Pilot Study of Transient Hearing Loss in Children from a Low Income Urban Setting

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Socioeconomic status is a risk factor for hearing impairment. Any type or degree of hearing loss in early childhood will affect educational achievement. This pilot study sought to examine the prevalence of middle ear pathologies in an urban, low income, primary school setting. Forty four second-grade students from a diverse immigrant community were recruited. Pure-tone hearing screenings and tympanometry were performed on those who consented to the test. However, the consent form return rate was only 40%. This may be a reflection of the community from which the data was collected. Additionally, students in low-income urban settings tend to exhibit higher than normal amounts of middle ear pathology, as indicated by study findings. Future research should expand methods to evaluate hearing in the school setting and incorporate tests of the middle ear. Parent and teacher education about minimal hearing loss and its subsequent effects on learning may also improve outcomes for high-risk children.

Introduction

The auditory system develops through sound exposure (Kilgard & Merzenich, 1998; Nakahara, Zhang, & Merzenich, 2004; Norena, Gourévitch, Aizawa, & Eggermont, 2006; Sanes & Constantine-Paton, 1985; Zhang, Bao, & Merzenich, 2001). Any form or degree of auditory deprivation during development can lead to changes in auditory processing (Sharma, Dorman, & Spahr, 2002; Syka, 2002; Xu, Kotak, & Sanes, 2007). For many children, otitis media is a recurrent and persistent problem (Roush, 2001; Teele, Klein, & Rosner, 1984). Fluid accumulation in the middle ear, which accompanies otitis media, impedes sound transmission to the auditory cortex and often results in a mild-to-moderate conductive hearing loss (Bluestone & Klein, 2001).

The fluctuating nature of a fluid-induced hearing loss results in an inconsistent transfer of sound energy, and may lead to persistent central auditory deficits (Whitton & Polley, 2011). For example, significant changes in the temporal properties of auditory cortex synapses and spikes were observed when researchers induced a conductive hearing loss in gerbils during the postnatal period (Xu et al., 2007). There were also significant deficits in membrane and inhibitory synaptic properties in these gerbils during the critical period of development. Yet, when the conductive hearing loss was reversed prior to the end of the critical period, most membrane properties recovered to normal values. However, when the hearing loss was treated and reversed a few days after the end of the critical period, the deficits persisted for several months. These findings suggest that long-lasting deficits may result from untreated hearing loss (Xu et al., 2007).

Changes in the auditory cortex that result from these deficits likely contribute to auditory processing difficulties observed in those with mild to moderate hearing loss and may contribute to the observed behavioral delays following a hearing loss in childhood (Johnson, Nicol, & Kraus, 2005; Whitton & Polley, 2011). Additional evidence suggests that elevated thresholds during development result in a child's continued difficulty locating sounds and may explain a child's difficulty detecting signals in background noise (Hall & Grose, 1994; Hall, Grose, & Pillsbury, 1995; Hogan, Meyer, & Moore, 1996; Wilmington, Gray, & Jahrsdoerfer, 1994). Restoration of hearing is, therefore, essential for normal development in the auditory cortex (Mowery, Kotak, & Sanes, 2014). In humans, an earlier age of hearing loss identification and restoration is positively correlated with improved auditory skills performance (May-Mederakeet et al., 2010; Svirsky, Teoh, & Neuburger, 2004). However, if auditory deprivation extends beyond the critical period of development, the amount of recovery is significantly reduced (Mowery et al., 2014).

Newborn hearing screening programs have significantly improved the diagnosis and subsequent treatment of infants with moderate to profound hearing losses. However, current screening protocols are not sensitive enough to identify hearing losses less than 30 dB HL (Norton, Gorga, Widen, Folsom, Sininger, Cone-Wesson, Vohr, Mascher, & Fletcher, 2000). Additionally, it is estimated that almost 15% of school-aged children have some degree of hearing loss that was either missed by universal newborn hearing screening programs or developed later in infancy and early childhood (Niskar, Kieszak, Holmes, Esteban, Rubin, & Brody, 1998). Unfortunately, after newborn hearing screening there are no government-mandated hearing screening programs in place.

However, the American Speech-Language-Hearing Association (ASHA) recommends that children be screened for hearing loss at 20 dB HL at 1.0, 2.0, and 4.0 kHz upon school entry, annually from kindergarten to third grade, and in the seventh and eleventh grades (ASHA, 1997). ASHA also recommends that children be screened if they exhibit risk factors or upon teacher or parental concern. The American Academy of Audiology (AAA) additionally recommends the use of tympanometry for younger children in grades preschool to first (AAA, 2011). The AAA also recommends otoacoustic emission (OAE) screening for preschool and school-aged children for whom pure tone screening is not developmentally appropriate. New York State, where the study was conducted, recommends that children be screened at 20 dB HL for the frequencies 1.0, 2.0, and 3.0 kHz. New York State also recommends tympanometry if it is available (The University of the State of New York, State Education Department, 2008). Unfortunately, despite the above recommendations, New York

City no longer offers school-based hearing assessment (New York City Department of Education, Office of School Health, 2016). In the New York City school system, teacher observation and recommendation are the primary means of referring children for hearing evaluations.

New York City's decision to suspend school-based hearing screening programs is unfortunate because a large number of the students served by the New York City Board of Education come from challenged socio-economic backgrounds (American Community Survey 5-Year 2006-2010 Estimates, 2010). These children are at a greater risk for middle ear disorder (Auinger, Lanphear, Kalkwarf, & Mansour, 2003) and would, therefore, benefit from hearing screening programs and follow-up treatment.

Tympanometry is a quick and objective means for screening middle ear disorders. ASHA and AAA criteria for abnormal tympanometry include flat, type B tympanograms or tympanic peak pressures (TPPs) beyond -200 daPa. However, studies have indicated that the air-bone gap increases with increasing negative middle ear pressure beyond -50 daPa (Cooper, Langley, Meyerhoff, & Gates, 1977). Additionally, OAEs, an objective test of outer hair cell function and sensitive indicator of hearing health (Lonsbury-Martin, & Martin, 1990), are adversely affected by negative middle ear pressures of -50 daPa and beyond (Marshall, Heller, & Westhusin, 1997; Prieve, Calandruccio, Fitzgerald, Mazevski, & Georgantas, 2008; Thompson, Henin, & Long, 2015).

The children tested in this pilot study came from a low-income population in Queens, NY. Due to their backgrounds, these children are at a higher risk for middle ear pathologies. Testing was performed in the teacher's lounge, as the school did not have a nurse's office or library. Following New York State guidelines, pure tone screening was performed at 20 dB HL for 1.0, 2.0, and 3.0 kHz. Due to this population's risk for middle ear pathologies, tympanometry was held to strict criteria, namely TPPs beyond -50 daPa were considered abnormal.

Methods

Participants

Data were collected from second grade students (age 7-8 years) at a parochial school in Queens, NY. The demographic estimates for the school were reported as follows (www.greatschools.com): 75% of the students were Black, 11% Asian, 11% Hispanic, and 3% White. Children who met the classification of Black were mainly from the West Indies (i.e. Haiti, Jamaica, Trinidad, Antiga). Children who met the classification for Asian were primarily from South East Asia. Additionally, 78% of the children qualified for the free lunch program but only 34% applied. As reported by the school principal, the children were immigrants or children of immigrants and tended to be highly transient. For example, 15 to 20% of the student population enters or leaves the school each year.

Procedure

Consent forms requesting that the child have his or her hearing tested in the school by a state-licensed audiologist were sent home to the child's guardian in English only. Following New York State guidelines, students' hearing was screened. Pass criteria of 20 dB HL was used for the screen at 1.0, 2.0, and 3.0 kHz bilaterally. To evaluate middle ear health, tympanometry was performed, and TPPs were recorded. Pure tone audiometry and tympanometry were performed using an Interacoustics AA22 portable audiometer and middle ear analyzer (Interacoustics A/S, Denmark).

Testing was done in a quiet corner of the teachers' lounge during class time. The students verbally assented to the hearing test and were given erasers for their participation. The St. John's University Office of the Institutional Review Board approved this study.

Results

Forty-four (44) consent forms were sent home. Eighteen (18) were completed and returned. Thirteen (13) families consented to have their child's hearing evaluated and were present on the day of testing; one child was absent. Four parents did not consent to the hearing test. The consent form return rate was 40.1%, and approximately 30% of the second grade students had their hearing tested. Of the 13 students tested, 26 ears, passed the pure-tone screen. Pure-tone screening and TPPs for each subject are shown in Table 1.

Table 1. *Pure Tone Screening Results (left) and TPPs (right) for each subject*

	Pure Tone Screening (20 dB HL) (Pass/Fail)		Tympanometric Peak Pressure (daPa)	
Subjects	PT Right	PT Left	TPP Right	TPP Left
N1	Pass	Pass	CNT	-90
N2	Pass	Pass	-40	-25
N3	Pass	Pass	-31	-49
N4	Pass	Pass	CNT	CNT
N5	Pass	Pass	-15	-13
N6	Pass	Pass	5	14
N7	Pass	Pass	-7	-70
N8	Pass	Pass	CNT	-15
N9	Pass	Pass	-297	-285
N10	Pass	Pass	CNT	-50
N11	Pass	Pass	-40	flat
N12	Pass	Pass	-74	-8
N13	Pass	Pass	-390	-283

As shown in Table 2, TPP results were as follows: 13 ears had TPPs between 0 and -50 daPa, three ears fell between -50 and -100 daPa, four ears had TPPs beyond -200 daPa, and one ear had a flat type B tympanogram. Five ears could not be tested (see Table 2).

Table 2. *TPPs for Each Ear (N=26) Grouped in 50 daPa Blocks.*

TPP (daPa)	N
$0 < TPP \leq -50$	13
$-50 < TPP \leq -100$	3
$-100 < TPP \leq -150$	0
$-150 < TPP \leq -200$	0
$-200 < TPP$	4
Flat type B	1
CNT	5

Discussion

Unfortunately, almost sixty percent (60%) of the consent forms were not returned. The poor return rate could be related to the consent form, written only in English. Alternately, the poor return rate may be a reflection of the effects low socio-economic status has on health care access and knowledge (Adler, Boyce, Chesney, Cohen, Folkman, Kahn, & Syme, 1994). It may also be an additional indicator that this population, which consists of mostly immigrant parents, is overwhelmed by other childcare and work related responsibilities.

Low socio-economic status is a risk factor for middle ear pathology, and any type or degree of hearing loss may affect educational achievement (Bess, Dodd-Murphy, & Parker, 1998; Davis, Elfenbein, Schum, & Bentler, 1986). Based on the strict criteria used for this study, 30% of the ears tested had some degree of negative middle ear pressure and possible middle ear pathology. Additionally, though all the children passed the pure-tone hearing screen, New York State guidelines only required that the hearing be screened at three frequencies at a threshold of 20 dB HL. It is possible that some of children tested had minimal hearing loss, which was not identified by the pure-tone screen (Wake et al., 2006).

Undetected hearing loss in early elementary school is an important problem because this is a critical time in the child's development (Sharma et al., 2002; Syka, 2002; Xu et al., 2007). Minimal or unilateral hearing loss has implications for a child's ability to listen to and understand auditory information, a child's speech and language development, and a child's behavior (Bess, et al., 1998; Bess, Klee, & Culbertson, 1986; Brackett, Maxon, & Blackwell, 1993; Oyler, Oyler, & Matkin, 1988). Additionally, school-age children with minimal or unilateral hearing losses are at an elevated risk for developmental delays (Bess, et al., 1998; Bess, et al., 1986; Oyler, et al., 1988).

A child's hearing thresholds should be at least 15 dB HL (Bess et al., 1998; Brackett et al., 1993; Davis et al., 1986). This lower threshold is recommended because research indicates that children between 6 and 16 years of age with minimal or unilateral hearing loss are twice as likely to score two standard deviations below the norm on standardized arithmetic and reading tests (Niskar et al., 1998). Future research could include follow-up hearing threshold tests in the third grade with a comparison to achievement test scores, as third graders with minimal hearing loss have been found to exhibit significantly lower scores in reading, language mechanics, word analysis, and science (Bess et al., 1998).

This pilot study highlights the need for more thorough testing and follow-up care in low-income urban settings. The low consent form return rate indicates that parents may not fully understand the importance hearing has on development and academic success. Additionally, as New York City relies solely on teacher referral, teachers should be more formally educated about the warning signs of hearing loss and be informed of classroom modifications that would make the environment most conducive for learning. Accommodating students appropriately in the classroom to compensate for deficits that result from minimal or unilateral hearing, possibly caused by middle ear disorders, would improve educational outcomes (Johnson et al., 2005).

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References

Adler, N. E., Boyce, T., Chesney, M. A., Cohen, S., Folkman, S., Kahn, R. L., & Syme, S. L. (1994). Socioeconomic status and health: the challenge of the gradient. *American Psychologist*, 49(1), 15.

American Academy of Audiology. (2011). Childhood hearing screening guidelines. Available from www.cdc.gov/ncbddd/hearingloss/documents/AAA_Childhood%20Hearing%20Guidelines_2011.pdf

American Community Survey 5-Year 2006-2010 Estimates. (2010). *Table C17002 ratio of income to poverty level in the past 12 months*. Available from the Official Website of the City of New York, http://www1.nyc.gov/home/search/index.page?search-terms=income%20poverty%20level%20past&start-number=0

American Speech-Language-Hearing Association. (1997). *Guidelines for audiologic screening* [Guidelines]. Available from www.asha.org/policy

Auinger, P., Lanphear, B. P., Kalkwarf, H. J., & Mansour, M. E. (2003). Trends in otitis media among children in the United States. *Pediatrics, 112*(3), 514-520.

Bess, F. H., Dodd-Murphy, J., & Parker, R. A. (1998). Children with minimal sensorineural hearing loss: prevalence, educational performance, and functional status. *Ear and Hearing, 19*(5), 339-354.

Bess, F. H., Klee, T., & Culbertson, J. L. (1986). Identification, assessment, and management of children with unilateral sensorineural hearing loss. *Ear and Hearing, 7*(1), 43-51.

Bluestone, C. D., & Klein, J. O. (2001). Otitis media in infants and children (3rd ed.). Philadelphia: W.B. Saunders.

Brackett, D., Maxon, A. B., & Blackwell, P. M. (1993). Intervention issues created by successful universal newborn hearing screening. In *Seminars in Hearing* (Vol. 14, No. 01, pp. 88-101). Copyright© 1993 by Thieme Medical Publishers, Inc..

Cooper, J. C., Langley, L. R., Meyerhofp, W. L., & Gates, G. A. (1977). The significance of negative middle ear pressure. *The Laryngoscope, 87*(1), 92-97.

Davis, J. M., Elfenbein, J., Schum, R., & Bentler, R. A. (1986). Effects of mild and moderate hearing impairments on language, educational, and psychosocial behavior of children. *Journal of Speech and Hearing Disorders, 51*(1), 53-62.

Hall, J. W., & Grose, J. H. (1994). Effect of otitis media with effusion on comodulation masking release in children. *Journal of Speech, Language, and Hearing Research, 37*(6), 1441-1449.

Hall, J. W., Grose, J. H., & Pillsbury, H. C. (1995). Long-term effects of chronic otitis media on binaural hearing in children. *Archives of Otolaryngology–Head & Neck Surgery, 121*(8), 847-852.

Hogan, S. C., Meyer, S. E., & Moore, D. R. (1996). Binaural unmasking returns to normal in teenagers who had otitis media in infancy. *Audiology and Neurotology, 1*(2), 104-111.

Johnson, K. L., Nicol, T. G., & Kraus, N. (2005). Brain stem response to speech: a biological marker of auditory processing. *Ear and Hearing, 26*(5), 424-434.

Kilgard, M. P., & Merzenich, M. M. (1998). Plasticity of temporal information processing in the primary auditory cortex. *Nature Neuroscience, 1*(8), 727-731.

Lonsbury-Martin, B. L., & Martin, G. K. (1990). The clinical utility of distortion-product otoacoustic emissions. *Ear and Hearing, 11*(2), 144-154.

Marshall, L., Heller, L. M., & Westhusin, L. J. (1997). Effect of negative middle ear pressure on transient-evoked otoacoustic emissions. *Ear and Hearing, 18*(3), 218–226.

May-Mederake, B., Kuehn, H., Vogel, A., Keilmann, A., Bohnert, A., Mueller, S., Witte, G., Neumannf, K., Heyf, C., Stroeleg, A., Streitbergerh, C., Carnioh, S., Zorowkai, P., Nekahm-Heisi, D., Esser-Leydingj, B., Brachmaierk, J.,& Coninx, F. (2010). Evaluation of auditory development in infants and toddlers who received cochlear implants under the age of 24 months with the LittlEARS® Auditory Questionnaire. *International Journal of Pediatric Otorhinolaryngology, 74*(10), 1149-1155.

Mowery, T. M., Kotak, V. C., & Sanes, D. H. (2014). Transient hearing loss within a critical period causes persistent changes to cellular properties in adult auditory cortex. *Cerebral Cortex*, bhu013.

Nakahara, H., Zhang, L. I., & Merzenich, M. M. (2004). Specialization of primary auditory cortex processing by sound exposure in the “critical period”. *Proceedings of the National Academy of Sciences of the United States of America, 101*(18), 7170-7174.

New York City Department of Education, Office of School Health. (2016). *Vision and hearing screening*. Available from http://schools.nyc.gov /Offices/Health/HearingVisionScreening

Niskar, A. S., Kieszak, S. M., Holmes, A., Esteban, E., Rubin, C., & Brody, D. J. (1998). Prevalence of hearing loss among children 6 to 19 years of age: The Third National Health and Nutrition Examination Survey. *Jama, 279*(14), 1071-1075.

Norena, A. J., Gourévitch, B., Aizawa, N., & Eggermont, J. J. (2006). Spectrally enhanced acoustic environment disrupts frequency representation in cat auditory cortex. *Nature Neuroscience, 9*(7), 932-939.

Norton, S. J., Gorga, M. P., Widen, J. E., Folsom, R. C., Sininger, Y., Cone-Wesson, B., Vohr, B. R., Mascher, K., & Fletcher, K. (2000). Identification of neonatal hearing impairment: evaluation of transient evoked otoacoustic emission, distortion product otoacoustic emission, and auditory brain stem response test performance. *Ear and Hearing, 21*(5), 508-528.

Oyler, R. F., Oyler, A. L., & Matkin, N. D. (1988). Unilateral hearing loss demographics and educational impact. *Language, Speech, and Hearing Services in Schools, 19*(2), 201-210.

Prieve, B. A., Calandruccio, L., Fitzgerald, T., Mazevski, A., & Georgantas, L. M. (2008). Changes in transient-evoked otoacoustic emission levels with negative tympanometric peak pressure in infants and toddlers. *Ear and Hearing, 29*(4), 533-542.

Roush, J. (2001). *Screening for hearing loss and otitis media: basic principles. Screening for hearing loss and otitis media in children. San Diego, California: Singular*, 3-32.

Sanes, D. H., & Constantine-Paton, M. (1985). The development of stimulus following in the cochlear nerve and inferior colliculus of the mouse. *Developmental Brain Research, 22*(2), 255-267.

Sharma, A., Dorman, M. F., & Spahr, A. J. (2002). A sensitive period for the development of the central auditory system in children with cochlear implants: implications for age of implantation. *Ear and Hearing, 23*(6), 532-539.

Svirsky, M. A., Teoh, S. W., & Neuburger, H. (2004). Development of language and speech perception in congenitally, profoundly deaf children as a function of age at cochlear implantation. *Audiology and Neurotology, 9*(4), 224-233.

Syka, J. (2002). Plastic changes in the central auditory system after hearing loss, restoration of function, and during learning. *Physiological Reviews, 82*(3), 601-636.

Teele, D. W., Klein, J. O., & Rosner, B. A. (1984). Otitis media with effusion during the first three years of life and development of speech and language. *Pediatrics, 74*(2), 282-287.

The University of the State of New York, State Education Department. (2008). *School hearing screening guidelines*. Available from www.p12.nysed.gov/sss/documents/Hearing Guidelines.pdf

Thompson, S., Henin, S., & Long, G. (2015). Negative middle ear pressure and composite and component distortion product otoacoustic emissions. *Ear and Hearing, 36*(6), 695-704.

Wake, M., Tobin, S., Cone-Wesson, B., Dahl, H. H., Gillam, L., McCormick, L., Poulakis, Z., Rickards, F. W., Saunders, K., Ukoumunne, O. C., & Williams, J. (2006). Slight/mild sensorineural hearing loss in children. *Pediatrics, 118*(5), 1842-1851.

Whitton, J. P., & Polley, D. B. (2011). Evaluating the perceptual and pathophysiological consequences of auditory deprivation in early postnatal life: a comparison of basic and clinical studies. *Journal of the Association for Research in Otolaryngology, 12*(5), 535-547.

Wilmington, D., Gray, L., & Jahrsdoerfer, R. (1994). Binaural processing after corrected congenital unilateral conductive hearing loss. *Hearing Research, 74*(1), 99-114.

Xu, H., Kotak, V. C., & Sanes, D. H. (2007). Conductive hearing loss disrupts synaptic and spike adaptation in developing auditory cortex. *The Journal of Neuroscience, 27*(35), 9417-9426.

Zhang, L. I., Bao, S., & Merzenich, M. M. (2001). Persistent and specific influences of early acoustic environments on primary auditory cortex. *Nature Neuroscience, 4*(11), 1123-1130.