

Prevalence of Hearing Loss Among Children 6 to 19 Years of Age

The Third National Health and Nutrition Examination Survey

Amanda Sue Niskar, RN, BSN, MPH; Stephanie M. Kieszak, MA, MPH; Alice Holmes, PhD, CCC-A; Emilio Esteban, DVM, MBA, PhD; Carol Rubin, DVM, MPH; Debra J. Brody, MPH

Context.—Hearing loss in children influences the development of communication and behavioral skills, but few studies in the United States have used pure-tone audiometry to derive hearing loss prevalence estimates for children.

Objective.—To describe the prevalence of hearing loss among US children by sociodemographic characteristics, reported hearing loss, and audiometric screening factors.

Design.—National population-based cross-sectional survey with an in-person interview and audiometric testing at 0.5 to 8 kHz.

Setting/Participants.—A total of 6166 children aged 6 to 19 years completed audiometry in the mobile examination center of the Third National Health and Nutrition Examination Survey conducted between 1988 and 1994.

Main Outcome Measure.—Hearing loss, defined as audiometric threshold values of at least 16-dB hearing level based on a low or high pure-tone average.

Results.—A total of 14.9% of children had low-frequency or high-frequency hearing loss of at least 16-dB hearing level, 7.1% had low-frequency hearing loss of at least 16-dB hearing level, and 12.7% had high-frequency hearing loss of at least 16-dB hearing level. Most hearing loss was unilateral and slight in severity (16- to 25-dB hearing level). Of those with measured hearing loss, 10.8% were reported to have current hearing loss during the interview.

Conclusions.—This analysis indicates that 14.9% of US children have low-frequency or high-frequency hearing loss of at least 16-dB hearing level in 1 or both ears. Among children in elementary, middle, and high school, audiometric screening should include low-frequency and high-frequency testing to detect hearing loss.

JAMA. 1998;279:1071-1075

A CHILD'S ABILITY to hear influences the development of communication and behavioral skills that affect educational experience and relationships with other people.^{1,2} Public health screening and intervention play an important role in improving the health (including hearing status) and well-being of children. Children are most often administered audiometric evaluations at speech frequencies as part of routine

physical examinations or in school settings. The majority of conductive hearing loss affects the low frequencies, while the majority of sensorineural hearing loss affects the high frequencies.³ Impacted cerumen, a foreign body, edema of the auditory canal, and otitis media are just a few of many possible causes of conductive hearing loss among children.^{2,3} Noise, medications, meningitis, and congenital syphilis are among the many possible causes of sensorineural hearing loss among children.^{2,3} Studies have shown that high-frequency hearing loss from noise exposure during childhood can lead to further hearing loss from acute or chronic noise exposure at older ages.⁴

The effect of noise in the environment on hearing levels has gained increased recognition.⁵ In the United States, few studies have included a range of high-

frequency audiometry (≥ 3 kHz) from which hearing loss prevalence estimates can be derived for children.⁶⁻⁹ Recent data from the Third National Health and Nutrition Examination Survey (NHANES III), conducted from 1988 to 1994 by the National Center for Health Statistics of the Centers for Disease Control and Prevention, offer the opportunity to examine both low and high audiometric frequencies and to evaluate the presence of hearing loss by sociodemographic characteristics in a national sample of children aged 6 to 19 years.

METHODS

NHANES III Sample Design

NHANES III used a stratified multi-stage probability design.¹⁰ The sample consisted of approximately 40 000 people who were representative of the US civilian noninstitutionalized population 2 months of age or older.¹⁰ National population estimates, as well as estimates for the 3 largest racial and ethnic subgroups in the US population (non-Hispanic white, non-Hispanic black, and Mexican American), can be derived from the 6-year survey.¹⁰ Data were collected through household interviews, and standardized audiometric examinations were conducted in a mobile examination center.¹¹ The NHANES III protocol for audiometry included persons aged 6 to 19 years, and did not include otoscopic examinations.

Audiometric Measures

Audiometry was conducted in a sound-treated room in the mobile examination center by trained examiners using a standardized protocol. An audiometer (model GSI 16; Grason-Stadler, Milford, NH) was calibrated with the same specifications at the start and end of testing at each field location.¹² Additional calibration audiometric equipment included a sound level meter (model 2235; B&K, Denmark), an artificial ear cou-

From the Epidemic Intelligence Service, Epidemiology Program Office (Ms Niskar), and National Center for Environmental Health (Ms Kieszak and Drs Esteban and Rubin), Centers for Disease Control and Prevention, Atlanta, Ga; the University of Florida, Gainesville (Dr Holmes); and the National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, Md (Ms Brody).

Reprints: Amanda Sue Niskar, RN, BSN, MPH, National Center for Environmental Health, Centers for Disease Control and Prevention, 4770 Buford Hwy NE, MS F46, Atlanta, GA 30341-3724 (e-mail: abn0@cdc.gov).

Table 1.—Hearing Levels Based on the Low Pure-Tone Average Among US Children Aged 6 to 19 Years: NHANES III, 1988-1994 (N = 6166)*

% Prevalence, Left Ear (95% CI)	% Prevalence, Right Ear (95% CI)		
	-10- to 15-dB HL (Normal)	16- to 25-dB HL (Slight)	≥26-dB HL (≥Mild)
-10- to 15-dB HL (normal)	92.9 (91.6-94.2)	2.0 (1.4-2.5)	0.3 (0.2-0.5)
16- to 25-dB HL (slight)	2.7 (1.8-3.6)	0.7 (0.5-1.0)	0.2 (0.1-0.3)
≥26-dB HL (≥mild)	0.6 (0.3-1.0)	0.2 (<0.1-0.3)	0.4 (0.2-0.7)

*Low pure-tone average = (0.5 + 1 + 2) kHz/3. NHANES III indicates Third National Health and Nutrition Examination Survey; CI, confidence interval; and HL, hearing level.

pler (model 4151, B&K), a 2.5-cm condenser microphone (model 4144, B&K), a 1.3-cm condenser microphone (model 4155, B&K), an octave band filter (model 1624, B&K), an acoustic calibrator (model 1624, B&K), an adapter (model DB 0375, B&K), and a 500-g weight.¹²

Air-conduction thresholds were measured for each ear at 0.5, 1, 2, 3, 4, 6, and 8 kHz, with testing repeated at 1 kHz.¹² The correlation of the threshold for the 1-kHz first test with the retest was 0.9 ($P < .001$) for the left and right ears of each child. The 1-kHz first test was the value used for this analysis.

If a subject had air-conduction threshold values at a given frequency that differed by 40 dB or more between ears, masking was performed to assure accuracy in measurement.¹³ Threshold values were obtained between -10- and 110-dB hearing level (dB HL). If no response was obtained at the limits of the test protocol, a threshold of 105-dB HL was recorded for statistical purposes.¹³ In this sample, 106 children (1.7%) had masking performed. If present, the masked values were used for this analysis.

Sociodemographic Variables and Hearing-Related Covariates

Age at interview was categorized as 6 to 11 years or 12 to 19 years. Race-ethnicity was grouped as non-Hispanic black, non-Hispanic white, or Mexican American. The "all other" race-ethnicity category (eg, other Hispanics, Asians, and Native Americans) was too small to be analyzed separately, but was included in all totals.¹⁴ These 4 race-ethnicity groups are mutually exclusive. The poverty-income ratio (PIR) was defined as the total family income divided by the poverty threshold, as determined by the US Bureau of the Census, for the year of the interview.¹⁴ To be consistent with major government food assistance programs that use a PIR cutoff of 1.3 to determine eligibility, PIR categories used in analyses were low ($PIR \leq 1.3$), middle ($1.3 < PIR \leq 3.5$), and high ($PIR > 3.5$).¹⁴ No family income data were available for 8.6% of the children tested.

Self-reported hearing status was determined from questions administered during the household interview to par-

ents or guardians of children aged 6 to 16 years. Youths aged 17 to 19 years were also asked about hearing status as part of the adult questionnaire during the household interview. Prior to the audiometric examination, a screening questionnaire was administered to determine test exclusions and to assess factors that may affect test results (draining ears, cold, sinus or earache problems, exposure to music through use of earphones or headphones, and exposure to very loud noise within the past 24 hours). Parents or guardians responded to these questions for children aged 6 to 12 years. Youths aged 13 to 19 years responded for themselves. Responses to the household interview and screening questions were dichotomized into yes and no categories.

Analytic Sample

Of the 6908 children aged 6 to 19 years who were interviewed in NHANES III, 6497 children (94.1%) were also examined. Children who were interviewed but not examined did not differ by age, sex, race-ethnicity, or PIR from children who were interviewed and examined. Of the 6497 children examined in NHANES III, 331 (5.1%) were excluded from our analyses because they missed all audiometric items ($n=256$), had only 1 ear tested ($n=36$), or had other incomplete audiometric testing ($n=39$). Of the 331 children excluded from this analysis, 44 were excluded from audiometry on the ear(s) with drainage per the NHANES III protocol.^{11,12} Children with incomplete data did not differ by age, sex, race-ethnicity, or PIR from children with complete data. A total of 6166 children were available for analysis.

Analysis

The traditional pure-tone average (PTA) for speech-affected frequencies was calculated by averaging thresholds per ear obtained at 0.5, 1, and 2 kHz, and was labeled as the low pure-tone average (LPTA) for this report.^{2,15} A high pure-tone average (HPTA) was calculated by averaging thresholds per ear obtained at frequencies of 3, 4, and 6 kHz.^{15,16} For this report, low-frequency hearing loss (LFHL) was defined as

LPTA of at least 16-dB HL, and high-frequency hearing loss (HFHL) was defined as HPTA of at least 16-dB HL. Low pure-tone averages and HPTAs were also grouped into finer categories of hearing capacity^{2,17}: normal (-10- to 15-dB HL), slight loss (16- to 25-dB HL), mild loss (26- to 40-dB HL), moderate loss (41- to 65-dB HL), severe loss (66- to 95-dB HL), and profound loss (≥ 96 -dB HL). Because of the very small numbers in these finer categories, the categories were collapsed. Categories of hearing were examined by left and right ear, and by better ear (ear with lower PTA) and worse ear (ear with higher PTA). The better ear definition includes children with unilateral hearing loss as normal, whereas the worse ear definition does not. Hearing thresholds were evaluated at each tested frequency. The worse ear HPTAs and LPTAs were examined by reported sociodemographic characteristics. Reported hearing loss and responses to the audiometric screening questions were analyzed by the categories of low-frequency and high-frequency hearing loss. Odds ratios for the risk of hearing loss were calculated for the screening questions.

All prevalence estimates and 95% confidence intervals were derived using SUDAAN, a statistical package compatible with SAS that accounts for the complex survey design and weights.^{18,19} In estimating the number of children in the US population with hearing loss, we adjusted estimates to the 1991 US census data for the population of children aged 6 to 19 years.¹⁴

RESULTS

The prevalence of either LFHL or HFHL of at least 16-dB HL in 1 or both ears among US children was 14.9% (>7 million children). The prevalence of both LFHL and HFHL was 4.9%. The prevalence of LFHL was 7.1% (1.5% bilateral and 5.6% unilateral) (Table 1). Of all children, the proportion with slight LFHL in either ear was 5.7% (Table 1), mild to moderate was 1.4%, and severe to profound was 0.3%. The prevalence of HFHL was 12.7% (3.1% bilateral and 9.6% unilateral) (Table 2). Of all children, the proportion with slight HFHL in either ear was 10.5% (Table 2), mild to moderate was 2.6%, and severe to profound was 0.4%.

Based on the better ear, 1.3% to 2.8% of all children had hearing loss of at least 16-dB HL at the individual frequencies of 0.5, 1, 2, 3, and 4 kHz. The prevalence of hearing loss in the better ear was highest at 6 kHz (5.8%) and 8 kHz (7.6%). Based on the worse ear, 5.5% to 10.6% of all children had hearing loss at 0.5, 1, 2, 3, and 4 kHz (Table 3). The prevalence of

hearing loss in the worse ear was highest at 6 kHz (24.7%) and 8 kHz (27.3%) (Table 3).

The hearing loss prevalence estimates based on the worse ear for LFHL and HFHL by various sociodemographic characteristics are presented in Table 4. Overall, there was little variability in the prevalence of LFHL by sex, age group, race-ethnicity, or PIR. There were, however, some pronounced differences in the prevalence of HFHL by sociodemographic characteristics. The prevalence of HFHL was higher among males than females (Table 4). The prevalence of HFHL in the age group of 6 to 11 years did not differ by sex. However, in the age group of 12 to 19 years, the prevalence of HFHL was 15.9% for males as compared with 10.3% for females. The prevalence of HFHL differed only slightly by race-ethnicity (Table 4). Mexican American children had the highest prevalence of HFHL (15.1%) as compared with non-Hispanic black children (11.7%) and non-Hispanic white children (12.3%). Children from low-income families had greater HFHL (16.3%) than either children from middle-income families (12.7%) or high-income families (7.9%), as presented in Table 4.

Of those children who had measured LFHL or HFHL of at least 16-dB HL, only 10.8% were reported to have current hearing loss at the time of household interview. Of the 3.4% of children who were reported to have current hearing loss, almost half had measured LFHL or HFHL. However, of children who were reported to have normal hearing, 13.8% had measured hearing loss at the time of audiometric testing (6.0% had LFHL and 11.6% had HFHL).

The prevalence of responses to audiometric screening questions are reported in Table 5. These results are limited to children who had reported answers to the screening questions. Use of headphones or earphones to listen to loud music in the past 24 hours was reported by 10.2%, and exposure to a loud noise in the past 24 hours was reported by 6.0%. These 2 factors did not appear to affect the prevalence of measured LFHL or HFHL. The presence of a cold or sinus problem the day of audiometric testing was reported by 14.8%, and the presence of buzzing or ringing in the ear(s) on the day of audiometric testing was reported by 3.2%. Children with these 2 factors had a higher prevalence of measured LFHL but not of measured HFHL. The presence of an earache in the past week was reported by 3.7%, and the presence of tube(s) in the ear(s) was reported by 1.6%. Children with these 2 factors had a higher prevalence of LFHL and HFHL than children without these conditions

Table 2.—Hearing Levels Based on the High Pure-Tone Average Among US Children Aged 6 to 19 Years: NHANES III, 1988-1994 (N = 6166)*

% Prevalence, Left Ear (95% CI)	% Prevalence, Right Ear (95% CI)		
	-10- to 15-dB HL (Normal)	16- to 25-dB HL (Slight)	≥26-dB HL (≥Mild)
-10- to 15-dB HL (normal)	87.3 (85.9-88.7)	2.9 (2.3-3.5)	0.5 (0.3-0.8)
16- to 25-dB HL (slight)	5.2 (4.1-6.3)	1.6 (1.0-2.1)	0.4 (0.2-0.7)
≥26-dB HL (≥mild)	1.0 (0.6-1.4)	0.4 (0.1-0.7)	0.7 (0.4-1.0)

*High pure-tone average = (3 + 4 + 6) kHz/3. NHANES III indicates Third National Health and Nutrition Examination Survey; CI, confidence interval; and HL, hearing level.

Table 3.—Prevalence of Hearing Levels Among US Children Aged 6 to 19 Years for Each Child's Worse Hearing Level Threshold by Frequency: NHANES III, 1988-1994 (N = 6166)*

Frequency, kHz	-10- to 15-dB HL (Normal)		16- to 25-dB HL (Slight)		≥26-dB HL (≥Mild)	
	Prevalence, %	95% CI	Prevalence, %	95% CI	Prevalence, %	95% CI
0.5	90.5	88.8-92.1	7.1	5.8-8.4	2.5	1.8-3.1
1	92.4	91.2-93.7	5.3	4.3-6.4	2.2	1.6-2.9
2	94.5	93.5-95.5	4.2	3.3-5.0	1.3	1.0-1.6
3	91.4	90.2-92.7	6.3	5.2-7.3	2.4	1.8-2.9
4	89.4	88.1-90.8	7.7	6.5-8.9	2.9	2.3-3.4
6	75.4	73.1-77.7	18.3	16.3-20.3	6.4	5.3-7.4
8	72.7	70.5-74.8	20.4	18.5-22.3	6.9	6.0-7.9

*NHANES III indicates Third National Health and Nutrition Examination Survey; HL, hearing level; and CI, confidence interval.

Table 4.—Prevalence of Hearing Loss Among US Children Aged 6 to 19 Years in Worse Ear by Pure-Tone Average and Sociodemographic Characteristics: NHANES III, 1988-1994 (N = 6166)*

Reported Characteristic	Prevalence by LPTA†		Prevalence by HPTA‡	
	% ≥16-dB HL	95% CI	% ≥16-dB HL	95% CI
Total children	7.1	5.8-8.4	12.7	11.3-14.1
Sex				
Male	6.4	4.8-7.9	14.4	12.7-16.2
Female	7.8	6.1-9.5	10.9	9.0-12.8
Age group, y				
6-11	7.6	5.9-9.3	12.2	10.0-14.5
12-19	6.6	5.0-8.2	13.0	11.1-14.8
Race-ethnicity				
Non-Hispanic white	6.8	5.2-8.3	12.3	10.6-14.1
Non-Hispanic black	6.7	5.5-7.8	11.7	9.9-13.4
Mexican American	8.1	6.1-10.2	15.1	12.7-17.5
Poverty income ratio§				
Low	8.4	6.5-10.3	16.3	13.6-18.9
Middle	7.0	5.0-8.9	12.7	10.8-14.6
High	5.5	2.6-8.4	7.9	5.1-10.7

*NHANES III indicates Third National Health and Safety Examination Survey; HL, hearing level; and CI confidence interval.

†Low pure-tone average = (0.5 + 1 + 2) kHz/3.

‡High pure-tone average = (3 + 4 + 6) kHz/3.

§Poverty income ratio could not be calculated for 529 children with missing values for income.

or symptoms. For example, children reported to have had an earache in the past week were 3 times more likely to have LFHL than children who were not reported to have had an earache in the past week.

COMMENT

This study estimated hearing ability in a range of 0.5 to 8 kHz in a sample that is representative of the US population of children aged 6 to 19 years. The data from NHANES III demonstrate that approximately 14.9% (more than 7 million) of US children have LFHL or HFHL of at least 16-dB HL. The major-

ity of hearing loss was determined to be unilateral and slight with respect to severity. Unilateral hearing loss in children impacts speech perception, learning, self-image, and social skills.¹ Slight hearing loss affects children in classrooms and other reverberant listening environments in which a child with transient auditory dysfunction can have difficulty perceiving and understanding speech sounds.^{1,2} Children with unilateral hearing loss or with slight hearing loss may require interventions such as speech therapy and consideration of the need for a hearing aid.^{1,2} Because the decibel scale is exponential, even a slight

Table 5.—Hearing Loss Prevalence in Worse Ear Among US Children Aged 6 to 19 Years by Pure-Tone Average and Audiometric Screening Questions: NHANES III, 1988-1994*

Question§	LPTA†		HPTA‡	
	≥16-dB HL	Odds Ratio (95% CI)	≥16-dB HL	Odds Ratio (95% CI)
Cold or sinus today				
No	6.6	1.5 (1.1-2.0)	12.4	1.2 (0.9-1.6)
Yes	9.3		14.2	
Earache in past week				
No	6.6	3.0 (1.7-5.1)	12.1	2.5 (1.7-3.8)
Yes	17.5		25.7	
Tube in ear now				
No	6.7	5.0 (1.8-14.0)	12.3	3.6 (1.6-8.1)
Yes	26.6		33.4	
Buzz, ringing, or other noise in ear today				
No	6.7	3.0 (1.9-4.7)	12.4	1.6 (1.0-2.5)
Yes	17.6		18.5	
Music with headphones in past 24 h				
No	7.1	0.8 (0.5-1.4)	12.7	0.9 (0.5-1.6)
Yes	5.7		11.7	
Exposed to very loud noise in past 24 h				
No	7.1	0.8 (0.4-1.6)	12.4	1.3 (0.7-2.3)
Yes	5.4		15.5	

*NHANES III indicates Third National Health and Nutrition Examination Survey; CI, confidence interval; and HL, hearing level.

†Low pure-tone average = (0.5 + 1 + 2) kHz/3.

‡High pure-tone average = (3 + 4 + 6) kHz/3.

§Sample sizes for each screening question ranged from 6103 to 6113 children.

decibel change in a child's hearing threshold at any frequency can significantly affect that child's ability to hear.⁴

The measurement of hearing thresholds at low and high frequencies for both ears provides an extensive assessment of a child's ability to hear clear, distorted, quiet, and noisy sounds that are a part of the everyday environment.^{20,21} Children with conductive hearing loss may have difficulty hearing low frequencies such as human speech, while children with sensorineural hearing loss may have difficulty hearing high frequencies such as doorbells, telephones, or a high-pitched voice.^{2,3} In this analysis, the proportion of children exhibiting HFHL was higher than that of children exhibiting LFHL. Although this analysis did not determine the etiology of hearing loss, the affected frequencies are described.

As in previous studies, this study shows unilateral hearing loss (hearing loss in only 1 ear) to be more prevalent among children than bilateral hearing loss (hearing loss in both ears).^{16,22} Prevalence estimates of hearing loss that are based on measurements in the better ear define children with unilateral hearing loss as having normal hearing. Therefore, estimates of hearing loss that are based on measurements in the worse ear, as used in Table 4 of this report, may be a more accurate indicator of the number of US children who need intervention at home and school to prevent hearing loss from impairing their development.^{16,23}

Of those children who had measured LFHL or HFHL, only 10.8% reported having current hearing loss at the time of the household interview. This differ-

ence may be explained by several factors. First, a child with transient or temporary hearing loss at the time of audiometric testing may not have had the hearing loss at the time of the household interview, which could have been as many as 8 weeks prior to the examination. In addition, a child may have had temporary or transient hearing loss at the time of the interview, but not at the time of the examination. Second, hearing loss was reported by a parent or guardian for youths aged 6 to 16 years and thus, may not have reflected the true hearing status as recognized by the child. Third, because the majority of detected hearing loss was in the slight range, parents, as well as children aged 17 to 19 years who answered questions on hearing loss for themselves, may not have recognized hearing loss.^{1,24} Although some children do not recognize hearing loss, these children may be missing listening information and are at risk for learning disabilities.^{1,2} The overall prevalence of hearing difficulty by self-report (3.4%) from the NHANES III household interview is almost double that found in the 1990-1991 National Health Interview Survey Hearing Supplements for children aged 3 to 17 years (1.8%).²⁵

Other studies have reported results of high-frequency testing^{9,24}; however, to our knowledge, no nationally representative study has examined hearing at high frequencies in children since the National Health Examination Surveys (NHES) conducted from 1963 to 1970.^{7,8} The documentation of the results of NHES audiometric testing are presented in a different format with different

definitions and methods than the present study. Thus, the results of this analysis cannot be compared with documented analyses of NHES audiometric data. Caution should be used when comparing results of hearing loss studies because of the variations used in determining screening methods and definitions of hearing loss (eg, different age ranges, frequencies tested, decibel levels used to screen, and some studies only include the better ear).

The following findings are in agreement with our results that more children have hearing loss in high frequencies than in low frequencies. Holmes et al⁹ found that 7% of 342 Florida students sampled (aged 10-20 years) had hearing loss of at least 25-dB HL at the individual frequencies of 1, 2, and 4 kHz in 1 or both ears, and 17% had hearing loss when 6 kHz was included. These findings are similar to our findings that 7.1% of US children aged 6 to 19 years had either unilateral or bilateral LFHL, and 12.7% had HFHL. Cozad et al²⁴ found that 10.6% of their sample of children aged 6 to 18 years in Kansas had hearing loss greater than 10-dB HL at the individual frequencies of 0.25, 0.5, 1, 2, 3, 4, 6, and 8 kHz in 1 or both ears, with 34.4% of the 10.6% failing low-frequency screening and 64.6% of the 10.6% failing high-frequency screening.

Including 3, 4, and 6 kHz for audiometric screening and PTA calculations results in a more accurate measurement of hearing loss throughout childhood and adolescence, especially among those children who do not recognize that they have hearing loss.^{4,15,16,24,26,27} Hearing loss may be detected early by looking at each tested frequency, particularly for noise-induced hearing loss, which initially involves 1 or more frequencies in the 3- to 6-kHz range.⁴ The audiometric screening questions regarding noise did not show an association with temporary threshold shifts. However, historically, noise-induced hearing loss is the most common cause of permanent HFHL.³ Exposure to very loud noises may explain the prevalence of HFHL (low frequencies are initially unaffected by noise).^{3,4,15,16,20} Persons with hearing loss in the high frequencies need to be advised as to appropriate hearing protection and methods to minimize noise exposure (eg, earplugs at a noisy concert or in shop class).²⁸

Otitis media is common in childhood,^{1,2} and may explain why 3.7% of all children were reported to have had an earache in the past week. Due to the absence of an otoscopic examination, temporary or transient hearing loss due to an obstructed auditory canal (eg, impacted cerumen) could not be determined. Con-

ductive hearing losses due to pathology in the outer and middle ear are usually temporary and can fluctuate greatly.^{28,29} Nonetheless they can have detrimental effects educationally and on the development of speech and language.^{1,31} These hearing losses need to be treated medically to afford the child the advantages of better hearing.^{29,30}

More studies are needed to look at sociodemographic characteristics and hearing loss. The findings of this study are consistent with other findings that male adolescents have a greater prevalence of HFHL than do females.^{1,24} Although this study found no difference by race-ethnicity for LFHL, Mexican American children had more HFHL than non-Hispanic white or non-Hispanic black children. Lee et al³¹ found that Mexican American children (2.8%) have more bilateral LFHL than African American children (1.7%) or non-Hispanic white children (1.6%). Our results also show children with low PIRs to have more HFHL than children with middle or high PIRs. However, PIR is a variable that other hearing loss studies need to explore.

The screening questions administered the day of the audiometric examination

were designed to assess factors that may affect hearing status. The use of headphones or earphones in the past 24 hours and exposure to loud noise in the past 24 hours did not appear to affect the prevalence of measured LFHL or HFHL. Children who were reported to have a cold or sinus problem on the day of the examination had a marginally higher prevalence of LFHL. Children who were reported to have buzzing or ringing in the ear(s) on the day of the examination had a higher prevalence of LFHL. However, children who reported having had an earache in the past week or tube(s) in the ear(s) on the day of the examination had a higher prevalence of LFHL and HFHL. A child with a tube in an ear is most likely being treated for chronic ear infections.² Because of the limitations of the survey, we cannot discern what proportion of children have temporary hearing loss.

The results of this study suggest a need for further research to explain differences in the prevalence of hearing loss in high frequencies among children by age group, sex, race-ethnicity, and PIR. These differences may be related to variations in environmental exposures

(eg, noisy hobbies, smoking).^{22,23,32} Further studies also are needed to assess differences in hearing thresholds over time. Currently, hearing screening in schools is commonly performed in elementary grades at 1, 2, and 4 kHz.¹ If hearing loss is identified early, particularly when it may be due to factors such as noise exposure, education and counseling may help prevent educational difficulties and further potentially handicapping hearing loss from developing, and may help maintain residual hearing.^{1,2,28} With 14.9% of US children aged 6 to 19 years having LFHL or HFHL in 1 or both ears, audiometric screening should include low-frequency testing (0.5, 1, and 2 kHz) and high-frequency testing (3, 4, and 6 kHz) to detect hearing loss among children in elementary, middle, and high school.

We thank Maureen Hannley, PhD, consultant for NHANES III audiometry, from the American Academy of Otolaryngology-Head and Neck Surgery Foundation, Inc, Alexandria, Va; Holly Kaplan, PhD, CCC-A, from the American Speech-Language-Hearing Association, Rockville, Md; and Judy Schafer, PhD, and Lucille Beck, PhD, from the Veterans Administration Audiology Department, Washington, DC, for their contributions to this study.

References

1. Anderson KL. Keys to effective hearing conservation programs: hearing status of school age children. In: Cherow E, ed. *Proceedings of the ASHA Audiology Superconference*. ASHA. 1992;21:38-47.
2. Disorders of the eye and ear. In: Behrman RE, Kliegman RM, Nelson WE, Vaughan VC, eds. *Nelson Textbook of Pediatrics*. Philadelphia, Pa: WB Saunders Co; 1992:1602-1608.
3. Gulya AJ. Evaluation of impaired hearing. In: Gore AH, May LA, Mulley AG Jr, eds. *Primary Care Medicine*. Philadelphia, Pa: JB Lippincott Co; 1995:985-1004.
4. Brookhouser PE. Prevention of noise-induced hearing loss. *Prev Med*. 1994;23:665-669.
5. National Institutes of Health Consensus Development Panel. *Noise and Hearing Loss: NIH Consensus Development Conference Consensus Statement*. Vol 8. Bethesda, Md: National Institutes of Health; January 22-24, 1990:3-5.
6. Leske MC. Prevalence estimates of communicative disorders in the U.S.: language, hearing and vestibular disorders. *ASHA*. 1981;23:229-237.
7. National Center for Health Statistics. Plan, operation, and response results of a program of children's examinations. *Vital Health Stat 1*. 1967;No. 5. US Dept of Health, Education, and Welfare publication PHS 1000.
8. National Center for Health Statistics. Hearing levels of youths 12-17 years: United States. *Vital Health Stat 11*. 1975;No. 145. US Dept of Health, Education, and Welfare publication DHEW 75-1627.
9. Holmes AE, Kaplan HS, Phillips RM, Kemker FJ, Weber FT, Isart FA. Screening for hearing loss in adolescents. *Lang Speech Hear Serv Sch*. 1997;28:70-75.
10. Ezzati TM, Massey JT, Waksberg J, Chu A, Maurer KR, for the National Center for Health Statistics. Sample design: Third National Health and Nutrition Examination Survey. *Vital Health Stat 2*. 1992;No. 113. US Dept of Health and Human Services publication PHS 92-1387.
11. National Center for Health Statistics. Plan and operation of the Third National Health and Nutrition Examination Survey, 1988-94. *Vital Health Stat 1*. 1994;No. 32. US Dept of Health and Human Services publication PHS 94-1308.
12. National Center for Health Statistics. *National Health and Nutrition Examination Survey III: Audiometry and Tympanometry for Health Technicians' Manual*. Rockville, Md: Westat Inc; 1988.
13. National Center for Health Statistics. *NHANES III Reference Manuals and Reports*. Hyattsville, Md: Centers for Disease Control and Prevention; 1996.
14. Johnson C. *NHANES III Analytic and Reporting Guidelines*. Rockville, Md: National Center for Health Statistics; 1994.
15. Hanner P, Axelsson A. Acute acoustic trauma. *Scand Audiol*. 1988;17:57-63.
16. Brookhouser PE, Worthington DW, Kelly WJ. Noise-induced hearing loss in children. *Laryngoscope*. 1992;102:645-655.
17. Goodman A. Reference zero levels for pure-tone audiometer. *ASHA*. 1965;7:262-263.
18. SAS Institute Inc. *SAS Language: Version 6*. Cary, NC: SAS Institute Inc; 1990.
19. Shal BV, Barnwell BG, Hunt PN, Lavange LM. *SUDAAN User's Manual, Release 5.50*. Research Triangle Park, NC: Research Triangle Institute; 1991.
20. Veterans Administration. Rules and regulations. 52 *Federal Register* 44117-44118 (1987).
21. American Academy of Otolaryngology Committee on Hearing and Equilibrium, American Council of Otolaryngology Committee on the Medical Aspects of Noise. Guide for the evaluation of hearing handicap. *JAMA*. 1979;241:2055-2059.
22. Rytznar B, Rytznar C. School children and noise. *Scand Audiol*. 1981;10:213-216.
23. Naeem Z, Newton V. Prevalence of sensorineural hearing loss in Asian children. *Br J Audiol*. 1996;30:332-339.
24. Cozad RL, Marston L, Joseph D. Some implications regarding high frequency hearing loss in school-age children. *J Sch Health*. 1974;44:92-96.
25. Ries PW. Prevalence and characteristics of persons with hearing trouble: United States, 1990-91. *Vital Health Stat 10*. 1994;No. 188:9-10.
26. Clark JG. Uses and abuses of hearing loss classification. *ASHA*. July 1981;23:493-500.
27. Holmes AE, Kaplan HS, Nichols SW, Griffiths SK, Weber FT, Isart FA. Screening for hearing loss in juvenile detention centers. *J Am Acad Audiol*. 1996;7:332-338.
28. Anderson KL. Hearing conservation in the schools revisited. *Semin Hear*. 1991;12:340-364.
29. Klein JO. Epidemiology and natural history of otitis media. In: Bess FH, Hall JW, eds. *Screening Children for Auditory Function*. Nashville, Tenn: Bill Wilkerson Center Press; 1992:31-38.
30. Barrett KA. Hearing and middle-ear screening of school age children. In: Katz J, Gabbay WL, Gold S, Medwetski L, Ruth R, eds. *Handbook of Clinical Audiology*. 4th ed. Baltimore, Md: Williams & Wilkins; 1994:476-489.
31. Lee DJ, Gomez-Marin O, Lee HM. Prevalence of childhood hearing loss: The Hispanic Health and Nutrition Examination Survey and the National Health and Nutrition Examination Survey II. *Am J Epidemiol*. 1996;144:442-449.
32. Barone JA, Peters JM, Garabrant DH, Bernstein L, Krebsboch R. Smoking as a risk factor in noise-induced hearing loss. *J Occup Med*. 1987;29:741-745.