Trends in Hearing Loss Among Adolescents

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abstract

OBJECTIVES: Our aim with this article is to evaluate whether the prevalence of hearing loss is increasing among adolescents living in the United States.

METHODS: All available data about hearing loss among adolescents from the large, federally funded National Health and Nutrition Examination Survey (NHANES) were analyzed. By using the 4 data releases between 1994 and 2010 (a total of 6891 adolescents), the prevalence of adolescent hearing loss >15 and ≥25 dB at low frequencies (0.5, 1, and 2 kHz) and high frequencies (3, 4, 6, and 8 kHz) for bilateral, unilateral, and any loss were calculated.

RESULTS: Only 13 of 90 comparisons of prevalence across combinations of degree, frequency, and laterality of hearing loss revealed a statistically significant increase at $P < .05$. Among the 18 subgroups of degree, frequency, and laterality, 61% had a lower prevalence of hearing loss in 2010 than in 1994, and 100% of the subgroups had a lower prevalence in 2010 than in 2006.

CONCLUSIONS: With previous analyses of NHANES data from 1994 to 2006, researchers showed that hearing loss among US adolescents was increasing. Based on the NHANES data from 1994 to 2010 that are now available, there is no consistent evidence that hearing loss among adolescents in the United States is increasing. Results reveal that conclusions about trends using data from 2 time points can be misleading. NHANES should resume collecting audiometric data as part of their data collection protocol so that trends in the prevalence of childhood hearing loss can be documented.

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WHAT'S KNOWN ON THIS SUBJECT: Previous researchers have concluded that the prevalence of adolescent hearing loss increased by >30% from 1994 to 2006. However, this conclusion was based on only 2 time points and needs to be assessed further.

WHAT THIS STUDY ADDS: The conclusion from an earlier study that the prevalence of adolescent hearing loss is increasing is not substantiated when more recent data are included. Because the original article is frequently cited, this article presents essential information for clinicians and policymakers.

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Hearing loss often has negative effects on the psychosocial health of a child, including performance in school, social engagement, language development, and self-esteem.[1–5] This is even true for children and adolescents with a mild hearing loss, regardless of whether that loss is unilateral or bilateral.[6–10] Congenital hearing loss is one of the most common conditions for which screening is done at birth.[5,11] Given that hearing loss is relatively common, the findings of Shargorodsky et al[12] in 2010 that adolescent hearing loss had increased by >30% over an 8-year span (1994–2006) were concerning. Their analyses considered both the level (in dBs) and the frequency (low frequency at 0.5, 1, and 2 kHz and high frequency at 4, 6, and 8 kHz) of hearing loss at >15 and ≥25 dB for adolescents aged 12 to 19 years. Their report has been frequently cited and has important implications for policy and clinical practice. The conclusions were based on data released by the National Health and Nutrition Examination Survey (NHANES)[13] at the 2 available time points in 1994 and 2006. These data were all that were available from NHANES at the time Shargorodsky et al[12] did their analyses about the prevalence of adolescent hearing loss.

TABLE 1 Demographics of the Samples by Year of Data Release

	Year			
	1994	2006	2008	2010
	n = 2906	*n* = 1806	*n* = 1037	*n* = 1142
Age				
12–13	771 (26.5)	432 (23.9)	232 (22.4)	268 (23.5)
14–15	717 (24.7)	439 (24.3)	276 (26.6)	289 (25.3)
16–17	763 (26.3)	472 (26.1)	275 (26.5)	321 (28.1)
18–19	655 (22.5)	463 (25.6)	254 (24.5)	264 (23.1)
Race				
White	1020 (35.1)	594 (32.9)	279 (26.9)	248 (21.7)
African American	982 (33.8)	596 (33.0)	249 (24.0)	313 (27.4)
Mexican American	150 (5.2)	153 (8.5)	184 (17.7)	204 (17.9)
Other	754 (25.9)	463 (25.6)	325 (31.3)	377 (33.0)
Sex				
Male	1535 (52.8)	916 (50.7)	490 (47.3)	525 (46.0)
Female	1371 (47.2)	890 (49.3)	547 (52.7)	617 (54.0)

Data are presented as *n* (%).

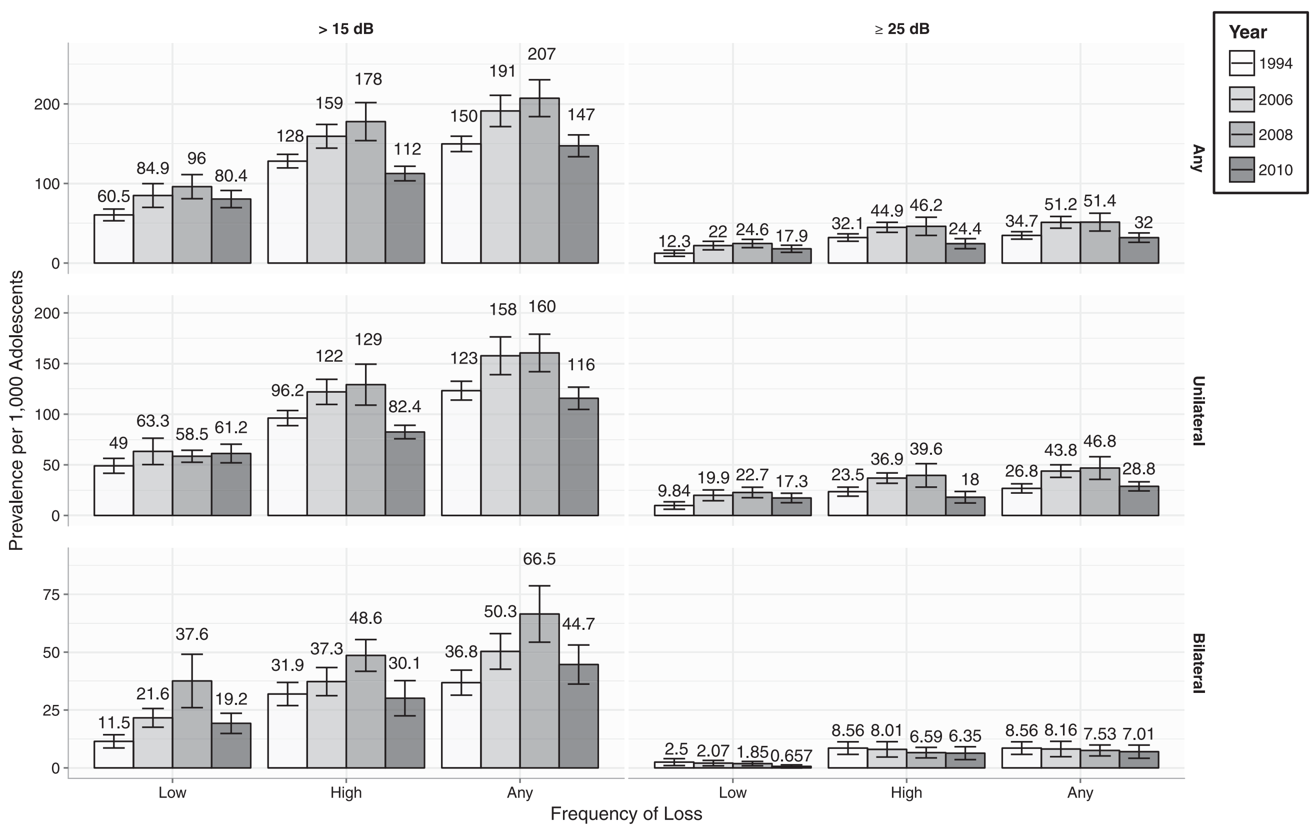

FIGURE 1
Hearing loss per 1000 adolescents. LPTA is the average threshold at 0.5, 1, and 2 kHz; HPTA is the average threshold at 3, 4, 6, and 8 kHz. Values shown are the number per 1000 adolescents that had hearing loss at the specified degree, frequency, and laterality (the horizontal bars show 1 SE greater than and less than the mean).

Of the nationally representative data sets that can be used to estimate the prevalence of hearing loss among adolescents, NHANES is the only large national data set that measures hearing loss with audiometry examination.[11,14,15] The others, including the National Health Interview Survey[16] and the National Survey of Children's Health,[17] use parent- or self-report, which may not be as reliable or accurate. Because the audiometrically measured hearing loss is the gold standard, the results from Shargorodsky et al[12] provided important information about adolescent hearing loss given the data that were available at that time. But now that more data are available, further evaluation is warranted.

Data releases from NHANES in 2008 and 2010 are now available and included data about audiometrically measured adolescent hearing loss that were collected in the same way as the data that were used by Shargorodsky et al[12] in their earlier report. To better examine the prevalence of hearing loss among adolescents, we extended the analyses by Shargorodsky et al[12] to include the next 2 releases of NHANES data. Having results over more time periods enabled us to be more confident about our conclusions and provides better information to inform pediatricians and other health care providers working with adolescents as well as other researchers about the most recent evidence regarding the prevalence and trend of adolescent hearing loss.

METHODS

Study Population

Shargorodsky et al[12] provided details about the participant selection, audiometry testing procedures, and analyses for participants aged 12 to 19 years. We replicated these procedures for 1994 (n = 2906) and 2006 (n = 1806) as well as the additional data in 2008 (n = 1037) and 2010 (n = 1142). The number of observations for each year already reflects the removal of 1047 adolescents (13.2%) because of missing data or faulty audiometry examination as defined by Shargorodsky et al.[12] Although we used the same exclusion criteria reported by Shargorodsky et al,[12] their sample sizes after exclusion were slightly different from ours (2928 in 1994 and 1771 in 2006). The average discrepancy in samples size used for our prevalence estimates compared with the earlier estimates was small (mean difference = 2.2 children per 1000 for the 1994 release and 0.8 children per 1000 for the 2006 release), with most differences within 1 child per 1000. With such small differences, the results were likely unaffected in any meaningful way. Importantly, our conclusions for data from the same time periods were identical. In Table 1, we present age, race, and sex by the year of the sample used in our analyses. Shargorodsky et al[12] included more demographic characteristics for the purpose of assessing risk factors. Because the focus of our analyses is to examine the trend of hearing loss rather than to assess the predictive value of risk factors, in Table 1, we do not include data about all the variables included by Shargorodsky et al.[12]

It is important to note that the data in the sample used for these analyses are weighted so that data from each year are nationally representative of major demographic characteristics. The same weighting procedures were used by Shargorodsky et al,[12] as noted in their article: "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…. 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."

Audiometric Measures

Similar to other analyses of the NHANES audiometric data,[14,15] Shargorodsky et al[12] examined both low-frequency pure-tone averages (LPTAs) (0.5, 1, and 2 kHz) and high-frequency pure-tone averages (HPTAs) (3, 4, 6, and 8 kHz) . Definitions of hearing loss used in our analyses were the same as those used by Shargorodsky et al[12]: "Low-frequency hearing loss 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)...and mild or worse (LPTA or HPTA ≥25 dB)."

Statistical Analyses

Sample counts and proportions were compared for each data release by age, race, and sex. Descriptive statistics for the years across laterality (unilateral, bilateral, or any hearing loss), frequency (high, low, or any), and degree of loss (>15 or ≥25 dB) were computed, accounting for the weighting and clustering of the sample. For simplicity of comparison, these statistics are presented graphically in Fig 1. Additionally, comparisons of prevalence across

TABLE 2 Results of the 18 Design-Based Simple Logistic Regressions for 1994 Through 2010 in Log Odds Units (SE in Log Odds)

	LPTA			HPTA			Any Frequency		
	Any	Bilateral	Unilateral	Any	Bilateral	Unilateral	Any	Bilateral	Unilateral
Threshold >15 dB									
1994	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
2006	0.365	0.645*	0.270	0.255	0.161	0.267	0.294*	0.326	0.287
	(0.227)	(0.323)	(0.261)	(0.135)	(0.234)	(0.150)	(0.145)	(0.222)	(0.165)
2008	0.501**	1.213**	0.186	0.386*	0.437*	0.332	0.394*	0.622*	0.308
	(0.217)	(0.407)	(0.191)	(0.180)	(0.219)	(0.199)	(0.160)	(0.249)	(0.162)
2010	0.306	0.526	0.234	−0.148	−0.061	−0.170	−0.019	0.201	−0.072
	(0.195)	(0.342)	(0.225)	(0.120)	(0.307)	(0.123)	(0.133)	(0.250)	(0.138)
Threshold ≥25 dB									
1994	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
2006	0.585	(0.192)	0.714	0.350	−0.067	0.465	0.405	−0.048	0.511*
	(0.400)	(0.820)	(0.457)	(0.221)	(0.472)	(0.257)	(0.218)	(0.467)	(0.244)
2008	0.700	−0.303	0.849	0.379	−0.263	0.537	0.410	−0.128	0.581
	(0.385)	(0.785)	(0.444)	(0.300)	(0.473)	(0.361)	(0.269)	(0.450)	(0.305)
2010	0.379	−1.340	0.570	−0.282	−0.300	−0.271	−0.086	−0.201	0.074
	(0.408)	(1.171)	(0.468)	(0.305)	(0.545)	(0.375)	(0.236)	(0.520)	(0.237)

Positive values represent increasing odds of hearing loss, negative values represent decreasing odds hearing loss, and 0 represents no change in hearing loss. The constant in each model is not shown. $N = 6891$ for each model.
* Shows statistical significance at $P < .05$; ** shows statistical significance at $P < .01$.

years were tested by frequency and laterality for both >15 and ≥25 dB. The year variable was treated categorically with 4 levels and 1994 as the reference year, allowing direct comparisons across years without assuming a linear (or quadratic) trend. Post hoc linear contrasts were used to provide comparisons of consecutive year pairs (2006 with 2008, 2008 with 2010). Each of the comparisons were tested via design-based logistic regression, accounting for the weighting and clustering of the sample, thus making the estimates nationally representative. The analyses were conducted in R version 3.3.2 by using the "survey" package. The data and code used for all analyses are available at https://osf.io/w5t2f.

RESULTS

In Table 1, we show demographic characteristics of the sample by year of the data release. Any differences in proportion are not important for our purposes because in our analyses, we used the sample weights, which make the estimates nationally representative of noninstitutionalized US citizens across these characteristics.

The estimates of adolescent hearing loss at >15 and ≥25 dB per 1000 adolescents across laterality and frequency are presented in Fig 1. With the first 2 time periods (1994 and 2006) at >15 and ≥25 dB, we show results similar to those presented by Shargorodsky et al.[12] On the basis of the 1994 and 2006 data only, it could be concluded that adolescent hearing loss did increase. However, when data from 2008 and 2010 were included, the best conclusion is that adolescent hearing loss is not increasing.

Several different patterns emerge when data from all 4 data releases are analyzed. First, most categories

TABLE 3 Results of the Linear Contrasts of Consecutive Year Pairs (2006 With 2008 and 2008 With 2010)

	LPTA						HPTA						Any Frequency					
	Any		Bilateral		Unilateral		Any		Bilateral		Unilateral		Any		Bilateral		Unilateral	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Threshold >15 dB																		
χ^2	0.272	0.73	0.12	0.926	2.341	3.047	0.021	0.841	0.119	0.063	0.143	0.598	0.443	8.112	0.009	3.175	1.509	2.763
P	.602	.393	.729	.336	.126	.081	.884	.359	.731	.802	.706	.439	.506	.004	.923	.075	.219	.096
Threshold ≥25 dB																		
χ^2	0.13	0.004	0.092	6.282	0.046	3.347	0.28	5.384	0	2.76	1.357	2.284	0.024	0.019	0.011	4.715	0.057	2.892
P	.719	.947	.762	.012	.83	.067	.597	.02	.986	.097	.244	.131	.877	.889	.915	.03	.811	.089

Model = 1 is comparing 2006 with 2008 values; Model = 2 is comparing 2008 with 2010. The χ^2 tests have 1 degree of freedom.

show the same initial increase and subsequent decrease in prevalence (see for example the results for >15 dB across all categories). This pattern is weaker for hearing loss ≥25 dB than for >15 dB. Second, the prevalence in 2010 is nearly equivalent to that of 1994 (there were no statistically significant differences in the prevalence from 1994 to 2010; see below). Third, there is a high degree of variability for hearing loss >15 dB, especially in later years. Fourth, consistent with what Shargorodsky et al[12] reported, unilateral hearing loss has a much higher prevalence than bilateral hearing loss.

These descriptive observations are supported by the yearly comparisons tested via design-based logistic regression. The results (the estimates and SEs) are presented in Table 2 in log odds units, thereby indicating the direction of the trend. The reference year was 1994, with all other years being compared with that year. Most comparisons were not statistically significantly different from 0, indicating no increase or decrease in the prevalence of hearing loss compared with 1994. Only 7 of the 18 models revealed a statistically significant trend, with most of the statistically significant differences between 1994 and 2008. The other 11 models revealed no statistically significant differences across years.

Of the 9 total statistically significant differences, 6 were between 1994 and 2008, each with log odds >0.38 (odds ratio of 1.46 or higher). This is visually apparent in Fig 1, in which 2008 is generally higher (and statistically significantly so in many instances) for hearing loss at >15 dB. There was only a single statistically significant difference at $P < .05$ in hearing loss at the >25 dB level (ie, unilateral at any frequency), although given the low incidence rate, this may be due to low power, even with a large sample.

In addition, linear contrasts were used to compare 2006 with 2008 and 2008 with 2010 (see Table 3). Only 4 of the 36 comparisons were statistically significantly different at $P < .05$ for any combination of laterality, frequency, and degree of hearing loss. Again, this is approximately what is expected by chance. These results suggest that there were no consistent changes in biyearly prevalence from 2006 to 2010.

DISCUSSION

By using NHANES data only from 1994 and 2006, Shargorodsky et al[12] concluded that hearing loss >15 dB among adolescents in the United States had increased by 31% and that any hearing loss ≥25 dB had increased by 51%. Their conclusion that "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" was based on the best evidence given the data available at the time. However, now that additional NHANES data for later time periods are available, a better conclusion is that hearing loss among adolescents is not systematically increasing. Of the 18 combinations of laterality (unilateral, bilateral, or any hearing loss), frequency (HPTA or LPTA), and degree of loss (>15 or ≥25 dB), examined over 4 data collection periods released by NHANES from 1994 to 2010, only 13 of the 90 comparisons showed a statistically significant increase at $P < .05$, most of which were between 1994 and 2008. When comparisons between 1994 and 2008 are excluded, only 7 of the remaining 72 comparisons were statistically significant, not much more than what would be expected by chance. Therefore, at most, there may have been an increase in prevalence from 1994 to 2008. However, given the precipitous drop in prevalence in 2010, we must carefully consider whether this increase was a function of sampling conditions instead of a true increase in prevalence.

The evidence that the prevalence of adolescent hearing loss is not increasing should not cause policy makers and clinicians to lose sight of the fact that adolescent hearing loss is still a significant public health issue. For the time period covered by the NHANES data released 1994 to 2010, there are 7.01 to 8.56 adolescents per 1000 with bilateral hearing loss ≥25 dB and 26.8 to 46.8 per 1000 with unilateral hearing loss ≥25 dB. It is important to note that these estimates of hearing loss prevalence are likely a little low because NHANES data collection procedures excluded children who had cochlear implants or were using hearing aids that could not be removed for testing. Unfortunately, NHANES does not report how many children this involved. Given the abundant evidence that hearing loss is associated with poorer school achievement, social engagement, language development, and self-esteem,[1–5] more needs to be done to identify and provide assistance to adolescents that suffer the negative consequences associated with hearing loss.

With these analyses, we also underscore the risks in using only 2 data points to draw conclusions about trends. Given that only 2 data points were available to address this important issue when Shargorodsky et al[12] published their results, we are not criticizing what they did. But now that more data are available, we can conclude that the prevalence of hearing loss among adolescents in the United States did not increase from 1994 to 2010. However, especially given the large variability in estimates from year to year, it is important that these findings continue to be examined as more data become available. Unfortunately, NHANES has not collected audiometric data on children's hearing loss since the cohort released in 2010. We think this is a mistake and recommend that NHANES resume collecting audiometric data about hearing loss, not only for adolescents (aged 12–19 years) but also for children 6 to 11 years of age, as was the case for the data collected from 1988 to 1994. In fact, given the expansion of universal newborn hearing screening in the United States during the last 20 years,[18] it would be valuable to have similar data for a large enough sample of 3- to 5-year-old children that estimates of prevalence could also be made for these younger children.

There are notable limitations to the current study. The main issue is statistical power. This may be surprising given the large sample size, but with low-incidence conditions such as hearing loss, some analyses may be underpowered because there are so few data points for the targeted variable (eg, the analyses for hearing losses ≥25 dB). The second, as we have discussed, is the lack of data at more time points. Some conclusions regarding the trend and the sampling variability cannot be reached without additional data at more time points. Finally, the estimates rely on the accuracy of the complex sampling and weighting used in NHANES, which are likely reliable, but that is not testable.

CONCLUSIONS

Hearing loss among adolescents has serious negative consequences if it is not identified and treated. Nationally representative data from NHANES provide compelling evidence that hearing loss ≥25 dB affects 3% to 5% of adolescents and hearing loss >15 dB affects 15% to 20% of adolescents. Thus, hearing loss among adolescents in the United States is an important public health issue that deserves continued attention. Contrary to what would be reasonably concluded if only NHANES data[12] from 1994 to 2006 were examined, with our analyses of all currently available NHANES data from 1994 to 2010, we demonstrate that hearing loss among adolescents in the United States is not increasing. It is important for NHANES to resume collecting audiometrically measured data about hearing loss among children in the United States.

ABBREVIATIONS

HPTA: high-frequency pure-tone average
LPTA: low-frequency pure-tone average

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