

The Socioeconomic Impact of Hearing Loss in U.S. Adults

*†Susan D. Emmett and *Howard W. Francis

*Department of Otolaryngology–Head and Neck Surgery, Johns Hopkins University School of Medicine;

†Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore,
Maryland, U.S.A.

Objective: To evaluate the associations between hearing loss and educational attainment, income, and unemployment/underemployment in U.S. adults.

Study Design: National cross-sectional survey.

Setting: Ambulatory examination centers.

Patients: Adults aged 20 to 69 years who participated in the 1999 to 2002 cycles of the NHANES (National Health and Nutrition Examination Survey) audiometric evaluation and income questionnaire (N = 3,379).

Intervention(s): Pure-tone audiometry, with hearing loss defined by World Health Organization criteria of bilateral pure-tone average of more than 25 dB (0.5, 1, 2, 4 kHz).

Main Outcome Measure(s): Low educational attainment, defined as not completing high school; low income, defined as family income less than \$20,000 per year; and unemployment or underemployment, defined as not having a job or working less than 35 hours per week.

Results: Individuals with hearing loss had 3.21 times higher odds of low educational attainment (95% confidence interval

[95% CI], 2.20–4.68) compared with normal-hearing individuals. Controlling for education, age, sex, and race, individuals with hearing loss had 1.58 times higher odds of low income (95% CI, 1.16–2.15) and 1.98 times higher odds of being unemployed or underemployed (95% CI, 1.38–2.85) compared with normal-hearing individuals.

Conclusion: Hearing loss is associated with low educational attainment in U.S. adults. Even after controlling for education and important demographic factors, hearing loss is independently associated with economic hardship, including both low income and unemployment/underemployment. The societal impact of hearing loss is profound in this nationally representative study and should be further evaluated with longitudinal cohorts. Received institutional review board approval (National Center for Health Statistics Institutional Review Board Protocol no. 98-12). **Key Words:** Hearing loss—Epidemiology—Nutrition surveys—Socioeconomic status—United States.

Otol Neurotol 36:545–550, 2015.

The World Health Organization (WHO) estimates that hearing loss affects 360 million people worldwide (1). Hearing impairment ranked as the 13th highest contributor to the global burden of disease in 2002 and is projected to be the ninth leading contributor worldwide and the seventh in high-income countries by 2030 (2). In the United States alone, 12.7% of individuals older than 12 years are estimated to be affected (3). Given the prominence of hearing loss both globally and domestically, understanding its societal impact is essential.

Address correspondence and reprint requests to Susan D. Emmett, M.D., Department of Otolaryngology–Head and Neck Surgery, Johns Hopkins University School of Medicine, 601 North Caroline St., 6th Floor, Baltimore, MD 21287, U.S.A.; E-mail: semmett2@jhmi.edu

The authors disclose no conflicts of interest.

This study was supported by T32 Research Training Grant 5T32DC000027-25 from the National Institutes of Health.

This work was presented at the American Otological Society 147th Annual Meeting in Las Vegas, NV, U.S.A., on May 17, 2014.

We have long recognized that severe to profound losses have a tremendous impact on education and employment (4–6). It is now becoming clear that even mild losses can adversely affect speech and language development and school performance in childhood (7–11). Data from Finland suggest that decreased school performance early in life in individuals with hearing loss continues to have an adverse effect into young adulthood, with a higher likelihood of not qualifying for intermediate or higher education and more frequent unemployment (12). These data highlight the importance of examining the societal impact of hearing loss from a broader perspective, using population-based methods to assess the socioeconomic consequences of all levels of hearing loss.

We have therefore evaluated the associations between hearing loss and low educational attainment, low income, and unemployment/underemployment using the 1999 to 2000 and 2001 to 2002 cycles of the National Health and

Nutrition Examination Survey (NHANES), a nationally representative cross-sectional survey that evaluates the health of the civilian noninstitutionalized U.S. population. By pursuing this study, we seek to assess the relationship between socioeconomic status and hearing loss in the United States.

MATERIALS AND METHODS

Study Cohort

The NHANES is an ongoing nationally representative cross-sectional survey that assesses the health of the civilian noninstitutionalized U.S. population. Every 2 years, a complex multistage probability sampling design is used to select a sample of the population for interview and examination. Low-income individuals, racial minorities, and older adults are oversampled. Sampling weights are used to account for this complex design, yielding results that are generalizable to the U.S. population (13).

We used the 1999 to 2000 and 2001 to 2002 cycles of NHANES, which collected audiometric data and income information on adults aged 20 to 69 years. These cycles were combined to analyze a total of 4 years of data based on the National Center for Health Statistics (NCHS) recommendations (13). One-half of all participants aged 20 to 69 years were selected to participate in audiometric testing. Reported annual family income was required for inclusion in the study cohort ($n = 157$ excluded), yielding a final sample size for the analysis of $N = 3,379$.

Audiometric Assessment

Audiometry was performed by trained examiners in a dedicated sound-isolating room in the mobile examination center according to established NHANES protocols (14). Briefly, air-conduction thresholds were obtained from 0.5 to 8 kHz over an intensity range of -10 to 120 dB using an Interacoustics Model AD226 audiometer with automated and/or manual testing per protocol. Stimuli were presented through supra-aural headphones (TDH-39) except in cases of ear canal collapse or crossover retesting, when insert earphones (Ear Tone 3A) were used. Equipment was calibrated daily, and ambient noise levels were monitored with a sound meter.

The 1-kHz threshold was tested twice in each ear, and audiometry was repeated if a greater than 10-dB discrepancy was observed. Crossover retesting for asymmetric hearing loss was performed whenever thresholds differed between ears by 25 dB (0.5, 1 kHz) or 40 dB (≥ 2 kHz). Masking was not performed. Hearing loss was defined by WHO criteria of pure-tone average greater than 25 dB (0.5, 1, 2, and 4 kHz) in both ears (15). The first 1-kHz threshold and manual retesting thresholds, when performed, were used in all analyses.

Demographic and Socioeconomic Variables

Demographic and socioeconomic data were obtained from interviews. Race/ethnicity was categorized as non-Hispanic white (white), non-Hispanic black (black), Mexican-American/other Hispanic (Hispanic), or other. *Low educational attainment* was defined by the National Center for Education Statistics classification of not completing high school (15). *Low income* was defined as family income less than \$20,000 per year (16). Employment was assessed using a modified Bureau of Labor Statistics' definition combining *unemployment and underemployment*, defined as not having a job or working less than 35 hours per week (17).

Analysis

Sample weights were used to account for a complex sampling design according to NCHS guidelines in all analyses except for Table 1 (13). The purpose of Table 1 was to provide descriptive statistics of the study cohort instead of nationally generalizable estimates, and therefore weights were excluded. Demographic and socioeconomic characteristics were compared by hearing status using the χ^2 test. Simple and multiple logistic regression analyses were used to evaluate the associations between hearing loss and low education, low income, and unemployment/underemployment. Adequate fit of multiple logistic regression models was assessed using the Archer and Lemeshow *F*-adjusted mean residual test (18). Odds ratios (ORs) reported in the text are from multiple logistic regression models unless otherwise stated. The Taylor Series Linearization method for variance estimation was used per NCHS guideline (13). All analyses were conducted using STATA 12.1 (StataCorp, College Station, TX, USA). Two-sided values of $p < 0.05$ were considered statistically significant.

Ethics

Consent was obtained from all participants. Study protocols were approved by the NCHS Institutional Review Board (Protocol no. 98-12).

RESULTS

Study Cohort

There were notable demographic and socioeconomic differences between individuals with hearing loss ($n = 318$) and those with normal hearing ($n = 3,061$) in this cohort (Table 1). Individuals with hearing loss tended to be male (70% versus 45%; $p < 0.001$), aged 45 years or older (90% versus 41%; $p < 0.001$), and were less likely to be black (12% versus 20%; $p = 0.01$) than normal-hearing individuals. Socioeconomically, individuals with hearing loss were more likely to have not completed high school (48% versus 28%; $p < 0.001$), have an annual income less than \$20,000 (38% versus 28%; $p = 0.001$), and be unemployed or underemployed (62% versus 45%; $p < 0.001$).

TABLE 1. Demographic and socioeconomic characteristics by hearing status of participants with both audiometric and income data, NHANES 1999 to 2002, $N = 3,379^a$

Characteristic	Normal hearing ($n = 3,061$)	Hearing loss ^b ($n = 318$)	<i>p</i> value
Male	1,363 (45)	222 (70)	<0.001
Age ≥ 45 years	1,247 (41)	285 (90)	<0.001
Race/ethnicity			0.01
White	1,437 (47)	167 (53)	
Black	614 (20)	39 (12)	
Hispanic	918 (30)	102 (32)	
Other	92 (3)	10 (3)	
Education <high school	863 (28)	153 (48)	<0.001
Income <\$20,000	871 (28)	120 (38)	0.001
Unemployed or underemployed ^c	1,374 (45)	197 (62)	<0.001

^aAll values are n (%).

^bDefined as bilateral pure-tone average >25 dB (0.5, 1, 2, and 4 kHz).

^cNot having a job or working less than 35 hours per week.

Low Educational Attainment

Low educational attainment, defined as not completing high school (15), was associated with race/ethnicity and hearing status (Table 2). Black and Hispanic individuals had more than three times higher odds of low educational attainment (OR, 3.44; 95% confidence interval [95% CI], 2.62–4.53; OR, 6.14; 95% CI, 4.83–7.80, respectively) than white individuals. Individuals with hearing loss had more than three times higher odds of low educational attainment (OR, 3.21; 95% CI, 2.20–4.68) than normal-hearing individuals. These associations remained significant and of similar magnitude after controlling for sociodemographic factors (sex, age, and race). Sex and age were not associated with education.

Low Income

Low income, defined as an annual family income less than \$20,000 (16), was associated with multiple sociodemographic factors and hearing status (Table 3). Black and Hispanic individuals had more than two times higher odds of having a low income (OR, 2.45; 95% CI, 1.84–3.27; OR, 2.19; 95% CI, 1.44–3.33, respectively) than white individuals. Individuals with low educational attainment had three times higher odds of having a low income (OR, 3.10; 95% CI, 2.33–4.14) than those who had completed a high school education or greater. In addition, individuals with hearing loss demonstrated 1.5 times higher odds of having a low income (1.58; 95% CI, 1.16–2.15) than individuals with normal hearing. Men and individuals aged 45 years or older were less likely to report having a low income (0.65; 95% CI, 0.56–0.75; OR, 0.65; 95% CI, 0.54–0.77, respectively). All associations remained significant and of similar magnitude after controlling for sociodemographic factors, including education.

TABLE 2. Unadjusted and adjusted odds ratios and 95% confidence intervals of low educational attainment (less than high school) by sociodemographic characteristics and hearing status

Characteristic	Unadjusted		Adjusted ^a	
	OR (95% CI)	p value	OR (95% CI)	p value
Sex				
Female	Reference		Reference	
Male	1.06 (0.87–1.30)	0.56	0.95 (0.77–1.18)	0.65
Age (yr)				
<45	Reference		Reference	
≥45	1.08 (0.87–1.34)	0.46	1.09 (0.84–1.41)	0.52
Race/ethnicity				
White	Reference		Reference	
Black	3.10 (2.39–4.02)	<0.001	3.44 (2.62–4.53)	<0.001
Hispanic	5.63 (4.49–7.06)	<0.001	6.14 (4.83–7.80)	<0.001
Other	1.52 (0.92–2.50)	0.10	1.56 (0.92–2.64)	0.10
Hearing status				
Normal hearing	Reference		Reference	
Hearing loss	2.61 (1.95–3.49)	<0.001	3.21 (2.20–4.68)	<0.001

^aAdjusted for all variables in the table.

TABLE 3. Unadjusted and adjusted odds ratios of low income (annual family income less than \$20,000) by sociodemographic characteristics and hearing status

Characteristic	Unadjusted		Adjusted ^a	
	OR (95% CI)	p value	OR (95% CI)	p value
Sex				
Female	Reference		Reference	
Male	0.71 (0.61–0.81)	<0.001	0.65 (0.56–0.75)	<0.001
Age (yr)				
<45	Reference		Reference	
≥45	0.69 (0.59–0.81)	<0.001	0.65 (0.54–0.77)	<0.001
Race/ethnicity				
White	Reference		Reference	
Black	2.98 (2.24–3.97)	<0.001	2.45 (1.84–3.27)	<0.001
Hispanic	3.16 (2.25–4.43)	<0.001	2.19 (1.44–3.33)	0.001
Other	1.79 (0.98–3.28)	0.06	1.69 (0.93–3.08)	0.08
Education				
≥High school	Reference		Reference	
<High school	3.87 (3.08–4.87)	<0.001	3.10 (2.33–4.14)	<0.001
Hearing status				
Normal hearing	Reference		Reference	
Hearing loss	1.30 (1.01–1.68)	0.04	1.58 (1.16–2.15)	0.005

^aAdjusted for all variables in the table.

Unemployment and Underemployment

Unemployment or underemployment, characterized by the modified Bureau of Labor Statistics’ definition of not having a job or working less than 35 hours per week (17), was associated with age, education, and hearing status (Table 4). Individuals aged 45 years or older and those with low educational attainment had higher odds of being unemployed or underemployed (OR, 1.32; 95% CI, 1.10–1.59; OR, 1.92; 95% CI, 1.52–2.44, respectively). Individuals with hearing loss had nearly two times higher odds of unemployment or underemployment (OR, 1.98; 95% CI, 1.38–2.85) than individuals with normal hearing.

TABLE 4. Unadjusted and adjusted odds ratios of unemployment or underemployment (not working or working for less than 35 hours per week) by sociodemographic characteristics and hearing status

Characteristic	Unadjusted		Adjusted ^a	
	OR (95% CI)	p value	OR (95% CI)	p value
Sex				
Female	Reference		Reference	
Male	0.30 (0.25–0.37)	<0.001	0.28 (0.23–0.34)	<0.001
Age (yr)				
<45	Reference		Reference	
≥45	1.47 (1.22–1.78)	<0.001	1.32 (1.10–1.59)	0.005
Race/ethnicity				
White	Reference		Reference	
Black	1.28 (1.03–1.58)	0.03	1.17 (0.93–1.48)	0.17
Hispanic	1.00 (0.79–1.27)	0.98	0.90 (0.65–1.23)	0.50
Other	1.24 (0.67–2.32)	0.48	1.15 (0.60–2.21)	0.66
Education				
≥High school	Reference		Reference	
<High school	1.85 (1.53–2.24)	<0.001	1.92 (1.52–2.44)	<0.001
Hearing status				
Normal hearing	Reference		Reference	
Hearing loss	1.77 (1.26–2.47)	0.002	1.98 (1.38–2.85)	0.001

^aAdjusted for all variables in the table.

Men were less likely to be unemployed or underemployed (OR, 0.28; 95% CI, 0.23–0.34). Race/ethnicity was not associated with unemployment or underemployment. All associations again remained significant and of similar magnitude after adjustment for sociodemographic factors, including education.

DISCUSSION

In this nationally representative study of U.S. adults aged 20 to 69 years, hearing loss was independently associated with low educational attainment, low income, and unemployment/underemployment. The associations between hearing loss and both income and employment status remained significant even after accounting for the low educational attainment observed in the hearing-impaired population. These findings suggest that hearing loss has substantial socioeconomic implications. There are few prior studies investigating the socioeconomic impact of hearing loss. Our results are consistent with population-based studies from Norway (19), Sweden (20), Finland (12), and Australia (21), contributing valuable U.S. data to this small but growing literature. Importantly, our study represents one of four in the world using standardized audiometric testing instead of self-report to define hearing loss (12,19,22). The only other nationally representative survey on the topic in the United States relied on a coded diagnosis of hearing loss to identify affected individuals (23). The strengths of our study therefore include use of standardized audiometric testing and an adjudicated definition of hearing loss from the WHO in the context of a nationally representative sample.

The results of our study reveal notable demographic differences in the U.S. population with hearing loss. Individuals with hearing loss were more likely to be male, aged 45 years or older, and less likely to be black. Male sex and increasing age are known nonmodifiable risk factors for hearing loss that have been elucidated in other studies (20,24–26). Black race is consistently associated with a 60% to 70% decreased odds of hearing loss in observational studies (24,26–28). Lin and colleagues (28) suggest that skin color, and by extension melanin levels in the cochlea, may be the mechanism behind this protective association.

In our study, low educational attainment was associated with race and hearing status. Black and Hispanic individuals had greater than three and six times the odds of not completing high school, respectively, compared with white individuals. The Current Population Survey conducted by the U.S. Census Bureau and the Bureau of Labor Statistics corroborate this racial disparity, reporting a significant difference based on race in the proportion of U.S. adults who have not completed high school (29). The association between hearing loss and low educational attainment has not previously been studied in the United States to our knowledge. Our study suggests that individuals with hearing loss have a higher likelihood of low educational attainment, which is consistent with the

Finnish longitudinal cohort of young adults of Järvelin et al. (12) in which individuals with hearing loss were at more than two times higher odds of not continuing from secondary to higher education. A Norwegian-based study found a similar association between hearing loss and not completing high school (19). Aside from the influence of race and hearing loss, other evidence suggests a difference in educational attainment based on sex (29). Our study did not demonstrate a sex-based disparity in low educational attainment, however. Both the Current Population Survey and NHANES are based on self-report and are thus subject to recall and social desirability bias, which may explain, in part, the discrepancies in results.

Low income was associated with multiple factors in our study, including race/ethnicity, sex, age, educational attainment, and hearing status. Racial disparities in low income are well documented in other studies, with non-Hispanic blacks and Hispanics significantly more likely to report having a low income than non-Hispanic whites (29,30). The U.S. Current Population Survey corroborates the sex- and age-related differences observed in our study, reporting that women and younger age groups are significantly more likely to report having a low income (29). Low educational attainment is another well-established risk factor for low income described elsewhere in existing literature (15,29,30). In our study, hearing loss increased the likelihood of low income more than 1.5-fold. Income was not directly addressed in the international articles on socioeconomic status and hearing loss. In the only U.S. article on the topic to date, Jung and Bhattacharyya (23) noted that individuals with a coded diagnosis of hearing loss were 2.5 times less likely to report any wage income than those without hearing loss, and the mean wage income for individuals with hearing loss was nearly \$8,000 less than the mean wage of the population without hearing loss.

Lastly, our study revealed associations between unemployment/underemployment and age, educational attainment, sex, and hearing status. The Centers for Disease Control and Prevention report similar discrepancies in age and educational attainment, with a significantly higher prevalence of unemployment among younger age groups and those who did not complete a high school education (31). Multiple international studies corroborate the association between hearing loss and unemployment/underemployment (12,20,21), along with Jung and Bhattacharyya (23) domestically. It is important to note that our study did not reveal racial differences in employment/underemployment status. This finding conflicts with those of other sources, such as the Centers for Disease Control's Behavioral Risk Factor Surveillance System (BRFSS), which found a twofold higher prevalence of unemployment among non-Hispanic blacks compared with non-Hispanic whites (31). There are a few possible explanations for this discrepancy. The BRFSS does not consider underemployment in its definition of unemployment, and the survey excludes certain populations, including individuals without landline telephones and those who are homeless (31). Both the BRFSS and NHANES rely on self-report, raising the risk of recall bias and social

desirability bias. The BRFSS had a low median state response rate (51.4%), which also increases the risk of non-response bias (31). However, given that discrepancies were observed between our study and other established economic data sources with regard to both race in unemployment and sex in educational attainment, it is possible that underreporting of socioeconomic information in NHANES could be responsible.

Our study highlights important racial and sex-based socioeconomic disparities that have been described in the wider disparities literature. Notably, it also emphasizes hearing loss as another potential source of socioeconomic disparity. In this study, hearing loss was the only factor that was independently associated with all three measures of socioeconomic status: low educational attainment, low income, and unemployment/underemployment. The mechanisms for these associations are not well defined. Considering possible pathways from existing literature, Järvelin et al. (12) postulates that the lower levels of education associated with hearing loss is the likely driver behind a higher likelihood of unemployment in this population. The independent effect of hearing loss on unemployment/underemployment after controlling for education in our study suggests that education alone is not the only mechanism through which hearing loss is associated with employment status. Kramer et al. (32) proposes a possible non-education-related pathway for this association in a Dutch survey of 150 hearing-impaired individuals and 60 job-matched normally hearing controls. In this study, hearing-impaired individuals reported significantly less “control” in the workplace, higher effort required during listening, and more frequent sick leave because of distress than their normal-hearing colleagues.

There are alternative explanations for the relationship between socioeconomic status and hearing loss that should be considered. Low socioeconomic status itself could be the driver behind the development of hearing loss, particularly if less-educated individuals pursue types of work that increase their exposure to noise. Other alternative explanations include higher levels of recreational noise exposure and increased perinatal risk factors in lower socioeconomic groups. In a large survey of Dutch adolescents aged 12 to 19 years, Vogel et al. (33) observed a difference in risk-taking behavior related to high-volume music on MP3 players based on socioeconomic status. In considering early-life effects of socioeconomic status, there are substantial data demonstrating an association between a low socioeconomic status and an intrauterine growth restriction, which places children at an increased risk of both perinatal complications that may be associated with hearing loss and cognitive delays (34). In a retrospective cohort of greater than 300,000 children entering kindergarten in Florida, Resnick et al. (35) observed that sociodemographic predictors, including poverty, low maternal education, and nonwhite race, substantially raised the risk of mild educational disabilities. Because of their high prevalence, the attributable impact of each of these sociodemographic predictors on adverse educational outcomes was between five and 10 times greater than the effect of a low birth weight alone (35).

The design of NHANES limited our ability to assess potential mediators in the relationship between hearing loss and socioeconomic status. Its cross-sectional nature does not allow for assessment of temporality in mediating relationships, and we were further restricted to exploring medical conditions and environmental exposures that were collected as a part of the study. We nevertheless evaluated available known risk factors for hearing loss as potential mediators in the socioeconomic status relationship, including diabetes, hypertension, body mass index, smoking, and noise exposure from occupational and non-occupational sources (36–39). None of these medical conditions or environmental exposures demonstrated statistical mediation in our study (data not shown). The relationship between socioeconomic status and hearing loss is undoubtedly complex, likely involving multiple simultaneous pathways. Future longitudinal studies will be critical to better understand the mechanisms behind these associations.

There are notable weaknesses in our study. During data collection on underemployment, the NHANES protocol did not differentiate between individuals who work 35 hours or less per week because of choice and those who work part time because of not being able to find full-time employment. The absence of this distinction required us to use a modification of the Bureau of Labor Statistics definition of underemployment, which could have led to an overinflation of unemployment/underemployment in our study. Because of the nature of the income information released in NHANES, we were unable to assess the numeric difference in income between the hearing-impaired and normal-hearing populations. The NHANES participants have a choice of reporting their income based on a screening question of more than or less than \$20,000 or reporting an exact figure, with deidentified income data then released in \$5,000 to \$10,000 increments. A substantial number of participants chose to answer only the screening question, and thus, to maximize the number of eligible participants, we analyzed the available income data using the screening cut point of \$20,000. Reliance on this screening question prevented us from being able to use the standard income-to-poverty ratio definition of *low income* that incorporates number and age of individuals in the household (29). In future studies, more precise information on the differences in income would be extremely valuable for evaluating the economic cost of hearing loss.

Cross-sectional surveys such as NHANES are by nature unable to assess temporality, and thus we were unable to conclude causation in the observed associations between hearing loss and socioeconomic status. Longitudinal studies will be essential for better delineation of this relationship and improved understanding of the underlying mechanisms. Our study was also not equipped to investigate effective interventions to reduce the impact of hearing loss on education, income, and employment. It is possible that consistent hearing aid use is able to reduce the impact of hearing loss on one or all of the measures of socioeconomic status we explored. The number of individuals using hearing aids in this NHANES cohort was too small to evaluate this effect, however. A priority

in future research should be investigation of successful strategies to reduce or, ideally, ameliorate the untoward socioeconomic effects of hearing loss.

With 5% of the world's population experiencing hearing loss, understanding and quantifying its societal impact are critical. This study contributes important data to the small but growing literature suggesting that hearing loss has an adverse effect on educational attainment, income, and employment status. Further longitudinal studies are urgently needed to better define these relationships and provide possible solutions for reducing this important disparity.

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