Trends in the Prevalence of Hearing Loss Among Young Adults Entering An Industrial Workforce 1985 to 2004

Peter M. Rabinowitz, Martin D. Slade, Deron Galusha, Christine Dixon-Ernst, and Mark R. Cullen

Objectives: **Studies have suggested that hearing loss due to recreational noise exposure may be on the rise among adolescents and young adults. This study examines whether the hearing status of young US adults entering an industrial workforce has worsened over the past 20 yr.**

Design: **The baseline audiograms of 2526 individuals ages 17 to 25 beginning employment at a multisite US corporation between 1985 and 2004 were analyzed to determine the yearly prevalence of hearing loss.**

Results: **Approximately 16% of the young adults in the sample had high frequency hearing loss (defined as hearing thresholds greater than 15 dB in either ear at 3,4, or 6 kHz). In a linear regression model, this prevalence decreased over the 20-yr period (odds ratio (OR) = 0.96, 95% confidence interval (CI): 0.94, 0.99). Almost 20% of subjects had audiometric "notches" consistent with noise exposure; this rate remained constant over the 20 yr, as did the prevalence (5%) of low frequency hearing loss.**

Conclusions: **These results indicate that despite concern about widespread recreational noise exposures, the prevalence of hearing loss among a group of young US adults has not significantly increased over the past two decades.**

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Introduction

Hearing loss is a common chronic medical condition in adults (Cruickshanks, 1998) that develops largely as a result of aging and noise exposure. Occupational exposure to excessive noise levels has long been recognized as an important cause of significant hearing loss (American College of Occupational and Environmental Medicine, 2003). In recent years, a number of studies have suggested that in adolescents and young adults, high frequency hearing loss from recreational exposure to amplified music and other loud noise sources in the environment is increasing in prevalence. The scope of this problem could have important public health implications that will be compounded as the US population ages.

The National Health Interview Survey (NHIS) compared survey responses between 1971 and 1991 and found a 14% increase in the age-adjusted prevalence of self-reported hearing trouble. Among persons ages 18 to 44 yr, the increase was 17.1%. For individuals younger than 64 yr in the NHIS, the most frequently reported cause of hearing trouble was "noise from machinery, aircraft, power tools, loud music, appliances, Walkman personal stereos, hair dryers, etc." (Ries, 1994). Analysis of audiograms from the Third National Health and Nutrition Examination Survey (NHANES III), performed between 1988 and 1994, found that 12.7% of children ages 6 to 19 yr had evidence of high frequency hearing loss, whereas 7% demonstrated loss at lower frequencies (Niskar et al., 1998). Overall, 12.5% of the children in the NHANES III sample were found to have high frequency audiometric "notches" suggestive of noise damage; the prevalence increased with age and was greater in boys than in girls (Niskar et al., 2001).

Whether the rate of noise-induced hearing loss is on the rise among adolescents and young adults remains controversial. An analysis of audiograms from 37,381 Swedish military conscripts ages 18 to 19 from 1969 to 1977 found that hearing actually improved over this period; the authors speculated that this might be due to changes in therapy for ear infections and other disorders in the 1950s and 1960s (Persson, 1993). A study of US Army inductees compared the average hearing of 300 conscripts in 1974 with that of 3500 inductees in 1989 and found no significant differences between the two groups (U.S. Army Environmental Hygiene Agency, 1992). No published studies have reported on hearing trends since 1990.

We analyzed yearly rates of hearing loss among young adults starting work for a large US industrial corporation between 1985 and 2004 to determine the prevalence of hearing loss in this population and

Yale University School of Medicine, Occupational and Environmental Medicine Program, New Haven, Connecticut (P.M.R., M.D.S., D.G., M.R.C.), and Alcoa, Inc., Pittsburgh, Pennsylvania (C.D.-E.).

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whether a worsening trend in hearing status occurred over this time period.

METHODS

Population and Study Sample

Alcoa, Inc. is an aluminum producing company that maintains an electronic file of audiometric records for employees. A de-identified set of records from this database has been assembled for research purposes (Rabinowitz, 2003). By the early 1980s, Alcoa had installed audiometric test booths and audiometers at all US locations and was performing baseline hearing screening as part of pre-placement medical examinations for all new employees being hired into either hourly or salaried positions. Company-wide protocols for audiometric quality control were in place before the 1983 OSHA Hearing Conservation Standard, and these protocols continue to ensure data quality under the direction of a supervising audiologist. During the study period, two significant company-wide changes in audiometer use took place. In the late 1980s, microprocessor audiometers replaced manual audiometers. The other systemic change occurred in 2000, when Y2K-compliant audiometers replaced the previous microprocessor units.

Under Alcoa policy, baseline hearing tests are conducted after a noise-free interval of at least 14 hr. Hearing screening of new employees also includes a series of questions relating to medical risk factors for hearing loss as well as questions related to noise exposures including noisy hobbies, previous noisy jobs, and hunting and shooting. Questionnaire responses were recorded as yes or no. The questionnaire does not specifically inquire about exposure to loud music. Demographic data available for individuals included age at hire, race, and sex. We noted, as an indicator of socioeconomic status, whether individuals in the study sample had been hired into either an hourly or salaried job (based on personnel records).

We included in our sample 2617 employees hired from 1985 to 2004, age 25 or younger, who had a hearing test performed within the first 6 mo of employment at 11 Alcoa plants that had hired at least 50 employees over the study period and for which records were available continuously since at least 1985. The year 1985 was chosen as the beginning of the study period, because that is when questionnaire data became consistently available. These plants are located in nine different states (Indiana, Iowa, North Carolina, New York, Ohio, Pennsylvania, Tennessee, Texas, and Washington). Of these 2617 individuals, 91 did not complete a hearing questionnaire, leaving 2526 individuals included in the final study sample.

Assessment of Hearing Loss

Hearing loss was defined by using previously published criteria of an average in hearing thresholds of greater than 15 dB in either ear for the frequencies of 0.5, 1, and 2 kHz ("low frequency hearing loss") or the frequencies of 3, 4, and 6 kHz ("high frequency loss"). The cutoff of 15 dB was chosen as a sensitive indicator that has been previously used in studies of adolescent hearing loss (Niskar et al., 1998). An audiometric "notch" was identified by using previously published criteria to detect notches in adolescent audiograms; these criteria require normal hearing thresholds at the low frequencies of 0.5 and 1 kHz, worsening over the higher frequencies of 2 to 6 kHz, and improvement at 8 kHz, a pattern consistent with noise-induced hearing loss (Niskar et al., 2001).

Statistical Methods

A Mantel-Haenszel Chi-square test for dichotomous variables and simple linear regression for continuous variables were used to evaluate the time trend in hearing loss rates and demographic variables over four 5-yr periods. The prevalence rate for high and low frequency loss and the standard error around these estimates was graphed by year of hire. To detect whether any trend over time for hearing loss prevalence could be explained by temporal shifts in demographic factors among the study population, both bivariate and multivariate logistic regression analyses of the relation between year of hire and hearing loss prevalence were performed. The multivariate logistic regression adjusted for the effects of demographic and questionnaire variables by using a backwards elimination procedure with a selection criterion of $p \leq 0.05$ that eliminated nonsignificant variables from the final model. All analyses were performed with the use of SAS release 8.02 (SAS Institute, Cary NC).

RESULTS

Study Demographics and Risk Factor Prevalence

Table 1 shows the demographic characteristics of the 2526 study subjects, according to 5-yr intervals in the study period. The mean age was 22.2 yr. There was a trend toward hiring of younger people over the years of this study. Although this trend was statistically significant ($p < 0.001$), the average age of people hired in 2004 was only approximately 10 mo younger than those hired in 1985. The study

TABLE 1. Descriptive characteristics of young adults ages 17 to 25 yr at time of hire 1985 to 2004 (*N* = 2526), by 5-yr interval

	Total (*n* = 2526)		Hired date 1985–1989 (*n* = 618)		1990–1994 (*n* = 786)		1995–1999 (*n* = 726)		2000–2004 (*n* = 396)		
Characteristic	No.	%	No.	%	No.	%	No.	%	No.	%	*p**
Mean age, mean ± SD	22.2	2.1	22.6	1.7	22.2	2.0	22.0	2.3	21.8	2.1	<0.001
Male sex	1756	69.5	382	61.8	575	73.2	521	71.8	278	70.2	<0.01
Race/ethnicity											
White	2119	83.9	539	87.2	661	84.1	605	83.3	314	79.3	<0.01
Hispanic	140	5.5	11	1.8	43	5.5	60	8.3	26	6.6	<0.001
Black	210	8.3	55	8.9	67	8.5	51	7.0	37	9.3	0.73
Asian/Pacific Islander	50	2	11	1.8	14	1.8	8	1.1	17	4.3	0.06
Other	7	0.3	2	0.3	1	0.1	2	0.3	2	0.5	0.57
Job status											
Hourly (vs. salary)	1295	51.3	93	15.1	396	50.4	558	76.9	248	62.6	<0.001
Risk factors											
Served in military	260	10.3	42	6.8	96	12.2	86	11.8	36	9.1	0.13
Ear infections	496	19.6	123	19.9	201	25.6	125	17.2	47	11.9	<0.001
Head injury/unconsciousness	248	9.8	74	12.0	80	10.2	60	8.3	34	8.6	0.02
Noisy hobbies	518	20.5	125	20.2	170	21.6	154	21.2	69	17.4	0.39
Shoot or hunt	816	32.3	172	27.8	294	37.4	250	34.4	100	25.3	0.59
Previous noisy job	695	27.5	149	24.1	238	30.3	247	34.0	61	15.4	0.23
History of hearing loss in family	230	9.1	53	8.6	65	8.3	64	8.8	48	12.1	0.09
Hearing status											
Mean 5, 1, 2 kHz > 15 dB	123	4.9	34	5.5	32	4.1	41	5.6	16	4.1	0.67
Mean 3, 4, 6 kHz > 15 dB	398	15.8	120	19.4	117	14.9	104	14.3	57	14.4	0.02
Audiometric notch, either ear	497	19.7	143	23.2	135	17.2	139	19.3	80	20.4	0.32

**p values for trend were calculated by using Mantel-Haenszel Chi-square for dichotomous variables and simple linear regression for continuous variables.*

population was 70% men; this proportion increased slightly over time ($p < 0.01$). Hispanics made up a small but increasing proportion of new-hires, whereas the proportion of blacks remained essentially constant. Over the study period, the proportion of individuals being hired into hourly rather than salaried positions increased ($p < 0.001$). Approximately 20% of individuals reported a history of ear infections; this rate significantly decreased during the period ($p < 0.001$). Exposure to noise from noisy hobbies or prior jobs was reported by almost half of the new-hires, whereas a third of new-hires reported hunting and shooting and a tenth of the new-hires reported serving in the military; the prevalence of these self-reported exposures did not change significantly over time.

Hearing Loss Prevalence

As shown in Table 1, approximately 16% of new-hires met criteria for high frequency hearing loss in at least one ear, whereas nearly 20% had evidence of an audiometric "notch" consistent with noise-induced hearing loss. Among individuals with high frequency loss, the prevalence of notches was 57.4%. The prevalence of low frequency loss was approximately 5%.

Figure 1 displays the yearly prevalence and standard error for both high frequency and low frequency hearing loss as well as a linear regression line for both measures. The regression line for high frequency loss indicates a slight decline in this rate over the study period, whereas the line for low frequency loss is essentially level, indicating that the rate did not change significantly over the study period.

Multivariate Analysis

For high frequency hearing loss, the unadjusted odds ratio for time trend was 0.98 (confidence limits, 0.96, 1.00). After adjusting for age, race, sex, hourly versus salaried status, and reported noise exposures, the adjusted odds ratio was 0.96 (confidence limits, 0.94, 0.99), indicating an improving trend over the study period. In the multivariate model, other significant predictors of high frequency hearing included age (OR = 1.21, 95% CI: 1.15, 1.29), male sex (OR = 3.25, 95% CI: 2.34, 4.51), and being hired into an hourly versus salaried job (OR = 1.58, 95% CI: 1.24, 2.03). For low frequency hearing loss and audiometric notch, there was no significant association with year of hire. Factors significantly associated with low frequency hearing loss included reported ear infections (OR = 1.74, 95% CI: 1.16, 2.61), head injury (OR = 2.02, 95% CI: 1.24, 3.29), and lower job grade at hire (OR = 1.50, 95% CI: 1.03,

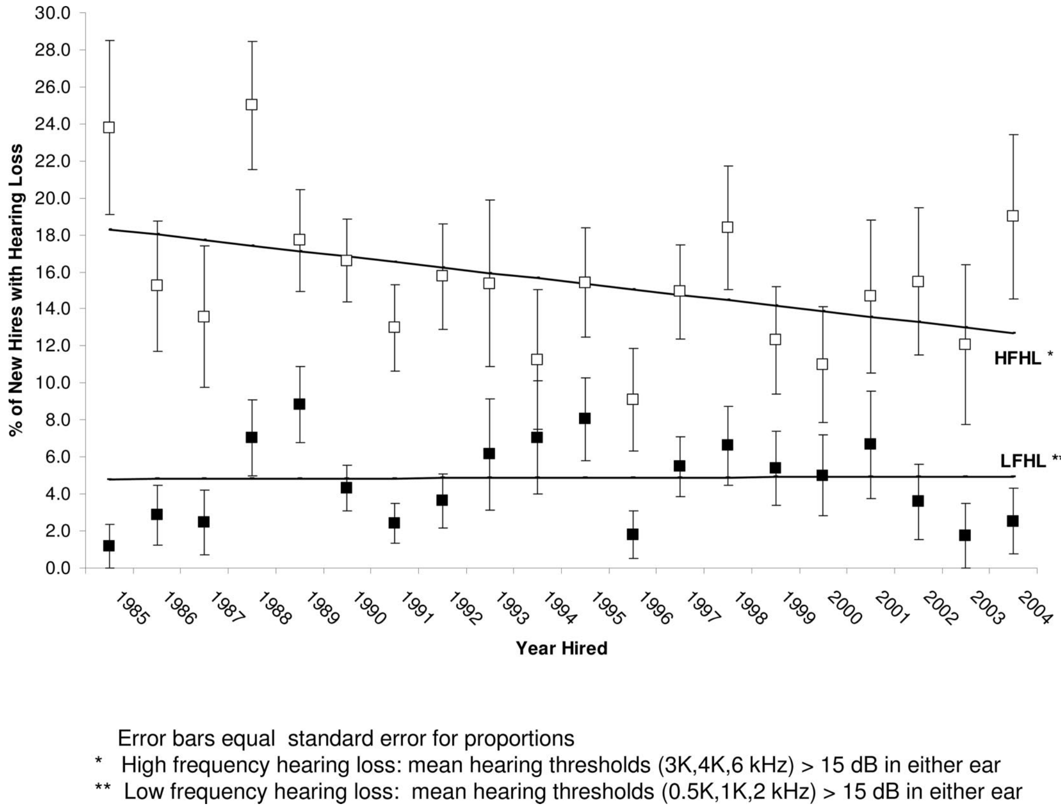

Fig. 1. Hearing loss prevalence among young adults at job hire, 1985 to 2004.

2.17). Factors significantly associated with an audiometric notch included age (OR = 1.09, 95% CI: 1.03, 1.14) and male sex (OR = 1.96, 95% CI: 1.53, 2.49).

DISCUSSION

This analysis of 20 yr of hearing tests on young adults indicates that high frequency hearing loss is a prevalent problem for young adults entering the US workforce. At the same time, the data show that over the past 20 yr, the prevalence has not significantly increased and in fact shows a statistically significant improving trend by linear regression. Similarly, the prevalence of low frequency hearing loss has not changed significantly over the past 20 yr.

Although the cross-sectional study design limits its ability to explore causation, it is likely that the identified high frequency loss, which was more prevalent than low frequency loss, is related at least in part to noise exposures. The majority of individuals with high frequency loss had audiograms meeting previously published criteria for a “notch” consistent with noise exposure. The prevalence of audiometric notches in our sample (19%) was higher than that found in a national survey of children and adolescents ages 12 to 19 yr (12%) (Niskar et al., 2001); although this could be due to demographic differences between the two study samples, a possible explanation is that the prevalence of noise-induced hearing loss increases during late adolescence and early adulthood. Even within the narrow age range (17 to 25 yr of age) of this study population, older individuals had worse high frequency hearing. Although this could reflect an early manifestation of age-related loss, it again seems likely, in this young cohort, to be a result of accumulating environmental noise exposures (Axelsson, 1994; Clark, 2002).

The finding that the prevalence of high frequency hearing loss did not significantly increase over the study period, however, runs contrary to the assertion that current generations of young Americans are being increasingly deafened, as never before, by exposures to amplified music and other aspects of modern noisy culture (Sadhra, 2002). Certainly environmental noise exposure is widespread. A recent web-based survey of adolescents and young adults found that a majority of respondents had attended a concert, club, or party with loud music in the last 6 mo, and 61% and 43%, respectively, experienced tinnitus or temporary hearing change with these exposures (Chung, 2005). There have also been changes in the past two decades in the technology that can deliver loud music to the ear: The Sony Walkman® was introduced in 1979, and a recent poll found that 19% of Americans under the age of 30 owned an Ipod® or MP3 personal digital music player (Rainey, 2005). Car stereos and movie theaters, power tools, and lawn machinery are among other common noise sources. Why is it, then, that the rate of high frequency loss among young people did not increase over the time of this study?

One possible explanation is that changing demographics in the sample over time obscured such an effect due to selection factors. We do not believe this is the case, because even though the average age of new-hires decreased during the time period, the decrease was slight (10 mo over the 20-yr period), and the proportion of other factors associated with hearing loss (such as the proportion of men and the proportion of workers hired in hourly positions) increased. As a result, in the multivariate logistic model, the improvement in high frequency hearing over time remained statistically significant.

System-wide improvements in audiometric test environments and testing technology could create the illusion that hearing thresholds were improving. The Alcoa test environments (including installation of audiometric booths compliant with OSHA standards) were created in the early 1980s, so this is an unlikely explanation. However, there was a change from manually operated to automatic microprocessor audiometers in the late 1980s and another change to Y2K-compliant audiometers in 1999 to 2000. A microprocessor audiometer relies less on operator input than does its manual predecessor to obtain an industrial audiogram. Although this could explain the fact that some of the high frequency rates in the late 1980s deviate significantly from the linear regression line, there were no systemic audiometer changes during the 1990s, a period when the prevalence of high frequency hearing loss remained essentially constant. A major change in test environment or quality would also be expected to influence low frequency hearing test results; however, the rate of low frequency hearing loss remains relatively constant over the study period. Greater experience with hearing testing (i.e., "learning" effect) could also lead to spurious evidence of improved hearing status (Royster, 1986). We are not aware of evidence that young adults today are more experienced at taking audiometric tests than their predecessors of two decades ago, and school screening tests generally test a narrower range of frequencies.

Another possible explanation for the lack of worsening in high frequency hearing is that although exposures to amplified music may have increased, perhaps some of these exposures, as has been suggested, are insufficient to cause widespread hearing loss (Mostafaour, 1998) whereas other more damaging noise exposures may have decreased. This study did not detect any significant decrease over time in the proportion of persons reporting noise exposures through hobbies, other jobs, or hunting and shooting, yet the questionnaires did not assess intensity of exposures, and it is possible that such intensity decreased over the study period. The questionnaire also did not inquire about use of hearing protection, and such usage may have changed over the time period. It is conceivable that greater public awareness of the risks of noise could have affected individual behavior regarding hearing protection. The survey by Chung et al. (2005) of adolescents and young adults found that 39% of respondents had received suggestions to use earplugs around loud noise, and 68% knew that ear plugs could be purchased in a drug store.

Susceptibility to noise-induced hearing loss appears to vary greatly between individuals (Davis, 2003). It is therefore possible that the roughly 16% of the newly hired employees demonstrating high frequency hearing loss represent a susceptible genetic subset of the sample and that despite increasing noise exposures, the prevalence of hearing loss did not increase due to lack of susceptibility in the rest of the population. Another way to reconcile the lack of increase in hearing loss with the apparent increase in ambient noise exposure would be the phenomenon of conditioning, whereby young people could be "toughening" their ears through frequent exposures to lower level noise. Although there is experimental support for such a concept (Niu, 2002), it has not been demonstrated on a population level.

Low frequency hearing loss was slightly less common (approximately 5%) in this sample of young adult workers than in the NHANES survey of children and adolescents (7%). Although this could be due to demographic and other differences between the study samples, other possibilities include a waning effect of recurrent ear infections on hearing over time or historical improvements in the management of otitis media. Previous studies have shown a history of childhood ear infections was associated with a mixed sensorineural and conductive hearing loss at both low and high frequencies (de Beer, 2003), whereas others have implicated ear infections in high frequency hearing loss (Hunter, 1996; Job, 2000). In our study sample, a history of ear infections was a significant predictor of low frequency but not high frequency hearing status, after adjusting for other factors. The reported incidence of ear infections among the new-hires declined during the study period. In the future, the impact on population hearing status of recent changes in recommendations for the management of otitis media [including delaying the use of antibiotics (Darrow, 2003)] should be monitored.

We found a strong and consistent effect of socioeconomic status (using type of job at hire as a proxy) on both low and high frequency hearing. This is consistent with other studies showing a relation between socioeconomic status and hearing (Lee, 1997; Rosenhall, 1999; Sutton, 1997). Whether this effect is related to differences in nutrition, behavior, or other factors is deserving of further examination. Among employees being hired into hourly jobs, reported noise exposures were more frequent, and this could explain the association with high frequency hearing loss. Previous investigators have found greater self-reported use of hearing protection among individuals from higher socioeconomic strata (Widen, 2004). The higher rate of low frequency hearing loss among workers taking hourly jobs could also be related to differences in overall health status or the frequency and/or severity of ear infections.

Although stable over the past two decades, the prevalent nature of hearing loss even among young adults in this study suggests a need for greater awareness of this condition as a public health concern. Currently there is no scientific consensus for clinical preventive screening of adolescents and working age adults for hearing loss (U.S. Preventive Services Task Force, 1996), although Healthy People 2010 includes the objectives "Reduce noise-induced hearing loss in children and adolescents aged 17 yr and under" and "Reduce adult hearing loss in the noise-exposed public" (U.S. Department of Health and Human Services, 2000). Hearing loss caused by noise exposure is a preventable condition for which no effective treatment exists, and the need for more effective education has been stressed (Folmer, 2005). Therefore, further research is warranted to determine whether community-based prevention programs aimed at adolescents can be effective at both changing behavior and improving hearing outcomes.

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Address for correspondence: Peter Rabinowitz, MD, MPH, 135 College Street, 3rd Floor, New Haven, CT 06510. E-mail: peter.rabinowitz@yale.edu

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