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

The Third National Health and Nutrition Examination Survey

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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.

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A CHILD’S ABILITY to hear influences the development of communication and behavioral skills that affect educational experience and relationships with other people.12 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.24 Noise, medications, meningitis, and congenital syphilis are among the many possible causes of sensorineural hearing loss among children.25 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.5

The effect of noise in the environment on hearing levels has gained increased recognition.3 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-
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)*

<table>
<thead>
<tr>
<th>% Prevalence, Left Ear (95% CI)</th>
<th>% Prevalence, Right Ear (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Prevalence, Left Ear (95% CI)</td>
<td>-10- to 15-dB HL</td>
</tr>
<tr>
<td>Normal (Normal)</td>
<td>92.9 (91.6-94.2)</td>
</tr>
<tr>
<td>Mild (Slight)</td>
<td>2.0 (1.4-2.5)</td>
</tr>
<tr>
<td>Moderate (Mild)</td>
<td>0.3 (0.2-0.5)</td>
</tr>
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</table>

*Low pure-tone average = (0.5 + 1.0 + 2.0) kHz/3. NHANES III indicates Third National Health and Nutrition Examination Survey; CI, confidence interval; and HL, hearing level.


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The prevalence of hearing loss 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 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 majority 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. 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. 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. 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*

<table>
<thead>
<tr>
<th>Question§</th>
<th>LPTA‡</th>
<th>HPTA‡</th>
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<tbody>
<tr>
<td></td>
<td>≥16-db HL</td>
<td>Odds Ratio (95% CI)</td>
</tr>
<tr>
<td>Cold or sinus today</td>
<td>6.6</td>
<td>1.5 (1.1-2.0)</td>
</tr>
<tr>
<td>Yes</td>
<td>9.3</td>
<td>1.6 (1.1-2.4)</td>
</tr>
<tr>
<td>Earache in past week</td>
<td>6.6</td>
<td>3.0 (1.7-5.1)</td>
</tr>
<tr>
<td>No</td>
<td>17.5</td>
<td>3.0 (1.8-5.5)</td>
</tr>
<tr>
<td>Yes</td>
<td>26.6</td>
<td>3.0 (1.9-4.7)</td>
</tr>
<tr>
<td>Tube in ear now</td>
<td>6.7</td>
<td>5.0 (1.8-14.0)</td>
</tr>
<tr>
<td>No</td>
<td>26.6</td>
<td>3.0 (1.6-6.1)</td>
</tr>
<tr>
<td>Yes</td>
<td>5.7</td>
<td>0.8 (0.5-1.4)</td>
</tr>
<tr>
<td>Buzz, ringing, or other noise in ear today</td>
<td>6.7</td>
<td>3.0 (1.9-4.7)</td>
</tr>
<tr>
<td>No</td>
<td>17.6</td>
<td>3.0 (1.9-4.7)</td>
</tr>
<tr>
<td>Yes</td>
<td>7.1</td>
<td>0.8 (0.5-1.4)</td>
</tr>
<tr>
<td>Music with headphones in past 24 h</td>
<td>7.1</td>
<td>0.8 (0.4-1.6)</td>
</tr>
<tr>
<td>No</td>
<td>5.4</td>
<td>0.8 (0.4-1.6)</td>
</tr>
</tbody>
</table>

*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.

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

A 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.16,22

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 difference 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 as of the interview, which could have been as many as 8 weeks prior to the examination. Therefore, estimates of hearing loss that are based on measurements in the better ear may be an incomplete reflection of 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.3,8 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 Supplement for children aged 3 to 17 years (1.8%).28

Other studies have reported results of high-frequency testing24; 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 1970.16,23 The documentation of the results of NHES audiometric testing are presented in a different format with different definitions and methods from 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 al24 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.1,5,16,24,28 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).3,4,16,24 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.
ductive hearing losses due to pathology in the outer and middle ear are usually temporary and can fluctuate greatly.2,20 Non-ductive they can have detrimental effects educationally and on the development of speech and language.1,19 These hearing losses need to be treated medically to afford the child the advantages of better hearing.2,10

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.1,21 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 al23 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 head-phones 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.2 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.1,22 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.

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References