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Original Research Article

Acoustic Characteristics of Cry in Infants with Hyperbilirubinemia - A Preliminary Study

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ABSTRACT

Objective: The study delves into the use of infant cry as a powerful tool for understanding infants' physiological neurological and emotional states. Its primary objective is to compare the acoustic characteristics of cries in Healthy full-term infants and full-term infants with Hyperbilirubinemia.
Materials and method: A total of 30 infants took part in the study, with 15 being full-term infants with Hyperbilirubinemia and 15 Healthy full-term infants. Cry samples were recorded and meticulously analyzed using PRAAT software to measure Fundamental frequency measures, Frequency perturbation measures, amplitude perturbation measures, Noise-related measures, and Formants (F1, F2, F3).
Statistical analysis: Using SPSS Version 23.0 independent t was used to analyse the cries between healthy infants and infants with Hyperbilirubinemia
Results: The findings revealed that significant differences were observed in the acoustic characteristics of the infant cry fundamental frequency F0 and formants (F1, F2, F3) between infants with hyperbilirubinemia and Healthy infants
Conclusion: The infants with Hyperbilirubinemia exhibited higher average values in F0, jitter, shimmer, F1, F2, and F3 compared to Healthy full-term and significant difference($p<0.05$) was observed in mean, minimum and maximum F0 This result indicates that the higher Fo, jitter, shimmer and Formants are related with high risk factors in infants.

Keywords: Acoustic analysis, infant cry, fundamental frequency, formants. Hyperbilirubinemia.

INTRODUCTION

Infant crying is a crucial communication tool that reflects the child's physiological state and emotional well-being. While an infant's cry may seem uniform, there are significant differences between the cries of different infants. Mothers are often able to distinguish their child's cries based on their needs. Crying is a neurophysiological act that involves the coordination of several brain regions responsible for respiration, laryngeal muscle control, vocal cord vibration, and oral structures (9,1). The act of crying is believed to stem from the nervous system, serving as an indicator of the neural integrity. This can be valuable for early detection of infants who may be at risk for experiencing adverse developmental outcomes. Therefore, an unusual cry could suggest the presence of dysfunction or deficits within the central or peripheral nervous system. In the case of a preterm infant exhibiting excessive crying, it could signify the presence of behavioral issues and parenting stress, which may persist for years, aligning with findings from previous research. The acoustic characteristics of a cry can be affected by any central nervous system pathologies. Several studies have reported that neurological, metabolic, and chromosomal disturbances can affect the acoustic characteristics of a cry. They have also stated that infants with pathologies such as hyperbilirubinemia, meningitis, and hydrocephalus have a higher fundamental frequency (F0) of crying compared to normal healthy infants.

Hyperbilirubinemia
Neonatal hyperbilirubinemia is the condition where the level of bilirubin in the blood is higher than 5 mg per dL (86µmol per L) [13]. It is a common issue among infants around 60 percent of full-term newborns develop jaundice in their first week, and only a few actually have a serious underlying condition. However, high bilirubin levels in newborns can sometimes be linked to severe illnesses such as hemolytic disease, metabolic and endocrine disorders, liver abnormalities, and infections. so the need arises in the screening of infants, as cry is a non-invasive tool in infants, cry can be used as a screening tool to assess the neurological and medical status of infants [3, 7]. Since there are few studies which have compared the acoustic characteristics of full-term infants with Hyperbilirubinemia and Healthy full-term, this study analyses the acoustic characteristics of cry of infants with Hyperbilirubinemia and Healthy full-term infants.

Purpose of the study: The primary objective of the current research is to compare and analyse the acoustic, temporal, and spectral parameters of the cry exhibited by full-term infants with hyperbilirubinemia in comparison to those of Healthy full-term infants. It also determines the potential discrepancies between male and female infants in terms of the acoustic parameters.

MATERIAL AND METHODS

Participants:
This case control study consists of 30 full-term infants of age range 0 to 15 days A total of N=30 participants were grouped into two groups, as Group I Group II.
Group I: Group I includes Healthy full-term infants 36-42 weeks (n=15) [Males=6, Females=9].
Group II: Group II includes full-term infants with Hyperbilirubinemia, (n=10) [Males= 8, Females=7].
This study protocol was approved by the institutional scientific and ethics committee. Informed consent was obtained from the parents before the collection of cry sample.

Inclusion and Exclusion criteria:
The Healthy full-term infants with no risk factors and full-term infants with Hyperbilirubinemia were included in the study. The preterm and full-term infants experiencing complications such as respiratory distress, sepsis, meningitis, seizures, and hydrocephalus, infants with syndromic features or congenital anomalies and the infants who had endotracheal intubation were also excluded from the study.

Recording and Acoustic analysis Procedure
Ninety episodes of infant cries were recorded from 30 infants aged 0 to 15 days. The recordings took place in both the paediatric ward and NICU departments. To capture the crying episodes, the infants were placed in a crib and kept non-crying for 1 minute before the cry was elicited by tapping the infant’s foot. A Zoom H1 wave recorder was positioned 10 to 20 cm from the infant's mouth to capture the cry, and the recordings lasted for 30 seconds. The collected cry data underwent acoustic analysis using PRAAT software version 5.2.35. The cry recordings had a sampling rate of 44.1 kHz and were low-pass filtered at 10 kHz to eliminate artifacts and outliers. After the filtration process, the acoustic parameters were analyzed using the PRAAT software. This

detailed analysis aimed to provide insights into the acoustic characteristics of infant crying within the specified age range. The cry had a sampling rate of 44.1 kHz, and the cry utterance was low-pass filtered at 10 kHz to eliminate artifacts and outliers.

Acoustic analysis:

The vocal cry will be analysed using the following acoustic parameters:

a) **Fundamental Frequency (F0):** F0 represents the frequency at which the vocal cords vibrate to produce sound, measured in Hertz (Hz). It indicates the number of vocal cord opening and closing cycles within a specific time frame. This study evaluates the mean, minimum, and maximum F0.

b) **Perturbation Measures:**

1. **Jitter (ppq):** Jitter quantifies the cycle-to-cycle variations in the fundamental glottal period. This study specifically focuses on ppq5, which assesses the period-to-period variability of the pitch within the sample. Voice breaks are excluded from this measurement.
2. **Shimmer (apq):** Shimmer evaluates the period-to-period variability of peak-to-peak amplitude.

c) **Intensity Measures:** Intensity measures the loudness level of the vocal sound, expressed in decibels (dB). This study examines the mean, minimum, and maximum intensity levels of the cry.

d) **Harmonic Measures:**

- **Harmonic-to-Noise Ratio (HNR):** HNR represents the ratio between the regular vibrations produced by the vocal folds and the additional sound generated by both the vocal folds and the vocal tract.
- **Noise-to-Harmonic Ratio (NHR):** NHR measures the balance between the random noise component and the regular harmonic component of the sound.

e) **Formants:** Formants are the resonant frequencies of the human vocal tract, appearing as peaks in the sound signal's spectrum. In acoustic analysis, these peaks are specifically identified as formants.

RESULTS

SPSS Version 23.0 was used for the analysis. The acoustic parameters of vocal cry were analysed using an independent t-test. The current study aimed to analyse the comparative acoustic characteristics of cry in healthy infants and infants with Hyperbilirubinemia.

Acoustic analysis:

The stimuli were analysed using PRAAT software version 5.2.35. The crying sound had a sampling rate of 44.1 kHz and was low-pass filtered at 10 kHz to remove artifacts and outliers.

Table -1 Acoustic parameters of cry in Group-1(Healthy full-term infants) and Group-2 (full-term infants with Hyperbilirubinemia)

Acoustic parameters	Group 1 Mean (SD)	P value	Group 2 Mean (SD)	P value
Mean F0	434.26(69.9)	0.001*	528.73(64.59)	.001*
Min F0	378.66(88.456)	0.029*	453.53(89.53)	.029*
Max F0	486.66(69.526)	0.000*	603.66(88.18)	0.00*
INT	71.44(8.828)	0.450	73.75(7.632)	0.451
Jitt	0.466(0.498)	0.257	6.552(20.35)	0.266
Shim	3.66(2.373)	0.101	5.74(4.086)	0.103
HNR	9.22 (5.558)	0.443	7.916(3.344)	0.444
NHR	0.214(0.1708)	0.876	0.21(0.1281)	0.876
F1	1086.35(155.20)	0.715	1105.22(123.04)	0.715
F2	1716.32(307.49)	0.140	1867.471(232.06)	0.141
F3	2834.03(277.97)	0.134	2974.5(217.57)	0.135

=p<0.05 (significantly different), Mean F0= Mean fundamental frequency, Min F0= Minimum fundamental frequency, Max F0= Maximum fundamental frequency, Int= Mean intensity, Jitt=Jitter, Shim=Shimmer, HNR= Harmonic noise ratio, NHR=Noise Harmonic ratio, F1= Formant 1, F2=Formant 2, F3= Formant 3.

1. **Fundamental Frequency measures:**

The average, maximum, and minimum fundamental frequency values of Group- 1 were found to be lower (434.261Hz) compared to Group 2 (528.73Hz), and significant differences were observed between the group-1 and group -2 at Mean (p=0.001), Minimum (p=0.029) and Maximum (p=0.000) Fundamental frequencies (9). The mean f0 in male infants with hyperbilirubinemia (508.5Hz) is higher compared to healthy male infants (420.16Hz) and the female infants with hyperbilirubinemia (551.85Hz) have high f0 compared to healthy female infants (443.6 Hz). The F0 of healthy males ranged from 344Hz to 540Hz and male infants with hyperbilirubinemia ranged from 480 to 713Hz, in healthy female infants the F0 ranged from 356Hz to 516Hz, the F0 of 457 to 730Hz ranged in female infants with hyperbilirubinemia, which indicates that infants with hyperbilirubinemia have higher fundamental frequency than healthy infants.

2. **Perturbation measures:**

Jitter: On comparing the perturbation measure Jitter between the Group 1 and Group 2 higher values of mean Jitter (PPQ) were observed in Group 2 (6.552%) than in Group 1 (0.466%) and Overall higher mean in jitter was observed in male infants with Hyperbilirubinemia (11.3 %) and when comparing the jitter between male and female healthy male infants (0.3 %) has lower jitter value compared to healthy female infants (0.576%) and in male infants with Hyperbilirubinemia (11.3 %) has higher jitter values than female infants with Hyperbilirubinemia (1.045%).

Shimmer: On comparison of shimmer between group 1 and group 2 higher values were present in group 2 (5.74%) compared to group 1 (3.66%). The higher mean values were observed in healthy female infants (4.53%) compared to healthy male infants (2.37%). Similar mean values in shimmer were observed in both male and female infants with hyperbilirubinemia.

3. **Intensity measures:**

Higher mean values for intensity measures were observed in Group 2 (73.75 dB) compared to Group 2 (71.44dB). and on comparison of healthy male and female infants' a higher intensity value was observed in healthy male infants (74.1dB) and similar mean values are observed in both male and female infants with hyperbilirubinemia. (74.3dB).

4. **Harmonic measures:**

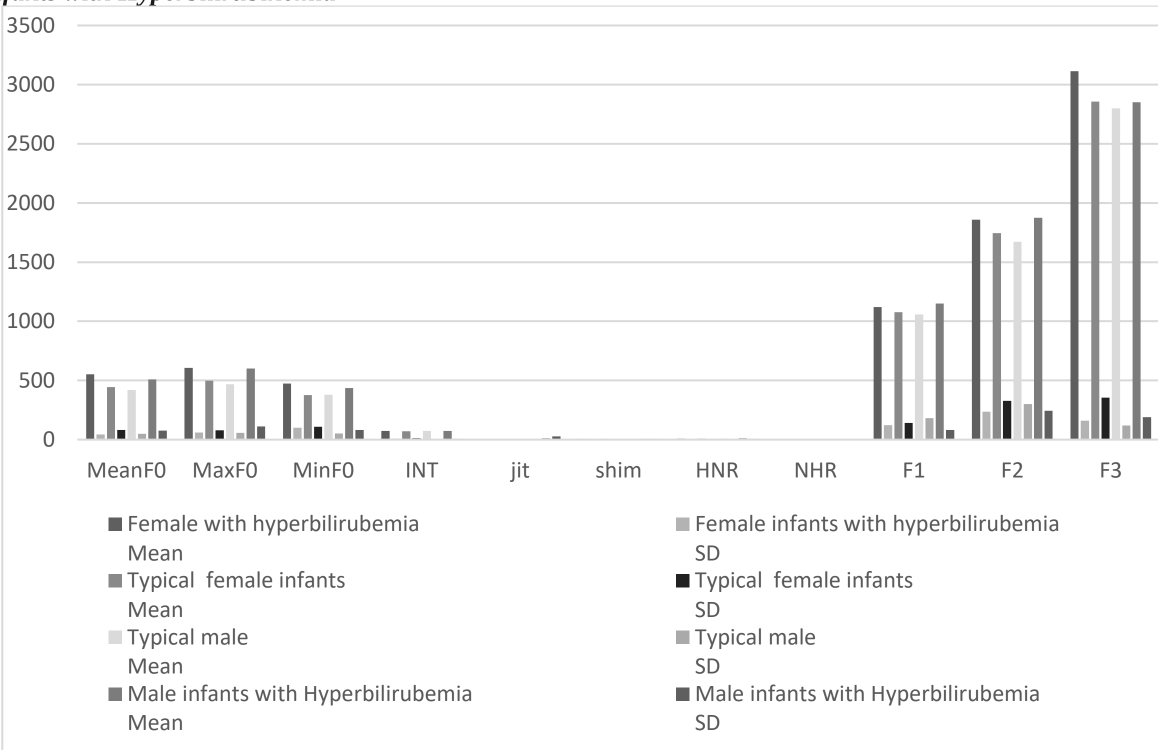
HNR: The Harmonic to noise ratio is higher in group 1 (9.22dB) compared to group 2 (7.916dB). when comparing the harmonic-to-noise ratio in males and females the healthy male infant (8.2dB) has higher HNR compared to the healthy female (7.7dB) and in infants with hyperbilirubinemia the male with hyperbilirubinemia has higher (11.4dB) HNR compared to female (7.58dB).

NHR: similar mean values were observed in the comparison of Group 1 and Group 2 (0.21) and also in typical males and females (0.24) but the NHR is higher in male infants with hyperbilirubinemia (11.4) than in female infants with hyperbilirubinemia (7.58).

5. **Formants:**

The higher mean formants F1, F2, and F3 were observed in Group 2 F1(1105.22 Hz), F2 (1867. 4710 Hz), F3 (2974.5Hz) compared to Group 1 F1 (1086.35Hz), F2(1716.32), F3 (2834.03Hz) and no significant differences were observed between group 1 and group 2. while comparing the F1, F2, and F3 between male and female infants, higher mean value was observed in healthy male infants in F1 1215.1Hz than in healthy female infants 1146Hz, F2 mean is higher in female infants (2179Hz) than male (1474.06 HZ) and F3 is also higher in female infants (3318.5 Hz) than in male infants (2680.05Hz). during the comparison of male and female infants with hyperbilirubinemia the Female infants had Higher F1 (1289.6Hz), F2(2194.1Hz), and F3 (3284.6Hz) than male infants F1 (1150.08Hz), F2 (2194.1Hz), F3 (3284.6Hz) but no significant differences were observed between the male and female groups.

Figure -1 ***Comparison of acoustic parameters of cry among gender-based groups in Healthy infants and infants with Hyperbilirubinemia***



Mean F0= Mean fundamental frequency, Min F0= Minimum fundamental frequency, Max F0= Maximum fundamental frequency, Int= Mean intensity, Jitt=Jitter, Shim=Shimmer, HNR= Harmonic noise ratio, NHR=Noise Harmonic ratio, F1= Formant 1, F2=Formant 2, F3= Formant 3.

DISCUSSION

The present study aimed to compare and analyse the acoustic characteristics of cries in Healthy full-term infants and full-term infants with Hyperbilirubinemia. The study included 15 Healthy full-term infants and 15 full-term infants with Hyperbilirubinemia of 0 to 15days of age range, they were grouped into two groups as group1(healthy infants) and group 2(infants with Hyperbilirubinemia). The cry elicited from them are subjected to acoustic analysis.

Comparison of Acoustic parameters between Group-1 and Group-2

The comparison of acoustic parameters between Group-1 and Group-2 showed significant differences ($p<0.05$) in MeanF0 ($p=0.001^*$), Minimum F0 (0.029^*), Maximum F0 (0.000^*). The study revealed that the fundamental frequency (F0) of the Group 1 ranged from 250 Hz to 490 Hz and Group 2 ranged from 430 Hz to 790 Hz, which indicates that full-term infants with Hyperbilirubinemia has higher fundamental frequency compared to Healthy full term. Similarly, Mukesh (1990) has stated that increased F0 was observed in infants with Hyperbilirubinemia [1]. The mean obtained for jitter is higher in Group 2(6.55%) than in Group 1 (0.466%) however there is no significant difference (P=0.257) obtained between the groups and the mean value of shimmer is higher in group 2 (5.74%) compared to group 1(3.66%). As per Orlikoff & Baken (1989), even small variations or asymmetries in muscle tension, changes in subglottal pressure, or perturbations in muscular innervations can lead to noticeable changes in Jitter and Shimmer values. Buder (2000) highlighted the impact of irregularities in the rate or extent of vibration, which can contribute in harmonic components to the acoustic signal, introducing noise. Moreover, air leakage through the glottis due to incomplete vocal fold closure adds to the noise in the signal. These aperiodicities and noise are commonly referred to as jitter and shimmer. The results of this study are similar because the fundamental frequency measures, perturbation, noise and formants are higher in infants with Hyperbilirubinemia compared to healthy infants. The intensity of cry in Group 2 (73.75dB) is higher than Group 1 (71.44 dB) and the mean formants F1, F2, and F3 were higher in Group 2: F1 (1105.22 Hz), F2 (1867.4710 Hz), and F3 (2974.5 Hz) compared to Group 1: F1 (1086.35 Hz), F2 (1716.32 Hz), and F3 (2834.03 Hz). However, no significant differences were observed between Group 1 and Group 2.

CONCLUSION

The study aimed to identify specific acoustic parameters that distinguishes similarity and differences between healthy infants and infants with Hyperbilirubinemia. The findings of this study revealed a significant difference in the fundamental frequency between healthy infants and infants with Hyperbilirubinemia. The formants and intensity measures are higher in infants with Hyperbilirubinemia than in healthy infants. Hence, the differences in the acoustic parameters of cries of infants with Hyperbilirubinemia and healthy infants will aid in early diagnosis, predicting prognosis and planning appropriate interventions.

Declaration by Authors

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