Differences in the Acoustic Characteristics of the Cries of Infants with Colics and the Cries of Healthy Infants

Sonja Jovančević[1], Natalija Bolfan-Stošić[2] and Milivoj Jovančević[3]
[1]Polyclinic for the Rehabilitation of Listening and Speech of Children and Adults SUVAG
[2]Faculty of Special Education and Rehabilitation Sciences, University of Zagreb
[3]Center for Child Health

Abstract

A child's early development is the period during which various very important life processes appear. The first three years of a child's life are considered critical in a child's development, and they are affected by various factors in the child's environment. The leading role in this period is played by the parents. Their role is to get to know and to feel their newborn, as well as to establish a close relationship with the child to instil a feeling of safety and warmth in the environment where he or she will develop. The establishment of this link between a parent and a child begins as early as in pregnancy and continues throughout the childhood period. From the moment the child is born, the newborn sends important signals to his or her environment. In this paper, we focus on the acoustic analysis of the child's cry as the first and the most important signal a newborn uses to communicate with the environment and send different types of information. In our research, we attempt to analyse and distinguish between various types of cries of children with colics and the children who do not suffer from colics. The aim of the paper is to establish the differences in the characteristics of the cry of children with colics and the cry of healthy infants by using acoustic analysis programs, and to establish acoustic standards to differentiate between healthy and sick crying/voice for diagnostic purposes.

Key words: *acoustic analysis; colics; cry; diagnostics; disorder.*

Introduction

Crying – An Infant's Most Powerful Signal

A newborn's and an infant's cry is sometimes the child's only way to communicate with the environment, signalling the state he or she is currently in. Crying changes during the child's development, especially in the first year of life. In the first weeks, crying is a signal that the infant is experiencing an altered homeostasis, such as discomfort or hunger (Grgurić, 2004). Towards the second half of the first year of life, the neurological maturation process grows in intensity, and crying increasingly becomes an expression of frustration and fear (Grgurić, 2004). Various scientific disciplines have dealt with the crying phenomenon: paediatrics, psychology, phonetics, logopaedia, etc. Paediatricians have mostly been interested in the reason why children cry and in when they cry, as well as giving advice to parents on how to recognise and react to various types of crying. Crying is used by infants to provide information about being hungry, tired, ill, hot, cold, when they need a nappy change, etc. Crying may be divided into several categories. Hence, it can be divided into normal or physiological crying, excessive crying caused by an organic problem, and excessive crying without a known cause (Grgurić, 2004).

Physiological crying sends the information that it is necessary to satisfy the child's physiological needs, such as hunger, thirst or change of nappy.

Excessive crying due to a known, primarily organic cause, signals that there might be an inflammation somewhere (ear infection, appendicitis), a hernia, intestinal obstruction or a congenital anomaly (chromosomopathy or genetic disorder). Other organic causes of known etiology may be allergies caused by proteins in cow's milk and lactose intolerance.

Parent–Child Relationship and Socio–Emotional Development

A child's attachment to the primary caregiver may be best observed at six to eight months of age. This special emotional bonding has its course of development. Some theoreticians propose a three-stage process (Bowlby, 1696; Schaffer & Emerson, 1964) to describe the development of attachment. The first stage, known as indiscriminate social responsiveness, ends when the child is around two months old. At this stage, the attention of the child is not exclusively focused on the mother, which means that the child will react in a positive way to anyone. However, it seems that in spite of this indiscriminate responsiveness, children still recognize their mother. Research shows that, only a few days after birth, newborn infants prefer to look at their mother or at her photograph than at a stranger (Field, Sandburg, Garcia, Vega-Lahr, Goldstein, & Guy, 1985; Walton, Bower, & Bower, 1992).

In a number of studies, a connection was found between secure attachment and other positive qualities which are not expressed by those children who have not been able to develop this form of attachment. Several studies show that children who have experienced secure attachment are more cognitively competent than other children. They are more successful in problem solving (Frankel & Bates, 1990), more curious, and

show more tendencies to explore (Slade, 1987). Research on the social aspects of life also shows that children who have developed secure attachment are superior, more open to cooperation, and get on better with their peers (Jacobson & Wille, 1986)**.** They also develop fewer emotional and behavioural problems than children who have experienced other types of attachment (Lewis, Sullivan, & Michalson, 1984).

Ainsworth considers that the most important factor for the development of secure attachment is a caregiver who is sensitive to the child's needs (Cassidy & Shaver, 1999). Such a caregiver can provide the necessary security for the child, appreciates the child's individuality, and understands him or her.

Understanding child's cry is particularly important in the development of a normal relationship between a mother and her child. In a colicky baby the mother does not usually know why the child is crying. This indicator shows that the mother does not have the capacity to understand the child's signals and needs (requests), which deprives her of the possibility to respond suitably and to meet the child's needs (Groh & Roisman, 2009; Leerkes & Siepak, 2006). High level of stress and fear in mother may disturb the complex process of "fine tuning" in the exchange of signals with her baby and undermine her self-confidence and self-esteem.

Characteristics of a Normal (Healthy) Cry

Crying is a sound that is the consequence of a link between the functioning of the brain, the larynx and the oral cavity. Crying originates in the central nervous system, which is responsible for the inhibition and modulation of the crying signal. The peripheral nervous system is responsible for the laryngeal and respiratory activity. When the presence of abnormal crying is identified, it is normal to suspect a dysfunction of the central or peripheral nervous system (Živković, 2001). The duration of crying depends on the tension of the vocal chords, the form and position of the resonance cavities and the intensity of the air flow. Michelsson and Sirvio (1976) define healthy crying as a sound lasting on average 1.1-2.8 sec, where the latency period lasts 0.6-3.6 sec. The fundamental frequency (F0) amounts to 400-600 Hz. A sudden shift in intensity appears more frequently at the beginning of the signal. The melody rises, or rises and falls. The fundamental frequency is stable, and there is no bi-phonation or noise.

Analyses of a Child's Cry

Analyses of newborns', infants' and toddlers' cries play an increasingly important role in establishing diagnoses in clinical work. A growing number of experts are trying to focus on the characteristics of crying specific to particular diseases or conditions, and can differentiate between normal and pathological crying. Many studies have found a correlation between the acoustic characteristics of crying in the case of confirmed diseases and risk conditions. Today's crying research focuses on two different areas. Some of these studies focus on the link between crying and speech development, while others are more oriented towards researching the link between abnormal crying and pathological conditions (Živković, 2001).

Colics

Colics, also known as three-month stomach cramps, trimestrial colics, infant (newborn) cramps and *colicae neonati* (*infanti*), most frequently appears in the first 3 to 4 months of an infant's life. It is marked by sudden episodes of painful crying, and, according to the definition, it appears at least three days a week, lasts for a week or more, while the child gains normal weight and develops properly. Crying is accompanied by pallor or flushing and painful grimaces. The tummy is tense and bloated, and the child pulls the legs to the abdomen, raises the head and clenches the fists. Colics most frequently appears in the late afternoon or evening, during or after feeding. It is estimated that 5 to 20% of infants suffer from colics (Shergill-Bonner, 2010), most often in the third week of life, the pain being the most intense at around the age of 6 weeks. It usually disappears spontaneously by the age of three or four months. The frequency of infant colics does not depend on the infant's sex, or on the feeding method (mother's milk or formula), socio-economic status or presence of allergies in the family. Attempts have been made to understand the causes of infant colics through scientific research. Some of the possible causes thus identified are: allergies to the proteins in cow's milk, physiological lactose intolerance leading to excessive gas formation, the development (immaturity) of the digestive system (increased bowel activity) and of the central nervous system (oversensitivity), neuro-hormonal immaturity, emotional tension in the mother, and stressful family circumstances (Savino, 2007).

Research Purpose

The purpose of this research was to identify the differences between the characteristics of the cry of colicky infants and that of healthy infants.

The results of the research may serve as a basis for establishing the acoustic standards for differentiating normal crying from crying caused by colics.

Such criteria may help diagnose various disorders and thus contribute to early disorder identification and prompt intervention.

The aim of this research is to identify whether there are differences in the sensitivity of measuring instruments applied when measuring the same voice samples, i.e. the cries of healthy and colicky babies.

Educational Implications

Fears that baby is ill or hungry, besides innate sensitivity to child cry, are the most common factors causing high level of stress and despair.

Teaching mothers about the characteristics of the child cry in colics babies would help them understand one of the strongest signals in early parent–child communication. Accompanied by the emotional support from professionals (psychologists, nurses, paediatricians) and her family, it is expected to help her establish calm and harmonious relationship with the baby. On the other hand, in such relationship, baby will get an opportunity to learn about the basic trust, emotions, communication and the world surrounding him or her.

Hypotheses

Based on the aims of the research, three hypotheses are posed:

H1: Statistically significant differences are expected in the basic parameters of crying (voice) between healthy and colicky infants.

H2: Significant deviations from normative values are expected in all the measured parameters of the cry of colicky babies measured with the EZVoicePlus acoustic program.

H3: Significant deviations from normative values are expected in all the measured parameters of the cry of colicky babies measured with the Multi-Dimensional Voice Program.

Research Method

Respondent Sample

The sample consists of two groups of respondents. One group is the control group consisting of infants not suffering from colics, i.e. infants with a healthy cry, while the second group consists of infants suffering from colics, i.e. infants with a painful cry. To achieve the aim of this research, an analysis was conducted of 7 healthy and 7 painful cries of male and female full-term (GA (Gestational age) ± 2 weeks of 40 weeks) infants aged from one to three months.

Data Collection Method

The cries were recorded with a ZoomHDD recorder with an in-built microphone placed about 20 cm from the baby's mouth. After the signing of an Informed Consent, and before the recording, data were collected on the age of the children and their health condition in order to exclude potential associated illnesses or disorders that could distort the reliability of the recorded data. The data were collected in a primary paediatric surgery in Zagreb. All the data were collected from the child's parents, and at least one of the parents was required to be present during the recording. The work was done in compliance with the code of ethics for scientific research of the Faculty of Education and Rehabilitation Sciences in Zagreb.

Description of the Variables

The following variables were taken into consideration during the acoustic analysis carried out with the EZVoicePlus program: fundamental frequency (F0) of the laryngeal source, frequency perturbation (Jitter), intensity perturbation (Shimmer), range/difference between the highest and lowest pitch (F0), harmonics to noise (HTN) and signal to noise (STN) ratio on a spectrum.

The following variables were taken into account in the acoustic analysis carried out with the Multi-Dimensional Voice Program: fundamental frequency (F0) of the laryngeal source, fundamental frequency variation coefficient, frequency perturbation (Jitter), intensity perturbation (Shimmer), Degree of Sub-harmonics (DSH), Number of Unvoiced Segments (NUV).

Data Processing Methods

An acoustic analysis was carried out by using the acoustic program Adobe Audition, EZ VoicePlus, Gram 2.3 and Multi-Dimensional Voice Program (MDVP, Copyright 1990-2000, Kay Elemetrics), and the obtained data were statistically analysed using the computer program Statistica for Windows version 5.0.

Results and Discussion

Table 1 shows the results of the t-test of the significance of variables of the acoustic gap between sick and healthy infants. The results are derived from the values obtained from the EZVoicePlus program.

Table 1.
T-test results

	Mean G1	Mean G2	Std.Dev. G1	Std.Dev. G2	t-value	df	p
F0HZ	**382.00**	**483.28**	**49.49**	**38.64**	**2.37**	12	**.0353**
JITT%	.86	.79	.53	.45	.26	12	.7938
SHIMMDB	1.12	.78	.62	.35	1.25	12	.2327
RANGE F0	18.04	15.87	8.68	7.37	.50	12	.6224
HNR	-1.58	-1.69	2.83	2.67	.07	12	.9409

Legend: 1- children with colics; 2 - healthy children

The t-test shows that there is a statistically significant difference between the cries of healthy infants and infants with colics only in the variable of the pitch of the fundamental frequency of the laryngeal source. The mean value of the laryngeal frequency of the cry of infants with colics (382.00 Hz), knowing that the average fundamental frequency (F0) of healthy babies according to Michelsson and Sirvio (1976) ranges between 400 and 600 Hz, shows a divergence, while the mean value of the fundamental frequency of the laryngeal source of healthy infants' cries (483.28 Hz) falls within the norm. These results may be linked to the data obtained by Brestovci and Bolfan Stošić (2000) in a study which showed that the F0 values are higher in children of a younger age and when their vocalisation is associated with pleasure (play, wonder, satisfaction), and lower F0 values are present in vocalisations associated with pain, hunger, anger and dissatisfaction, which, in this case, is associated with the pain resulting from colics.

Table 2 shows the results of the t- test of variables of the acoustic gap between sick and healthy infants. The results are derived from the values obtained from MDVP.

Table 2.
T-test results

	Mean G1	Mean G2	Std.Dev. G1	Std.Dev. G2	t-value	df	p
F0HZ	385.71	446.85	59.55	50.76	-2.06	12	.061005
JITT%	3.18	2.30	1.79	1.25	1.07	12	.305429
VF0	16.12	18.10	8.36	14.01	-.31	12	.754757
SHDB	.41	.30	.18	.18	1.21	12	.249118
DSH	9.82	3.82	12.43	4.48	1.20	12	.253130
NUV	**9.85**	**3.85**	**6.28**	**3.02**	**2.27**	12	.041931

(*Legend:* 1- children with colics; 2 – healthy children)

The t-test shows a statistically significant difference between the characteristics of the cry of healthy infants and the cry of infants with colics only in relation to the Number of Unvoiced Segments (NUV) variable. The mean value of the Number of Unvoiced Segments amounts to 9.85 in infants with colics, whereas the mean value of the Number of Unvoiced Segments in the cry of healthy children amounts to 3.85. The presence of a larger number of unvoiced segments is the consequence of the tension of the vocal cords caused by gastrointestinal pain. A large number of studies also show that there is more dysphonation in children suffering from a disorder, which can be associated with the fact that the presence of unvoiced segments arises from dysphonic moments combined with the interruption of the air flow caused by sudden intensive pain.

The results obtained on the other variables in both programs are not statistically significant. EZVoicePlus (S. Awan, Bloomsburg University, USA) as the counterpart of Key Elemetrics's MDVP which is, according to its author, very user-friendly for clinical purposes, does not measure a large range of parameters, as more complex acoustic programs do, but, in controlled recording conditions, provides reliable and accurate data on voice and speech deviations. Therefore, both EZVoicePlus and MDVP programs were used in this research. Acoustic parameters, as is known, affect one another, thus the results obtained in this way for the group of children with colics show a significant correlation and mutual effect of the RANGE F0 and SHIMMDB variables. Such relations indicate that the presence of large oscillations in intensity also results in a large range of frequencies of the fundamental laryngeal tone. In the group of healthy children, there are significant correlations between the SHIMMDB and JITT% variables, and this shows that greater intensity perturbations also imply greater frequency perturbations. The correlations of variables of both groups of children in principle appear in similar or identical variables, hence the SHIMBD variable is in correlation with the RANGE F0 and JITT% variables related to the frequency values of crying.
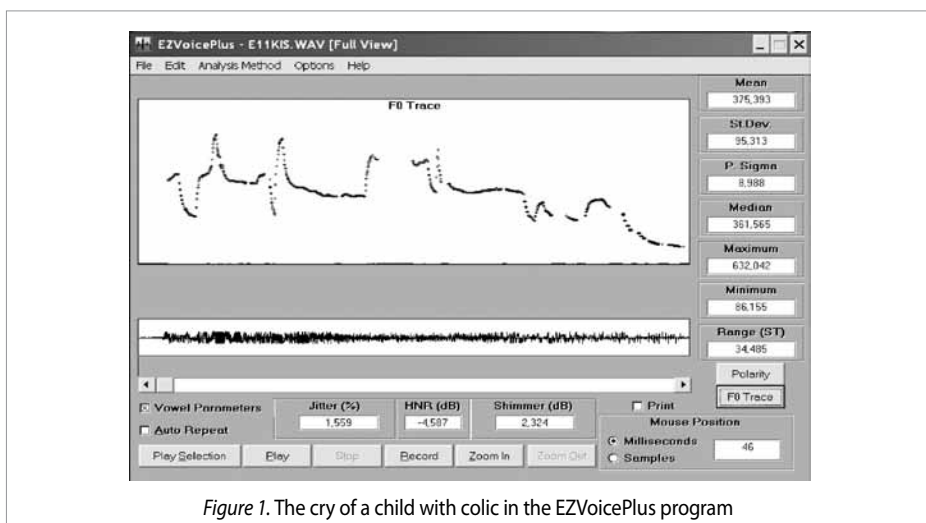

Figure 1. The cry of a child with colic in the EZVoicePlus program
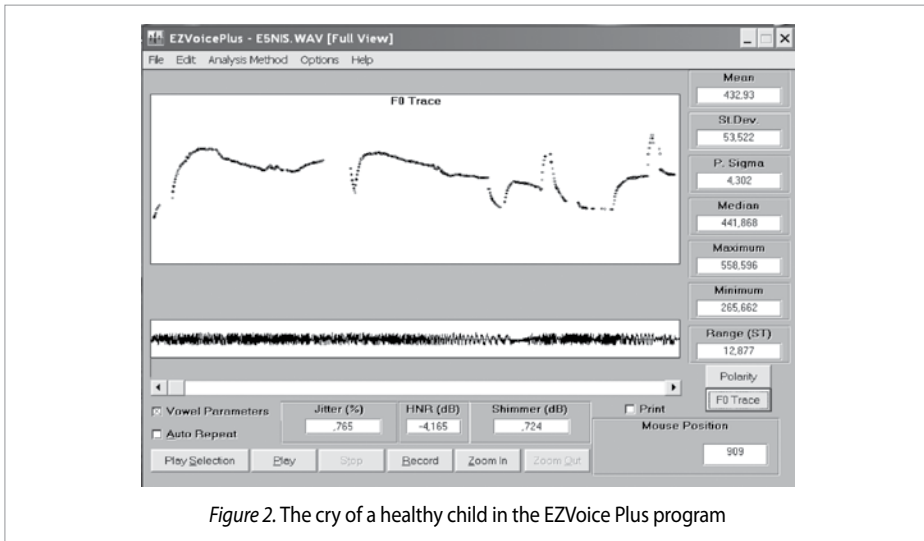
Figure 2. The cry of a healthy child in the EZVoice Plus program

The obtained results confirm the importance of variables as indicators of a particular pathology: the fundamental frequency of the laryngeal source (F0Hz) and the number of unvoiced segments (NUV) by applying both acoustic programs. As such, they are highlighted as more important than other cry (voice) parameters in determining or differentiating between the cries of healthy and unhealthy infants.

Conclusion

The cry of infants with colics and that of healthy infants significantly differ with regard to the F0HZ variable, according to data obtained from the EZVoicePlus program, while, according to data obtained from MDVP, there are statistically significant differences with regard to the NUV (number of unvoiced segments) variable, which confirms the prognosis related to some earlier research. By using these two programs, the conclusion was drawn that these two parameters constitute significant indicators of pathological crying characteristics. Deviations in the parameters of the cry of children with colics can be identified by analysing the voice parameter with acoustic programs, as well as by using a subjective assessment relying on one's own ear. To establish acoustic standards to differentiate unhealthy from healthy crying and to meet the interests of the logopaedic profession, work must be done on creating a subjective scale of children's crying, both for parents and professionals, to contribute to the success and efficiency of the diagnostic process for high-quality and prompt intervention in the case of children suffering, not just from colics, but also from other disorders. Finally, understanding the causes of the children's cry contributes to better communication between parents and the child and to establishing a safe type of intimacy and optimum conditions for normal emotional development.

References

Bowlby, J. (1969). *Attachment and Loss, Vol. 1: Attachment.* New York: Basic Books.

Brestovci, B., & Bolfan-Stošić, N. (2000). *Acoustical Analysis of Newborn Infant Cries.* In T. Braunschweig (Ed.), *Proceedings of the 4th International Workshop Advances in Quantitative Laryngoscopy,* Jena, Germany, April 7-8, pp. 29-33.

Cassidy, J., & Shaver, P.R. (Eds.) (1999). *Handbook of Attachment: Theory, Research and Clinical Applications*, London: Guilford Press.

Field, T., Sandburg, S., Garcia, R., Vega-Lahr, N., Goldstein, S., & Guy L. (1985). Pregnancy problems, postpartum depression, and early mother-infant interactions. *Developmental Psychology*, 21, 1152–1156.

Frankel, K. A., & Bates, J.E. (1990). Mother-toddler problem-solving: Antecedents in attachment, home behavior and temperament. *Child Development,* 61, 810 – 819.

Grgurić, J. (2004). Plač djeteta – između komunikacije i patnje. *Pediatria Croatica*, 48 (1), 1- 6.

Groh, A.M., & Roisman, G.I. (2009). Adults' autonomic and subjective emotional responses to infant vocalizations: The role of secure base script knowledge. *Developmental Psychology*, 45(3), 889-893.

Jacobson, J.L., & Wille, D.E. (1986). The influence of attachment pattern on developmental changes in peer interaction from the toddler to the preschool period. *Child Development,* 57(2), 338-347.

Leerkes, E.M., & Siepak, K.J. (2006). Attachment linked predictors of women's emotional and cognitive responses to infant distress. *Attachment and Human Development*, 8(1), 11-32.

Lewis, M., Sullivan, M.W., & Michalson, L. (1984). The cognitive-emotional fugue. In C.E. Izard, J. Kagan, & R. Zajonc (Eds.), *Emotions, Cognition, and Behavior* (pp. 264-288). New York: Cambridge University Press.

Michelsson, K., & Sirvio, P. (1976a). Cry Analysis in Congenital Hypothyroidism. *Folia Phoniatrica et Logopaedica*, 28, 40-47.

Michelsson, K., & Sirvio, P. (1976b). Sound-spectrographic Cry Analysis of Normal and Abnormal Newborn Infants. *Folia Phoniatrica et Logopaedica*, 28, 161-173.

Savino, F. (2007). Focus on Infantile Colic. *Acta Paediatria*, 96 (9), 1259-1264.

Schaffer, H.R., & Emerson, P.E. (1964). The development of social attachments in infancy. *Monographs of Social Research in Child Development*, 29(3), 1-77.

Shergill-Bonner, R. (2010). Infantile Colic: Practicalities of Management, Including Dietary Aspects. *Journal of Family Health Care,* 20 (6), 206-209.

Slade, A. (1987). A longitudinal study of maternal involvement and symbolic play during the toddler period. *Child Development*, 58, 367-375.

Walton, G.E., Bower, N.J.A., & Bower, T.G.R. (1993). Recognition of familiar faces by newborns. *Infant Behavior* & *Development,* 15, 265-269.

Živković, D. (2001). *Glas i zdravstveno stanje novorođene djece* (Diploma thesis). Faculty of Education and Rehabilitation Sciences, University of Zagreb: Zagreb.

Sonja Jovančević
Polyclinic for the Rehabilitation of Listening
and Speech of Children and Adults SUVAG
Ljudevita Posavskog 10, 10 000 Zagreb, Croatia
jovancevics@gmail.com

Natalija Bolfan-Stošić
Faculty of Special Education and Rehabilitation Sciences
Department of Speech Pathology, University of Zagreb
Borongajska cesta 83f, 10 000 Zagreb, Croatia
bolfanstosic@gmail.com

Milivoj Jovančević
Centre for Child Health,
Udbinska 16, 10 000 Zagreb, Croatia
milivoj.jovancevic@zg.t-com.hr

Usporedba karakteristika plača dojenčadi s kolikama i plača zdrave dojenčadi

Sažetak

Rani razvoj djeteta razdoblje je u kojem se javljaju razni kompleksni i vrlo važni životni procesi. Prve tri godine smatraju se kritičnim razdobljem u djetetovom razvoju koji je pod utjecajem različitih okolinskih faktora. Glavnu ulogu u tom razdoblju imaju roditelji. Njihova je uloga upoznati i osjetiti novorođenče i postići bliski odnos s njim kako bi dijete razvilo osjećaj sigurnosti i topline u okolini koja ga okružuje i u kojoj će se razvijati. Ostvarivanje takve povezanosti roditelja i djeteta počinje već u trudnoći i nastavlja se u djetinjstvu. Kada se dijete rodi, od samog početka, ono šalje važne znakove svojoj okolini. U ovom smo se radu usmjerili na akustičku analizu plača kao najvažnijeg i prvog znaka kojim dijete komunicira s okolinom i šalje različite informacije. Istraživanjem smo pokušali analizirati i razlikovati tipove plača djece s kolikama i djece bez kolika. Cilj ovog rada bio je programima akustičke analize utvrditi razlike u obilježjima plača djece s kolikama i plača zdrave dojenčadi te utvrditi akustičke standarde za razlikovanje zdravog od bolesnog plača/glasa u dijagnostičke svrhe.

Ključne riječi: *akustička analiza; dijagnostika; kolike; plač; poremećaj.*