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Hearing impairment and poverty: The epidemiology of ear disease in Peruvian schoolchildren

Josephine Ann Czechowicz, B.A.¹, Anna H. Messner, M.D.¹, Edith Alarcon-Matutti, Ph.D.², Jorge Alarcon, M.D., M.P.H.², Gina Quinones-Calderon, M.D.², Silvia Montano, M.D., M.P.H.³, and Joseph Raymond Zunt, M.D., M.P.H.⁴

¹Department of Otolaryngology-Head and Neck Surgery, Stanford University School of Medicine, Stanford, CA, USA

²Universidad Nacional Mayor de San Marcos, Peru

³U.S. Naval Medical Research Center Detachment, Lima, Peru

⁴Departments of Neurology, Global Health and Medicine (Infectious Diseases) and Epidemiology, University of Washington, Seattle, WA, USA

Abstract

Objectives—1.) To measure prevalence of hearing impairment (HI) in schoolchildren living in poverty in Peru. 2.) To identify risk factors for HI and assess its impact on academic performance.

Study design—Cross-sectional.

Setting—Elementary schools in an “*asentimiento humano*” (shantytown) near Lima, Peru, October 2008–March 2009.

Subjects—Schoolchildren (n=335), ages 6–19 years.

Methods—Audiologic health was assessed with pure-tone audiometry, tympanometry and otoscopy. The primary outcome was HI, defined as average threshold >25dB HL for 0.5, 1, 2, and 4 kHz, in one or both ears (per World Health Organization/International Organization for Standardization). A questionnaire on health history was administered to parents. Statistical analysis included univariate analysis for chi-squared values and odds ratios, and multivariate logistic regression.

Corresponding author: Josephine Ann Czechowicz, Address: 801 Welch Road, Stanford, CA 94305, jaczecho@stanford.edu, Phone: 651-492-2114, Fax: 650-725-6685.

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None of the authors has a conflict of interest to declare.

Results—HI prevalence: 6.9% (95%CI 4.2–9.6%). Risk factors for HI (OR 95%CI, p-value): neonatal jaundice (5.59, 1.63–19.2, 0.015), seizure (7.31, 2.50–21.4, 0.0013), trauma-related hospitalization (5.80, 1.66–20.3, 0.003), recurrent otitis media (5.06, 1.98–12.9, 0.002), past otorrhea (4.70, 1.84–12.0, 0.003), family history of HI at <35 years (2.91, 1.19–7.14, 0.026), TM abnormality (13.8, 4.48–42.7, <0.001), cerumen impaction (15.8, 4.71–53.1, <0.001) and Eustachian tube dysfunction (4.87, 1.74–13.7, <0.001). HI was an independent predictor of academic failure (3.36, 1.15–9.82, 0.03).

Conclusions—Impoverished Peruvian schoolchildren were 4–7 times more likely to experience HI than children living in higher-income countries. Untreated middle-ear disease in the context of limited access to pediatric care was a major risk factor for HI. Furthermore, HI was associated with worse scholastic achievement. These results support prioritization of pediatric ear health as an essential component of the global health agenda, especially in resource-poor countries.

Introduction

The World Health Organization (WHO) estimates that 278 million people suffer from disabling hearing impairment (HI); 70% of these people live in low-income countries, and 25% develop hearing loss during childhood.^{1,2} Compared to infants born in resource-rich countries, infants born in resource-poor countries are nearly twice as likely to have hearing loss (6 cases/1000 children versus 2–4 cases/1000 children).^{3,4} Based on the disability adjusted life-years (DALYs), WHO ranks HI as the 12th most common contributor to disease burden and the third most common cause of years lived with disability.²

Compared to children without HI, children with hearing loss have poorer academic achievement, are less likely to finish secondary school, and are more likely to be unemployed as adults.⁵ As schools are auditory environments, hearing loss is a major barrier to education.^{6,7} Children with moderate to severe HI (hearing threshold greater than 40 decibels) are usually identified early by relatives or teachers, while mild or unilateral hearing impairment often goes unnoticed, but can still result in communication difficulties, especially in noisy classrooms.⁸

A resolution was passed at a 1995 meeting of the World Health Assembly affirming the importance of interventions to control preventable hearing loss. This resolution emphasized the importance of primary prevention of hearing loss with vaccination, improved education and prenatal care, and recommended that all nations perform population-based epidemiologic studies to determine the prevalence and causes of HI, to permit targeting of preventive efforts against the most common causes.⁹ Unfortunately, only a handful of developing nations have collected data on the prevalence and etiology of hearing impairment in children, three of which were Latin American countries.^{10–12}

Peru is a developing Latin American nation of 28 million people. The proportion of people living in poverty has dropped from 48.6% in 2004 to 39.3% in 2006.¹³ This improvement in standard of living has been accompanied by more funding for health-related interventions. Universal childhood vaccination is now common in urban areas and access to prenatal care has improved substantially. To date, however, no data have been published on the prevalence of HI or ear disease in children in Peru. The aim of this study was to determine the

prevalence and correlates of HI and ear disease in a population of school-aged children living in an impoverished area of Lima, Peru, and to determine the effect of HI upon academic achievement.

Materials and Methods

This cross-sectional study was conducted in the public school system of Zapallal Hills of the Puente Piedra district of Lima, Peru, one of seven *Pueblos Jovenes* (literally “young towns”) in Lima. The majority of Puente Piedra’s 210,000 inhabitants live in makeshift housing with concrete or dirt floors. The study was approved by institutional review boards of the University of Washington, the Universidad Nacional Mayor de San Marcos, and the Parent-Teacher Association of Zapallal Hills. Participants were selected from a numbered district roster using a random number generator. Of 600 invited to participate, 335 were enrolled. Informed consent was obtained from all families and participants.

Otoscopy

Each ear was examined by pneumatic otoscopy (Welch-Allyn otoscope model 728). Potential diagnoses included: cerumen in canal, tympanic membrane (TM) retraction, TM scar, TM inflammation, TM perforation, fluid in middle ear, and otorrhea. Cerumen in the ear canal was classified as either “view obstructing” or “impacted” based on tympanometry: cerumen was deemed “impacted” if it made a seal, producing a type B tympanogram. All abnormal findings were confirmed by a trained otolaryngologist.

Audiometry

Hearing tests were carried out in an insulated audiometry room at the Zapallal Hills School (Interacoustics AT220 pure tone audiometer - bio-calibrated daily). Bilateral pure-tone air thresholds were recorded at: 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and 8000Hz. If the participant had an air conduction threshold greater than 20 decibels (dB HL) at any frequency, then bone conduction thresholds were obtained for that ear. Masking was performed if the difference between the impaired and better ear was greater than 40 dB HL. Participants were diagnosed as “hearing impaired” using the World Health Organization/ International Standardization Organization definition of a mean threshold of >25dB HL for 500Hz, 1000Hz, 2000Hz and 4000Hz for one or both ears.¹⁴ HI was further classified as conductive, sensorineural or mixed.

Tympanometry

Middle ear analysis was performed with the tympanometry apparatus on the Interacoustics AT220 machine. Tympanic membrane compliance, middle ear pressure and canal volume were recorded. Eustachian tube dysfunction (ETD) was diagnosed if tympanometry measured middle ear pressure as <-150 or >50 deca-Pascals.

Review of Academic Achievement

Each participant’s final report card of the academic year was examined. Students were documented to be either passing, in need of remediation, or failing.

Questionnaire

A survey detailing each child's prenatal, pediatric and otologic history, as well as demographics, was administered to the parent or guardian by study staff.

Statistical Analysis

Univariate analysis and multivariate logistic regression analyses were used to identify risk factors for hearing impairment (SPSS Version 16.0 Chicago, IL).

Results

A total of 335 children between ages of 6–19 years (mean 11.3) from the Zapallal Hills school system were enrolled between October 2008 and January 2009. Characteristics of the study population are shown in Table 1. Several participants (n=16) declined to answer one or more survey questions.

HI as defined by the standardized WHO population-based survey (pure tone average >25dB HL for 0.5kHz, 1kHz, 2kHz and 4kHz) was diagnosed in 23 of 335 participants, for a prevalence of 6.9% (95% CI: 4.2–9.6%). Of these 23 hearing-impaired children, 16 had conductive HI (9 unilateral, 7 bilateral), four had sensorineural HI (2 unilateral, 2 bilateral) and three had mixed HI (2 unilateral, 1 bilateral). The prevalence of degree of HI based on the WHO definition as well as the “Mild-Moderate-Severe” classification system is shown in Table 2. The prevalence of otoscopic findings and tympanometry results are shown in Table 3. The most common finding on otoscopic exam was excessive cerumen in the ear canal (seen in 19.4% of children). The overall prevalence of abnormal middle ear findings on examination (TM pathology and/or ETD) was 10.7% (36 children). A history of middle ear disease (either an ear infection requiring antibiotics, more than three episodes of otitis media in a year, or a history of otorrhea) was reported in 85 children (25.4%).

HI (pure tone average >25dB HL) was associated with numerous otologic and non-otologic variables. Non-otologic risk factors identified on univariate analysis were history of neonatal jaundice, seizure, and hospitalization. Otologic risk factors included history of recurrent otitis media, otorrhea, use of antibiotics for otitis media, family history of hearing loss in a person younger than 35 years, eustachian tube dysfunction, any TM pathology, and cerumen impaction (Table 4). An abnormal middle ear examination (TM pathology on otoscopy or ETD) was associated with an OR for HI of 6.79 (95% CI 2.69–17.1). A reported history of middle ear disease correlated with an OR of 2.95 (95% CI 1.25–6.96).

Multivariate logistic regression was performed on risk factors identified in the univariate analysis. The following risk factors were correlated with HI: history of seizure, hospitalization, surgery, otorrhea, family history of hearing loss, and ETD (Table 4).

The investigators hypothesized that the most measurable negative impact of hearing impairment in this population would be academic problems. Thus, students' school records were examined. Of the 335 children, 257 (76.7%) passed, 67 (20.0%) were required to do remedial work, and 10 (3.0%) failed their current grade (Table 5). Hearing impairment was an independent risk factor for requiring remediation or failing by multivariate logistic

regression (OR=3.36, 95% CI=1.15–9.82). The only other risk factor for academic problems was headphone use for more than an hour per day (OR=2.44, 95% CI=1.23–4.86).

Discussion

We detected hearing impairment in 6.9% of Peruvian children; a rate significantly higher than HI in children living in resource-rich countries such as the United States (3.1%)¹⁵ or Japan (1.2%).¹⁶ The definition of hearing impairment used in the study (unilateral or bilateral pure tone average of >25dB HL) was taken from the standardized WHO protocol.¹⁴ However, the threshold used to define HI varies in the literature. Several studies use more inclusive definitions (pure tone average for 500Hz–4000Hz of >15dB HL in either ear)^{17,18} while others are more stringent (pure tone average of >31dB HL in the better ear).¹⁹ We chose to use a threshold of 25 decibels as it would be specific enough to exclude false positive diagnoses, but sensitive enough to include those with mild hearing impairment. This level has been used by studies in Tanzania²⁰, Nigeria²¹, and Brazil.²²

HI was associated with a history of recurrent middle ear infection, hospitalization, seizure and family history of hearing impairment. Otoloscopic examination and tympanometry detected abnormalities of the TM or Eustachian tube in 15 (4.5%) and 27 (8.1%) of children, respectively; both were associated with HI. Children with HI were at greater risk of poor academic performance.

HI was most common in children with a history of recurrent middle ear infection and otorrhea, but only 56 (16.7%) of 335 participants reported ever receiving antibiotic treatment for an ear infection and no participant had undergone placement of pressure equalization tubes. Non-otologic factors associated with HI included prior hospitalization, jaundice, seizure and family history. Nearly 40% of hospitalizations were for respiratory complaints, including asthma, bronchitis and pneumonia, supporting the documented association between upper respiratory congestion and Eustachian tube dysfunction.²³ A history of seizure was the strongest predictor of HI in the multivariate analysis; six patients with HI reported having at least one seizure. Interestingly, five of the six patients had conductive type HI, while only one had sensorineural type HI. A family history of a hearing impairment in a young person was associated with HI. Whether this association represents a familial predisposition to middle ear disease or a heritable problem could be investigated in future studies.

Otoscopic examination detected an abnormal TM in 15 (4.5%) of 335 children and was associated with HI. The positive and negative predictive values of the otoscopic exam as a diagnostic tool for HI were 40% and 95% respectively. In a developing world setting, the otoscopic exam could have utility in identifying children most likely to benefit from the more sensitive (and expensive) audiometric exam. Our study distinguished between copious cerumen with a normal tympanogram (“view obstructed”) and cerumen forming an airtight seal in the canal, resulting in a flat (Type B) tympanogram (“cerumen impaction”). Not surprisingly, 7 (37%) of 19 participants who met our definition of cerumen impaction had conductive hearing loss and HI resolved after removal of the impaction. Only 3 (6%) of 47 participants with “view obstructed” TMs had HI. Although only impaction produced hearing

impairment, copious cerumen obstructing the view of the TM can prevent accurate diagnosis and subsequent treatment of middle ear pathology.

Eustachian tube dysfunction was detected in 8.1% of children and was also associated with HI. The association between Eustachian tube dysfunction, abnormal middle ear pressure and chronic otitis media is well-described.²⁴ This study did not assess whether Eustachian tube dysfunction was permanent, due to the cumulative result of years of abnormal middle ear pressure, or transient, due to Eustachian tube congestion from allergy or upper respiratory infection.

Finally, we observed an incidental correlation between poor academic performance and reporting an hour or more per day of headphone use. This suggests that students in the developing world are equally susceptible to the distraction of technology as their counterparts in higher-income countries.

In conclusion, this study provides the first estimate of hearing impairment and ear disease in impoverished children living in Peru. Otologic problems associated with HI were also factors associated with lack of adequate primary care- perhaps explaining the disparity between the prevalence of HI in Peru and higher income countries. Potential methods to decrease this disparity include: increasing access to primary care; enhancing parental education on basic primary prevention including safe ear cleaning, avoidance of noise induced hearing loss, proper use of antibiotics; and incorporating hearing and audiologic examinations into routine pediatric visits, especially for children with risk factors for HI. Finally, this study found that children with HI were over three times more likely to have academic problems than those with normal hearing. For children in developing countries like Peru, educational advancement is often the only way to overcome destitution. Reducing the burden of preventable pediatric hearing impairment will allow more children in poor countries to access opportunity and to escape the cycle of poverty.

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Table 1

Demographic characteristics of study population.

Characteristic	Prevalence, n (%)
Gender	
Female	197 (58.8)
Male	138 (41.2)
Household Size (number of inhabitants)	
5 or fewer	212 (64.8)
6 or more	115 (35.2)
Employment (head of household)	
Employed	291 (89.0)
Unemployed	36 (11.0)
Education Level (head of household)	
Grade school or less	85 (26.3)
Some or completed high school	202 (60.3)
Some technical school or university	36 (10.7)
Birth City	
Greater Lima Area	225 (68.8)
Rural Province	102 (31.2)
Birth	
Full Term	294 (91.0)
Pre-term	29 (9.0)
Hospital/Health Center Birth	225 (69.2)
Home Birth	100 (30.8)
History of:	
Neonatal Jaundice	15 (4.6)
Seizure	20 (6.1)
Hospitalization	82 (25.2)
Surgery	9 (2.8)
More than three ear infections in one year	37 (11.3)
Otorrhea	39 (11.9)
Family history of hearing loss at <35 years of age	69 (20.6)
Noise Exposure	
<i>Distance of home from Panamerican Highway</i>	
1km or more	217 (64.8)
Less than 1km	84 (25.1)
Unknown	34 (10.1)
<i>Time per day of headphone use:</i>	

Characteristic	Prevalence, n (%)
None	210 (64.2)
Less than 30 minutes	63 (19.3)
More than 30 minutes	54 (16.5)

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Table 2

Prevalence of Hearing Impairment. Proportions of participants with HI per the WHO definition (pure tone average greater than 25dB HL at 0.5, 1kHz, 2kHz and 4kHz) and per definitions of “Mild,” “Moderate,” “Moderate-Severe,” and “Severe” hearing impairment.

	Prevalence, n (%)
One or both ears	Threshold 25dB HL or greater (WHO): 23 (6.9) — Mild (20–40dB HL): 37 (11.0) <ul style="list-style-type: none"> • 20–24dB HL: 16 (4.8) • 25–29dB HL: 13 (3.9) • 30–40dB HL: 8 (2.4) Moderate (41–55dB HL): 4 (1.2) Moderate-Severe (56–70dB HL): 3 (0.9) Severe: (71–90dB HL): 1 (0.3)
Both ears	Threshold 25dB HL or greater (WHO): 10 (3.0) — Mild (20–40dB HL): 18 (5.4) <ul style="list-style-type: none"> • 20–24dB HL: 13 (3.9) • 25–29dB HL: 4 (1.2) • 30–40dB HL: 0 Moderate (41–55dB HL): 0 Moderate-Severe (56–70dB HL): 1 (0.3) Severe: (71–90dB HL): 0

Table 3

Prevalence of otoscopic and tympanometric abnormalities.

Ear Pathology	Prevalence, n (%)
TM pathology (perforation, retraction, scar, inflammation)	15 (4.5)
External malformation (tragal tag, cup ear)	5 (1.5)
Foreign body	3 (1.0)
Copious Cerumen	66 (19.4)
-Impacted (Type B tympanogram)	19 (5.7)
-View obstruction (Normal tympanogram)	47 (13.7)
Eustachian tube dysfunction	27 (8.1)

Table 4

Factors associated with hearing impairment in Peruvian schoolchildren.

Risk Factor	# of impaired children with risk factor (of 23)	Univariate			Multivariate logistic regression	
		Odds Ratio (95% CI)	P-value	Odds Ratio (95% CI)	P-value	
Pediatric History						
-Neonatal Jaundice	4	5.59 (1.63–19.2)	0.015	*		
-Seizure	6	7.31 (2.50–21.4)	0.001	6.38 (1.50–27.2)	0.012	
-Hospitalization	12	4.01 (1.66–9.68)	0.003	4.65 (1.61–13.4)	0.004	
-Surgery	2	4.04 (0.790–20.7)	0.126	10.2 (1.56–66.3)	0.015	
Otologic History						
-Otitis media (OM) treated with antibiotics	10	4.31 (1.79–10.4)	0.002	*		
-More than 3 episodes of OM in a year	8	5.06 (1.98–12.9)	0.002	*		
-Otorrhea	8	4.70 (1.84–12.0)	0.003	3.32 (0.98–11.3)	0.054	
Family History of hearing loss at 35 years or less	9	2.91 (1.19–7.14)	0.026	4.97 (1.63–15.1)	0.005	
Eustachian Tube Dysfunction	6	4.87 (1.74–13.7)	0.006	5.72 (1.55–21.0)	0.006	
TM Pathology	6	15.80 (4.71–53.1)	<0.001	*		
Cerumen impaction	7	13.83 (4.48–42.7)	<0.001	*		

* Found to be correlated with another variable on logistic regression

Table 5

Hearing loss and academic performance.

	Normal Hearing, n (%)	Hearing Impaired, n (%)
Passed	244/312 (78.2)	14/23 (60.8)
Required remediation	60/312 (19.2)	7/23 (30.4)
Failed	8/312 (2.5)	2/23 (8.7)