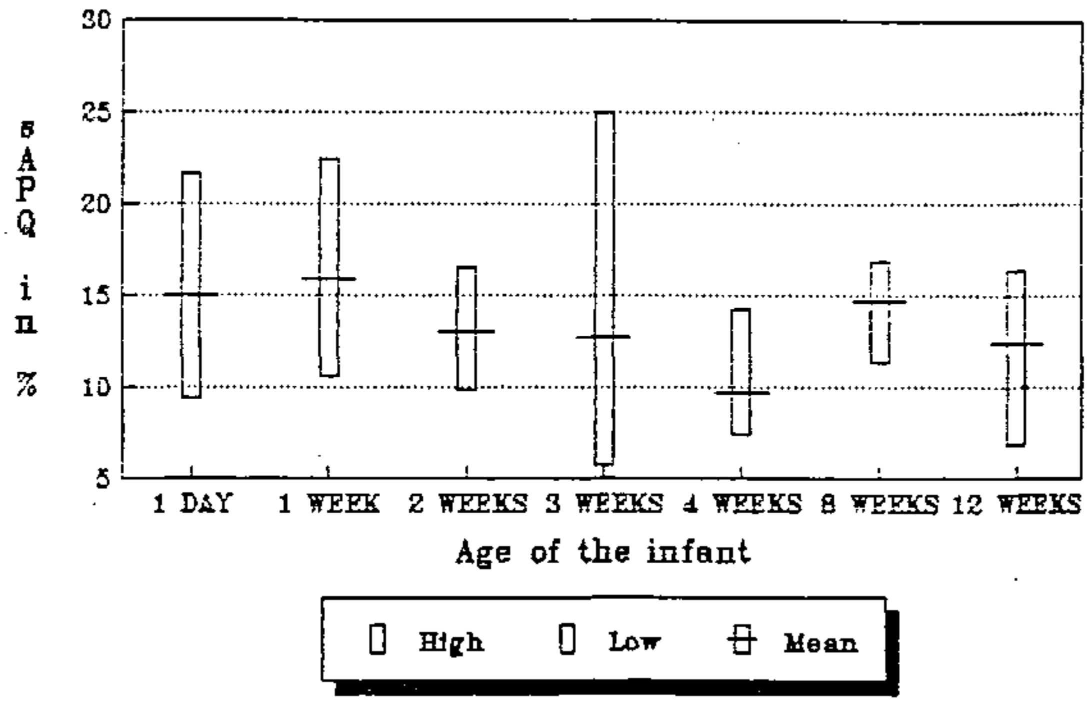
The smoothed pitch perturbation quotient varied from a minimum of 5.7% to a maximum 25%. The lowest percent seen was 9.6% in the 5th recording i.e., during 4th week.

Examination of table and graph showed that there was no consistent change in smoothed pitch perturbation quotient across the recordings made from 1st day to 3 months, and had shown a maximum of 15.8% in the 2nd recording.

The subjects showed maximum variation in the 4th recording i.e., 7.7% and minimum variation on 6th recording i.e., 2.2%.

**Table:17** Showing Mean, S.D and Range for Smoothed Amplitude Perturbation Quotient and its variations in the cry of infants during the 1st day (l), 1st week (2), 2nd week (3), 3rd week (4),4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 14.9 | 5.2 | 9.3 - 21.6 |
| 2 | 15.8 | 4.4 | 10.6 - 22.3 |
| 3 | 13.0 | 2.8 | 9.9 - 16.5 |
| 4 | 12.7 | 7.7 | 5.7 - 25.0 |
| 5 | 9.6 | 2.8 | 7.3 - 14.2 |
| 6 | 14.6 | 2.2 | 11.3 - 16.8 |
| 7 | 12.4 | 5.0 | 6.7 - 16.3 |




**Graph:17** Smoothed Amplitude Perturbation Quotient (sAPQ) and its variations in the cry of infants at difrerent ages

Further the administration of wilcoxin test confirmed the observation made earlier based on study of table and graph i.e., no significant change had occurred over the period of study i.e., 1st day to 3 months. However, a significant difference between 2nd and 5th recording (4th week) and 5th and 6th recording. (2nd month).

The smoothed pitch perturbation quotient had varied significantly after 2nd recording. It may be because subjects had shown 15.8% as the mean smoothed pitch perturbation quotient on 2nd recording and decreased to 9.6% on 5th recording.

However, since no systematic change in smoothed pitch perturbation quotient was observed over the period. Hypothesis: 17 stating that there was no significant difference between recordings (1st day to 3rd month) in terms of smoothed pitch perturbation quotient was accepted, except for 2nd and 5th recording. Therefore it was concluded that no systematic variation in a smoothed pitch perturbation quotient was found from age 1st day to 3rd month, in the cry of infants.

**Co-efficient of Amplitude variation (vAm)** /%/ :

The Mean, S.D. and Range for Co - efficient of amplitude variation of infant cry are presented in Table: 18 and Graph: 18.

The co-efficient of amplitude variation varied from a minimum of 22.2% to maximum 76.4 %. The lowest percent seen was 34.8%, on the 4th recording i.e., during 3rd weeks.

Further examination of table and graph showed that there was no consistent change in co-efficient of amplitude variation in cry samples recording were made from 1st day to 3 months, and had shown a maximum of 56% in the 1st day i.e., 1st cry recording. Subjects had shown maximum variation in the 2nd recording i.e., 13.3% and minimum variation on 7th recording i.e., 6.3%

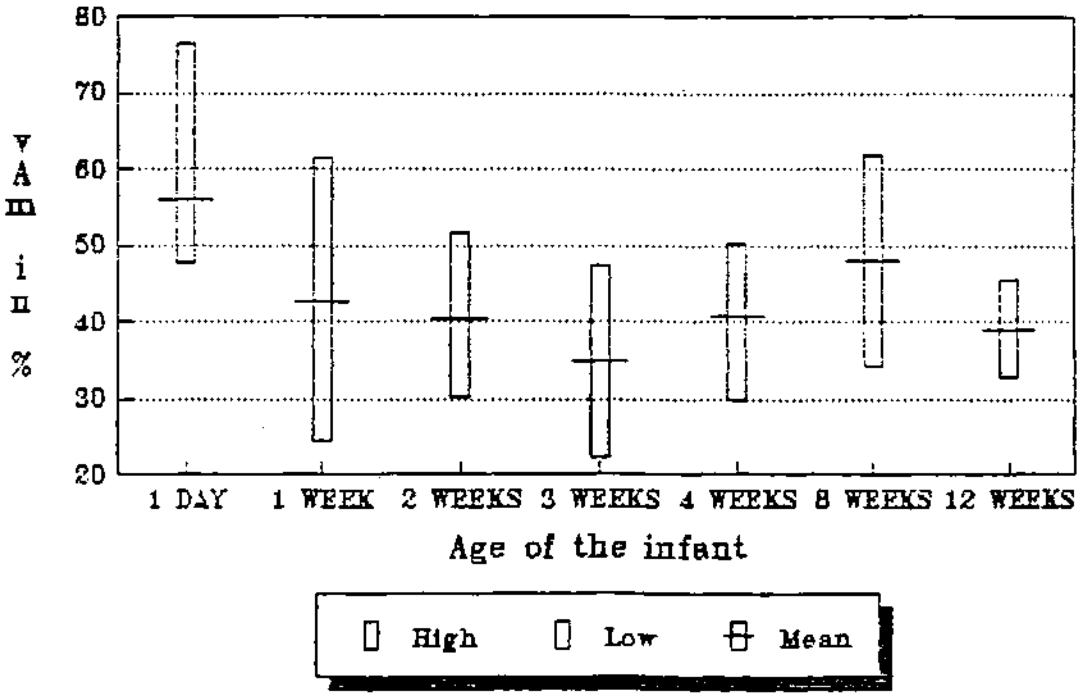
Further the administration of wilcoxin test confirmed the observation made earlier based on the study of table and graph i.e., no significant change occurred over the period of 3 months i.e., 1st day to 3 months. However, a significant difference in 1st cry recording with 3rd, 4th, 5th, and 6th i.e., (2nd week, 4th week and 3rd month), cry recording were noticed.

The co-efficient of amplitude variation had varied significantly after at 1st recording. It may be because subjects had shown 56% as the mean co-efficient of amplitude variation on 1st recording and it had became 34.8% on 4th recording.

However, since no systematic change in co-efficient of amplitude variation was observed over the period. Hypothesis: 18 stating that there in no significant

**Table:18** Showing Mean, S.D and Range for Peak-Amplitude Variation and its variations in the cry of infants during the 1st day (1), 1st week (2), 2nd week (3). 3rd week (4),4th week (5), 2nd month (6) and 3rc month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 56.0 | 12.0 | 47.5 - 76.4 |
| 2 | 42.5 | 13.3 | 24.4 - 61.3 |
| 3 | 40.3 | 9.2 | 30.2 - 51.8 |
| 4 | 34.8 | 11.4 | 22.2 - 47.2 |
| 5 | 40.6 | 9.5 | 29.8 - 50.3 |
| 6 | 48.1 | 12.2 | 34.1 - 61.9 |
| 7 | 38.8 | 6.3 | 32.9 - 45.5 |




**Graph:18** Peak - Amplitude Variation (vAm) and its variations in the cry of infants at different ages difference between cry recordings (1st day to 3 months) in terms of co-efficient of amplitude variation was accepted, except for 1st recording when compared to 3rd, 4th , 5th and 7th cry recordings. Therefore it was concluded that no systematic variation in co-efficient of amplitude variation was found from age 1st day to 3 months and no significant difference was noticed.

**Noise to harmonic Ratio (NHR)**

The Mean, S.D and Range for noise to harmonic ratio of infant cry are presented in Table: 19 and Graph: 19.

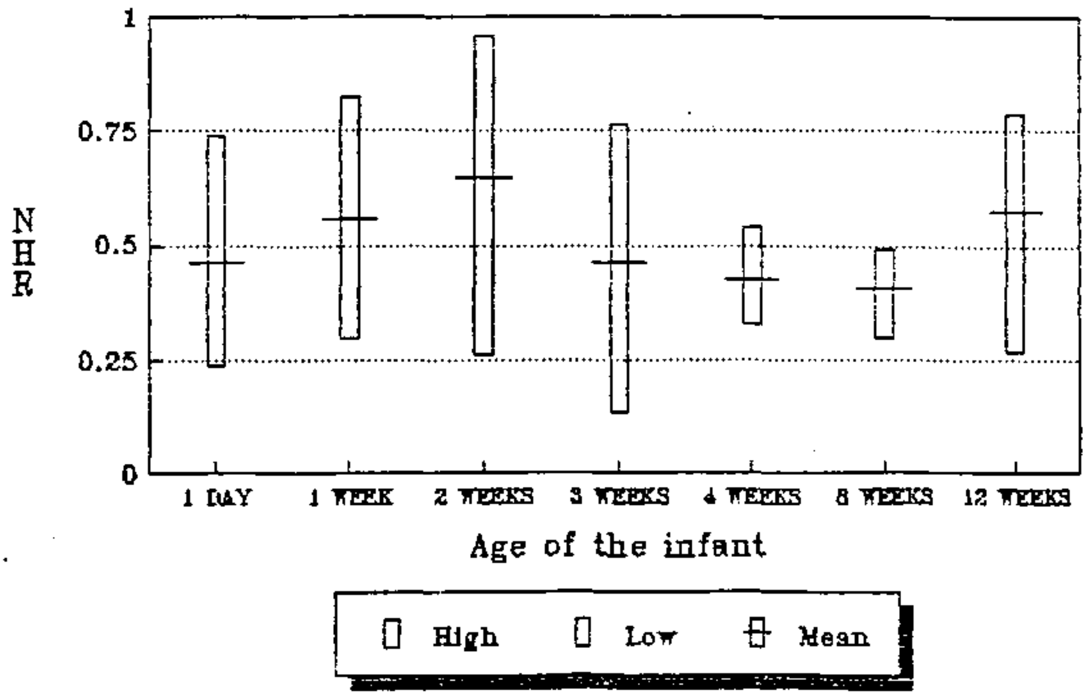
The noise to harmonic ratio varied from a minimum of 0.13 and maximum variation 0.95. The lowest ratio seen was (0.40 in the 6th recording i.e., 2nd month).

Examination of table and graph showed that there was no consistent change in noise to harmonic ratio across the cry recordings made from 1st day to 3 months and had shown a maximum of 0.85 in the 1st recording. Subjects had shown maximum variation in the 2.89 i.e., 1st recording and a minimum variation in 6th recording i.e., 0.08.

Further the administration of wilcoxin test confirmed the observation made from earlier examination i.e., no significant change had occurred over a period of three months. The noise to harmonic ratio had varied significantly in the 1st recording, when compared to the remaining recordings i.e.,, it had shown 0.85 as mean noise to harmonic

**Table:19** Showing Mean, S.D and Range for Noise to Harmonic Ratio and its variations in the cry of infants during the 1st day (1), 1st week (2), 2nd week (3), 3rd week (4),4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 1.8 | 2.8 | 0.3 - 0.7 |
| 2 | 0.5 | 0.2 | 0.2 - 0.8 |
| 3 | 0.6 | 0.2 | 0.2 - 0.9 |
| 4 | 0.4 | 0.2 | 0.1 - 0.7 |
| 5 | 0.4 | 0.0 | 0.3 - 0.5 |
| 6 | 0.4 | 0.0 | 0.2 - 0.4 |
| 7 | 0.5 | 0.3 | 0.2 - 0.7 |




Graph:19 Noise to Harmonic Ratio (NHR) and its variation: in the cry of infants at different ages ratio in 1st recording and had decreased to 0.40 in the 6th cry recording.

However, since no systematic change in noise to harmonic ratio was observed over the period of three months, i.e., (1st day to 3rd month). It was decided to accept, hypothesis: 19 stating that there is no significant difference between cry recording in terms of noise to harmonic ratio during first three months. Thus it was concluded that no systematic variation in noise to harmonic ratio was found from age 1st day to 3 months, in the cry of infants.

**Voice turbulence Index (VTI):**

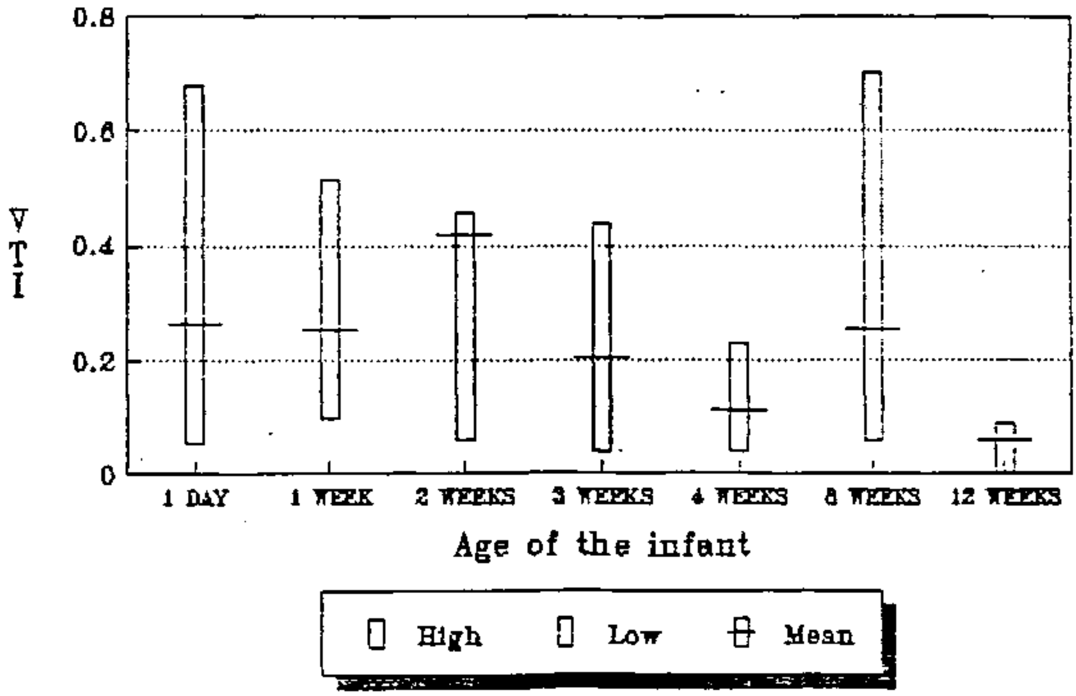
The Mean, S.D and Range for voice turbulence index of infant cry are presented in Table: 20 and Graph: 20.

The voice turbulence index varied from a minimum of zero to maximum variation 0.70. The lowest seen was ( 0.056 in the 7th recording i.e., 3rd month).

Examination of table and graph showed that there was no consistent change in noise to harmonic ratio across the cry recordings made from 1st day to 3 months and had shown a maximum of 0.4 in the 3rd recording. Subjects had shown maximum variation in the 1.3 i.e., 3rd recording and a minimum variation in 6th recording i.e., 0.04.

Table:20 Showing Mean, S.D and Range for Voice Turbulence Index and its variations in the cry of infants during the lstday (1), 1st week (2), 2nd week (3), 3rd week (4),4th week (5), 2nd month (6) and 3rc month (7).

| | Mean | S.D | Rarige |
|---|---|---|---|
| 1 | 0.26 | 0.25 | 0.05 - 0.67 |
| 2 | 0.25 | 0.19 | 0.09 - 0.55 |
| 3 | 0.4 | 1.30 | 0.05 - 0.4 |
| 4 | 0.20 | 0.16 | 0.03 - 0.43 |
| 5 | 0.11 | 0.03 | 0.03 - 0.23 |
| 6 | 0.25 | 0.25 | 0.06 - 0.70 |
| 7 | 0.05 | 0.04 | 0- 0.08 |




**Graph:20** Voice Turbulence Index (VTI) and its variations in the cry of infants at different ages

Further the administration of wilcoxin test confirmed the observation made from earlier examination i.e., no significant change had occurred over a period of 3 months.

The voice turbulence index had varied significantly in the 1st recording, when compared to the remaining recordings i.e., it had shown 0.4 as mean voice turbulence index in 3rd recording and it had decreased to 0.56 in the 7th cry recording.

However, since no systematic change in voice turbulence index was observed over the period of three months. i.e., (1st day to 3rd month). It was decided to accept, hypothesis: 20 Stating that there is no significant difference between cry recordings in terms of voice turbulence index during first-three months. Thus it was concluded that no systematic variation in voice turbulence index was found from age 1st day to 3 months, in the cry of infants.

**Soft phonation Index: (SPI)**

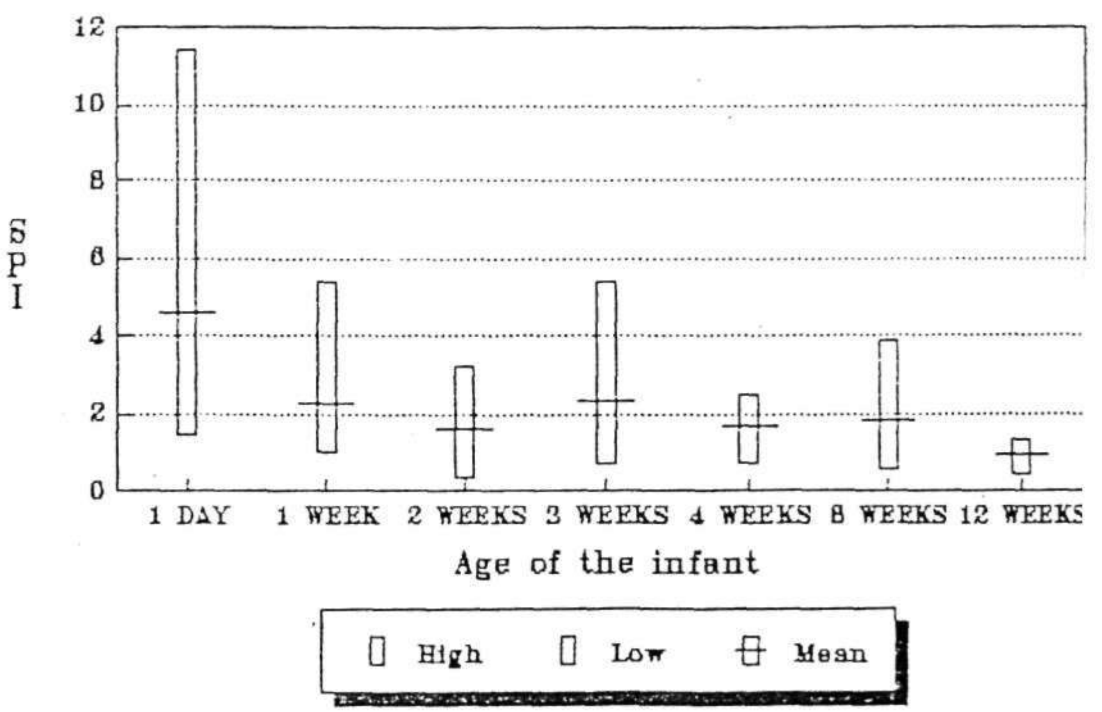
The Mean, S.D and Range for soft phonation index of infant cry are presented in Table: 21 and Graph: 21.

The soft phonation index varied from a minimum of 0.3 to maximum 11.4. The lowest seen was 0.96 in the 7th recording i.e., 3rd month.

Examination of table and graph showed that there was no consistent change in soft phonation index across the cry

Table:21 Showing Mean, S.D and Range for Soft Phonation Inde and its variations in the cry of infants during th lstday (1), 1st week (2), 2nd week (3), 3rd wee (4),4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Ranjie |
|---|---|---|---|
| 1 | 4.6 | 3.9 | 1.4 - 11.4 |
| 2 | 2.2 | 1.7 | 1.0 - 5.3 |
| 3 | 1.6 | 1.1 | 0.3 - 3.1 |
| 4 | 2.3 | 1.7 | 0.7 - 5.3 |
| 5 | 1.7 | 0.6 | 0.7 - 2.4 |
| 6 | 1.8 | 1.2 | 0.5 - 3.8 |
| 7 | 0.9 | 0.4 | 0.4 - 1.2 |




Graph:21 Soft Phonation Index (SPI) and its variations i the cry of infants at different ages recordings made from 1st day to 3 months and had shown a maximum of 4.61 in the 3rd recording. Subjects had shown maximum variation of 3.9 i.e., 1st recording and a maximum variation in 6th recording i.e., 0.47.

Further the administration of wilcoxin test confirmed the observation made from earlier examination i.e., no significant change had occurred over a period of 3 months.

In soft phonation index had varied significantly in the 1st recording, when compared to the remaining recordings i.e., it had shown 4.61 as mean soft phonation index in 1st recording and it had decreased to 0.96 in the 7th cry recording.

However, since no systematic change in soft phonation index was observed over the period of three months. i.e., (1st day to 3 months). It was decided to accept, hypothesis: 21 stating that there is no significant difference between cry recordings in terms of soft phonation index during first-three months. Thus it was concluded that no systematic variation in soft phonation index was found from age 1st day to 3rd month, in the cry of infants.

**Fo-Tremor Intensity Index (Fo-Tremor Intensity Index):** /%/

Table: 22 and Graph: 22 percent the Mean, S.D and Range for Fo-Tremor Intensity Index of infant cry.

Index was found from age 1st day to 3rd month, in the cry of infants.

**Amplitude Tremor Intensity Index (ATRl)** /%/:

The Mean, S.D and Range for amplitude tremor intensity index of infant cry are presented in Table: 23 and Graph: 23.

The amplitude tremor intensity index varied from a minimum of Zero to maximum 29.83%. The lowest percent seen was 7.5 in the 5th recording i.e., 4th weeks.

The examination of table and graph showed that there was no consistent change in amplitude tremor intensity index across the cry recordings made from 1st day to 3 months and had shown a maximum of 14.7% in the 1st recording. Subjects had shown maximum variation in the 1st recording i.e., 10.2% and minimum variation in 5th recording i.e., 1.4%.

Further the administration of wilcoxin test confirmed the observation made from earlier examination i.e., no significant change had occurred over a period of 3 months.

The amplitude tremor intensity index had varied significantly in 4th recording, when compared to the remaining recordings i.e., it had shown 14.7% as mean amplitude tremor intensity index in 1st recording and had decreased to 7.5% in the 5th recording.

However, since no systematic change in amplitude tremor intensity index was observed over the period of three months.

recordings made from 1st day to 3 months and had shown a maximum of 4.61 in the 3rd recording. Subjects had shown maximum variation of 3.9 i.e., 1st recording and a maximum variation in 6th recording i.e., 0.47.

Further the administration of wilcoxin test confirmed the observation made from earlier examination i.e., no significant change had occurred over a period of 3 months.

In soft phonation index had varied significantly in the 1st recording, when compared to the remaining recordings i.e., it had shown 4.61 as mean soft phonation index in 1st recording and it had decreased to 0.96 in the 7th cry recording.

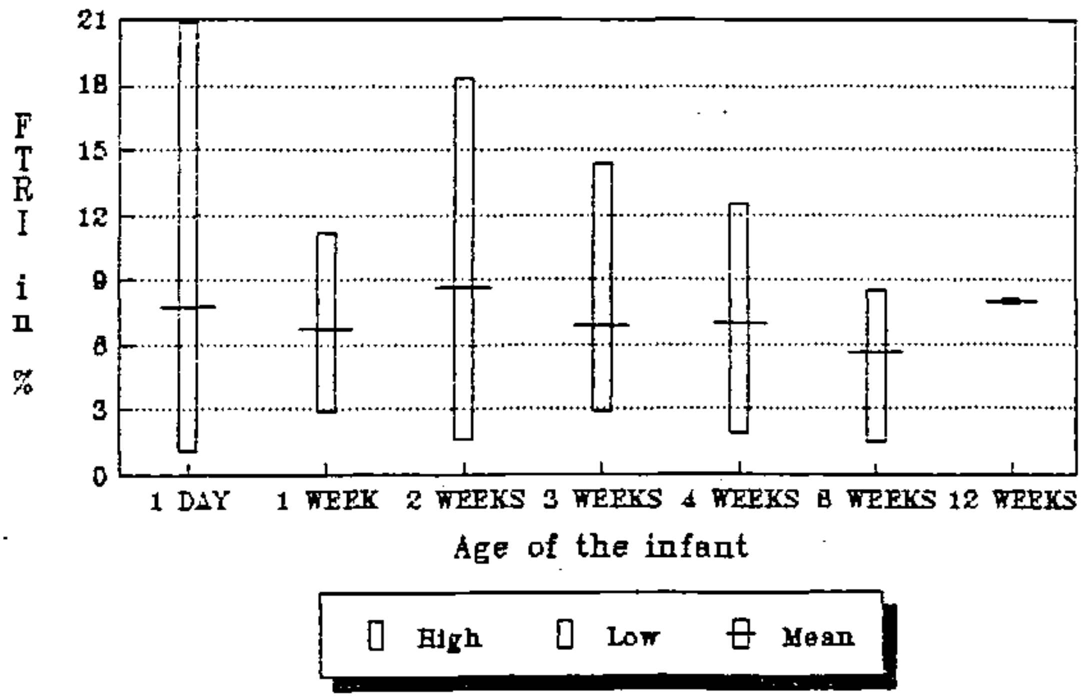
However, since no systematic change in soft phonation index was observed over the period of three months. i.e., (1st day to 3 months). It was decided to accept, hypothesis: 21 stating that there is no significant difference between cry recordings in terms of soft phonation index during first-three months. Thus it was concluded that no systematic variation in soft phonation index was found from age 1st day to 3rd month, in the cry of infants.

**Fo-Treraor Intensity Index (Fo-Tremor Intensity Index):** /%/

Table: 22 and Graph: 22 percent the Mean, S.D and Range for Fo-Tremor Intensity Index of infant cry.

**Table:22** Showing Mean, S.D and Range for Fo-Tremor Intensity Index and its variations in the cry of infants during at the 1st day (1), 1st week (2), 2nd week (3), 3rd week (4),4th week (5), 2nd month (6) anc 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 7.7 | 8.3 | 1.1- 20.8 |
| 2 | 6.7 | 3.0 | 2.8- 11.1 |
| 3 | 8.6 | 6.3 | 1.7- 18.3 |
| 4 | 6.8 | 5.1 | 2.9- 14.4 |
| 5 | 7.0 | 5.3 | 1.9- 12.5 |
| 6 | 5.5 | 2.7 | 1.4- 8.4 |
| 7 | 8.0 | 0.1 | 7.9- 8.1 |




**Graph:22** Fo - Tremor Intensity Index (FTRI) and its variations in the cry of infants at different ages

The Fo-Tremor Intensity Index varied from a minimum of 1.18% to a maximum 20.8%. The lowest percent seen was 5.5% in the 6th recording i.e., 2nd month.

The examination of table and graph showed that there was no consistent change in Fo-Tremor Intensity Index across the cry recordings made from 1st day to 3 months and had shown a maximum of 8.6% in the 3rd recording. Subjects had shown maximum variation of 8.3% i.e., 1st recording and a minimum variation in 7th recording i.e., 0.11%.

Further the administration of wilcoxin test confirmed the observation made from earlier examination i.e., no significant change had occurred over a period of 3 months.

The Fo-Tremor Intensity Index had varied significantly in the 3rd recording. When compared to the remaining recordings i.e., it had shown 8.6% as mean Fo-Tremor Intensity Index in 3rd recording and it had decreased to 5.5 in the 6th recording.

However, since no systematic change in Fo-Tremor Intensity Index was observed over the period of three months, i.e., 1st day to 3 months. It was decided to accept, hypothesis: 22 stating that there is no significant difference between cry recordings in terms of Fo-Tremor Intensity Index during first three months. Thus it was concluded that no systematic variation in Fo-Tremor Intensity

Index was found from age 1st day to 3rd month, in the cry of infants.

**Amplitude Tremor Intensity Index (ATRI)** /%/:

The Mean, S.D and Range for amplitude tremor intensity index of infant cry are presented in Table: 23 and Graph: 23.

The amplitude tremor intensity index varied from a minimum of Zero to maximum 29.83%. The lowest percent seen was 7.5 in the 5th recording i.e., 4th weeks.

The examination of table and graph showed that there was no consistent change in amplitude tremor intensity index across the cry recordings made from 1st day to 3 months and had shown a maximum of 14.7% in the 1st recording. Subjects had shown maximum variation in the 1st recording i.e., 10.2% and minimum variation in 5th recording i.e., 1.4%.

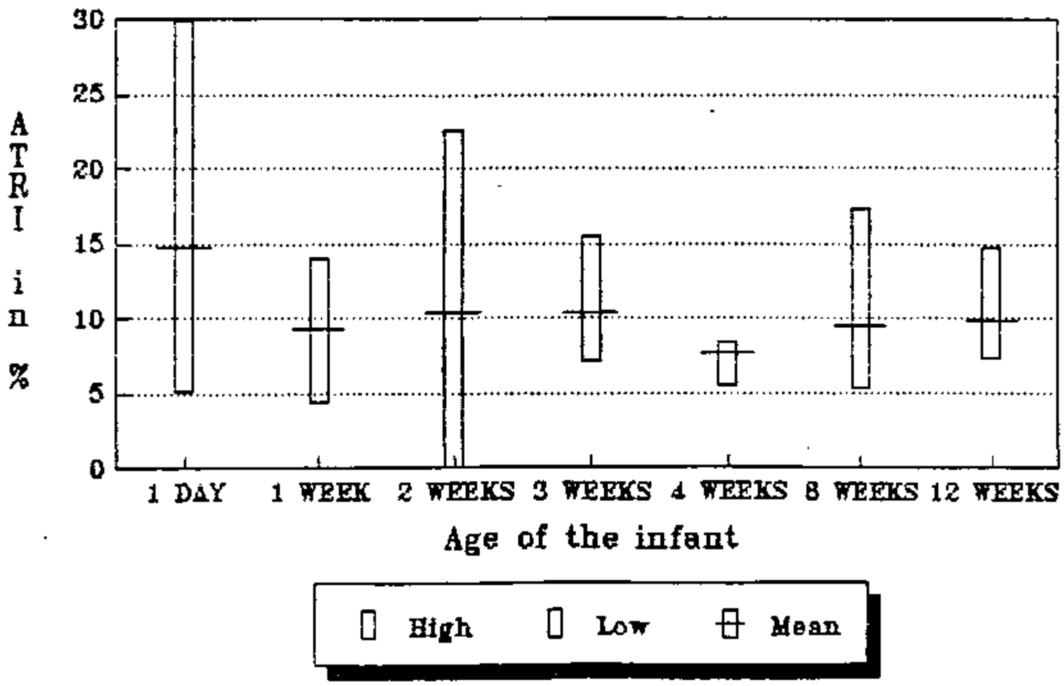
Further the administration of wilcoxin test confirmed the observation made from earlier examination i.e., no significant change had occurred over a period of 3 months.

The amplitude tremor intensity index had varied significantly in 4th recording, when compared to the remaining recordings i.e., it had shown 14.7% as mean amplitude tremor intensity index in 1st recording and had decreased to 7.5% in the 5th recording.

However, since no systematic change in amplitude tremor intensity index was observed over the period of three months.

**Table:23** Showing Mean, S.D and Range for Amplitude Tremor Intensity Index and its variations in the cry of infants during the 1st day (1), 1st week (2), 2nd week (3), 3rd week (4),4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 14.7 | 10.2 | 5.0 - 29.8 |
| 2 | 9.2 | 3.8 | 4.3 - 14.0 |
| 3 | 10.3 | 8.0 | 0 - 22.6 |
| 4 | 10.2 | 3.2 | 7.0 - 15.3 |
| 5 | 7.5 | 1.4 | 5.3 - 8.4 |
| 6 | 9.5 | 4.5 | 5.3 - 17.2 |
| 7 | 9.8 | 4.2 | 7.1 - 14.7 |




**Graph:23** Amplitude Tremor Intensity Index (ATRI) and its variations in the cry of infants at different ages i.e., (1st day to 3 months). It was decided to accept, hypothesis: 23 stating that three is no significant difference between cry recordings in terms of amplitude tremor intensity index during first three months. Thus it was concluded that no systematic variation in amplitude tremor intensity index was found from age 1st day to 3rd month, in the cry of infants.

**Degree of Voice Breaks**:/%/

Degree of voice breaks was measured using MDVP software. The Mean , S.D and Range for Degree of voice breaks of infant cry are presented in Table: 24 and Graph: 24.

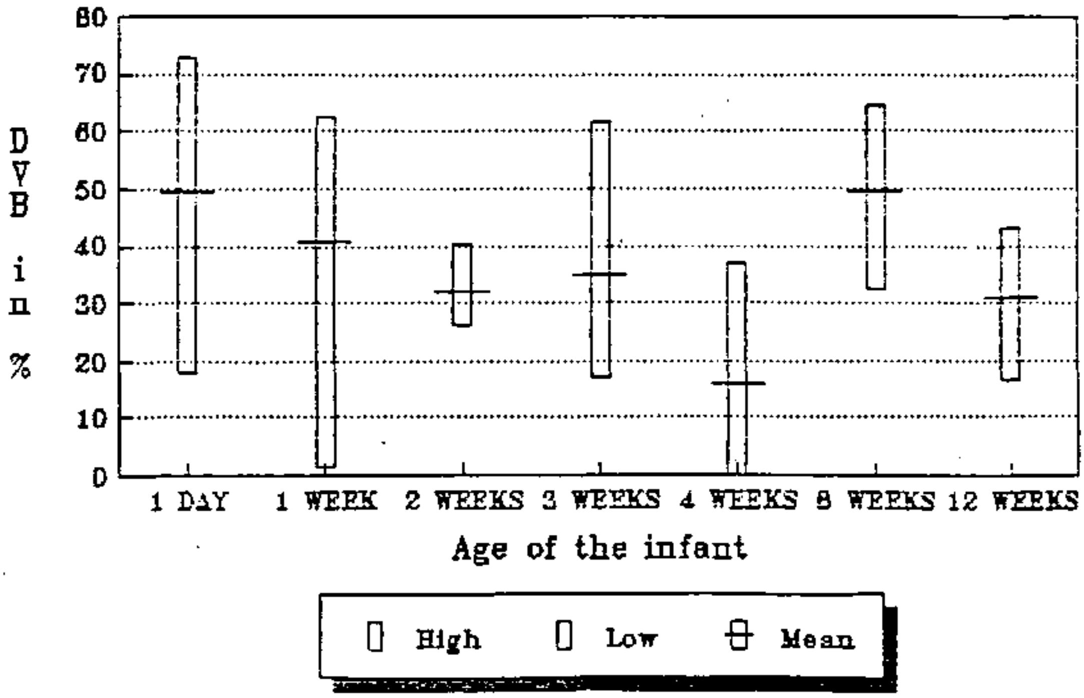
The Degree of voice breaks varied from a minimum of 0 to maximum 72.7%. The lowest seen was (16.0 on the 5th recording i.e., during 4th week.)

Examination of table and graph showed that there is no consistent change in Degree of voice breaks across the recordings made from 1st day to 3 months, and had shown a maximum of 49.4% in the 6th recording. Subjects showed maximum variation in the 2nd recording i.e., 24.7% and minimum variation on 3rd recording i.e., 6.5 %.

Further the administration of wilcoxin test confirmed the observation made earlier based on the study of table and graph i.e., no significant change had occurred over the period of study i.e., 1st day to 3 months. However, a significant difference between 1st, 2nd, and 3rd recording

Table:24 Showing Mean, S.D and Range for Degree of Voic Breaks and its variations in the cry of infant during the 1st day (l), 1st week (2), 2nd week (3) 3rd week (4),4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 49.2 | 20.8 | 18.2 - 72.7 |
| 2 | 40.8 | 24.7 | 1.4 - 62.4 |
| 3 | 31.9 | 6.5 | 26.1 - 40.2 |
| 4 | 34.8 | 17.9 | 16.8 - 61.6 |
| 5 | 16.0 | 13.7 | 0 - 37.0 |
| 6 | 49.4 | 14.3 | 32.6 - 64.4 |
| 7 | 31.1 | 13.5 | 16.5 - 43.3 |




Graph:24 Degree of Voice Breaks (DVB) and its variations in the cry of infants at different ages with 5th cry recording and 3rd and 4th recording with 6th cry recording. (2nd month) was noticed.

The Degree of voice breaks had varied significantly after 5th recording. It may be because subject's had shown 16.0 as the mean Degree of voice breaks on 5th recording and it increased to 49.4 on 6th recording.

However, since no systematic change in Degree of voice breaks in observed over the period. Hypothesis: 24 stating that there is no significant difference between recordings (1st day to 3 month) in terms of Degree of voice breaks was accepted, except for 1st, 2nd, 3rd recording. When compared the 5th recording. And 4th and 5th recording with 6th cry recording (2nd month).

Therefore it was concluded that no systematic variation in Degree of voice breaks was formed from age 1st day to 3 months and no significant was noticed.

**Degree of Sub-harmonic segments (DSH)**

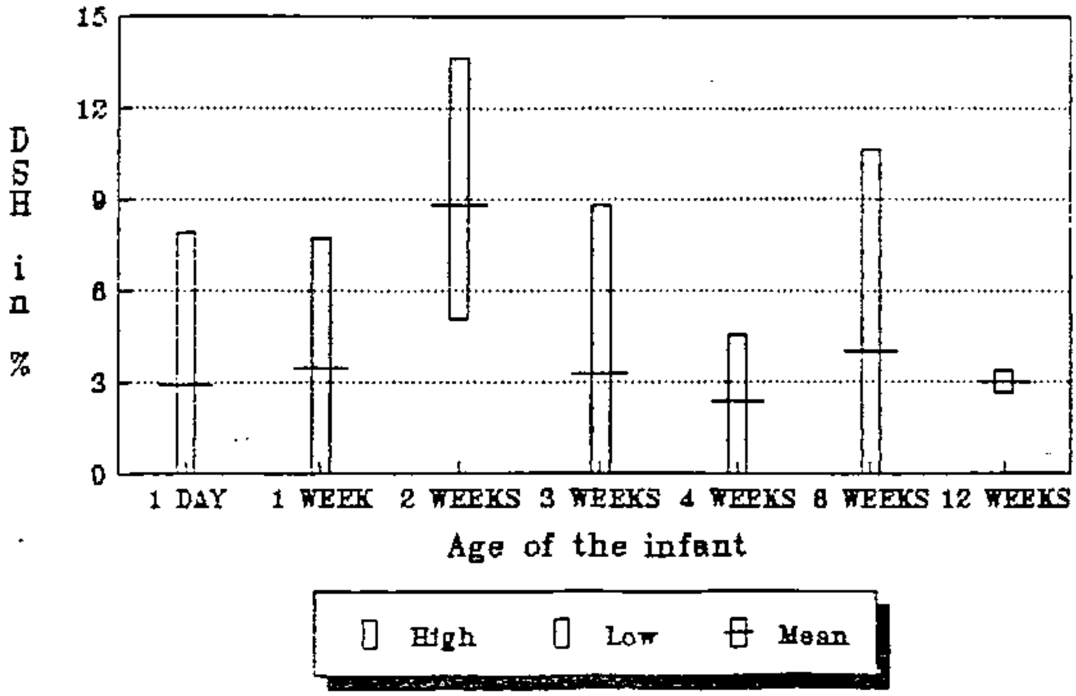
Table: 25 and Graph: 25 present the Mean, S.D and Range for Degree of sub-harmonic segments of infant cry.

The Degree of sub-harmonic segments varied from a minimum of 0 to maximum 13.6. The lowest seen was 2.3 in the 5th recording i.e., 4th week.

The examination of table and graph showed that there was no consistent change in Degree of sub-harmonic segments

Table:25 Showing Mean, S.D and Range for Degree of Sub harmonic segments and its variations in the cr of infants during the 1st day (1), 1st week (2), 2ni week (3), 3rd week (4),4th week (5), 2nd month (6 and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 2.8 | 3.1 | 0 - 7.9 |
| 2 | 3.4 | 3.3 | 0 - 7.6 |
| 3 | 8.7 | 3.6 | 5.1 - 13.6 |
| 4 | 3.3 | 3.5 | 0 - 8.8 |
| 5 | 2.3 | 2.2 | 0 - 4.5 |
| 6 | 3.9 | 5.1 | 0 -10.6 |
| 7 | 2.9 | 0.3 | 2.6 - 3.3 |




Graph:25 Degree of Sub - harmonic segments (NSH) and its variations in the cry of infants at different ages across the cry recordings made from 1st day to 3 months and had shown a maximum of 8.7 in the 3rd recording. Subjects had shown maximum variation of 5.18 i.e., 6th recording and a minimum variation in 7th recording i.e., 0.37.

Further the administration of wilcoxin test confirmed the observation made from earlier examination i.e., no significant change had occurred over a period of 3 months.

Degree of sub-harmonic segments had varied significantly in the 3rd recording, when compared to remaining recordings i.e., it had shown 8.78 and it had decreased to 2.36 in the 5th recording.

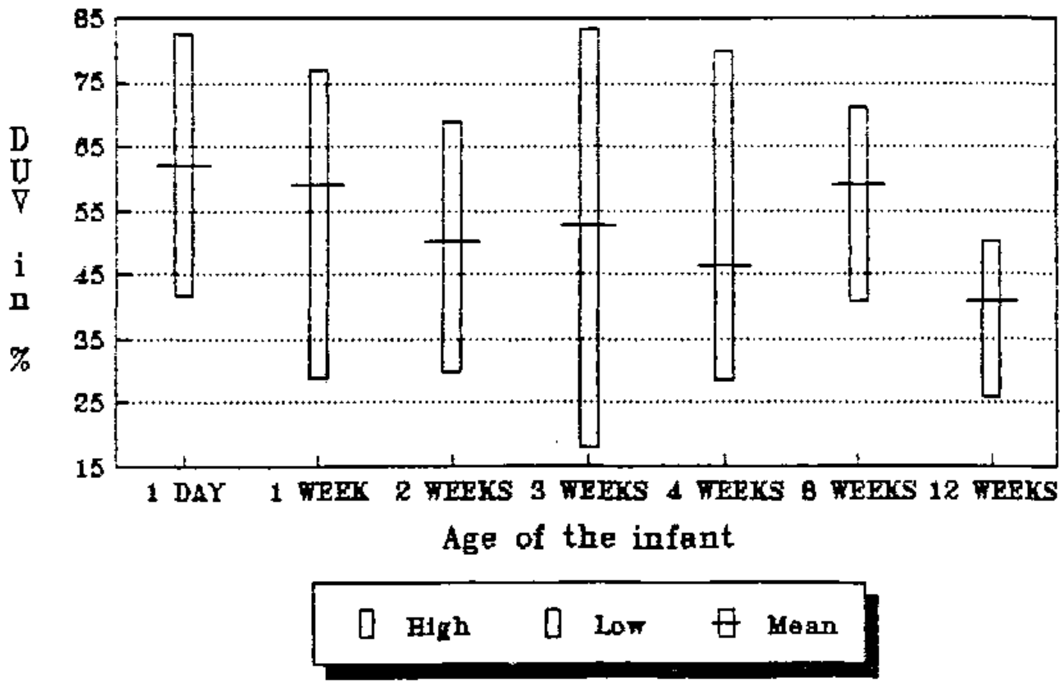
However, since no systematic change in Degree of Sub-harmonic segments in observed over the period.
Hypothesis: 25 stating that there is no significant difference between recording (1st day to 3rd month) in terms of Degree of Sub-harmonic segments was accepted, except for 1st and 2nd recording with 3rd cry recording; 3rd recording with 4th, 5th and 7th cry recording i.e., (3rd week, 4th week and 3rd month). Therefore it was concluded that no systematic variation in Degree of sub-harmonic segments was found from age 1st day to 3 months and no consistent was noticed.

**Degree of Voiceless (DUV)** /%/:

The Mean, S.D and Range for Degree of voice less of infant cry are presented in Table: 26 and Graph: 26.

Table:26 Showing Mean, S.D and Range for Degree of Voice less and its variations in the cry of infants during the 1st day (1), 1st week (2), 2nd week (3), 3rd week (4),4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 62.1 | 15.7 | 41.9 - 82.3 |
| 2 | 58.9 | 19.2 | 29.0 - 76.9 |
| 3 | 50.3 | 14.0 | 30.0 - 68.7 |
| 4 | 52.7 | 24.6 | 17.9 - 83.1 |
| 5 | 46.5 | 2.9 | 28.6 - 78.7 |
| 6 | 58.9 | 12.7 | 40.8 - 70.1 |
| 7 | 41.0 | 13.1 | 25.9 - 50.1 |




**Graph:26** Degree of Voice less (DUV) and its variations in the cry of infants at different ages

**Number of voice breaks: (NVB)**

The Mean, S.D and Range for Number of voice breaks of infant cry are presented in table: 27 and Graph: 27.

The Number of voice breaks varied from a minimum of zero to maximum 32.

The examination of table and graph showed that there was no consistent change in Number of voice breaks across the cry recordings made from 1st day to 3 months and had shown a maximum of 11.4 in the 1st recording. Subjects had shown maximum variation in the 4th recording i.e., 24.6 and minimum variation in 6th recording i.e., 12.7.

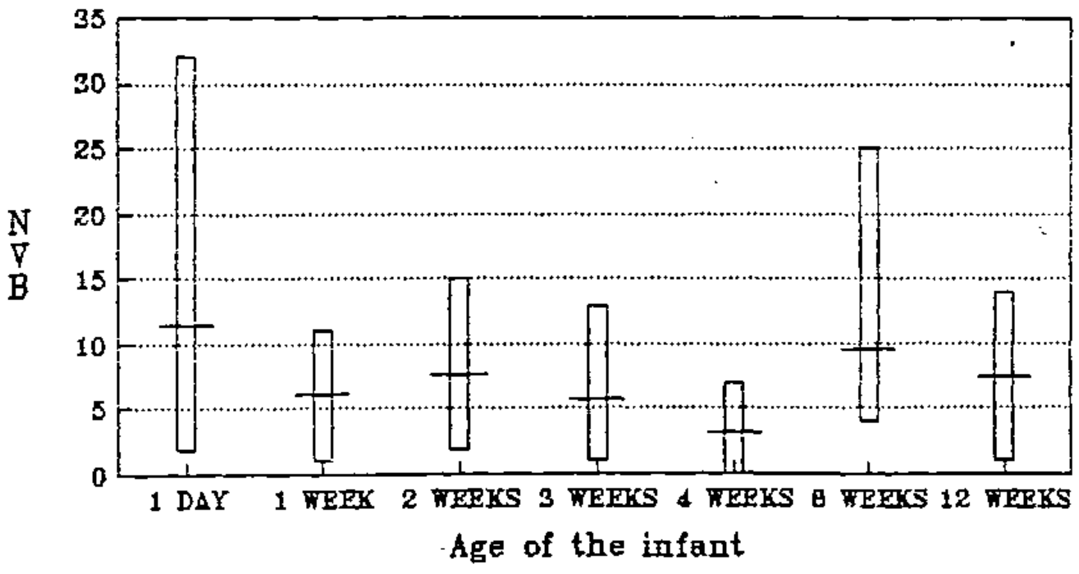
Further the administration of wilcoxin test confirmed the observation made from earlier examination i.e., no significant change had occurred over a period of 3 months.

The Number of voice breaks had varied significantly in 1st recording. When compared to the remaining recordings i.e., it had shown 11.4 as mean Number of voice breaks in 1st recording and had decreased to 3.2 in the 5th recording.

However, since no systematic change in Number of voice breaks was observed over the period of three months. i.e., (1st day to 3 months). It was decided to accept, hypothesis: 27 stating that there is no significant difference between cry recordings in terms of Number of voice breaks curing first three months. Thus it was concluded that no systematic

Table:27 Showing Mean, S.D and Range for Number of Sub-harmonic segments and its variations in the cry of infants during the 1st day (1), 1st week (2), 2nc week (3), 3rd week (4),4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 11.4 | 12.1 | 2 - 32 |
| 2 | 6.2 | 4.2 | 1 - 11 |
| 3 | 7.6 | 5.2 | 2 - 15 |
| 4 | 5.8 | 4.7 | 1 - 13 |
| 5 | 3.2 | 2.8 | 0 - 7 |
| 6 | 9.6 | 8.7 | 4 - 25 |
| 7 | 7.3 | 6.5 | 1 - 14 |




Graph:27 Number of Voice Breaks (NVB) and its variations i the cry of infants at different ages variation in Number of voice breaks was found from age 1st day to 3rd month, in the cry of infants.

**Number of Sub-harmonic segments (NSH)**

Table: 28 and Graph: 28 depict, Mean, S.D and Range, for Number of sub-harmonic segments of infant cry.

The Number of sub-harmonic segments varied from a minimum of 0 to maximum 22. The lowest seen was (2.6 on the 1st recording i.e., 1st day).

Examination of table and graph showed that there is no consistent change in Number of sub-harmonic segments across the recordings made from 1st day to 3 months and had shown a maximum of 14.2 in the 3rd recording.

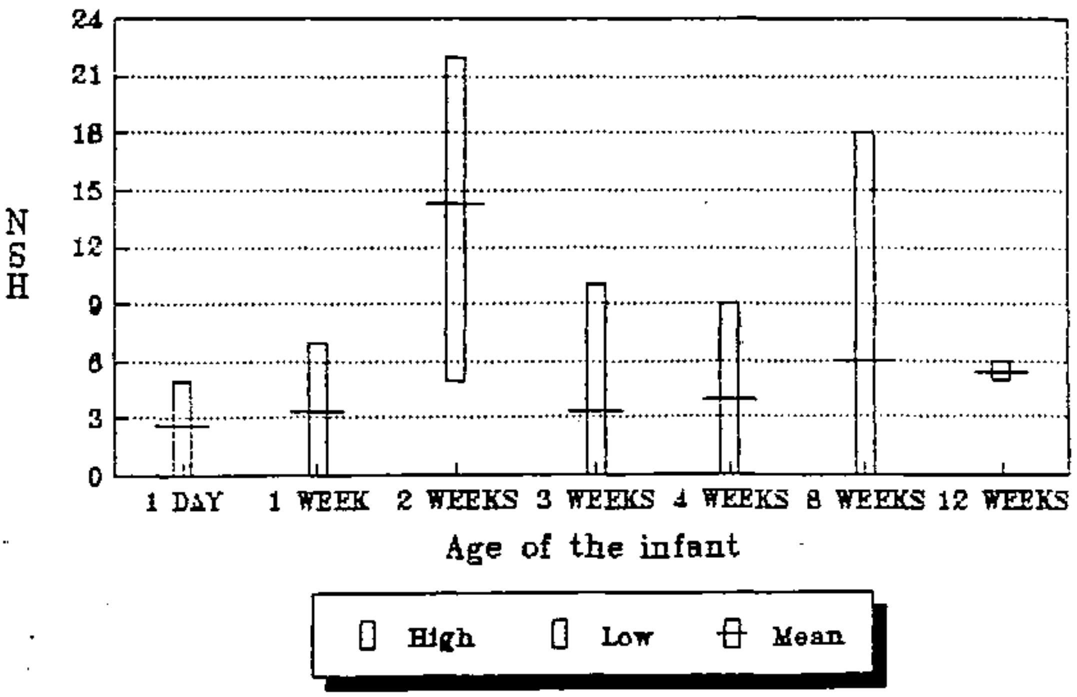
The subjects showed maximum variation in 6th recording i.e., 8.15 and minimum variation on 7th recording i.e., 0.57.

Further the administration of wilcoxin test confirmed the observation made earlier based on study of table and graph i.e., no significant change had occurred over the period of study i.e., 1st day to 3 months. However, a significant difference between 1st, 2nd recording with 3rd recording; 3rd recording with 4th and 5th cry recording and 1st recording with 7th cry recording was noticed.

The Number of sub-harmonic segments had varied significantly after 1st recording. It may be because subjects

Table:28 Showing Mean, S.D and Range for umber of Sub-harmonic segments and its variations in the cr of infants during the 1st day (l), 1st week (2), 2nd week (3), 3rd week (4),4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range |
|---|---|---|---|
| 1 | 2.6 | 2.07 | 0 - 5 |
| 2 | 3.4 | 3.36 | 0 - 7 |
| 3 | 14.2 | 8.07 | 5 - 22 |
| 4 | 3.4 | 3.97 | 0 - 10 |
| 5 | 4 | 4.30 | 0 - 9 |
| 6 | 6 | 8.15 | 0 - 18 |
| 7 | 5.3 | 0.57 | 5 - 6 |




**Graph:28** Number of Sub-harmonic segments (NTSH) and it: variations in the cry of infants at different age:

had shown 2.6 as the mean Number of sub-harmonic segments on 1st recording and it increased to 14.2 on 7th cry recording.

However, since no systematic change is Number of sub-harmonic segments is observed over the period. Hypothesis: 28 stating that there is no significant difference between recordings (1st day to 3 month) in terms of Number of sub-harmonic segments was accepted, except for 1st, 2nd recording with 3rd cry recording; 3rd recording with 4th and 5th cry recording and 1st recording with 7th cry recording.

Therefore it was concluded that no systematic variation in Number of sub-harmonic segments was found from age 1st day to 3 months and no significant was noticed.

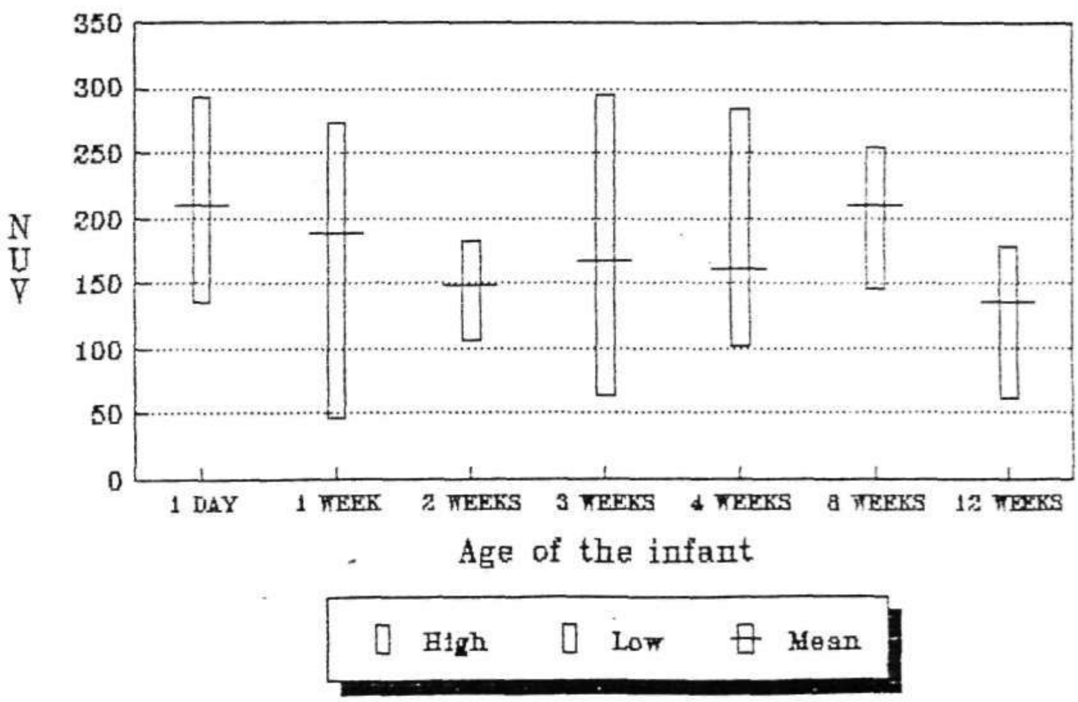
**Number of Unvoice segments: (NUV)**

The Mean, S.D and Range for Number of unvoice segments of infant cry are presented in Table: 29 and Graph: 29. The Number of unvoice segments varied from a minimum 47 and to maximum 296.

Examination of table and graph showed that there was no consistent change in Number of unvoice segments across the cry recording made from 1st day to 3 months and has shown a maximum of 210.6 in the 6th recording. Subjects had shown maximum variation in the 4th recording i.e., 98.1 and minimum variation in the 3rd recording i.e., 30.2.

Table:29 Showing Mean, S.D and Range for Number of Unvoice segments and its variations in the cry of infants during the 1st day (1), 1st week (2), 2nd week (3), 3rd week (4), 4th week (5), 2nd month (6) and 3rd month (7).

| | Mean | S.D | Range | |
|---|---|---|---|---|
| 1 | 209.6 | 68.5 | 135 | 293 |
| 2 | 189 | 91.8 | 47 | 274 |
| 3 | 149.4 | 30.2 | 107 | 183 |
| 4 | 168 | 98.1 | 64 | 286 |
| 5 | 162 | 84.5 | 101 | 284 |
| 6 | 210.6 | 45.3 | 146 | 254 |
| 7 | 136 | 65.1 | 61 | 179 |




Graph:29 Number of Unvoice segments (NUV) and it variations in the cry of infants at different ages

Further the administration of wilcoxin test confirmed the observation made from earlier examination i.e., no significant change had occurred over a period of 3 months. However, a significant difference between the 3rd recording with the 6th recording (2nd month) was noticed.

The Number of unvoice segments had veined significantly after 6th recording. It may be because subjects had shown 210.6 as the mean Number of unvoice segments on the 6th recording and it decreased to 136 on 7th recording.

However, since no systematic change in Number of unvoice segments in observed over the period. Hypothesis: 29 stating that there is no significant difference between recordings (1st day to 3 months) in terms of Number of unvoice segments was accepted, except for 5th recording when compared to 7th recording. Therefore it was concluded that no systematic variation in Number of unvoice segments was found from age 1st day to 3 months and no significant was noticed.

Thus it was concluded that there was no significant change in the parameters: Average Fundamental Frequency (Fo), Average Pitch Period, (To), Highest Fundamental Frequency (Fhi), Lowest Fundamental Frequency (Flo), Standard Deviation of Fo (STD), FO - Tremor Frequency (Fftr), Amplitude Tremor Frequency (Fatr), Absolute Jitter (Jita), Jitter Percent (Jitt), Relative Average Perturbation (RAP), Pitch Perturbation Quotient (PPQ), Smoothed Pitch Perturbation Quotient (sPPQ), Fundamental Frequency Variation (vFo), Shimmer in dB (ShdB), Shimmer percent (Shim), Amplitude perturbation Quotient (Apq), Smoothed Amplitude Perturbation Quotient (sAPQ), Peak - Amplitude Variation (vAm), Noise to Harmonic Ratio (NHR), Voice Turbulence Index (VTI), Soft Phonation Index (SPI), Fo - Tremor Intensity Index (FTRI),Amplitude Tremor Intensity Index (ATRI), Degree of Voice Breaks (DVB), Degree of Sub - harmonic segments (NSH), Degree of voice less(DUV), Number of Voice Breaks (NVB), Number of Sub-harmonic segments (NSH), Number of Unvoice segments (NUV). Measured using Multi-dimentional Voice Prolfile Software (Kay Elementrics Inc.,), in seven Pain cry samples recorded from day one to three months in five normal infants. This shows that the changes are taking place in the anotomical structures and the Physiological changes in the infants may not contributing to the cry to bring about any significant change in the cry. The MDVP has been found to be sensitive enough to record the small variation that occur in the voice. Therefore it was considered that the pain cry does not change significantly in the infant in the first three months. There are no other study which can be compare this study.

# SUMMARY & CONCLUSION

# SUMMARY AND CONCLUSION

In the present study "Multidemisional voice programme model 4305" was used to acquire, analyse and display the 29 acoustic parameters from infant cries. Pain samples recorded from 1st day to 3 month (Seven occasions).

**Parameters :**

**I Frequency Parameters:**

1. Average Fundamental Frequency
2. Average Pitch Period
3. Highest Fundamental Frequency
4. Lowest Fundamental Frequency
5. Standard Deviation of Fo
6. Fo Tremor Frequency
7. Absolute Jitter
8. Jitter Percent
9. Relative Average Perturbation
10. Pitch Perturbation Quotient
11. Smoothed 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. Smoothed Amplitude Variation

across the cry recordings made from 1st day to 3 months and had shown a maximum of 8.7 in the 3rd recording. Subjects had shown maximum variation of 5.18 i.e., 6th recording and a minimum variation in 7th recording i.e., 0.37.

Further the administration of wilcoxin test confirmed the observation made from earlier examination i.e., no significant change had occurred over a period of 3 months.

Degree of sub-harmonic segments had varied significantly in the 3rd recording, when compared to remaining recordings i.e., it had shown 8.78 and it had decreased to 2.36 in the 5th recording.

However, since no systematic change in Degree of Sub-harmonic segments in observed over the period.

Hypothesis: 25 stating that there is no significant difference between recording (1st day to 3rd month) in terms of Degree of Sub-harmonic segments was accepted, except for 1st and 2nd recording with 3rd cry recording; 3rd recording with 4th, 5th and 7th cry recording i.e., (3rd week, 4th week and 3rd month). Therefore it was concluded that no systematic variation in Degree of sub-harmonic segments was found from age 1st day to 3 months and no consistent was noticed.

Degree of Voiceless (DUV) /%/:

The Mean, S.D and Range for Degree of voice less of infant cry are presented in Table: 26 and Graph: 26.

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 Voice less

27. Number of Voice Breaks

28. Number of Sub-harmonic segments

29. Number of Unvoiced segments

All the 20 parameters were meausred in five subjects (2 males and 3 females) on 7 different occassions i.e., 1st day, 2nd week, 3rd week, 4th week, 2nd month and 3rd month. The results were subjected to statistical analysis using impaired Wilcomin test and discriptive statistics and the following conclusions have been drawn.

**The results indicated the following** : -

In the Average Fundamental Frequency (Fo), Average Pitch Period (To), Highest Fundamental Frequency (FHI), Standard Deviation of Fo (STD), Amplitude Tremor Frequency (FATR), Fundamental Frequency Variation (VFo), Shimmer percent (Shim), Smoothed Amplitude Perturbation Quotient (SAPQ), Peak-Amplitude Variation (vAm), Degree of Voice Breaks (DVB), Degree of Sub-harmonic segments (DSH), Number of Sub-harmonic segments (NSH), Significant difference was observed over the period i.e., from 1st day to 3 months. But the significant difference was not consistant over the period.

The significant difference was not observed for the lowest fundamental frequency (Flo), Fo-Tremor Frequency (FFTR), Absolute Jitter (Jita), Jitter Percent (Jitt), Relative Average Perturbation (RAP), Pitch Perturbation Quotient (PPQ), Shimmer in dB (ShdB), Amplitude perturbation quotient (APPQ), Noise to Harmonic Ratio (NHR), Voice Turbulence Index (VTI), Soft-phonation Index (SPl), Fo-Tremor Intensity Index (FTRI), Amplitude Tremor Intensity Index (ATRI), Degree of Voice less (DUV), Number of Voice Breaks (NVB).

**Recommendations for further study** : -

1. These parameters may be studied with different age groups Eg. 0 to 1 year.
2. These parameters may be studied with different groups i.e., (Male and Female).
3. More number of infants (subjects) may be used for further study.

# REFERENCES

# BIBLIOGRAPHY


Bayley, N.(1918) - " A study of the crying of infants during mental and physical tests". The pediatrics seminar and Journal of Genetic psychology. 40, 306-329.

Cullen, J.K Jr., Fargo, N., Chase, R.A and Baker, P. (1968) "The development of delayed auditory feedback studies on infant cry". Journal of Speech and Hearing Research, 11, 85-93.

Charles, D. (1981) - "The expression of emotion in man and animals". New York, Appleton.

Downs, M.P (1978) - "Return to the basics of infant screening". In Cerlur, S.E and Mencher, G.T (Eds.).

Fairbanks, (1942) "An acoustical study of pitch of infant hunger wails". Child development, 13(3), 227-232.

Fiatan, T.S., and Gutzman, A. (1906) cited in Ostwald and Peltzman 1974.

Fisichelli, V.R., Kerelitz, S., Eichbauer, J. and Rosenfield, L.S., (1961) " Volume unit graphs : Their production and applicability in studies of infant's cries'. Journal of Psychology, 52, 423 -427.

Fisichelli, V.R., Kerelitz, and Halier, A. (1969) "The course of induced crying activity in the neonate". The Journal of psychology, 73, 183-191.

Fisichelli, V.R., Kerelitz, S., Fisichelli, R.M., and Cooper J. (1974) "The course of induced crying activity in the first year of life". Paediatric Research, 8, 921-928.

Gopal.,H.S. & Sanford., E. Gerben (1992) : "Why and how should we study infant cry" : International Journal of peadiatric otolaryngology 24, 145-159.

Gopal.,H.S. : "Infant cry analysis (1992) : Clinical applications, and research direction", Journal of the Indian Speech and Hearing association, 15-25.

Indira. N. "Analysis of infant cry", (1982) Unpublished Master s dissertation, University of Mysore.

Karelitz, S. and Fisichelli, V.R (1992) "The cry thresholds of normal infants and those with brain damage," - The Journal of paediatrics, 61, (5), 679-685.

Karelitz.S., Fisichelli, V.R. Davis, J and Halier, A. (1966) "The role of crying activity in Apgar scoring." The Journal of the American Medical Association, 198, 318-320.

Karelitz.S. Fisichelli, V.R. (1969) "Infant's vocalization and their significance" Clinical proceedings of the children's hospital, 15, (11), 345-361.

Katarina Michelsson., (1971) "Cry analysis of symptomless low birth weight neonatel and of asphyxiated newborn infants" Published in Finland by Tilgmann 15-40.

Keating, P and Buhr, R. (1978) "Fundamental frequency in the speech of infants and children". Journal of Acoustical Soceity of America, 63, (2), 567-571.

Lieverman, P., Harris, K.S., Wolf, P., and Russel, L.H.(1971) "Newborn infant cry and non-human primate vocalization". Journal of Speech and Hearing Research, 14(4), 710.

Lind, J., Warz-Hockert, 0., Vuorenkeski, V., and Valaune, E. (1975) - "The vocalization of a newborn, brain-damaged child". Ann. Pediats., 11, 32-37.

Long, E.C., and Heul, M.E. (1976) "Respiratory volume flow in the crying new-born infant". Pediatrics, Springfield, 27, 1961, 373-377 cited in Sirulo and Michelson.

Mc Carthy, D. (1952) "Organic interpretation of infant vocalizations" child development, 23, 273-280.

Mc Carthy, D.(1954). "Language development in children". In Carmichael, L., (Ed) "Manual of child psychology". NewYork: John Wiley and sons, Chap.9, 492-630.

Mc Carthy, D. (1952), "Organic interpretation of infant vocalizations" child development, 23, 273-280.

Michelsson and Warz-Hockert, 0.(1981). The value of cry analysis in neonatology and early infancy". Obtained by personal communication from K. Michelsson and Helsinki University Central Hospital, Children's Hospital, Second Department of Pediatrics, Stenbackslieet, 11, Sf-00290, Helsinki, 29, Finand.

Michelsson, K., Raes, J., Thoden, C.J., and Warz-Hockert, 0. (1982),"Sound spectrographic cry analysis in neonatal diagnostics on evaluate study". Journal of Phonetics, 10, (1), 79-88.

Murry,T and Murry,J.(1980). "Infant Communication-Cry and Early Speech." College Hill press, Texas.

Murry, T., Amundson, P., and Hollien, H. (1977), "Acoustical characteristics of infant cries : fundamental frequency". Journal of child language, 4, 321-323.

Ostwald, P.F Soundmaking (1963)."The acoustic communication of emotion". Spring field. Ill Charles C, Thomas.

Ostwald, P.F., and Peltzman, P. (1974), "The cry of the human infant". Scientific American, 230,(3), 84-90.

Ostwald, P., Peltzman, P., Cureenberg, M., and Meyer, J., (1981). "Cries of a trisomy 13-15 infant". Dev. Med. Child Neurol., 12, 472-477.

Parmler, H.A. Jr. (1962), "Infant crying and neurologic diagnosis". The Journal of Pediatrics, 61, 801-802.

Partanen, T.J., Warz-Hockert, 0., Vuosenkeski, V., Theosell, K., Valanne, E.H., and Lind, J. (1981). "Auditory identification of pain cry signals of young infants in pathological conditions and its sound spectrographic basis". Ann. Paediats. Fenn., 13, 56-631.

Prechtl, H.F.R & Beintema, D. (1964). The neurological examination of full term infant. Clinics in developmental medicine. 12 London. Meinemann; Philade.phia, Lippincott,

Rehelsky, F. , and Black, R (1981). "Crying in infancy: Jourl of Benet. Psychol., 121, 49-57.

Sherman, M. (1981). "The differenciation of emotional responses in infants". J. Comp. Physiol. Psychol., 7, 335-351.

Siruio, P., and Michelsson, K. (1976). "Sound spectrographic cry analysis of normal and abnormal infants -A review and a recommendation for standardization of the cry characteristics". Folio Phoniat., 28, 161-173.

Tenold, I.L., Crouell, D.H., Jones, R.H., Daniel, T.H., Mc Pherson and Popper, A.N., (1974). "Cepstral and stationary analysis of full-term and pre-mature cries". Journal of Accoustical Society of America, 56(3), 975-980.

Thoden, C.J. & Koivisto; (1980). Acoustic analysis of the normal pain cry In T. Murry & J. Murry (Eds), infant communication: cry and early speech. Houston: collage Hill Press.

Valanne, E.H., Vuorenkeski, V., Partanen, T.J., Lind, J., and Warz-Hockert, 0. (1967). "The abililty of human mothers to identify hunger cry signals of their own newborn infants during the crying period". Experintia, 23, 768. Cited in Michelsson and Warz-Hockert, (1981).

Vuorenkoski, V. Lind, J. Partanen T, Ujeune, J. Lafourcade. J and Warz-Hockert, 0. (1966). Spectrographic analysis of cries from children with maladie ducricuchat. Anna, paediatrcas Fehniae, 12, 174-180.

Warz-Hockert, J. Lind, V. Vurenski, T. Partnen and E. Valanne (1968) : "The infant cry : A spectrographic and Auditory analysis", Published by Spartais international medical publications, England, 1-40.

Warz-Hockert, 0. Vuore3nkeski, V., Valanne, E., and Michelsson, K., (1981)."Tonspektrophische Unter - suchungen des sauglingschreis". Expermintia, 13, 583. Cited in Michelsson and Warz-Hockert.

Warz-Hockert, 0., Partenen, T.J., Vuorenkeski, V., Valanne, E., and Michelsson, K. (1981). "Effect of training on ability to identify preverbal vocalizaions". Dev. Med. Child. Neurol. 6, 393-396. Cited in Michelsson and Warz-Hockert.

Warz-Hockert, 0., Partenen, T.J., Vuorenkeski, V., Valanne, E., and Michelsson, K. (1981). "The identification of some specific meanings in infant vocalization". Experientia, 20, 154. Cited in Michelsson and Warz-Hockert.

Warz-Hockert, 0., Lind, J., Vuorenkeski, V., Partanen, R.J., And Valanne. E. (1981). "The infant cry - A spectrographic and auditory analysis". clinics Developmental medicine No.29. Louenham, Suffolk : Spastics International Medical publications. Cited in Michelsson.

Watson, E.H., And Lowrey, G.H, (1951). "Growth and Development in children". Chicogo : Year Book Medicine.

Wolff, R.H. (1967), " The roll of bilogical rhythms in early psychological development". Bulletin of the Menninger clinic, 31, 197.

Wolff, P.H. (1969). " The natural history of crying and other vocalizations in early infancy". In B.M. F0SS (Ed). Determinants of infant behaviour (Vol.4) - London; Methuen.

Wolff, 0. (1952), "The effects of meaningococial meningitis on the intelleigence and hearing". Arch. Dis. Child., 27, 302.

Wolff, P.(1981). - "The natural history of crying and other vocalization in early infancy". The determinants of infant behaviour IV, Ed., B.M. Foss. London : Methuen and Co., Ltd. Cited in Michelsson.

# APPENDICES

## APPENDIX- A

The definitions considered in the present study are those given in the MDVP manual and are as follows :

**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 :

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

w h $Fo^{(i)} = \frac{1}{To^{(i)}}$ period-to-period fundamental frequency

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

**Highest fundamental frequency (HFo) - /Hz/:**

The greatest of all extracted period-to-period fundamental frequency values. Voice break areas are excluded. It is computed as

$$Fhi = Max\ (Fo^{(i)}),\ i = 1, 2, \ldots N$$

**Lowest fundamental frequency (LFo) - /Hz/:**

The lowest of all extracted period to period It is computed as :

$Flo = \min(Fo^{(i)}),\ i=1,2,...N$

The lowest fundamental within the defined period is extracted and displayed as Flo. However, the pitch extracted range is defined to either search for periods from 70-625 Hz or 200-1000 Hz. Therefore, the 'high' range will not determine a fundamental under 200 Hz.

**Standard Deviation of Fundamental Frequency (STD) - /Hz/:**

Standard deviation of all extracted period-to-period fundamental frequency values. Voice break areas are excluded.

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

where, $Fo = \frac{1}{N} \sum_{i=1}^{N} Fo^{(i)}$, $Fo^{(i)} = \frac{1}{To^{(i)}}$ Period to period Fo values

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

N = Number of extracted pitch periods.

**Fo-Tremor Frequency (FFTR)/Hz/:**

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

The method for frequency tremor analysis consists of the following.

A. Division of the fundamental frequency period-to-period (Fo) data into 2 sec windows at 1 sec step between. For every window, the following procedures apply.

   1. Low-pass filtering of the Fo data at 30Hz and downsampling at 400 Hz.

   2. Calculation of the total energy of the resulting signal.
   3. Subtraction of the DC component.
   4. Calculation of an auto correlation function on the residue signal.
   5. Division by the total energy and conversion to (%).
   6. Extraction to the period of variation.
   7. Calculation of Fftr corresponding to the period of variation found.

B. Computation of the average auto correlation curve and average Fftr for all processed window :

**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 threshold, the Fatr value is zero.

The method for amplitude tremor analysis consists of the following.

A. Division of the peak-to-peak amplitude data at 30Hz and down sampling to 400Hz.

1. Calculation of the total energy of the resulting signal.
2. Subtraction of the DC component.
3. Calculation of an auto correlation function of the residence signal.
4. Division by the total energy and conversion to (%).
6. Extraction to the period of variation.
7. Calculation of Fatr corresponding to the period of variation found.

B. Computation of the average auto correlation curve and average Fatr for all processed window :

**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 as :

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

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

N = Number of extracted pitch periods.

Absolute Jitter measures the very 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 absoluted jitter significantly.

The pitch of the voice can vary for a number of reasons, cycle-to-cycle irregularity can 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.

Both Jita and Jitt represent evaluations of the same type of pitch perturbation. 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 on Jita for men and women differ significantly. Higher pitch results into lower Jita. That's why, the Jita value of two subjects with different pitch are difficult to compare.

**Jitter Percent (Jitt)** */ % / :*

Relative evaluation of the period (very short-term) variability of the pitch within the analyzed voice sample. Voice break areas are excluded. It is computed as

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

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.

**Relative Average Perturbation (RAP)** / % / :

Relative evaluation of the period (very short-term) variability of the pitch within the analyzed voice sample with smoothing factor of 3 periods. Voice breaks areas are excluded. It is computes as :

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

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

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.

Pitch period perturbation quotient (PPQ) / % / :

Relative evaluation of the period-to-period variability of the pitch within the analyzed voice sample with smoothing factor of 5 periods. Voice breaks areas are excluded. PPQ is computes as :

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

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

N = PER, number of extracted pitch period.

PPQ measures the short-term (cycle-to-cycle with smoothing factor of 5 periods) irregularity 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.

**Smoothed Pitch Period Perturbation Quotient (SPPQ) / % / :**

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

$$SPPQ = \frac{\frac{1}{N-Sf+1} \sum_{i=1}^{N-Sf+1} \left| \frac{1}{Sf} \sum_{r=0}^{Sf-1} (To^{(i+r)} - To^{(i+m)}) \right|}{\frac{1}{N} \sum_{i=1}^{N} To^{(i)}}$$

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

N = Number of extracted pitch period.

Sf= Smoothing factor.

SPPQ allows the experimenter to define his own pitch perturbation measure by changing the smoothing factor from 1 to 99 periods. This is desirable because in the scientific literature researchers use pitch perturbation measures with different smoothing factors or without smoothing.

With a small factor, SPPQ is sensitive mostly to the short-term pitch variation of the voice impulses. With a smoothing factor of 1 (no smoothing), SPPQ is identical to Jitter Percent (Jitt). It is very sensitive to the pitch variations occurring between consecutive pitch periods. Usually this type of variation is random. It is typical f or hoarse voices. However, pitch extraction errors may affect jitter percent significantly.

With a smoothing factor of 3, SPPQ is identical to the Relative Average perturbation introduced by Koike (1973).

With a smoothing factor of 5, SPPQ is identical to the pitch perturbation quotient introduced by Koike and Calcatera (1977).

At high smoothing factors SPPQ correlates with the intensity of the long-term pitch period variations. The studies of patients with spasmodic dysphonia (Deliyski, Orlikoff and Kaharie, 1991) show that SPPQ with smoothing factor set in the range 45-65 periods has increased values in case of regular long-term pitch variations (frequency voice tremors).

The SPPQ smoothing factory setup is 55 periods. This set up allows using SPPQ as an additional evaluation of the frequency tremors in the voice. The intensity and the regularity of the frequency tremors can be assessed using SPPQ (55) in combination with VFo. The difference between VFo and SPPQ (55) is that VFo represents a general evaluation of the fundamental frequency (pitch) variation of the voice signal. 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. However, SPPQ (55) is more sensitive to regular long-term variations with a period near and above 55 pitch periods. If both SPPQ (55) and VFo are low, the intensity of pitch variations in the voice signal is very low. If VFo is high but SPPQ (55) is low, there are pitch variations but not a long-term periodic one. If both SPPQ (55) and VFo are high, there is a long-term periodic pitch variation (most likely a frequency tremor).

Co-efficient of Fo Variation VFO /% / :

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

$$VFo = \frac{\sigma}{Fo} = \frac{\sqrt{\frac{1}{N} \sum_{i=1}^{N} \left[ \frac{1}{N} Fo^{(i)} - Fo^{(i)} \right]^2}}{\frac{1}{N} \sum_{i=1}^{N} Fo^{(i)}}$$

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

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

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

N= per, 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 threshold assume that the Fo should not change, any variations in the fundamental frequency are reflected in VFo. These changes could be frequency tremors or non-periodic changes, very high jitter or simply rising a falling pitch over the analysis length.

**Shimmer in dB (shdB) /dB/** :

Evaluation in 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 is computed as,

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

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

N = Number of extracted impulses.

Shimmer in dB measure the very short term (cycle-to-cycle) irregularity of peak-to-peak amplitude of the voice. This measure is widely used in the research literature on voice perturbation (Iwata and Von laden 19700. 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 very for a number reasons. Cycle-to-cycle irregularity of amplitude can be associated with the inability of the vocal folds to supports a periodic vibration for a defined period and with the presence of turbulent noise in the voice signal usually, this type of variation in random. It is typically associated with hoarse and breathy voices. APQ is the 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.

**Shimmer percent ( % ) :**

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.

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

where, $A^{(i)}$ , 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.

**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, $A^{(i)}$ , i = 1,2,...N - extracted peak-to-peak amplitude.
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. 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 shi-mer in MDVP.

**Smoothed Amplitude Perturbation Quotient (SAPQ)** / % / :

Relative evaluation of the short or long term variability of the peak-to-peak amplitude within the analyzed voice sample at smoothing factor defined by the user. The factory set-up for the smoothing factor is 55 periods (providing relatively long-term variability ; the user can change t his value as desired.

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 $A^{(i)}$, $i = 1, 2, \ldots N$ extracted peak-to-peak amplitude data.

N = Number of extracted impulses.

Sf= Smoothing factor.

SAPQ allows user to define their own amplitude perturbation measure by changing the smoothing factor from 1 to 99 periods.

**Co-efficient of Amplitude Variation (VAm)** / % / :

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

$$VAm = \frac{\sqrt{\frac{1}{N} \sum_{i=1}^{N} \left| \frac{1}{N} \sum_{j=1}^{N} A^{(j)} - A^{(i)} \right|^2}}{\frac{1}{N} \sum_{i=1}^{N} A^{(i)}}$$

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.

**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.

NHR is computed using a pitch synchronous frequency domain method. In general terms, the algorithm functions as follows:

A) Divides the analyzed single into windows of 81.92 ms (4096 points at 50 KHz sampling rate or 2048 at 25 KHz). For every windows the following steps apply

1) Low pass filtering at 6 KHz (order 22) with Hamming window, down sampling of the single data down to 125KHz and conversion of the real signal into analytical one using Hilbert transform.

2) 1024 points complex fast fourier Transform (FFT) on the analytical signal corresponding to a 2048 - points FFT on real data.

3) Calculation of the power spectrum from the FFT

4) Calculation of the average fundamental frequency with in the window synchronous with the pitch extraction results.

5) Harmonic/inharmonic separation of the current spectrum synchronous with the current window fundamental frequency.

6) Computation of the noise-to-harmonic ratio of the current window. NHR is the ratio of the inharmonic (1500-4500Hz) - to the harmonic spectral energy (70-4500 Hz).

**B) Computes the average values of NHR for all previously processed windows.**

Increased values of NHR are interpreted as increased spectral noise which can be due to amplitude and frequency variations (i.e., Shimmer & Jitter). Turbulent noise, subharmonic components and or breaks which affects NHR globally measures the noise in the signal (includes contributions of jitter, shimmer and turbulent noise).

**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 noise.

VTI is computed using a pitch synchronous frequency domain method. The algorithm consists of the following steps :

A. Selects up to four but atleast two 81.92 msec windows where the frequency and amplitude perturbations are lowest for the signal. These windows are located in different areas of the signal and don't include voice breaks and subharmonic components.

For every window, the following steps apply :

1. Low-pass filtering at 6KHz.
2. Down sampling 12.5 KHz.
3. Conversion of the real signal to analytical one.
4. Computation of a 1024 points complex fast fourier transform on the analytical signal.
5. Computation of power spectrum from the FFT.
6. Calculation of the average fundamental frequency within the window.
7. Harmonic/inharmonic separation of the current spectrum synchronous with the current window fo.
8. Computation of the VTI for every window, VTI is the ratio of the spectral inharmonic high frequency energy (2800-5800 Hz) to the spectral harmonic energy (70-4500 Hz).

B. Calculate the average VTI values for all processed windows. VTI measures the relative energy level of high-frequency noise.

VTI mostly correlates with the turbulence caused by incomplete or loose addiction of the vocal folds. VTI, unlike NHR, analyses high frequency components to extract an acoustic correlate to "breathiness". However, it is unlikely that users will find a one-to-one correspondence between their perceptual impression of a voice and this acoustic analysis. However, VTI is a new attempt to compute a parameter which correlates with breathiness. Because VTI is a new parameter, normative values cannot be found in the professional literature.

**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 1600-450 Hz.

SPI is computed using a pitch synchronous frequency domain method. The algorithm does the following procedures :

A. Divides the analysed signal into windows of 81-92 MS.

For everyone of these windows, the following steps apply :

1. Low-pass filtering at 6KHz order 22 with Hamming window, down sampling of the signal data down to 12.5Hz and conversion of the real signal into analytical one using Hilbert transform.
2. 1024 points complex fast fourier transform on the analytical signal.

3. Computation of power spectrum from the FFT.
4. Calculation of the average fo frequency within the window synchronous with the pitch extraction results.

5. Harmonic/inharmonic separation of the current spectrum synchronous with the current window fo.

6. Computation of the SPI of the current window. SPI is a ratio of the lower-frequency (70-1600 Hz) to the higher frequency (1600-4500 Hz) harmonic energy.

B. Compute the average values of SPI for all previously processed windows.

SPI can be thought of as an indicator of how completely or tightly the vocal folds addict during phonation. Increased value of SPI is generally an indication of loosely or incompletely addicted vocal folds during phonation. However, it is not necessarily an indication of a voice disorder. Similarly, patients with "pressed" phonation may likely have a "normal" SPI though their pressed voice characteristic may not be desirable. Therefore, a high SPI value is not necessarily bad, nor a low SPI value necessarily good. Subjects with glottal chinks (determined stroboscopically) or with high phonatory air flow rates often exhibit an increased SPI. Spectral analysis will show a well defined higher formants when SPI is low, and less well defined when SPI is high.

SPI is very sensitive to the vowel formant structure because vowels with lower high frequency energy will result in higher SPI, only values computed for the same vowel can be compared.

Increased SPI values may be due to a number of factors. The subject may have a "soft" phonation because of a voice or speech disorder and may not be able to strongly addict his vocal folds. However, the subject may naturally speak with a softer "attack" and hence have an elevated SPI. Psychological stress could also be a factor that may increase SPI. Another important factor is the amplitude of the sustained vowel. If the subject phonates softly, SPI may be high.

**Frequency Tremor Intensity Index (FTRl)** / % / :

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.

The method for frequency tremor analysis consists of the following steps :

A. Division of the fundamental frequency period-to-period (Fo) data into 2 secs windows. For every window, the following procedures apply :
   1. Low-pass filtering of the Fo data at 30Hz and down sampling at 400 Hz.

2. Calculation of the total energy of the resulting signal.

3. Subtraction of the DC component.

4. Calculation of an auto correlation function on the residue signal.

5. Division by total energy and conversion to percent.

6. Extraction of the period of variation.

7. Calculation of Fftr and Ftri corresponding to the period of variation found.

B. Computation of the average auto correlation curve and average FTRI for all processed windows.

The algorithm for tremor analysis determines the strongest periodic frequency and amplitude modulation of voice. Tremor has both frequency and amplitude components (i.e., the fo may vary and/or the amplitude of the signal may vary in a periodic manner). Tremor frequency provides the rate of change with Fftr providing the rate of periodic tremor of the frequency and Fatr providing the rate of change of the amplitude. The program will determine the Fftr and Fatr of any signal if the magnitude of these tremors is above a low threshold of detection. Therefore, the magnitude of the frequency tremor and the magnitude of the amplitude tremor are more significant than the respective frequencies of the tremor.

**Amplitude Tremor Intensity Index (ATRI)** / % / :

Average ratio of the amplitude of the most intense low-frequency amplitude modulating component 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.

**Degree of Voice Breaks (DVB)** / % / :

Ratio of the total length of the areas representing voice breaks to the time of the complete voice sample.

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

Where $t_1$, $t_2$ . . . $t_n$ - length s of the Ist, IInd... voice break.

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

DVB does not reflect the pauses before the Ist and after the last voiced areas of the recording. It measures the ability of the voice to sustained uninterrupted voicing. The normative threshold is "0" because a normal voice, during the task of sustaining voice, should not have any voice break areas. In case of phonation with pauses (such as running speech, voice breaks, delayed start or earlier end of sustained phonation), DVB evaluates only the pauses between the voiced areas.

**Degree of Sub-harmonic Components (DSH)** / % / :

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

DSH is computed as a ratio of the number of auto-correlation segments where the pitch was found to be sub-harmonic of the real pitch (NSH) to the total number of auto-correlation segments.

The degree of sub harmonic components in normal voices should be equal to zero. It is expected to increase in voices where double or triple pitch periods replace the fundamental in certain segments over the analysis length. These effects are typical for diplophonic voices and voices with glottal fry. The experimental observation of patients with functional dysphonia or neurogenic voice disorders may show increased values of DSH.

**Degree of Voiceless (DUV)** / % / :

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

DUV is computed as a ratio of the number of auto-correlation segments where an unvoiced decision was made to the total number of auto-correlation segment.

DUV measures the ability of the voice to sustain uninterrupted voicing. The normative threshold is '0' because a normal voice, in the defined task of sustaining voices where double or triple pitch period replaces the fundamental in certain segments over the analysis length. These effects are typical for diplophonic voices and voices with glottal fry.

**Number of Unvoiced Segments (NUV)** :

Number of unvoiced segments detected during the auto-correlation analysis.

NUV measures the ability of the voice to sustain uninterrupted voicing. The normative threshold is '0' because a normal voice, during the task of sustaining voice, should not have any voiceless segments. In case of phonation with pauses (such as running speech, voice breaks, delayed start or earlier end of sustained phonation), NUV evaluates only the pauses before, after and/or between the voiced areas.

## 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: Telephone:

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 of Blood pressure
Yes / No

3) Any illness of complication and treatment, describe

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

Deficiency .............. Tropical disease ...........

Malnutrition .......................... ]

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

5) Abortions if any:
When:

6) History of Toxaemia of Pregnancy

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 / No

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 Pain
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:**

voicing, should not have any voiceless segments. In case of phonation with pauses (such as running speech, voice breaks, delayed start or earlier end of sustained phonation), DUV also evaluates the pauses before, after and/or between the voiced areas.

**Number of Voice Breaks (NVB)** :

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

NVB does not reflect the pauses before the first and after the last voiced areas of the recording. However, like NUV, it measures the ability of the voice to sustain uninterrupted voicing. The normative threshold is '0' because a normal voice, during the task of sustaining voice, should not have any voiceless breaks. In cases of phonation with pauses (such as running speech, voice breaks, delayed start or earlier end of sustained phonation), NVB evaluates only the pauses between the voiced areas.

**Number of Sub-Harmonic Segments (NSH)** :

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

The number of sub-harmonic components in normal voices should be equal to zero. It is expected to increase in