Hearing Difficulty Attributable to Employment by Industry and Occupation: An Analysis of the National Health Interview Survey—United States, 1997 to 2003

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Objective: *To estimate the national burden of hearing difficulty among workers in US industries and occupations.* ***Methods:*** *Data on 130,102 employed National Health Interview Survey respondents between the ages of 18 to 65 years who were interviewed between 1997 and 2003 were analyzed to estimate the population prevalence, adjusted prevalence ratios, and fractions of hearing difficulty attributable to employment.* ***Results:*** *The estimated population prevalence of hearing difficulty was 11.4% (24% attributable to employment). The adjusted prevalence ratios of hearing difficulty were highest for railroads, mining, and primary metal manufacturing industry. Occupations with increased risk of hearing difficulty were mechanics/repairers, machine operators, and transportation equipment operators.* ***Conclusions:*** *Hearing difficulty was differentially distributed across various industries. In industries with high rates, employers and workers should take preventive action to reduce the risk of occupational hearing loss.* (J Occup Environ Med. *2008;50:46–56*)

Occupational hearing loss (OHL) is a condition caused by work-related factors that result in hearing impairment.[1] OHL most commonly arises from excessive noise exposure, which can damage the inner ear, principally the sensory hair cells in the cochlea. Hearing loss caused by damage to the inner ear or the eighth cranial nerve is commonly referred to as sensorineural hearing loss. OHL caused by damage to these sensorineural structures can also be produced by various occupational factors, including barotrauma and exposure to organic solvents, heavy metals, and carbon monoxide. Sensorineural hearing loss is almost always permanent and irreversible. Physical damage to the outer and middle ear can also cause OHL, and damage to these structures is often referred to as conductive hearing loss. Fortunately, OHL is entirely preventable.

Surveillance of OHL is vital to prevention because it can identify the most problematic industries, occupations, and work activities, and because it can be used to evaluate the effectiveness of intervention activities. To our knowledge there are no published studies on the national prevalence of OHL or on the national distribution of hearing loss across industries and occupations. However, a limited number of studies confined to a specific industry or state of residence[2–6] have attempted to determine the proportion of per-

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The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention.

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sons with hearing loss attributable to noisy work environments. Worldwide, World Health Organization estimated in 2005 that 16% of the hearing loss of >25 dBHL (decibels hearing loss) in adults is attributable to occupational noise exposure.[7] Recent information on the prevalence of noise exposure, however, is not available. In 1981, the US Environmental Protection Agency estimated that more than 9 million US workers were occupationally exposed to daily noise levels above 85 dB.[8] Although exposures to noise and other ototoxicants in US workplaces are believed to have evolved since 1981, and new regulations for noise exposures were adopted in 1983, the recent impact of these actions on national OHL prevalence has not been determined.

The National Health Interview Survey (NHIS)[9,10] is a large population-based annual survey designed to monitor the health of the US population. One of the health conditions it monitors is hearing difficulty. The objective of the present study was to analyze NHIS data from 1997 to 2003 to estimate the prevalence, prevalence ratios (PRs), and attributable fractions (AFs) for hearing difficulty and employment by specific industry sectors and occupational categories. The aim was to estimate the contribution of workplace exposures to self-reported hearing difficulty and to identify the highest risk industries and occupations in the United States so that these can be targeted for hearing loss prevention programs and other protective interventions.

Materials and Methods

The NHIS is an annual cross-sectional, multipurpose, and multistage probability area survey of the US civilian noninstitutionalized population living at addressed dwellings.[9,10] Approximately 40,000 households are annually selected to participate in the NHIS. Data on adult hearing difficulty are available from the adult sample core questionnaire. One adult from each household included in the NHIS is selected at random and administered the sample adult core questionnaire. Although the sampling unit for the NHIS is the household, survey sample weights are calculated for each member of the household to allow for person-level analyses. For this report, NHIS data for 1997 to 2003 (2003 was the most recent year that occupation and industry data were available) were aggregated to increase the precision of the prevalence estimates. Combining years 1997 to 2003, 226,953 adults aged 18 years and over completed the sample adult core questionnaire. Annual response rates to the 1997 to 2003 sample adult core questionnaire ranged from 70% (in 1999) to 80% (in 1997), resulting in an average annual response rate of 74.0%.

Study Subjects

Sample adults between the ages of 18 and 65 years who were "working at a job or business" or "with a job or business but not at work" during the week before their interview were initially selected for the analysis (n = 136,971). If the occupation or industry was unknown or not ascertained, the individual was not included in the analysis (n = 5934). Because the NHIS targets the civilian population, those employed in the armed forces or and military were not included because of small sample size (n = 36). Persons who reported either being "deaf" (n = 131), whose hearing difficulty data were missing (n = 39), or who had hearing difficulty that caused limitation of routine activities of daily living (n = 159) were excluded from the analysis. There were no respondents who had hearing difficulty before the age of 18. In the final analysis, 570 respondents were excluded because of missing smoking status data. The present study included 130,102 subjects. The data used to analyze hearing difficulty and the relevant SAS program statements are available at this web site: http://www.cdc.gov/nchs/about/major/nhis/questdatarelated_1997_forward.htm

Definition of Hearing Difficulty

Hearing difficulty is assessed in the NHIS by the question "Which statement best describes your hearing (without a hearing aid)?" The response categories were "good," "a little trouble," "a lot of trouble," and "deaf." In our analyses, hearing difficulty was defined as those respondents who answered "a little trouble" or "a lot of trouble" to the hearing difficulty question. The validity of this question and its response categories have previously been validated, and are unlikely to be a major source of error.[11]

Attributable Hearing Difficulty

Attributable cases (AC) or the number of persons with hearing difficulty attributable to employment was estimated by multiplying the AF by the total number of individuals in the population at risk. The AF represents the fraction of persons with hearing difficulty that would not have occurred in the absence of exposure to a specific risk factor either in the exposed population or in the total population.[12] The population attributable fraction (PAF) was calculated according to the formula:

$$PAF = \sum_{i=1}^{k} p_i(PR_i - 1)/PR_i$$

where k is total number of industry categories; p_i is the proportion of the estimated number of persons with hearing difficulty in the ith industry-occupation compared with the total number of persons with hearing difficulty across industry-occupation categories; and PR_i is the adjusted PR for hearing difficulty estimated for the ith industry-occupation. The PR for each industry-occupation was estimated after adjusting for other potential confounders and using the reference groups described below.

Industry-Occupation Categories

Industry-occupation were determined based on two items on the

NHIS questionnaire. Study subjects answered questions about their place of work (industry) and the type of work they performed (occupation). Each industry was subsequently assigned industry codes that were consistent with the 1995 revisions to the Standard Industrial Classification system. This industry coding scheme provided 42 possible industry categories. Codes were also created from the occupation information and were consistent with the 1995 revisions to the Standard Occupational Classification system. The detailed occupation coding scheme provided 41 separate occupation categories.

For the analysis of industry, we combined all workers employed in the banking, insurance, and real estate industries because these workers are hypothesized to have minimal potential for occupational exposures to noise and other ototoxicants, and these workers were selected a priori as the comparison group. This recoding resulted in 40 detailed industry categories.

For the analysis of occupation, persons with finance, commodities, and sales occupations were selected a priori as the reference category against which other occupational groups were compared.

To identify the workers at highest risk of occupational hearing difficulty within each industry, we paired the industry categories with the occupation categories to produce pairs of industry and occupation categories. All workers employed in the banking, insurance, and real estate industries were used as the reference category against which other industry-occupation pairs were compared. Because of the small sample size for many industry-occupation pairs, we identified the 25 industry-occupation pairs with the highest prevalence of hearing difficulty and with a sample size of at least 50. The sample size of 50 was selected a priori, and was considered to be sufficient for analysis.

Statistical Analysis

All analyses were completed using the Software for the Statistical Analysis of Correlated Data (SUDAAN v9.0) package to take into account sample weights and design effects because of the complex sample survey design.[13] Variance estimates were adjusted for the population survey units, strata, and sampling weights assigned by NCHS. The weighted population size, prevalence, and PRs for hearing difficulty were estimated by industry-occupation. The SUDAAN Loglink program with Poisson distribution assumption was used to estimate robust PRs and the 95% confidence intervals (CIs) for hearing difficulty by industry-occupation adjusted for the effect of age, sex, race, smoking status, and education.[14] Age was categorized into five groups of which the first group (18 to 24 years) was used as the reference group. A dichotomous variable was created for education; respondents with college or higher education (16 years or more) and respondents with less than 16 years of education. For smoking status, subjects were categorized into never smokers, ex-smokers, and current smokers. For race, subjects were categorized into white, African American, and other. To examine the trend of hearing difficulty over the 7-year period, a linear regression model was fitted to the annual weighted prevalence rates of hearing difficulty among NHIS respondents from 1997 to 2003.

Results

Of the 130,102 subjects between the ages of 18 to 65 years for whom occupation and industry information were coded, 14,051 (weighted prevalence of 11.4%) reported having hearing difficulty. Figure 1 displays the estimated prevalence rates of hearing difficulty from 1997 through 2003. Annual weighted prevalence rates of hearing difficulty ranged from 10.2% to 12.6%. The prevalence rates monotonically decreased from 1997 to 2000, but no clear trend in rates is evident since the year 2000. The overall regression line represented a decrease in prevalence of 0.28% per year. Table 1 shows the unweighted and weighted population prevalence of hearing difficulty by stratum for each non-occupational risk factor. The estimated total employed workforce in the United States represented by the sample adult respondents was 122.2 millions. Male respondents had a higher prevalence (14.0%) than female respondents (8.5%). A monotonic increase in prevalence of hearing difficulty was observed with increasing age. Respondents aged 55 to 64 showed the highest prevalence of hearing difficulty (22%). By race, whites had the highest hearing difficulty prevalence (12.6%). Current smokers and former smokers reported more hearing difficulty (13% and 16%, respectively) than those who never smoked (9%). Persons with less education had a higher prevalence of hearing difficulty (12%) than those with education of 16 years or more (10%).

Hearing Difficulty by Industrial Sectors

Industry pertains to the place of work. Table 2 and Fig. 2 provide the estimated prevalence of hearing difficulty for each of the 40 industry categories. The analysis showed that compared with those employed in finance, insurance, and real estate industry, the adjusted PRs of hearing difficulty for all other industry categories were higher than 1, and the lower confidence bound for most of these industries exceeded 1.0. The adjusted PR for hearing difficulty was greatest for railroads (PR = 2.73, 95% CI: 2.25 to 3.32), followed by mining (PR = 2.23, 95% CI: 1.76 to 2.81), primary metal manufacturing industry (PR = 1.98, 95% CI: 1.64 to 2.38), and furniture, lumber, and wood manufacturing industry (PR = 1.75, 95% CI: 1.50 to 2.05).

The weighted number of hearing difficulty cases attributable to em-

ployment, after adjustment for non-occupational factors, was 3316,522, and the AF was 23.7%. The overall adjusted PR for hearing difficult was also estimated by comparing all industries grouped into one category with the reference group—finance, insurance, and real estate industry. The overall adjusted PR was estimated as 1.31 (95% CI: 1.19 to 1.44). Based on this PR, the AF was estimated to be 23.6% (95% CI: 15.9 to 30.4). Figure 2 shows the number of persons with hearing difficulty attributable to employment in various industries. The construction industry had the largest number of persons with hearing difficulty attributable to employment (weighted AC = 401,306, or 12% of all US workers with hearing difficulty attributable to their job).

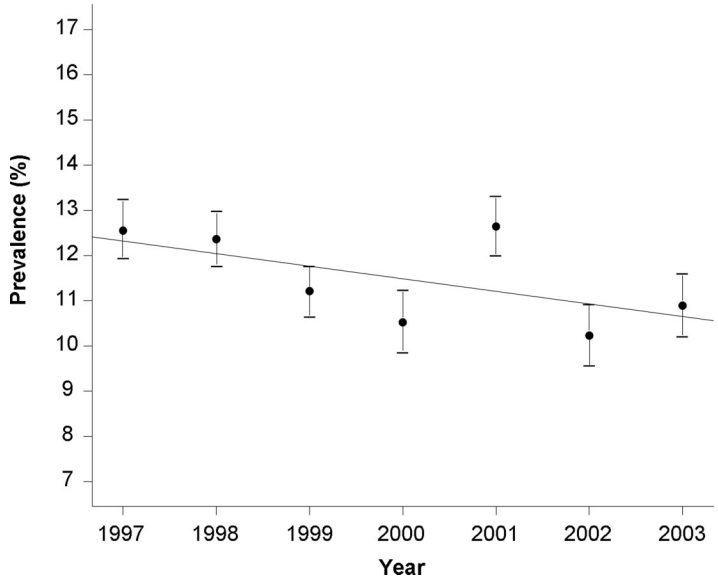

Fig. 1. Weighted prevalence and 95% confidence intervals of hearing difficulty among employed respondents. National Health Interview Survey years 1997 to 2003. The continuous line represents a decrease in prevalence of 0.28% per year.

Hearing Difficulty by Occupational Categories

Occupation pertains to the type of work performed. Except for those in health-diagnosing occupations (ie, physicians; PR = 0.98), the adjusted PRs for hearing difficulty among all other occupational categories were higher than 1, compared with those with finance, commodities, and sales occupations (Table 3). The adjusted PR for hearing difficulty was highest for transportation workers (except motor vehicle; PR = 2.56, 95% CI: 1.93 to 3.40) followed by material moving equipment operators (PR = 1.76, 95% CI: 1.49 to 1.86), farm operators and

TABLE 1
Estimated Population Prevalence of Hearing Difficulty, the Adjusted Prevalence Ratio (PR), and 95% Confidence Intervals for Hearing Difficulty by Risk Factor, United States, 1997–2003

Risk Factor	Unweighted Sample Size	Unweighted Prevalence, % (95% CI)	*N**	Weighted Prevalence* (95% CI)†	Adjusted PR‡	95% CI
Sex						
Male	64,233	13.4 (13.2–13.7)	656.1	14.0 (13.6–14.4)	1.59	1.54–1.65
Female	65,869	8.4 (8.1–8.6)	565.5	8.5 (8.2–8.8)		
Race						
White	103,592	12.0 (11.8–12.2)	1,011.3	12.6 (12.3–12.9)	2.14	1.99–2.29
African American	17,464	5.7 (5.3–6.0)	133.3	5.4 (5.0–5.8)	1.00	
Other	9,046	7.4 (6.9–8.0)	76.9	7.2 (6.6–7.9)	1.38	1.23–1.54
Age categories (yr)						
18–25	17,741	5.5 (5.2–5.9)	193.4	5.7 (5.3–6.2)	1.00	
25–34	34,495	6.6 (6.4–6.9)	301.1	7.1 (6.7–7.4)	1.29	1.17–1.41
35–44	36,927	10.2 (9.9–10.5)	344.9	10.8 (10.4–11.2)	1.92	1.77–2.08
45–54	27,849	15.8 (15.4–16.2)	265.7	16.8 (16.3–17.3)	2.93	2.70–3.17
55–64	13,090	20.1 (19.4–20.8)	116.5	21.9 (21.1–22.8)	3.68	3.37–4.01
Smoking status						
Current smoker	33,444	12.9 (12.6–13.3)	307.1	13.4 (12.9–14.0)	1.33	1.27–1.39
Former smoker	24,568	15.5 (15.1–16.0)	239	16.3 (15.7–16.8)	1.31	1.25–1.37
Never smoker	72,090	8.2 (8.0–8.4)	675.4	8.9 (8.6–9.2)	1.00	
Education						
16 yr or more	35,420	9.3 (9.0–9.6)	339.9	9.6 (9.2–10.0)	1.00	
<16 yr	94,682	11.4 (11.2–11.6)	881.7	12.2 (11.8–12.5)	1.33	1.27–1.39
Total	130,102	10.8 (10.7–11.0)	1,221.6	11.4 (11.2–11.7)		

*Estimated number of US working population in 100,000s.
†Confidence interval (CI) is obtained from the standard error estimated by SUDAAN (v9.0).
‡Prevalence ratios (PR) are adjusted for all other covariates.

TABLE 2
Estimated Prevalence of Hearing Difficulty, the Adjusted Prevalence Ratio (PR), and the Attribution to Employment by Industrial Sectors, United States, 1997–2003

Industrial Sector	*N**	Weighted Prevalence (%)	SE†	PR‡	95% CI	AC§	AF‖
Agriculture	2,783.2	14.5	0.8	1.43	1.25–1.63	120.9	29.9
Forestry and fisheries	143.8	15.0	3.6	1.45	0.92–2.27	6.7	31.0
Mining	475.3	24.3	2.8	2.23	1.76–2.81	63.9	55.3
Construction	8,722.2	15.1	0.5	1.43	1.31–1.57	401.3	30.4
Manufacturing—non-durable goods							
Food and kindred products	1,818.2	13.8	1.1	1.52	1.27–1.82	86.1	34.4
Textile mill and finished textile products	1,209.3	12.3	1.0	1.35	1.13–1.61	38.4	25.9
Printing, publishing, and allied industries	1,558.7	11.7	0.9	1.25	1.06–1.47	36.8	20.2
Chemicals and allied products	1,182.1	11.1	1.1	1.19	0.98–1.45	21.3	16.1
Other non-durable goods	1,511.3	16.7	1.2	1.61	1.39–1.86	95.8	37.9
Manufacturing—durable goods							
Primary metal industries	759.5	22.4	2.0	1.98	1.64–2.38	84.2	49.6
Furniture, lumber, and wood	1,410.7	17.3	1.2	1.75	1.50–2.05	105.4	43.1
Transportation equipment	2,268.8	16.9	1.0	1.65	1.45–1.87	151.2	39.4
Fabricated metal industries, including ordnance	1,086.1	15.8	1.3	1.45	1.22–1.73	53.5	31.2
Machinery, except electrical	2,064.3	15.6	1.0	1.49	1.30–1.70	105.9	32.9
Electrical machinery, equipment, and supplies	1,632.5	13.3	1.0	1.47	1.25–1.73	69.5	32.1
Other and not-specified durable goods	2,090.1	13.5	0.9	1.41	1.21–1.64	81.8	29.0
Transportation, communications, and other public utilities							
Railroads	270.8	34.8	3.6	2.73	2.25–3.32	59.9	63.6
Utilities and sanitary	1,374.3	17.2	1.3	1.61	1.36–1.91	90.4	38.2
Trucking service and warehousing	2,422.5	13.2	0.9	1.31	1.14–1.51	76.5	23.9
Other transportation	2,804.9	11.6	0.7	1.19	1.04–1.37	53.0	16.4
Communications	1,918.2	9.5	0.7	1.12	0.96–1.31	20.2	11.1
Wholesale trade	3,993.5	12.1	0.6	1.24	1.10–1.39	93.9	19.4
Retail trades							
Automotive dealers and gasoline stations	1,908.7	12.2	0.9	1.25	1.07–1.48	47.3	20.4
Food, bakery, and dairy stores	2,760.9	11.0	0.6	1.36	1.19–1.55	80.2	26.4
General merchandise stores	2,122.7	9.7	0.7	1.30	1.11–1.53	47.8	23.2
Eating and drinking places	5,668.1	7.8	0.4	1.15	1.03–1.30	59.4	13.4
Other and not-specified retail trade	6,070.1	9.9	0.4	1.19	1.06–1.33	97.0	16.1
Services							
Repair services	1,833.2	16.7	1.0	1.53	1.33–1.76	106.7	34.9
Legal, engineering, and other professional services	4,621.9	10.5	0.5	1.24	1.10–1.40	94.5	19.5
Business services	6,851.0	10.2	0.4	1.26	1.13–1.42	145.6	20.9
Other personal services	3,007.6	10.1	0.6	1.23	1.07–1.42	57.5	18.9
Social services, religious, and membership organizations	4,422.4	10.0	0.5	1.30	1.15–1.47	101.3	23.0
Elementary and secondary schools and colleges	10,284.1	9.3	0.3	1.21	1.09–1.33	166.7	17.3
Health services, except hospital	6,784.7	9.0	0.4	1.21	1.08–1.36	106.6	17.4
Entertainment and recreation services	2,195.9	8.8	0.7	1.09	0.92–1.30	16.6	8.6
Private households	684.5	8.7	1.1	1.18	0.92–1.52	9.2	15.5
Hospitals	5,071.2	8.6	0.4	1.16	1.03–1.31	60.5	13.9
Other educational services	495.8	9.7	1.5	1.16	0.85–1.59	6.6	13.7
Public administration	5,858.8	12.4	0.6	1.37	1.23–1.53	196.6	27.2
Finance, insurance, and real estate¶	8,014.5	8.3	0.3	1.00		0.0	0.0
Total working population	122,156.2	11.4	0.1			3,316.5	23.7

*Estimated number of US working population in 1,000s.
†Estimated population prevalence of hearing difficulty (%).
‡Prevalence ratios (PR) are adjusted for all other covariates (age, sex, race group, smoking status, and education).
§Attributable case (AC), number of hearing difficulty cases attributable to employment in 1,000s.
‖Attributable fraction (AF), percent of hearing difficulty cases attributable to employment.
¶Reference group.
SE indicates standard error.

managers (PR = 1.74, 95% CI: 1.44 to 2.10), and forestry and fishing occupations (PR = 1.73, 95% CI: 1.32 to 2.27). Transportation workers include air transportation (ie, pilots and flight engineers), rail transportation (ie, locomotive engineers and railroad conductors), water transportation (ie, sailors and ship/boat operators), and other workers (ie, bridge and lock tenders, service station or parking lot attendants, and transportation inspectors).

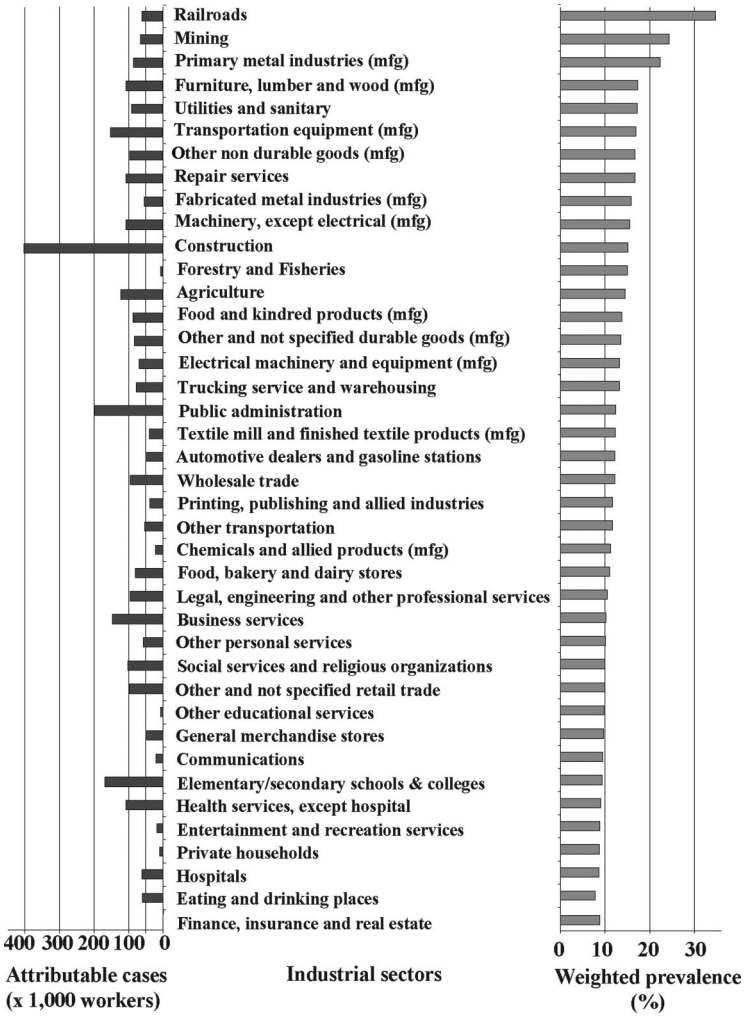

Fig. 2. Prevalence of hearing difficulty and the number of hearing difficulty cases attributable to employment by industry, United States, 1997 to 2003. Note: attributable cases are based on the prevalence ratios adjusted for age, sex, race, smoking status, and education.

For each occupation, Fig. 3 shows the number of persons with hearing difficulty attributable to employment in occupational categories, after adjustment for non-occupational factors. Mechanics and repairers had the largest number with hearing difficulty attributable to employment (weighted AC = 344,929 or 11% of all workers with hearing difficulty attributable to employment) whereas the highest prevalence of hearing difficulty attributable to employment was found among transportation workers (30%).

High-Prevalence Industry-Occupation Pairs

Among the 25 industry-occupation pairs with the highest prevalence of hearing difficulty, mechanics and repairers figured prominently. For example, the prevalence of hearing difficulty among mechanics and repairers in primary metal manufacturing was 39%, in other non-durable goods manufacturing was 35%, in transportation equipment manufacturing was 28%, in food and kindred products manufacturing was 26%, and in other transportation industry was 24% (Table 4).

Machine, vehicle, or equipment operators in several industries had a high prevalence of hearing difficulty, including the railroad industry (36%), mining (34%), machinery manufacturing (26%), and construction (24%). Construction and extractive trades showed high prevalence in mining (29%) and transportation equipment manufacturing industry (27%).

When compared with those employed in the finance, insurance, and real estate industry, the adjusted PR of hearing difficulty was the highest for mechanics and repairers in primary metal manufacturing industry (PR = 3.18, 95% CI: 2.23 to 4.54), followed by material moving equipment operators in mining (PR = 3.11, 95% CI: 2.15 to 4.51), and operators in the railroad industry (PR = 3.04, 95% CI: 2.28 to 4.06). The PR for farm operators and managers in agriculture was 1.81 (95% CI: 1.50 to 2.18).

Among the 25 industry-occupation pairs with the highest hearing difficulty prevalence, the pair with the largest number of persons with hearing difficulty was farm operators and managers (77,300 persons). Material moving equipment operators in construction industry had the second largest number of persons with hearing difficulty (48,196 persons). Some of the occupations found in the material moving equipment operators category are truck drivers and heavy equipment operators.

Discussion

The present study estimated that 24% of hearing difficulty in the US working population between the ages of 18 to 65 years is attributable to employment. That is to say, because OHL is preventable, approximately one fourth of hearing impairment among the US working population might be avoided by adopting various preventive measures. The present study also identified industries and occupations associated with an increased risk of hearing difficulty that can be targeted for hearing loss prevention programs. National Institute for Occupational Safety and Health (NIOSH) has recommended a national strategy for the prevention of occupational hearing loss.[15] The three main NIOSH recommendations for preventing hearing loss among workers are 1) developing technology that will substitute quiet pro-

TABLE 3
Estimated Prevalence of Hearing Difficulty, the Adjusted Prevalence Ratio (PR), and the Attribution to Employment by Occupational Categories, United States, 1997–2003

Occupational Category	*N**	Weighted Prevalence,† % (SE)	Adjusted PR‡	95% CI	AC§	AF‖
Executive, administrative, and managerial occupations						
Officials and administrators, public administration	753.9	15.8 (1.6)	1.55	1.25–1.92	42.4	35.5
Managers and administrators, except public administrators	12,020.1	11.0 (0.3)	1.14	1.02–1.28	164.2	12.4
Management-related occupations	4,947.8	9.5 (0.5)	1.15	1.01–1.32	62.0	13.1
Professional specialty occupations						
Engineers	1,947.2	14.1 (1.0)	1.51	1.28–1.78	92.5	33.8
Architects and surveyors	218.2	10.8 (2.6)	1.28	0.78–2.09	5.2	21.9
Teachers, librarians, and counselors	6,635.6	9.6 (0.5)	1.28	1.13–1.45	138.4	21.7
Natural mathematical and computer scientists	2,594.4	9.6 (0.7)	1.19	1.01–1.41	40.4	16.2
Writers, artists, entertainers, and athletes	2,240.4	9.2 (0.7)	1.15	0.95–1.39	26.8	13.0
Health-diagnosing occupations	1,009.3	8.4 (0.9)	0.98	0.79–1.23	0.0	0.0
Health assessment and treating occupations	3,247.1	7.9 (0.5)	1.09	0.94–1.26	20.7	8.0
Other professional specialty occupations	2,761.8	10.3 (0.6)	1.23	1.05–1.43	52.8	18.5
Technicians and related support occupations						
Technologists, technicians except health	2,645.6	11.5 (0.7)	1.35	1.15–1.57	78.6	25.7
Health technologists and technicians	1,828.8	7.3 (0.7)	1.02	0.83–1.25	2.9	2.1
Sales occupations						
Supervisors and proprietors	3,667.8	11.0 (0.6)	1.13	0.99–1.30	47.5	11.7
Other sales	5,856.6	9.6 (0.5)	1.29	1.13–1.47	126.3	22.5
Administrative support occupations, including clerical						
Mail and message distributing	843.2	13.2 (1.3)	1.38	1.13–1.70	30.9	27.7
Computer equipment operators	385.3	10.1 (1.6)	1.22	0.86–1.72	7.0	18.0
Financial records processing occupations	2,012.2	9.3 (0.7)	1.17	0.98–1.40	27.5	14.8
Secretaries, stenographers, and typists	2,520.8	9.0 (0.7)	1.12	0.94–1.34	24.4	10.8
Other administrative support	10,854.6	8.8 (0.3)	1.17	1.05–1.32	140.9	14.8
Private household occupations	603.2	9.1 (1.3)	1.26	0.94–1.70	11.4	20.8
Protective service occupations						
Police and firefighters	1413.4	11.5 (1.0)	1.29	1.07–1.56	36.5	22.5
Other protective service occupations	868.6	12.0 (1.3)	1.36	1.08–1.72	27.9	26.7
Other service occupations						
Cleaning and building service	2,888.4	12.3 (0.7)	1.33	1.15–1.54	89.3	25.0
Health service	2,494.2	9.8 (0.6)	1.46	1.24–1.72	76.8	31.5
Personal service	2,618.4	8.9 (0.6)	1.25	1.06–1.46	46.0	19.7
Food service	5,176.8	8.4 (0.4)	1.21	1.07–1.37	75.2	17.3
Farming, forestry, and fishing occupations						
Farm operators and managers	783.3	22.0 (1.8)	1.74	1.44–2.10	73.3	42.5
Forestry and fishing occupations	136.7	19.9 (3.1)	1.73	1.32–2.27	11.5	42.2
Farm workers and other agricultural workers	1,886.0	11.1 (0.8)	1.19	1.00–1.42	33.9	16.1
Precision production, craft, and repair occupations						
Mechanics and repairers	4,536.1	18.8 (0.7)	1.68	1.49–1.88	344.9	40.4
Precision production occupations	3,361.3	17.6 (0.8)	1.66	1.46–1.88	234.7	39.6
Construction and extractive trades	5,629.8	15.9 (0.6)	1.49	1.33–1.67	294.1	33.0
Operators, fabricators, and laborers						
Machine operators and tenders, except precision	4,371.3	15.6 (0.6)	1.65	1.46–1.86	266.9	39.2
Fabricators, assemblers, inspectors, and samplers	2,612.9	13.9 (0.8)	1.49	1.29–1.73	120.5	33.1
Transportation and material moving occupations						
Material moving equipment operators	1,164.1	18.7 (1.3)	1.76	1.49–2.07	94.1	43.1
Motor vehicle operators	3,754.2	14.9 (0.7)	1.37	1.20–1.56	151.1	26.9
Other transportation, except motor vehicles	187.4	30.3 (4.5)	2.56	1.93–3.40	34.6	61.0
Handlers, equipment cleaners, helpers, and laborers						
Freight, stock, and material handlers	3,710.4	11.2 (0.6)	1.41	1.23–1.63	121.3	29.2
Construction laborers	965.8	10.3 (1.1)	1.07	0.85–1.35	6.8	6.9
Finance, commodities, and sales representatives¶	4,003.6	9.7 (0.5)	1.00		0.0	0.0
Total working population	122,156.2	11.4 (0.1)			3,282.1	23.5

*Estimated number of US working population in 1,000s.
†Population prevalence of hearing difficulty (%).
‡Prevalence ratios (PR) are adjusted for all other covariates (age, sex, race group, smoking status, and education).
§Attributable case (AC), number of hearing difficulty cases attributable to employment in 1,000s.
‖Attributable fraction (AF), percent of hearing difficulty cases attributable to employment.
¶Reference group.
SE indicates standard error.

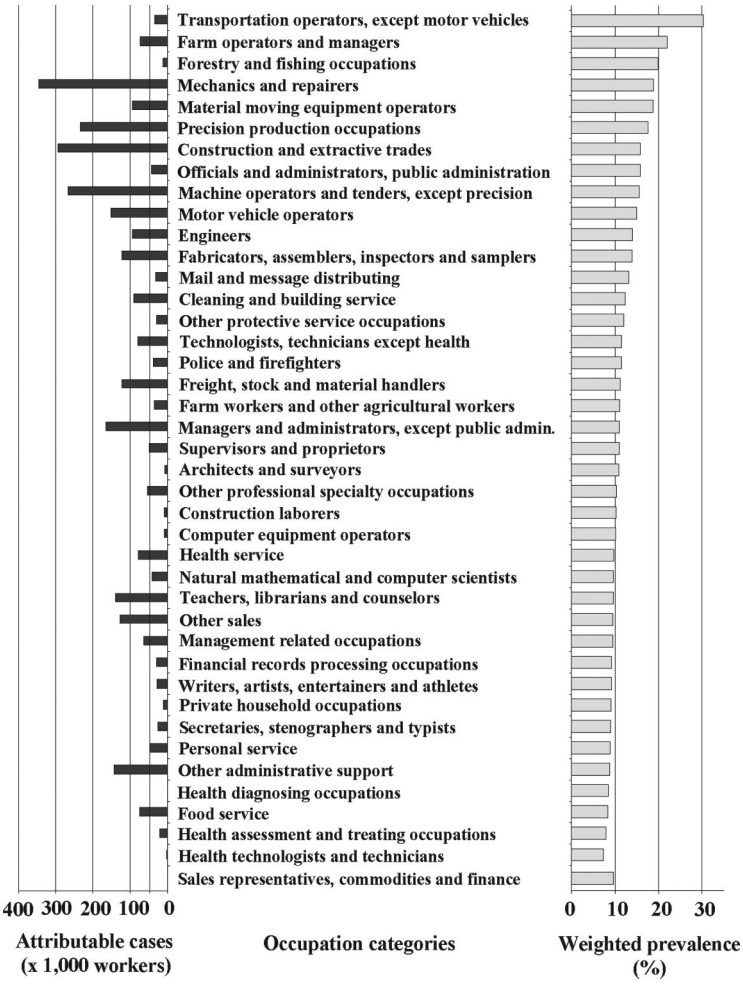

Fig. 3. Prevalence of hearing difficulty and the number of hearing difficulty cases attributable to employment by occupation, United States, 1997 to 2003. Note: attributable cases are based on the prevalence ratios adjusted for age, sex, race, smoking status, and education.

cesses for noisy ones; 2) controlling the noise of existing processes; and 3) developing hearing loss prevention programs, including proper use of personal protective equipment.

There is some evidence for the effectiveness of hearing loss prevention programs in general industry.[16] The hearing conservation amendment to the occupational noise exposure standard, 29 CFR 1910.95, is applicable to all employees who work for employers who are covered by the Occupational Safety and Health Act (OSHA) except those engaged in construction.[17] The hearing conservation amendment for general industry requires the initiation of hearing loss prevention programs at an action level of 85 dBA, which includes periodic audiometric testing when employees' noise exposures are equal to, or exceed, an 8-hour time-weighted average of 85 dBA. The OSHA standard for noise in construction (29 CFR 1926.52) is less complete than the standard for general industrial workers (29 CFR 1910.95).[18] The construction regulation mandates the initiation of hearing loss prevention program and use of administrative controls, engineering controls, or personal hearing protection only after noise exposure exceed the permissible exposure limit. However, audiometric testing is not required under the OSHA standard for noise in construction. Construction companies can voluntarily provide audiometric testing, but there is at least one disincentive for providing voluntary testing as companies are required to log any hearing loss cases that meet recording criteria on the appropriate OSHA record-keeping forms per 29 CFR 1904.1. In our analysis of industrial sectors, we found that the construction industry had the largest number of workers with hearing difficulty attributable to employment. The construction occupations with the highest OHL risk included craft and precision production occupations, and motor vehicle or material moving equipment operators.

Our findings with respect to construction are consistent with those of other investigators. One study showed that the rate of workers compensation claims for hearing loss in the construction industry in Washington State was approximately five times higher than the average rate for all industries combined.[19] The number of US construction workers exposed to potentially hazardous levels of noise (greater than 90 dB) has previously been estimated to be about 4,700,000.[20] Noise exposure levels of Canadian construction workers in Ontario ranged from 81 to 113 dBA.[21] The noise exposure levels among heavy equipment operators in construction were also shown to be high. The 8-hour time-weighted average noise exposure levels ranged from 88 to 99 dBA for power shovel operators and heavy-duty bulldozer operators, respectively.[22] These findings suggest that there may be benefits for noise reduction in machinery design. Enhancing hearing loss prevention programs in construction should reduce the prevalence of OHL among construction workers. Because of the mobility of construction workers and the small size of many construction companies, the portability of record keeping is an important consideration for effective audiometric testing in the construction industry.

Our study found that farm operators and managers have the second highest prevalence of hearing difficulty among all occupational categories. Farm operators and managers can have high

TABLE 4
Estimated Prevalence of Hearing Difficulty, the Adjusted Prevalence Ratio (PR), and the Attribution to Employment for the 25 Occupation-Industry Pairs With the Highest Prevalence of Hearing Difficulty, United States, 1997–2003

Occupation-Industry	*N**	Weighted Prevalence,† % (SE)	Adjusted PR‡	95% CI	AC§	AF‖
Mechanics and repairers—primary metal mfg.	78.7	39.0 (6.6)	3.18	2.23–4.54	21.1	79.9
Operators—railroads	110.6	36.4 (5.9)	3.04	2.28–4.06	27.1	77.9
Mechanics and repairers—other non-durable goods	84.2	35.0 (5.4)	2.78	2.07–3.73	18.8	74.4
Material moving equip. operators—mining	59.2	34.2 (6.7)	3.11	2.15–4.51	13.7	77.7
Craft and precision production—primary metal mfg.	92.1	29.4 (6.1)	2.52	1.67–3.80	16.3	69.4
Construction and extractive trades—mining	128.8	29.2 (5.4)	2.74	1.89–3.96	23.8	72.4
Mechanics and repairers—transportation equip. mfg.	155.8	28.1 (3.7)	2.38	1.86–3.05	25.4	67.1
Construction trades—transportation equip. mfg.	50.9	27.5 (7.3)	2.47	1.50–4.07	8.3	68.4
Mechanics and repairers—other durable goods	73.7	26.6 (6.1)	2.59	1.71–3.93	12.0	69.9
Machine operators and tenders—machinery mfg.	198.8	26.2 (3.9)	2.40	1.81–3.18	30.3	66.9
Mechanics and repairers—food and kindred products	94.1	26.1 (6.0)	2.41	1.57–3.71	14.4	67.5
Craft and precision production occupations—construction	103.8	25.0 (4.8)	2.24	1.59–3.17	14.4	63.8
Forestry and fishery—furniture, lumber, and wood mfg.	61.0	24.6 (5.8)	2.26	1.52–3.35	8.3	64.2
Craft and precision production—printing and publishing	64.8	24.6 (6.1)	2.41	1.49–3.90	9.3	66.5
Mechanics and repairers—other transportation	227.6	24.3 (3.4)	2.07	1.56–2.73	28.6	59.8
Material moving equip. operators—construction	360.3	24.2 (2.6)	2.24	1.80–2.78	48.2	63.4
Fabricators, assemblers, and inspector—repair services	112.3	23.8 (5.1)	2.16	1.46–3.19	14.3	62.1
Engineers—communications	86.7	23.5 (7.4)	2.13	1.09–4.17	10.8	61.0
Motor vehicle operators—construction	191.8	23.4 (3.5)	2.07	1.54–2.78	23.2	59.4
Mechanics and repairers—communications	91.1	23.2 (4.8)	2.18	1.46–3.25	11.4	62.0
Craft and precision production—transportation equip. mfg.	247.7	23.0 (2.7)	2.10	1.63–2.72	29.9	60.5
Material moving equip. operators—furniture, lumber, and wood mfg.	57.6	22.8 (5.9)	2.25	1.32–3.81	7.3	63.5
Farm operators and managers—agriculture	777.8	22.2 (1.8)	1.81	1.50–2.18	77.3	51.3
Craft and precision production—furniture, lumber, and wood mfg.	163.9	21.7 (4.1)	2.35	1.59–3.48	20.5	65.1
Mechanics and repairers—public administration	141.1	21.5 (3.9)	1.96	1.36–2.81	14.8	56.3

*Estimated number of US working population in 1,000s.
†Estimated population prevalence of hearing difficulty (%).
‡Prevalence ratios (PR) are adjusted for all other covariates (age, sex, race group, smoking status, and education), compared with workers employed in the finance, insurance, and real estate industries.
§AC, number of hearing difficulty cases attributable to employment in 1,000s.
‖AF, percent of hearing difficulty cases attributable to employment.
SE indicates standard error; equip., equipment; mfg., manufacturing.

noise exposures, by operating or working in proximity to farm equipment (eg, 91 dB for tractors),[23] and working in or around animal confinement facilities (eg, 87 dB for sheep farming).[24] Our findings are consistent with those of other investigators who found these workers to be at high risk of hearing difficulty.[25,26] Considering the high prevalence of hearing difficulty among farm operators and managers, hearing protection interventions should be developed to address the unique needs of the agriculture industry.[23] Similar efforts are also needed for fishing and forestry workers.

Because of the historically high rate of hearing loss in mining, MSHA (Mine Safety and Health Act) requires hearing loss prevention program rules that are similar to OSHA's, except that MSHA does not require a written program.[27] Our study found that the mining industry has the second highest prevalence of hearing difficulty among all industrial sectors, suggesting that further efforts are needed to prevent hearing loss in this industry.

The railroad industry had the highest prevalence (35%) and adjusted PR (PR = 2.7) of hearing difficulty. Noise exposures and hearing loss among rail yard and railway workers have been long understudied. A recent study sum-

marizing noise exposures to rail workers at a large chemical facility in North America showed that peak-impact sound levels exceeded 140 dB in 94% of total samples with a mean peak sound level of 144 dB, and concluded that rail workers at this facility were at risk of noise-induced hearing loss from high-impact noise exposures.[28] Our results suggest that workers in the railroad industry are at significantly high risk of hearing impairment, and underscore the need for further research efforts to confirm and reduce the magnitude of hearing loss in this industry.

Mechanics and repairers are at high risk of hearing impairment across a variety of industries. To our knowledge, there is no study specifically addressing noise exposure levels and OHL among those in this occupation. There are possible explanations for these high rates of hearing difficulty among mechanics and repairers. Mechanics and repairers are potentially exposed to high noise levels because of the nature of their work. Mechanics in the heavy equipment manufacturing industry, for example, use a variety of pneumatic tools that generate high noise exposure. Because mechanics and repairers often need to hear and detect the unusual noises coming from machinery or equipment to diagnose mechanical problems, they may not consistently use hearing protection devices. Our findings suggest that further surveillance and intervention efforts should be focused on this occupation across all industrial sectors.

Exposure to certain chemicals may also result in hearing loss.[29,30] In settings where noise exposure may be combined with carbon monoxide, lead, manganese, styrene, toluene, or xylene exposure, periodic audiograms are advised and should be carefully reviewed.[31]

The large sample size of the present study allowed reliable estimation of the prevalence for various industries and occupations. However, our study has several limitations. Industry-occupation categories used in this analysis may not be homogenous with respect to exposure to noise and ototoxicants, which may lead to attenuation of risk estimates (ie, PRs) because of misclassification.[32] It should be also noted that the cross-sectional study design of NHIS has limitations for the ascertainment of causal relationships. Persons previously in the US workforce, but not employed during the preceding year were not interviewed. Misclassification could also have occurred if some workers left the job that contributed to their hearing difficulty, and were working in a job without exposures to noise and other ototoxicants at the time of their interview. Because the respondent's work history in the NHIS data is linked only to the most recent job, errors may have been introduced to the estimated magnitude of associations. It is uncertain whether these effects would lead to an underestimation or overestimation of the risk of hearing difficulty.

Another limitation is that these hearing difficulty data are self-reported assessments and were not validated by audiometric tests. Errors might arise due to the potential inaccuracy of self-report. In a study of workers in construction and farming, analysis of perceived and measured hearing loss data demonstrated low sensitivity of a one-item self-report of hearing ability (ie, 1 = excellent to 5 = poor), suggesting that perceived hearing loss may not be a good indicator of actual hearing loss.[33] Therefore, prevalence of hearing difficulty in our study may have been underestimated because of low sensitivity of the question used to define hearing difficulty. However, this same self-rating of hearing ability involving four categories (good, a little trouble hearing, a lot of trouble hearing, deaf) was shown to be useful in an earlier study in detecting cases of hearing loss.[11] Furthermore, a recent validation study of self-reported hearing loss also showed that the single question, "Do you feel you have a hearing loss?" yielded reasonable sensitivity and specificity for hearing impairment validated against audiometric measurement of hearing loss, and was minimally affected by age and gender.[34] The prevalence of hearing difficulty among those (n = 5934) excluded from the analysis was lower (5.4%) than the total employed population (11.4%). Because of this exclusion, national prevalence of hearing difficulty may have been overestimated. It is uncertain whether this impact would differ between occupational groups or industry sectors.

Consistent with previous studies,[4,23,35,36] our study found that hearing difficulty was significantly variable across non-occupational characteristics, such as age, sex, race, smoking status, and education level. Despite our attempt to adjust for non-occupational risk factors, the lack of information on recreational noise exposures (eg, hunting, listening to loud music) and past military experiences may have led to insufficient adjustment for non-occupational risks of hearing loss. For example, the excess hearing difficulty observed in farm operators and managers could be in part due to non-occupational exposures such as using firearms. We do not know whether these noisy hobbies are differentially distributed across occupations or industrial sectors. Including questions on hobbies in the NHIS could improve the future assessment of OHL.

Conclusion

The present analysis of NHIS data showed that workers in certain industries and occupations are at an increased risk of hearing difficulty. Our findings strengthen the need for workplace-based hearing loss prevention programs. Hearing loss prevention programs should focus on industries and occupations at high risk and with a large number of workers with hearing difficulty at-

tributable to employment. More research is needed to identify effective interventions to reduce the prevalence of OHL. Surveillance systems to track OHL in an ongoing and systematic manner should be established at the federal and state level.

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