The Cry of the Child and its Relationship to Hearing Loss in Parental Guardians and Health Care Providers

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Abstract

This study investigates the sound pressure levels produced by crying children and discusses the possible adverse effects that direct exposure may impose on a tending guardian or healthcare professional. Sound intensity levels from various pediatric patients (*N*=26) were measured under two segregate conditions, one imitating the exposure of an examining physician and the other resembling that of parental guardians. Interestingly, all of the recorded sound levels fell between 99-120 dB(A) of sound pressure; children presenting the greatest risk for intense cries with potentially harmful sound intensities were between the ages of 9 months and 6 years. This study found that elevated noise levels produced from crying children can cause acute discomfort and pain to those exposed. In addition, there is a theoretical risk that chronic exposure to these intense sound pressures may result in noise-induced hearing loss in a parental guardian or an examining physician. Parents of young children may also be more likely to succumb to impulsive reactions while attempting to arrest the crying, which could be a precipitating factor for child abuse. Employment of noise attenuating ear plugs in situations where parents, guardians, or healthcare professionals are commonly exposed to loud crying is recommended. The specific implementation of ear plugs by parental guardians of a frequently crying children is suggested as a possible modality for the prevention of child abuse.

Introduction

The principal objective of this study was to determine if the sound pressure produced by crying children can reach intensity levels that are associated with discomfort, pain, or even hearing loss in individuals exposed to the cries. Comparisons were made between the sound amplitudes of pediatric patients and those generated from various environmental stimuli known to be potentially harmful for the human ear, as well as to those stipulated through federal regulations. Doing so provided crucial insight regarding the relationship between the cry of the child and noise-induced hearing loss.

The National Institute for Occupational Safety and Health (NIOSH) and the Occupational Health and Safety Administration (OSHA) designate strict regulations for the maximum noise levels that are considered to be acceptable within various occupational settings, the community, and environmental contexts (McCammon & Sorenson, 2013). Noise exposure levels recommended by NIOSH and OSHA are not designed to prevent discomfort or circumvent psychological stress from noise exposure. NIOSH recommendations are based upon research that provides empirical evidence to justify the establishment of distinct standards and practices. NIOSH exposure limitations have not been determined for some levels of sound intensity, as these are designed to prevent the development of hearing loss based on a 40-hour work week over a span of 40 years. Although NIOSH begins to limit noise exposure at or above 85 dB(A), individuals are often exposed to many sources of noise that are equal to or greater than this level (See Table 1). OSHA standards form the fundamental basis of noise-related regulations and can be enforced (Niquette, 2011). However, OSHA limitations are comparatively less stringent than those of NIOSH.

It is estimated that over 30 million Americans are regularly exposed to sound levels in the workplace that exceed federal regulations and are potentially harmful (Rabinowitz, 2000). Noise-induced hearing loss most often occurs due to a mechanical injury or necrosis of the hair cells within the basilar membrane of the inner ear (McCammon & Sorenson, 2013; Schulte, Dunn & Chan, 2013). If mild, the effects may be reversible but often permanent loss occurs (Franks, Stephenson & Merry, 1996).

Exposure to excessive levels of noise may directly cause tinnitus or promote the development of tinnitus in some individuals. Subjective tinnitus is a medical condition typified by the feeling of a constant "ringing" sensation, but can also involve a variety of other subjective sounds that are only heard by someone with the condition. According to Sanders (2004) roughly 50 million Americans experience tinnitus, and while most only encounter transient tinnitus with occasional symptoms, approximately 12 million individuals suffer from more intrusive symptoms of chronic tinnitus. Temmel, Kierner, Steurer, Riedls, & Innitzer (1999) found that 83.6% of subjects with noise-induced hearing loss complained of subjective tinnitus. Both tinnitus and elevated ear pressure can serve as warning signs that a nearby sound is too loud and could lead to temporary or permanent inner ear damage (Phoon, Lee & Chia, 1993).

Perpetual crying has been attributed to causing psychological stress for the tending parent and is considered a significant factor in shaken baby syndrome and child abuse (Reijneveld, Van der Wal, Brugman & Hira Sing, 2004). However, the development of physical discomfort and possible hearing loss have not been widely implicated as precipitating factors. Taken together, this study will determine if exposure to the repetitive cries of children places the parental guardian or healthcare professional at risk for developing adverse effects and if those effects may play a role in the onset of child abuse.

Materials and Methods

Equipment

Measurements of cries were collected in an otolaryngologist office during ordinary medical examination using a Radio Shack Sound Meter to measure their amplitude, or decibels of sound pressure. The "A" scale was utilized in order to mimic the degree of perception and sensitivity of the human ear. The sound meter was calibrated prior to data collection using a 1000 Hz stimulus at both 110 dB(A) and 94 dB(A). Calibration determined that the sound meter underestimated the amplitude of the stimuli by only 1.4 dB(A) and 1.0 dB(A) respectively. Data was not adjusted for this marginal disparity since it may have been due to the slight effusion of sound around the calibration coupler.

Methods

Permission to participate in this study was obtained through a legal consent form to observe each patient visiting the otolaryngologist office where the study was conducted. The mother or guardian of each participant was present to comfort the child throughout the medical exam and ensure the environment was routine and unencumbered.

Sound measurements were recorded over a 2 month period from the visits of a total of 561 patients, 50% of which were pediatric patients. Participants of the study were selected after observing their propensity for crying. The ages of the children (N=26) from whom the data was obtained ranged from 0.29 to 5.98 years with a mean of 2.08 years and a standard deviation of 1.39 years. The medical exam itself was not altered in any way by the implementation of sound recordings.

The children's cries were measured in two independent conditions. In the first condition, the cries of 20 children were measured by attaching the sound level meter to the operative

microscope which was placed at a 90 degree angle approximately 18 inches away from the child's mouth. In this instance, the sound meter's position approximated the location of the physician's ear while examining the patient. In the second condition, the cries of 6 children were measured by holding the sound level meter at a 90 degree approximately 12 inches away from the child's mouth. This method of positioning the instrument in closer proximity resembled the exposure of an attendant or parent comforting the child during a crying episode. It was expected that the sound intensity of the cries measured in condition 2 would be greater than those recorded in condition 1 due to the closer positioning of the sound meter. Similarly, it was presumed that a tending parental guardian is exposed to cries of higher sound intensities than an examining physician.

Results

In the first measurement condition, 20 patients were tested and recorded an average crying sound intensity of 105.15 dB(A) with a range of 99 to 110 dB(A) (see Table 2). The production of high intensity sounds was relatively infrequent. In the second recording condition, 6 children were tested and recorded an average crying sound intensity of 112 dB(A) with a range of 102 to 120 dB(A) (See Table 3). In this case, the presence of high intensity sounds was much more frequent. The overall average sound intensity of the children's cries from both condition 1 and condition 2 (N=26) was 108.58 dB(A). The patients showing the greatest risk for crying with particularly high sound intensity were those between the ages of 9 months and 6 years.

Discussion

This study found evidence that the amplitudes projected from crying children lie within a range that is commonly associated with otologic discomfort and even mild pain to those exposed. Moreover, some of the decibel levels reached during the study fall within the category that

NIOSH does not recommend any safe exposure to and cannot guarantee that subsequent damage to the ear and noise-induced hearing loss will be avoided (See Table 2 and 3).

Risk of Child Abuse

The instigation of child abuse through excessive crying has been postulated as a trigger for the shaken baby syndrome and child abuse by many authors (Barr, 2012; Lopes, Eisenstein & Williams, 2013; Stewart et al., 2011). A study conducted in the Netherlands involving 3,259 parents of infants reported that roughly 6% of the infants' mothers admitted to having smothered, slapped, or shaken their child because of the child's persistent crying (Reijneveld et al., 2004). This study indicated that an even higher percentage of mothers felt they were at a greater risk of committing such acts than parents without frequently crying children or those with baby colic. During their investigation, Reijneveld et al. (2004) found evidence to support these claims when a substantial rise in the shaking of infants between 3 and 6 months of age was observed- the time frame when an infant's cries are typically at their peak. According to the study, these instances of infants being shaken contributed to the emergence of battering as the main cause of hospitalization and death in this group. In 2007, Lee and Barr confirmed this finding by observing that the age-related incidence of shaken baby syndrome corresponded to the age-specific incidence curves of abusive-head-trauma (AHT) and shaken-baby-syndrome (SBS).

Although statistical evidence is limited, several researchers have observed the role of incessant infantile crying as a trigger for the SBS. Multitude of variables may provoke child maltreatment, including the perception of the cry, family social economic status, and family history of abuse (Sidebotham & Heron, 2003). However, many research efforts have related excessive crying to inciting frustration (Barr, 2012; Lopes et al., 2013; Stewart et al., 2011) and stress (Lopes, 2013) on the part of the caregiver.

Researchers have also reported that the high-pitched cry of an infant is particularly arousing to the human ear and recurrence of such cries can result in increased irritability, displeasure, and sleep deprivation for the parent (Crowe & Zeskind, 1992; Frodi & Lamb, 1980). Crowe and Zeskind (1992) go on to explain that these effects can alter behavioral patterns and facilitate a higher inclination for abusive actions. An additional study found that crying infants were a dominant stimuli in eliciting sadness and hostility in mothers at a high risk for child abuse (Miller, Halsey & Fultz, 1995). Castiglia (2001) reported that crying is the precipitating factor in the SBS.

The majority of child maltreatment studies examine the relationship of crying and child abuse from a psychosocial model, invoking frustration, stress and anger. Child abuse has been predicated as a stress-related affair and stress management is advocated for parents with an inclination for excessive arousal and anxiety, both of which can be hastily triggered by exposure to crying (Tyson, 1996; Tyson & Sobschak, 1994). Very few reports specifically identify the potential physical discomfort and enhanced risk for hearing loss that the parents of frequently crying children are exposed to as vectors for child abuse. It is possible that the nocuous parental responses caused by repetitious exposure to high intensity crying are not only psychologically based, but may also be misguided reactions to avoid further physical discomfort or even mild otologic pain.

Risk of Hearing Loss

Pervasive exposure to infantile crying at close proximity may cause a parent to experience enhanced ear pressure, headaches, otologic irritation, and even tinnitus. While these symptoms are often transitory, they can theoretically become permanent if the frequency and intensity of exposure is extensive enough.

While OSHA regulations are comparatively more lenient, recommendations from NIOSH are derived from scientific studies concerning noise exposure and hearing loss (Niquette, 2011). The maximum acceptable noise exposure for a 40-hour work week has been determined by NIOSH to be 85 dB(A) (McCammon & Sorenson, 2013). This explicit standard is set at an exposure level that will impel an 8% chance of hearing loss over a span of 40 years (Kavanagh, 2013). Above the threshold of 85 dB, the duration of exposure time recommended by NIOSH decreases by one-half for every 3 dB increase in intensity. For example, a daily exposure of 15 minutes is recommended for a noise level of 100 dB(A), and only 7.5 minutes is recommended for a noise level of 103 dB(A). Current evidence suggests that greater levels of exposure cannot be considered safe. Parents of young children are often exposed to prolonged episodes of crying lasting more than 15 minutes, and are typically in close proximity when attempting to soothe the child. Thus if the child's cries produce a sound intensity of 100 dB(A) or more, as did 25 of the 26 children in this study, then it can be gathered that the tending parent is at an exposure level NIOSH has deemed to be unsafe.

Cries in the first experimental condition were recorded between 99 and 110 dB(A) (See Table 2). In 75% of the recordings, the sound intensity exceeded 103 dB(A) and would place an examining physician at risk if the daily time of exposure was greater than 7.5 minutes according to NIOSH advocacy. Comparable environmental noise levels are the clamor of a weed whacker, chainsaw, and pneumatic drill (See Table 1). The loudest scream in this condition was measured to be 110 dB(A), which is equivalent to the sound pressure typically encountered at most rock concerts (See Table 1).

Cries in the second experimental condition were found to range from 102 to 120 dB(A), with the average crying sound intensity being approximately 112 dB(A) (See Table 3). As

expected, the decibel levels of this condition, which imitated the exposure of a parental guardian, were significantly greater than those in the first condition resembling, the exposure of a health care provider. In this instance, 83% of the children's cries exceeded the sound intensity for which NIOSH has been able to determine a safe exposure time. The loudest crying child in this condition was recorded at 120 dB(A) - an intensity comparable to the noise generated by snowmobiles and only 10 dB(A) below that of an airplane departure (see Table 1). While no cases are reported in the literature, daily exposure to sound pressure levels of this magnitude could theoretically result in hearing loss and even permanent otologic damage with prolonged exposure.

Recommendations

Noise attenuation devices such as earplugs or muffs are recommended to prevent auditory complications resulting from high intensity noise levels. Individuals, such as parents of young children and medical personnel, who are at an increased risk for exposure to high-decibel screams should consider wearing such attenuation devices. Theoretically, the use of these devices could alleviate the auditory and psychological distress experienced by parents of a crying child to a point that would greatly reduce the likelihood of child abuse occurring as a parent's inappropriate attempt to arrest the cries.

Types of ear protection include both passive and active devices. Passive devices include earplugs and earmuffs that are more commonly employed than active devices. Well-fitted earplugs have been shown to attenuate noise by approximately 20 dB(A) and decrease most of the sound pressures reported in Tables 2 and 3 to acceptable levels (Paakkonen, Lehtomaki, Savolainen, Myllyniemi & Hamalainen, 2000; Hempstock & Hill, 1990). Active devices work by electronically cancelling ambient noise by producing an equivalent out-of-phase sound. These

devices cost much more than passive devices and can be found in consumer electronic stores. Noise-cancelling headphones and earplugs, that are readily available to the consumer, will often have maximum cancellation in the low frequencies, but will likely be unable to completely eliminate the high frequency of a child's cry.

The authors would like to propose that usage of passive noise attenuation devices such as earplugs be exercised as part of the armamentarium of treatment for parents and physicians often exposed to the screams and cries of children. Doing so can effectively reduce the anxiety, otologic damage, and potential pain deriving from excessive noise exposure. Despite whether or not a health care provider believes a certain child's cries are inciting abusive responses from the parent, there is little downside in recommending the use of earplugs that can effectively prevent discomfort and cost little more than a dime. If a child was striking the parents with a hammer and the parents were complaining of intense pain and agitation from being struck, should one merely treat the parents with counseling? Or should one first remove the harmful stimuli which elicited this problem?

Conclusion

Many studies in the literature have associated excessive crying with Abusive Head Trauma in children along with the Shaken Baby Syndrome. Most have attributed this reaction on the part of caregivers to frustration and stress.

A crying child can expose caregivers and health care providers to sound pressures as high as 120 dB(A), merely 10 dB(A) less than the intensity of noise from an airplane departure. Continuous exposure to this amplitude may cause auditory discomfort, ear pressure, mild pain, and even tinnitus. Although the level of sound exposure observed in this study can theoretically cause noise-induced hearing loss, this occurrence has not been reported in the literature.

Our study suggests that the etiology of child abuse may not be based solely on psychological stress, but could also be a misguided response to relieve significant ear pain and physical discomfort caused by the high amplitude of the child's cries.

Social workers and medical personally should consider suggesting the use of ear plugs and noise attention devices by care givers of an excessively crying or colicky child and by all staff members when examining carrying patients in a clinical setting. Further research in this area is needed to determine if the use of noise attenuating devices will effectively reduce the incidence of AHT/SBS associated with the excessively crying child.

References

Barr, R.G. (2012, October). Preventing abusive head trauma resulting from a failure of normal interaction between infants and their caregivers. *Proceedings of the National Academy of Sciences of the United States of America, 109(2),* 17294-17301.

Castiglia, P.T. (2001). Shaken baby syndrome. *Journal of Pediatric Health Care, 15,* 78-80.

Crowe, H.P, Zeskind, P.S. (1992). Psychophysiological and perceptual responses to infant cries varying in pitch: Comparison of adults with low and high scores on the child abuse potential inventory. *Child Abuse & Neglect*, *16*, 19-29.

Franks, J.R, Stephenson, M.R, Merry, C.J. (1996, June). Preventing occupational hearing loss- A practical guide. Retrieved from http://www.cdc.gov/niosh/docs/96-110/

Frodi, A., Lamb, M. (1980). Child abusers' responses to infant smiles and cries. *Child Development*, *51,* 238-241.

Hempstock, T.I., Hill, E. (1990). The attenuations of some hearing protectors as used in the workplace. *Annals of Occupational Hygiene, 34*, 453-470.

Kavanagh, K.T. Occupational hearing loss. Retrieved from http://www.occupationalhearingloss.com

Lopes, N.R., Eisenstein, E., Williams, L. C. (2013). Abusive head trauma in children: a literature review. Jornal de Pediatria, 89(5), 426-433.

McCammon, C., Sorensen, B. (1996, October). Health hazard evaluation report, HETA 95-0406-2609: Matrix Auto Body. Retrieved from http://www.cdc.gov/niosh/hhe/reports/pdfs/1995-0406-2609.pdf

Miller, J.S., Halsey, L.B., Fultz, J. (1995). Empathic responsiveness and affective reactivity to infant stimuli in high-and low-risk for physical child abuse mothers. *Child Abuse & Neglect, 19*, 767-780.

Niquette, P.A. (2011). Noise exposure: Explanation of OSHA and NIOSH safe-exposure limits and the importance of noise dosimetry. Retrieved from https://www.etymotic.com/pdf/er_noise_exposure_whitepaper.pdf.

Paakkonen, R., Lehtomaki, K., Savolainen, S., Myllyniemi, J., Hamalainen, E. (2000). Noise attenuation of hearing protectors against heavy weapon noise. *Military Medicine, 165*, 678-682.

Phoon, W.H, Lee, H.S., Chia, S.E. (1993). Tinnitus in noise-exposed workers. *Occupational Medicine*; *43*, 35-38.

Rabinowitz, P. M. (2000). Noise-induced hearing loss. *American Family Physician, 61*(9), 2759-2760.

Reijneveld, S.A., Van der Wal, M.F., Brugman, E., Hira Sing, R.A. (2004). Infant crying and abuse. *The Lancet*, *364*, 1340-1342.

Sanders, B.T. (2004, September). What is tinnitus? Retrieved from http://www.ata.org/sites/ata.org/files/pdf/What_is_Tinnitus_Tabachnick_%20Sept%20%2704.pdf

Schulte, P.A., Dunn, D.E., Chan, H.S. (1998, June). Criteria for a recommended standard: Occupational noise exposure. Retrieved from http://www.cdc.gov/niosh/docs/98-126/

Sidebotham, P., Heron, J. (2003). Child maltreatment in the “children of the nineties:” The role of the child. *Child Abuse & Neglect, 27*, 337-352.

Stewart, T. C., Polgar, D., Gilliland, J., Tanner, D. A., Girotti, M. J., Parry, N., Fraser, D. D. (2011). Shaken baby syndrome and a triple-dose strategy for its prevention. *Journal of Trauma: Injury, Infection, and Critical Care, 71(6),* 1801-1807.

Temmel, A.F., Kierner, A.C., Steurer, M., Riedl, S., Innitzer, J. (1999). Hearing loss and tinnitus in acute acoustic trauma. *Wiener Klinische Wochenschrift*, *111*, 891-893.

Tyson, P.D. (1996). Biosensitization: Biofeedback-controlled systematic desensitization of the stress response to infant crying. *Biofeedback and Self-Regulation, 21*, 273-288.

Tyson, P.D, Sobschak, K.B. (1994). Perceptual responses to infant crying after EEG biofeedback assisted stress management training: Implications for physical child abuse. *Child Abuse & Neglect*, *18*, 933-943.

Table 1

Typical Sound Intensity Produced by Various Environmental Sources

Environmental Source	**dB SPL (A Scale)**
Jet Aircraft During Takeoff (20 m)	130
Snowmobile / Tractor Without Cab	120
Rock Concert	110
Die Forging Hammer / Chain Saw / Pneumatic Drill	100 - 105
Home Lawn Mower	50 - 100
Semi-Trailer (at 20 m)	90
Heavy Traffic	80
Automobile (at 20 m)	70
Vacuum Cleaner	65
Conversational Speech	60
Residential Area at Night	40
Whisper	20
Rustle of Leaves	10
Auditory Threshold	0

***Retrieved from www.occupationalhearingloss.com*

Table 2

Measurement Condition 1: Sound Intensity of Child's Cries Measured 18" from the Mouth

Age (Years)	Peak dB SPL (A Scale) of Cry	NIOSH Maximum Allowable Exposure	OSHA Maximum Allowable Exposure
1.8	106	None	0.87
1.24	106	None	0.87
1.39	106	None	0.87
0.29	100	0.25	2.00
2.17	109	None	0.57
2.64	109	None	0.57
0.76	102	0.16	1.52
1.14	99	0.31	2.30
1.94	106	None	0.87
0.99	101	0.20	1.74
1.69	108	None	0.66
0.65	101	0.20	1.74
2.60	108	None	0.66
0.92	108	None	0.66
1.98	105	None	1.00
5.98	105	None	1.00
2.85	104	None	1.15
1.48	104	None	1.15
5.42	106	None	0.87
2.16	110	None	0.50

Table 3

Measurement Condition 2: Sound Intensity of Child's Cries Measured 12" from the Mouth

Age (Years)	Peak dB SPL (A Scale) of Cry	NIOSH Maximum Allowable Exposure	OSHA Maximum Allowable Exposure
3.73	120	None	None
2.14	108	None	0.66
1.37	116	None	None
3.83	117	None	None
1.10	102	0.16	1.52
1.95	107	None	0.76