Change in Prevalence of Hearing Loss in US Adolescents

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Context Hearing loss is common and, in young persons, can compromise social development, communication skills, and educational achievement.

Objective To examine the current prevalence of hearing loss in US adolescents and determine whether it has changed over time.

Design Cross-sectional analyses of US representative demographic and audiometric data from the 1988 through 1994 and 2005 through 2006 time periods.

Setting The Third National Health and Nutrition Examination Survey (NHANES III), 1988-1994, and NHANES 2005-2006.

Participants NHANES III examined 2928 participants and NHANES 2005-2006 examined 1771 participants, aged 12 to 19 years.

Main Outcome Measures We calculated the prevalence of hearing loss in participants aged 12 to 19 years after accounting for the complex survey design. Audiometrically determined hearing loss was categorized as either unilateral or bilateral for low frequency (0.5, 1, and 2 kHz) or high frequency (3, 4, 6, and 8 kHz), and as slight loss (>15 to <25 dB) or mild or greater loss (≥25 dB) according to hearing sensitivity in the worse ear. The prevalence of hearing loss from NHANES 2005-2006 was compared with the prevalence from NHANES III (1988-1994). We also examined the cross-sectional relations between several potential risk factors and hearing loss. Logistic regression was used to calculate multivariate adjusted odds ratios (ORs) and 95% confidence intervals (CIs).

Results The prevalence of any hearing loss increased significantly from 14.9% (95% CI, 13.0%-16.9%) in 1988-1994 to 19.5% (95% CI, 15.2%-23.8%) in 2005-2006 (P=.02). In 2005-2006, hearing loss was more commonly unilateral (prevalence, 14.0%; 95% CI, 10.4%-17.6%, vs 11.1%; 95% CI, 9.5%-12.8% in 1988-1994; P=.005) and involved the high frequencies (prevalence, 16.4%; 95% CI, 13.2%-19.7%, vs 12.8%; 95% CI, 11.1%-14.5% in 1988-1994; P=.02). Individuals from families below the federal poverty threshold (prevalence, 23.6%; 95% CI, 18.5%-28.7%) had significantly higher odds of hearing loss (multivariate adjusted OR, 1.60; 95% CI, 1.10-2.32) than those above the threshold (prevalence, 18.4%; 95% CI, 13.6%-23.2%).

Conclusion The prevalence of hearing loss among a sample of US adolescents aged 12 to 19 years was greater in 2005-2006 compared with 1988-1994.

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Hearing loss is a common sensory disorder, affecting tens of millions of individuals of all ages in the United States.[1] In school-aged children, even slight hearing loss (>15-24 dB) can create a need for speech therapy, auditory training, and special accommodations.[2] Mild hearing loss in young children can impair speech and language development and lead to decreased educational achievement and impaired social-emotional development.[3,4]

The Third National Health and Nutrition Examination Survey (NHANES III), conducted between 1988 and 1994, demonstrated that 14.9% of US children aged 6 to 19 years had low-frequency or high-frequency hearing loss (pure tone average [PTA] >15 dB) in at least 1 ear,[5] and 12.5% had audiometric evidence of noise-induced hearing loss.[6] Although some hearing loss in children and adolescents can be attributed to identifiable causes such as infection, genetic syndromes, complications of prematurity, perinatal complications, ototoxic medications, head trauma, and hazardous noise exposure,[7] only limited data exist on potential risk factors for much of the acquired hearing loss in this population.

Adolescent hearing loss in particular is not well understood, although it is common[6,8,9] and can have important educational and social implications.[10] Some risk factors, such as loud sound exposure from music listening, may be of particular importance to adolescents as well.[8,11] We examined 2 serial comparable databases to evaluate whether there has been a change in the prevalence of hearing loss and to assess characteristics of hearing impairment in the 12- to 19-year-old age group.

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METHODS

Study Population

Participants aged 12 to 19 years from NHANES III, 1988-1994 (n=3211), and NHANES 2005-2006 (n=2288) were included. NHANES provides nationally representative cross-sectional data on the health status of the civilian, noninstitutionalized US population. After selection using a complex survey design, participants were interviewed and examined. The design of NHANES has been described previously.[9,12] Older individuals and Mexican American and black individuals were intentionally oversampled. Therefore, appropriate sample weights were used to obtain weighted regression estimates, and the final results of our analyses are generalizable to the US population.[9]

Audiometric Measures

For both of the NHANES cycles, audiometry was conducted in a dedicated sound-isolating room in the mobile examination center by trained examiners using a standardized protocol as provided by the National Center for Health Statistics.[9,13] The examiners were professionally trained by a certified audiologist from the National Institute for Occupational Safety and Health. The institute also conducted performance monitoring of each technician on a regular basis. Testing was conducted according to a modified Hughson Westlake procedure, a standard method of measuring pure-tone detection thresholds using a single stimulus of 1 to 2 seconds with the threshold set as the lowest level at which a listener detects 50% of the stimuli using the automated testing mode of the audiometer, except in cases where the hearing thresholds were greater than 100 dB, in which case those frequencies were tested manually.[9]

An audiometer was calibrated with the same specifications at the start and end of the testing at each field location. Air conduction thresholds were measured for each ear at 0.5, 1, 2, 3, 4, 6, and 8 kHz across an intensity range of −10 to 120 dB. The 1-kHz frequency was tested twice in each ear as a measure of the reliability of the participant's responses and the first test response was used in the analyses. Pure-tone audiograms were not accepted if there was a 10-dB or greater difference between the 1-kHz test-retest thresholds. Participants using hearing aids who were not able to remove them for testing, those who had sufficient ear pain at the time of the examination that they could not tolerate headphones, and those with cochlear implants were excluded from the audiometry component.

In some instances, if a pure-tone audiometric signal is sufficiently loud, it can "cross over" and be heard by the opposite ear via bone conduction. For the NHANES III cycle, if a participant had air-conduction threshold values at a given frequency that differed by 40 dB or more between ears, masking was performed to ensure accuracy in measurement. If present, the masked values were used for the analyses. For the 2005-2006 NHANES cycle, masking was not performed, but a crossover retesting protocol was performed whenever the observed threshold at any given frequency was poorer in one ear than the other by 25 dB at 0.5 kHz and 1 kHz, or by 40 dB at any higher frequency, to differentiate the true threshold of the test ear from an artifact of the nontesting ear. Retesting was accomplished using insert earphones, which are smaller and have less direct contact with the head. Thus, a much louder stimulus is required before crossover occurs.

Consistent with previous investigations of hearing in this age group, the low-frequency PTA (LPTA) was obtained by the average of air conduction pure-tone thresholds at 0.5, 1, and 2 kHz and the high-frequency PTA (HPTA) was obtained by the average of air conduction pure-tone thresholds at 3, 4, 6, and 8 kHz.[5] Low-frequency hearing loss was defined as LPTA greater than 15 dB in either ear, and high-frequency hearing loss was defined as HPTA greater than 15 dB in either ear. Any hearing loss was defined as LPTA or HPTA greater than 15 dB in either ear. Further, low-frequency and high-frequency hearing loss were characterized as either unilateral or bilateral, mutually exclusive categories. Consistent with previous literature, measures of hearing loss were more finely categorized according to the hearing sensitivity in the worse ear and defined as any (LPTA or HPTA >15 dB), slight (LPTA or HPTA >15 to <25 dB), and mild or worse (LPTA or HPTA ≥25 dB). These definitions have been used previously in studies of NHANES data.[5,6,14]

Noise-Induced Threshold Shift

A noise-induced threshold shift (NITS) was defined as an audiogram pattern that met all of the following 3 criteria for at least 1 ear: threshold values at 0.5 and 1 kHz were 15 dB or lower; the maximum threshold value at 3, 4, or 6 kHz was at least 15 dB higher than the highest threshold value for 0.5 and 1 kHz; and the threshold value at 8 kHz was more than 10 dB lower than the maximum threshold at a frequency of 3, 4, or 6 kHz.[6,15]

Demographic and Hearing-Related Covariates

Age was categorized as 12 to 13, 14 to 15, 16 to 17, and 18 to 19 years. Race/ethnicity was classified by the participants based on the options provided in the survey. Race/ethnicity was grouped as non-Hispanic black, non-Hispanic white, or Hispanic American (included responses of "Mexican American" or "other Hispanic"). The "other" race/ethnicity category was too small to be analyzed separately but was included in the overall estimates. Race/ethnicity was assessed in this study based on demonstrated associations with hearing loss in previous studies. The poverty-income ratio (PIR) was defined as the total family income divided by the poverty threshold, as determined by the US Census Bureau for the year of the interview. PIR values less than 1 were below the official poverty threshold, whereas PIR values of 1 or greater indicated income at or above the poverty level.[16] Participants were asked if they had ever had 3 or more ear infections. In NHANES 2005-2006, they

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were also asked if they had ever used firearms for target shooting, hunting, or any other purposes and if they had ever been exposed to steady loud noise or music for 5 or more hours in a week, either in a job or outside of a job. Responses were categorized into yes, no, and missing.

Statistical Analyses

We calculated the population prevalence with 95% confidence intervals (CIs) of the demographic variables for the NHANES III and NHANES 2005-2006 cycles. The prevalence of hearing loss (any, low-frequency, high-frequency, unilateral, and bilateral hearing loss of slight or mild or greater intensity) was calculated. Multivariate logistic regression was performed with age; sex; race/ethnicity; PIR; a history of 3 or more ear infections; and, for NHANES 2005-2006, a history of firearm use or loud noise exposure as covariates, and any, low-frequency, or high-frequency hearing loss as the outcome. The z statistic for comparison of proportions was used to compare hearing loss prevalence between the NHANES III and NHANES 2005-2006 cycles. All P values were 2-sided, and $P < .05$ was considered statistically significant. Data analysis was performed using SAS version 9.2 (SAS Institute, Cary, North Carolina). The SURVEYMEANS and SURVEYLOGISTIC procedures in SAS were used to account for the complex survey sampling design.

Protocols to recruit and study participants of NHANES III and 2005-2006 were reviewed and approved by the National Center for Health Statistics institutional review board. Written informed consent was obtained from all study participants. For all participants younger than 18 years, consent was obtained from the participant as well as a parent or guardian for interview and examination procedures. Results of examinations were provided to the individual participants or to the parents of child participants. In cases of abnormal results, the results were returned immediately and a physician referral was made.

Table 1. Demographic Characteristics of NHANES III (1988-1994) and NHANES 2005-2006 Populations of US 12- to 19-Year-Olds

	No. (%) [95% CI][a]	
	NHANES III (n = 2928)	NHANES 2005-2006 (n = 1771)
Age, y		
12-13	777 (25) [22-28]	417 (23) [20-27]
14-15	721 (26) [24-28]	436 (27) [24-29]
16-17	772 (26) [23-28]	466 (27) [24-30]
18-19	658 (23) [20-26]	452 (23) [18-27]
Race/ethnicity		
Non-Hispanic white	764 (66) [62-71]	453 (62) [55-69]
Non-Hispanic black	1023 (15) [13-18]	584 (14) [8-20]
Hispanic	1087 (14) [11-17]	581 (12) [9-14]
Other	54 (5) [3-7]	153 (12) [9-15]
Sex		
Male	1379 (51) [48-54]	877 (51) [47-54]
Female	1549 (49) [46-52]	894 (49) [46-53]
Poverty income ratio[b]		
≥1	1945 (80) [77-83]	1188 (79) [75-83]
<1	983 (20) [17-23]	583 (21) [17-25]
History of ≥3 ear infections		
No	2309 (55) [50-59]	1289 (61) [56-66]
Yes	610 (45) [40-49]	466 (38) [33-43]
History of firearm use		
No	NA	1466 (71) [66-76]
Yes	NA	303 (29) [24-33]
History of loud noise for ≥5 h/wk		
No	NA	1300 (71) [66-75]
Yes	NA	469 (29) [25-34]

Abbreviations: CI, confidence interval; NA, not available in that cycle; NHANES, National Health and Nutrition Examination Survey.

[a] Numbers are unweighted numbers of participants. Percentages are weighted to be nationally representative of the US population.

[b] Defined as total family income divided by poverty threshold, as determined by the US Census Bureau for the year of the interview. PIR values <1 were below the official poverty threshold, whereas PIR values ≥1 indicated income at or above the poverty level.

RESULTS

Of the 3211 12-to 19-year-old individuals who were eligible for audiometric evaluation in the NHANES III cycle, 283 were excluded because of an incomplete examination, missing values at 1 or more audiometric frequencies, or a 10-dB or greater difference between the 1-kHz test-retest thresholds; thus, 2928 participants (91%) were available for analysis. Of the 2288 12-to 19-year-old individuals who were eligible for audiometric testing in the 2005-2006 NHANES cycle, 517 were excluded because of an incomplete examination, missing frequency values, or 10-dB or greater difference between the 1-kHz test-retest thresholds; thus, 1771 participants (77%) were available for analysis. In both survey cycles, participants with incomplete data did not differ by age, sex, race/ethnicity, or PIR from participants with complete data.

Characteristics of US adolescents in NHANES III and NHANES 2005-2006 are shown in Table 1. No significant differences were observed between the 2 time periods for age, race/ethnicity, sex, and PIR. A history of 3 or more ear infections was slightly more common in NHANES III.

The prevalence of hearing loss in US adolescents based on NHANES III and 2005-2006 is shown in Table 2. The prevalence of any hearing loss (unilateral or bilateral LPTA or HPTA >15 dB) among 12- to 19-year olds was 14.9% (95% CI, 13.0%-16.9%) in 1988-1994 and 19.5% (95% CI, 15.2%-23.8%) (approximately 6.5 million individuals) in 2005-2006. This represents a 31% in-

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crease in the prevalence of hearing loss over this time ($P=.02$). The prevalence of any unilateral hearing loss was 11.1% (95% CI, 9.5%-12.8%) in 1988-1994 and 14.0% (95% CI, 10.4%-17.6%) in 2005-2006 ($P=.005$), and any bilateral hearing loss was 3.8% (95% CI, 2.6%-4.9%) in 1988-1994 and 5.5% (95% CI, 3.9%-7.1%) in 2005-2006 ($P=.003$). Any high-frequency hearing loss (prevalence, 12.8%; 95% CI, 11.1%-14.5% in 1988-1994; prevalence, 16.4%; 95% CI, 13.2%-19.7% in 2005-2006) was more common than any low-frequency hearing loss (prevalence, 6.1%; 95% CI, 4.5%-7.6% in 1988-1994; prevalence, 9.0%; 95% CI, 5.6%-12.5% in 2005-2006) in both survey cycles. The prevalence of high-frequency hearing loss was significantly higher in NHANES 2005-2006 than in NHANES III ($P=.02$), but the prevalence of low-frequency hearing loss was not ($P=.07$). Slight hearing loss occurred in 11.4% (95% CI, 9.7%-13.1%) in 1988-1994 and 14.2% (95% CI, 10.6%-17.8%) in 2005-2006, and mild or worse hearing loss in 3.5% (95% CI, 2.5%-4.5%) in 1988-1994 and 5.3% (95% CI, 3.6%-6.9%) in 2005-2006. The prevalence of mild or worse hearing loss was significantly higher ($P<.001$) in NHANES 2005-2006 than in the 1988-1994 cycle, representing a 77% increase. There was no change in the prevalence of NITS (16.2%; 95% CI, 13.9%-18.6% in 1998-1994; 16.4%; 95% CI, 13.1%-20.0% in 2005-2006; $P=.09$).

The multivariate-adjusted prevalence odds ratios (ORs) for risk of hearing loss according to participant characteristics are summarized in **Table 3**. The prevalence of hearing loss did not significantly differ by age or race/ethnicity in either the 1988-1994 or the 2005-2006 time period. Females (prevalence, 17.1%; 95% CI, 12.2%-22.1%) were significantly less likely than males (prevalence, 21.8%; 95% CI, 17.0%-26.6%) to demonstrate any hearing loss (OR, 0.76; 95% CI, 0.59-0.97) in 2005-2006 and were significantly less likely (prevalence, 10.1%; 95% CI, 7.4%-12.9%) than males (prevalence, 15.3%; 95% CI, 12.5%-18.0%) to demonstrate high-frequency hearing loss in 1988-1994 (OR, 0.61; 95% CI, 0.42-0.90). A PIR of less than 1 (prevalence, 23.6%; 95% CI, 18.5%-28.7%) was significantly associated with increased odds of any hearing loss as compared with a PIR of 1 or more (prevalence, 18.4%; 95% CI, 13.6%-23.2%; OR, 1.60; 95% CI, 1.10-2.32) in 2005-2006, but there was no significant association between PIR and hearing loss in 1988-1994. In 1988-1994, a history of 3 or more ear infections (prevalence, 18.9%; 95% CI, 13.3%-24.6%) was significantly associated with increased odds of any hearing loss (OR, 1.75; 95% CI, 1.09-2.81) as compared with fewer than 3 ear infections (prevalence, 13.3%; 95% CI, 11.2%-15.5%). Histories of 3 or more ear infections (prevalence, 23.7% vs 17.0%; OR, 1.53; 95% CI, 0.87-2.70), firearm use (prevalence, 21.6% vs 18.7%; OR, 1.07; 95% CI, 0.72-1.59), and loud noise exposure for 5 or more hours in a week (prevalence, 20.8% vs 19.0%; OR, 1.01; 95% CI, 0.64-1.61) were not significantly associated with any hearing loss in 2005-2006.

Table 2. Hearing Loss Prevalence in US Adolescents Aged 12 to 19 Years, NHANES III (1988-1994) and NHANES 2005-2006

	No. (Prevalence, %) [95% CI] by Hearing Threshold (HL Severity)[a]		
	>15 dB (Slight or Worse)	>15 to <25 dB (Slight)[b]	≥25 dB (Mild or Worse)
NHANES III			
Any HL[c]	480 (14.9) [13.0-16.9]	360 (11.4) [9.7-13.1]	120 (3.5) [2.5-4.5]
Any high-frequency HL	423 (12.8) [11.1-14.5]	339 (10.1) [8.5-11.6]	84 (2.7) [1.7-3.7]
Any low-frequency HL	186 (6.1) [4.5-7.6]	151 (5.2) [3.9-6.5]	35 (0.9) [0.1-1.7]
Unilateral HL	335 (11.1) [9.5-12.8]	278 (9.3) [7.9-10.7]	57 (1.8) [0.9-2.8]
Unilateral high-frequency HL	304 (9.6) [8.1-11.2]	245 (7.7) [6.4-9.1]	59 (1.9) [0.9-2.8]
Unilateral low-frequency HL	140 (5.0) [3.4-6.4]	113 (4.3) [3.0-5.5]	27 (0.7) [0.0-1.4]
Bilateral HL	145 (3.8) [2.6-4.9]	120 (2.9) [2.0-3.8]	25 (0.8) [0.3-1.4]
Bilateral high-frequency HL	119 (3.2) [2.2-4.1]	94 (2.3) [1.6-3.0]	25 (0.8) [0.3-1.4]
Bilateral low-frequency HL	46 (1.1) [0.6-1.7]	38 (0.9) [0.4-1.4]	8 (0.2) [0.0-0.5]
NHANES 2005-2006			
Any HL[c]	333 (19.5) [15.2-23.8]	239 (14.2) [10.6-17.8]	94 (5.3) [3.6-6.9]
Any high-frequency HL	279 (16.4) [13.2-19.7]	219 (11.7) [9.4-14.1]	60 (4.7) [3.3-6.1]
Any low-frequency HL	155 (9.0) [5.6-12.5]	126 (6.5) [3.5-9.4]	29 (2.5) [1.4-3.7]
Unilateral HL	234 (14.0) [10.4-17.6]	191 (11.3) [8.2-14.5]	43 (2.7) [1.4-3.9]
Unilateral high-frequency HL	209 (12.6) [9.9-15.3]	167 (9.8) [7.8-11.8]	42 (2.8) [1.7-3.9]
Unilateral low-frequency HL	113 (6.8) [3.8-9.8]	90 (5.3) [2.7-8.0]	23 (1.5) [0.6-2.3]
Bilateral HL	99 (5.5) [3.9-7.1]	80 (4.7) [3.5-5.8]	19 (0.8) [0.1-1.5]
Bilateral high-frequency HL	70 (3.8) [2.5-5.1]	52 (3.0) [2.1-3.9]	18 (0.8) [0.1-1.5]
Bilateral low-frequency HL	42 (2.2) [1.5-3.0]	36 (2.0) [1.4-2.7]	6 (0.2) [0.0-0.5]

Abbreviations: CI, confidence interval; HL, hearing loss; NHANES, National Health and Nutrition Examination Survey.
[a] Numbers are unweighted numbers of participants. All prevalence percentages are weighted to be nationally representative of the US population.
[b] The slight HL values for the bilateral HL rows include individuals with slight HL in one ear and mild HL in the other ear.
[c] Includes unilateral or bilateral hearing loss at either low or high frequency.

COMMENT

In the 2005-2006 NHANES, 1 in 5 US adolescents 12 to 19 years old demonstrated hearing loss. Compared with results from the 1988-1994 NHANES III, this constitutes a one-third increase in the prevalence of hearing loss. The majority of the hearing loss was slight. However, the prevalence of any hearing loss 25 dB or greater increased significantly from 3.5% to 5.3%, indicating that 1 in 20 children in this age group have mild or worse hearing loss. High-frequency hearing loss was more common than low-frequency loss, and most cases were unilateral. Although the finding that the majority of cases of hearing loss were unilateral was consistent with past literature,[5] the reasons for this are unknown. Interval factors between surveys, such as vaccination against *Haemophilus influ-*

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enzae and *Streptococcus pneumoniae*, as well as greater awareness of music-induced hearing loss, may have led to the expectation of no change or a reduction in the prevalence of hearing loss, but this was not observed.

Definitions of hearing loss, a continuous variable, have not been standardized among all investigators,[17] and previous studies have employed maximal threshold levels that range from 15 dB to 25 dB to define normal hearing.[5,14] Moreover, the definitions of low- and high-frequency ranges have varied, with some controversy as to the placement of the 2-kHz frequency in the low- vs high-frequency category. However, the 2-kHz frequency has been in-

Table 3. Multivariate Analyses of Potential Risk Factors for Hearing Loss in US 12 to 19-Year-Olds, NHANES III (1988-1994) and 2005-2006[a]

	Any HL			High-Frequency HL			Low-Frequency HL		
	No.[b]	Prevalence, % (95% CI)[c]	Multivariate OR (95% CI)	No.[b]	Prevalence, % (95% CI)[c]	Multivariate OR (95% CI)	No.[b]	Prevalence, % (95% CI)[c]	Multivariate OR (95% CI)
NHANES III									
Age, y									
12-13	124	16.0 (11.5-20.5)	1 [Reference]	117	14.9 (10.5-19.2)	1 [Reference]	42	7.0 (4.0-10.0)	1 [Reference]
14-15	115	13.7 (9.4-18.0)	0.90 (0.53-1.53)	100	10.5 (6.6-14.4)	0.72 (0.40-1.30)	52	6.2 (3.3-9.2)	0.91 (0.45-1.84)
16-17	120	14.9 (11.5-18.3)	1.12 (0.72-1.75)	103	12.6 (9.5-15.7)	0.99 (0.63-1.57)	46	5.6 (2.7-8.4)	0.97 (0.48-1.97)
18-19	121	15.2 (10.7-19.6)	1.30 (0.78-2.17)	103	13.3 (10.7-17.5)	1.18 (0.69-2.01)	46	5.4 (3.0-7.7)	1.13 (0.59-2.16)
Race/ethnicity									
Non-Hispanic white	115	15.1 (12.3-18.1)	1 [Reference]	95	12.6 (10.2-15.0)	1 [Reference]	50	6.6 (4.4-8.8)	1 [Reference]
Non-Hispanic black	147	13.7 (11.5-15.9)	0.95 (0.71-1.27)	130	12.1 (9.8-14.5)	0.98 (0.71-1.35)	51	4.7 (3.3-6.1)	0.77 (0.51-1.18)
Hispanic	212	16.2 (12.0-20.5)	1.12 (0.76-1.65)	192	14.7 (10.9-18.5)	1.19 (0.81-1.73)	83	6.0 (3.5-8.5)	0.94 (0.56-1.58)
Sex									
Male	260	16.9 (13.8-19.8)	1 [Reference]	238	15.3 (12.5-18.0)	1 [Reference]	86	5.4 (3.5-7.2)	1 [Reference]
Female	220	12.9 (9.6-16.1)	0.71 (0.49-1.04)	185	10.1 (7.4-12.9)	0.61 (0.42-0.90)	100	6.8 (4.2-9.4)	1.27 (0.74-2.18)
Poverty income ratio[d]									
≥1	291	14.6 (12.2-16.9)	1 [Reference]	253	12.2 (10.2-14.3)	1 [Reference]	111	6.0 (4.1-7.8)	1 [Reference]
<1	189	16.2 (12.6-19.9)	1.24 (0.88-1.73)	170	15.0 (11.6-18.4)	1.37 (0.97-1.93)	75	6.4 (3.8-9.0)	1.23 (0.73-2.06)
History of ≥3 ear infections									
No	359	13.3 (11.2-15.5)	1 [Reference]	320	11.7 (9.5-13.8)	1 [Reference]	131	4.8 (3.6-6.0)	1 [Reference]
Yes	120	18.9 (13.3-24.6)	1.75 (1.09-2.81)	102	15.7 (10.8-20.5)	1.66 (1.01-2.74)	54	9.2 (5.0-13.4)	2.04 (1.21-3.42)
NHANES 2005-2006									
Age, y									
12-13	79	16.0 (8.6-23.5)	1 [Reference]	64	12.9 (6.9-18.8)	1 [Reference]	38	7.3 (1.3-13.2)	1 [Reference]
14-15	78	20.1 (12.6-27.5)	1.30 (0.70-2.41)	67	18.2 (11.4-25.1)	1.47 (0.75-2.86)	39	9.9 (4.8-15.0)	1.40 (0.60-3.27)
16-17	93	21.5 (15.1-27.8)	1.45 (0.97-2.17)	81	17.7 (12.9-22.5)	1.42 (0.85-2.36)	34	8.1 (3.3-12.9)	1.16 (0.71-1.91)
18-19	83	20.1 (15.4-24.7)	1.28 (0.86-1.92)	67	16.5 (12.3-20.6)	1.23 (0.91-1.68)	44	10.9 (6.7-15.2)	1.62 (0.76-3.44)
Race/ethnicity									
Non-Hispanic white	97	21.2 (15.0-27.4)	1 [Reference]	81	17.6 (13.0-22.3)	1 [Reference]	46	9.9 (4.7-15.1)	1 [Reference]
Non-Hispanic black	122	20.8 (15.1-26.5)	1.00 (0.65-1.55)	101	17.2 (11.6-22.8)	1.04 (0.66-1.64)	56	9.5 (6.0-12.1)	0.91 (0.46-1.29)
Hispanic	98	17.2 (13.8-20.5)	0.78 (0.51-1.20)	84	14.8 (11.1-18.5)	0.85 (0.55-1.29)	45	8.0 (5.3-10.5)	0.77 (0.56-1.29)
Sex									
Male	184	21.8 (17.0-26.6)	1 [Reference]	160	19.4 (15.2-23.6)	1 [Reference]	79	8.8 (6.0-11.7)	1 [Reference]
Female	149	17.1 (12.2-22.1)	0.76 (0.59-0.97)	119	13.4 (10.1-16.6)	0.67 (0.52-0.87)	76	9.2 (4.2-14.2)	1.02 (0.60-1.73)
Poverty income ratio[d]									
≥1	212	18.4 (13.6-23.2)	1 [Reference]	181	15.7 (11.7-19.8)	1 [Reference]	96	8.5 (4.9-12.1)	1 [Reference]
<1	121	23.6 (18.5-28.7)	1.60 (1.10-2.32)	98	19.1 (13.5-24.6)	1.43 (0.87-2.36)	59	11.1 (6.5-15.7)	1.50 (0.94-2.41)
History of ≥3 ear infections									
No	212	17.0 (12.3-21.8)	1 [Reference]	177	14.9 (10.7-19.0)	1 [Reference]	97	7.5 (4.1-9.5)	1 [Reference]
Yes	118	23.7 (15.5-32.0)	1.53 (0.87-2.70)	99	19.2 (12.5-25.8)	1.36 (0.75-2.47)	61	11.5 (5.6-17.4)	1.64 (0.89-3.02)
History of firearm use									
No	272	18.7 (14.2-23.2)	1 [Reference]	224	15.1 (12.0-18.2)	1 [Reference]	128	9.3 (5.4-13.2)	1 [Reference]
Yes	60	21.6 (15.0-28.1)	1.07 (0.72-1.59)	54	19.7 (13.9-25.6)	1.17 (0.78-1.76)	26	8.5 (4.1-12.8)	0.85 (0.43-1.69)
History of loud noise ≥5 h/wk									
No	245	19.0 (13.7-24.2)	1 [Reference]	201	15.4 (11.8-18.9)	1 [Reference]	115	9.1 (4.4-13.7)	1 [Reference]
Yes	87	20.8 (14.8-26.7)	1.01 (0.64-1.61)	77	18.9 (13.2-24.6)	1.15 (0.73-1.80)	39	8.9 (5.2-12.6)	0.94 (0.46-1.93)

Abbreviations: CI, confidence interval; HL, hearing loss; NHANES, National Health and Nutrition Examination Survey; OR, odds ratio.

[a] Hearing loss includes unilateral or bilateral HL at either low or high frequency. NHANES III data were adjusted for age, race/ethnicity, sex, povertyincome ratio, history of ≥3 ear infections; NHANES 2005-2006 data were adjusted for age; race/ethnicity; sex; poverty income ratio; and history of ≥3 ear infections, firearm use, and loud noise for ≥5 h per week.

[b] All numbers represent unweighted numbers of participants.

[c] All prevalence values are weighted to be nationally representative of the US population.

[d] Defined as total family income divided by poverty threshold, as determined by the US Census Bureau for the year of the interview. Poverty income ratio values <1 were below the official poverty threshold, whereas values ≥1 indicated income at or above the poverty level.

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cluded in the low-frequency category and the 15-dB threshold has been used more consistently to define hearing loss in studies of children and young adults.[5,6,10] In this study, the significant increase in prevalence of hearing loss defined by thresholds greater than 15 dB and 25 dB or greater between 1988-1994 and 2005-2006, based on consistent definitions of hearing loss, demonstrates an overall worsening of hearing in this age group.

In the 2005-2006 NHANES, females had significantly lower odds of having any or high-frequency hearing loss than males. In addition, participants reporting a PIR of less than 1 had significantly increased odds of any hearing loss in NHANES 2005-2006 but not in NHANES III.[5] The association with income is consistent with past literature,[5,14] yet the mechanisms are unclear. A study in Peru found that school-aged children living in poverty were 4 to 7 times more likely to have hearing loss than children living in higher-income countries.[18] Although the authors suggested a major risk factor was untreated middle ear disease in the context of limited access to pediatric health care, we adjusted for history of multiple ear infections; thus, this is unlikely to explain our findings. Because much hearing loss is genetic, the role of parental hearing loss leading to poverty is possible, but we do not have data on the parents.

In younger age groups, even a slight change in the hearing threshold can impair learning and speech understanding.[19] Hearing loss in school-aged individuals can affect learning, speech perception, social skill development, and self-image.[20] In a study of 1218 third-, sixth-, and ninth-grade students, slight or worse hearing loss (defined as ≥20 dB) was associated with lower scores on communication tests, decreased self-esteem, and increased stress.[10] In addition, 37% of children with hearing loss were reported to have repeated at least 1 grade.[10] Given that children living in impoverished neighborhoods have been shown to have lower school performance,[21] the higher prevalence of hearing loss in participants living below the national poverty level observed in 2005-2006 places a further burden on this already vulnerable group.

Our study did not find a difference in estimated noise exposure between the 2 time periods or a significant association between self-reported noise exposure and hearing loss in 2005-2006. However, adolescents and young adults typically underestimate symptoms of loud sound, tinnitus, and temporary hearing impairment during music exposure and underreport concern for these conditions.[8,22] The prevalence of NITS, a purported marker of noise exposure, was 16.4% (95% CI, 13.1%-20.0%) in 2005-2006 NHANES, similar to that found in the earlier cycle. In adults, characterization of NITS using audiometric noise notches defined similarly to this study was poorly associated with noise exposure.[23] Alternatively, a higher PTA in the high-frequency range of hearing has been associated with loud noise exposure[14,24] and may be a more reliable marker of noise-induced hearing loss. Possibly, the finding of a significant increase in high-frequency hearing loss between the 1988-1994 and 2005-2006 time periods may indicate an increase in noise-induced hearing loss. Intriguingly, a recent cross-sectional study of children with slight to mild hearing loss in Australia found that reported use of personal stereo devices was associated with a 70% increased risk of hearing loss.[25] The effects of noise exposure on hearing loss in adolescents deserve further study.

The strengths and limitations of this study should be considered. Data from NHANES are comprehensive and nationally representative, drawing from a large and diverse sample of participants. The NHANES audiometric assessment of hearing loss is the gold standard objective measure and has been shown to be reliable in numerous studies.[5,14,26] Although the 1988-1994 and 2005-2006 NHANES study periods sampled 2 distinct groups of individuals, consistency was maintained in the methods of participant selection and hearing loss assessment. There was a minor difference in the treatment of crossover between the 2 surveys. Although masking was performed in NHANES III and not in NHANES 2005-2006, the 2005-2006 survey employed a crossover protocol to account for interference by the nontesting ear. The prevalence of hearing loss may be underestimated because children whose hearing aids could not be removed, who could not tolerate earphones, or who had cochlear implants were not tested. Also, due to the cross-sectional methodology of this study, causality with respect to risk factors for hearing loss cannot be examined. In NHANES III, the children's ears were not examined, nor were additional tests such as bone conduction performed, so causes of conductive hearing loss, such as wax or otitis media, cannot be excluded.

CONCLUSIONS

The prevalence of hearing loss among a sample of US adolescents aged 12 to 19 years was greater in 2005-2006 compared with 1988-1994. Further studies are needed to determine reasons for this increase and to identify potential modifiable risk factors to prevent the development of hearing loss.

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Acquisition of data: Shargorodsky.
Analysis and interpretation of data: Shargorodsky, S. G. Curhan, G. C. Curhan, Eavey.
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