Inspiratory Phonation in Baby Voice

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Summary: Objective. This study aimed to evaluate the developmental occurrence of inspiratory phonations (IPs) in the spontaneous cries of healthy infants across the first 10 weeks of life.
Study Design. This is a populational retrospective study.
Participants. The spontaneous crying of 17 healthy infants (10 were male) was retrospectively investigated.
Materials and Methods. Sound files of spontaneously uttered cries that were repeatedly recorded once per week for across the first 10 weeks of life were retrospectively analyzed. Frequency spectra and waveforms were used to identify the occurrence of IPs and to measure the duration and fundamental frequency (fo) of each instance of IP.
Results. A consistent number of IPs were identified across the 10-week period. All infants were observed to produce IPs in their spontaneous cries, although the frequency of occurrence was not consistent across infants. A marked sex difference was observed with female infants producing a higher number of IPs compared to males. The duration and fo of IPs did not differ significantly across the 10 weeks or between sexes.
Conclusions. The production of IPs is a regularly occurring phenomenon in healthy, normally developing infants' spontaneous crying. The proportional difference in the production of IPs between female and male infants, observed for the first time here, is postulated to be linked to sex-based differences (including steroidal hormones) in respiratory anatomy and physiology.
Key Words: Inspiratory phonation–Cry–Fundamental frequency–Infant–Sex difference.

INTRODUCTION

A baby's voice is characterized on the one hand by high melodic capacity and on the other hand by aperiodic, as well as inspiratory phonation (IP). IP is the audible phonation that occurs during the inspiratory phase of the breath cycle. Anecdotal reports of this striking acoustic feature date back to the classic cry research of Bosma et al.[1] In adults, this type of phonation can be either an involuntary or voluntary act. As an involuntary act, IP occurs naturally during situations such as laughing or sighing. Involuntary IP has also been found in pathologic voice conditions involving a prolapsed airway,[2] a subglottal obstruction,[3] or abnormal laryngeal muscle patterns.[4] IP can occur voluntarily as a form of speech production in various languages (eg, Scandinavian and New Zealand English) to achieve specific paralinguistic functions.[5] The deliberate production of IP has been used as a therapeutic tool to facilitate normal laryngeal valving in some vocal pathologies (eg, ventricular phonation).[6,7]

To produce deliberate IP, supraglottic pressure needs to be sufficiently high to create a Bernoulli effect, thereby closing the glottis during ingressive airflow. Vanhecke et al[8] and Orlikoff et al[9] have examined the acoustic and physiological characteristics of IP. Vanhecke et al's and Orlikoff et al's collective results indicate that IP is an acoustically harmonic phenomenon associated with distention of the laryngeal ventricles, lengthening of the quadrangular membrane of the vocal folds, reduced vocal fold contact, and increased transglottal airflow.

An example of involuntary IP can be found in infant crying. Although IP has not escaped recognition over the past 50 years of infant cry research, this feature has received less attention than expiratory features of crying. There remains only one dedicated report on the IP of infant cry.[10] Over 20 years ago, these researchers performed a detailed analysis of the pain cries produced by 20 healthy, full-term infants at 2 days of age. Their interest in IP was motivated by the assumption that IP reflects a form of laryngeal constriction of ingressive airflow. As such, this particular feature may hold diagnostic relevance for medical conditions thought to be linked to upper-airway obstruction (eg, obstructive sleep apnea and sudden unexpected death syndrome). The researchers found that most but not all infants produced IPs, and these particular sounds were significantly shorter in duration and higher in fo compared with expiratory cries. Two explanations were provided for the occurrence of IPs. First, IPs may reflect a disruption in the expected sequence of onset of the posterior cricoarytenoid muscle (ie, a vocal fold abductor) and diaphragmatic muscle activity, thereby disposing the infant to phonate upon inspiration. Alternatively, IP may relate to the configuration of the infant vocal tract, whereby the confined structures within the vocal tract obstruct the upper airway.

The single report by Grau et al[10] suggests that IP is a common feature of neonates' pain cries. However, the study was limited to the newborn period. In addition, cries were elicited via a painful stimulus rather than spontaneously, and hence were more excitatory in nature. Newman[11] has proposed differential neural circuitry for pain and spontaneous cries. Pain cries are a form of involuntary expression and appear to be controlled by the limbic system, whereas spontaneous cries reflect a form of voluntary expression and may be under cortical control.

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Based on the past results obtained by Grau et al,[10] which were paired with the acoustic and physiological characteristics of IP reported for adults,[8] we wished to further investigate the occurrence and the acoustic features of this unique aspect of baby voice in the context of naturally occurring spontaneous cries. The aim of the research presented here was to investigate (1) whether IP occurs regularly in healthy infants' spontaneous crying and (2) whether the phenomenon exists beyond the newborn period. Consequently, retrospective analysis of IP over the first 10 weeks was performed in a group of infants who showed no signs of developmental, psychological, or language disorder over the first 5 years of life.

MATERIALS AND METHODS

Participants

Seventeen healthy, full-term infants (10 were males) were considered in the present retrospective study. Participants were recruited, recorded, and medically examined at the Children's Hospital Lindenhof in Berlin, Germany. These infants were a subset of a broader longitudinal study examining genetic and environmental factors influencing language development during the first 5 years of age. Institutional ethics approval was granted and parents provided written consent for their infant's participation. The hearing capabilities of the infants across the observation period were assessed to be normal based on a combination of otoacoustic emission and brainstem evoked response audiometry. Relevant somatic measures were documented at birth, four and eight weeks (Table 1). None of these measures demonstrated a significant sex difference in this sample. All infants demonstrated normal development throughout the data collection period and as guaranteed by regular medical and developmental assessments across the first 2 years of life.

Data collection

Cry samples were collected from each infant once per week across the first 10 weeks of life. Cry signals were recorded using a portable digital recorder (Sony TCD-D100) and microphone (Sony ECM-950/957). Sampling frequency was 48 kHz and the dynamic range was 16 bits. All cry samples were obtained in quiet areas in the hospital (first week) or home environment (thereafter). The infants were recorded lying in a supine position in their mother's presence. Cry recording began when an infant started to fuss or at a time when the mother would normally feed the child. The microphone was handheld at a distance of approximately 10–15 cm from the child's mouth. Only spontaneous cries were recorded (ie, when the infants were hungry or thirsty), and no cries were induced through inflicting pain. Recordings had an average duration of 2 minutes per session.

Data analysis

The expiratory and inspiratory cries produced by each infant were analyzed using a commercially available hardware system (CSL-4500; Kay-PENTAX, Montvale, NJ). Each cry sample was displayed as an amplitude-by-time waveform with the corresponding narrow-band (45 Hz) spectrogram. Instances of IP were identified by visual inspection of waveforms and frequency spectra paired with auditory-perceptual cues. Vertical cursors were superimposed on the dual displays and manually positioned to identify onset and offset points within the cry. A typical display of expiratory crying and IP is illustrated in Figure 1. Each expiratory event and the corresponding inspiratory signal phonated within the complete recording session per infant was analyzed for IP occurrence (number of events = 100%). This was also the approach used by Grau et al[10] in their initial exploration of IP. Thus, for reason of comparability, we applied Grau et al's method here. However, a more elaborate analysis, including normalized temporal features, is in preparation to re-evaluate the observed sex difference.

The following features were measured:

- IP frequency of occurrence: defined as the total number of IPs occurring for each infant's session of crying. The proportional occurrence of IP was calculated for each infant based on the total number of expiratory cries produced during each recording session.
- IP duration: defined as the total duration from the onset to the offset of IP activity. Onset was defined as the initial increase in amplitude from the baseline signal. Offset was indicated by a decrease in amplitude and a return to baseline.

TABLE 1.
Somatic Measures

Sex	n		Birth	4 wk	8 wk
Female	7				
		Weight (g)	3332 (227)	4195 (479)	5094 (458)
		Length (cm)	50.1 (1.0)	54.6 (1.8)	58.0 (1.9)
		Head circumference (cm)	34.5 (0.8)	37.0 (1.0)	38.9 (0.8)
		Breast circumference (cm)	32.7 (1.2)	36.3 (1.3)	38.4 (1.7)
Male	10				
		Weight (g)	3326 (301)	4295 (277)	5328 (383)
		Length (cm)	50.3 (1.8)	54.4 (1.3)	58.3 (1.2)
		Head circumference (cm)	34.9 (1.4)	37.6 (1.1)	39.3 (1.2)
		Breast circumference (cm)	31.3 (1.4)	36.2 (1.1)	39.4 (0.9)

Data reported are mean values and corresponding standard deviations.