# Hearing Difficulty and Tinnitus Among U.S. Workers and Non-Workers in 2007

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**Background** *Hearing loss and tinnitus are two potentially debilitating physical conditions affecting many people in the United States. The purpose of this study was to estimate the prevalence of hearing difficulty, tinnitus, and their co-occurrence within U.S. populations.*
**Methods** *Data from the 2007 National Health Interview Survey (NHIS) were examined. Weighted prevalence and adjusted prevalence ratios for self-reported hearing difficulty, tinnitus, and their co-occurrence were estimated and compared by demographic, among workers with and without occupational noise exposure, and across industries and occupations.*
**Results** *Seven percent of U.S. workers never exposed to occupational noise had hearing difficulty, 5% had tinnitus and 2% had both conditions. However, among workers who had ever been exposed to occupational noise, the prevalence was 23%, 15%, and 9%, respectively ($P < 0.0001$).*
**Conclusions** *Hearing difficulty and tinnitus are prevalent in the U.S.; especially among noise-exposed workers. Improved strategies for hearing conservation or better implementation are needed.* Am. J. Ind. Med. Published 2016. This article is a U.S. Government work and is in the public domain in the USA

***KEY WORDS: occupational hearing loss; ringing in the ears; tinnitus; hazardous noise; noise-induced hearing loss; surveillance***

## INTRODUCTION

Hearing loss is a permanent and potentially debilitating physical condition affecting over 11 percent of the U.S. adult working population [Tak and Calvert, 2008]. Twenty-four percent of the cases of hearing loss among these employed adults are attributable to occupational exposures [Tak and Calvert, 2008]. Workers exposed to loud noise or ototoxic chemicals on the job can develop occupational hearing loss (OHL) [Johnson and Morata, 2010; Themann et al., 2013]. Hazardous noise is prevalent in the workplace; affecting approximately 22 million U.S. workers (17%) [Tak et al., 2009]. Among noise-exposed workers, 18% have material hearing impairment [Masterson et al., 2013], defined by the National Institute for Occupational Safety and Health (NIOSH) as a pure-tone average threshold across frequencies 1,000, 2,000, 3,000, and 4,000 Hz of 25 dB or more in either ear [NIOSH, 1998].

Hearing loss can have substantial adverse implications for work, interpersonal relationships, and quality of life. These include difficulty communicating on the telephone, in groups or when background noise is present, and in public spaces such as restaurants [Hetu et al., 1995; Morata et al., 2005]. Workers with hearing loss often have trouble localizing sounds or hearing warning signals and have an

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increased risk of accidents [Hetu et al., 1995; Morata et al., 2005]. These symptoms often lead to isolation in social situations, impediments in career progression, reduced autonomy, poor self-image, fatigue, frustration, and depression [Hetu et al., 1995; Morata et al., 2005].

Tinnitus, often known as "ringing in the ears," is the perception of sound in one or both ears or in the head in the absence of external noise [Sanders, 2004; Folmer et al., 2011]. It frequently co-occurs with hearing loss, though it can also occur in individuals with clinically normal hearing [Schaette and McAlpine, 2011]. Depending on the frequency and intensity of occurrence, tinnitus can greatly impact an individual's overall health and well-being [Sanders, 2004; Shargorodsky et al., 2010]. Tinnitus can disrupt sleep and concentration [Sanders, 2004], increasing fatigue, impacting alertness, degrading performance, and potentially increasing risks for accidents on and off the job [Rosekind, 2005]. Tinnitus is also associated with depression and anxiety [Shargorodsky et al., 2010]. Risk factors for tinnitus include hearing loss, exposure to loud noise, and increasing age [Shargorodsky et al., 2010].

Several papers have examined the prevalence of tinnitus within the general population, among veterans and in the youth population using the National Health and Nutrition Examination Surveys (NHANES) [Cooper, 1994; Shargorodsky et al., 2010; Folmer et al., 2011; Mahboubi et al., 2013]. However, limited information is available for non-military working populations or for specific U.S. industry or occupation groups. While papers examining the prevalence of hearing loss in the U.S. by demographic, industry or occupation are available [Stanbury et al., 2008; Tak and Calvert 2008; Masterson et al., 2013], research is lacking related to the co-occurrence of hearing difficulty and tinnitus in U.S. working populations.

In 2007, the National Health Interview Survey (NHIS) [CDC, 2013a,b] collected detailed self-report information on both hearing difficulty and tinnitus for workers and non-workers. This survey instrument also included self-report information on past/current exposure to occupational noise. The purpose of the current study was to estimate the prevalence of hearing difficulty, tinnitus, and the co-occurrence of these two conditions in the overall U.S. adult population and among noise-exposed and non-noise-exposed workers by examining data from the 2007 NHIS. We provided weighted prevalence estimates and adjusted relative risk estimates for hearing difficulty, tinnitus and their co-occurrence by industry and occupation.

## MATERIALS AND METHODS

### Study Design and Population

This study was a cross-sectional analysis of publicly available data from the 2007 NHIS. The prevalence of self-reported hearing difficulty and tinnitus for the entire adult sample and for adult individuals currently working or who had ever worked were examined. Males and females who were at least 18 years old with available data were included in the study. The NHIS is an in-person health survey conducted by the National Center for Health Statistics (NCHS) on the U.S. non-institutionalized civilian household population [CDC, 2008]. Survey participants were chosen using a multi-stage sample design and sampling weights were provided with the data. The 2007 survey was chosen since it included a hearing supplement with additional questions related to hearing difficulty, tinnitus and noise exposure. The 2007 NHIS was approved by the Research Ethics Review Board of the NCHS and the U.S. Office of Management and Budget. All 2007 NHIS respondents provided oral consent prior to participation in the 2007 NHIS.

### NHIS Outcome and Exposure Questions

Our outcomes were hearing difficulty, tinnitus and the presence of both conditions, determined from the NHIS variables AHEARST1, HRTIN, and HRTINOFT.

- Hearing difficulty was assessed based on the question: *Is your hearing excellent*, *good*, *a little trouble hearing*, *moderate trouble*, *a lot of trouble*, *or are you deaf*? When hearing difficulty was analyzed as a dichotomous variable, those with any difficulty hearing (a little trouble hearing, moderate trouble, a lot of trouble, deaf) were grouped together as Yes Has Difficulty and those with excellent or good hearing were grouped together as No Difficulty. These groupings are not intended to mirror common characterizations of audiometry results.
- Tinnitus was assessed based on the question: *In the past 12 months*, *have you been bothered by ringing*, *roaring, or buzzing in your ears or head that lasts for 5 min or more*? (*Yes/No*). This question was used when analyzing tinnitus as a dichotomous variable.
- Tinnitus frequency was assessed based on the question: *In the past 12 months*, *how often have you had this ringing*, *roaring*, *or buzzing in your ears or head*? *Would you say*: (i) *Almost always*; (ii) *At least once a day*; (iii) *At least once a week*; (iv) *At least once a month*; *or* (v) *Less frequently than once a month*?

Exposures of interest were employment status, occupational noise exposure, industry, and occupation, determined from the NHIS variables DOINGLW2, EVERWRK, HRWRKNOS, INDSTRN2, and OCCUPN2. Per the U.S. Census Bureau [2015a], "industry is the type of activity at a person's place of work; occupation is the kind of work a person does to earn a living. . ." The industry and occupation

variables were coded by NCHS from verbatim survey responses. Industry was coded using the 2-digit 2002 North American Industry Classification System (NAICS) [U.S. Census Bureau, 2015b] and occupation was coded using the 2-digit Standard Occupation Classification (SOC) System [U.S. Bureau of Labor Statistics, 2013]. Questions for determining employment status and occupational noise exposure are as follows:

- Current employment status was assessed based on the question: *Which of the following were you doing last week*? (i) *Working for pay at a job or business*; (ii) *With a job or business but not at work*; (iii) *Looking for work*; (iv) *Working, but not for pay, at a family owned job or business*; *or* (v) *Not working at a job or business and not looking for work*? Individuals were considered currently working if their responses regarding current employment were "working for pay at a job or business," "with a job or business but not at work," or "working, but not for pay, at a family owned job or business."
- Lifetime employment status was assessed based on the question: *Have you ever worked for a job or business*? (*Yes*/*No*). Individuals were considered to have ever worked if they were currently working or their lifetime employment question responses were "Yes." Individuals were considered to have never worked if their current employment responses were "looking for work" or "not working at a job or business and not looking for work," **and** their lifetime employment responses indicated they had never held a job or worked at a business.
- Occupational noise exposure was assessed based on the question: *Have you ever had a job*, *or combination of jobs*, *where you were exposed to loud sounds or noise for 4 or more hours a day*, *several days a week*? *Loud means so loud that you must speak in a raised voice to be heard* (*Yes*/*No*).

## Statistical Analysis

The outcome variables hearing difficulty, tinnitus, and their co-occurrence were each coded as zero or one, with a one indicating that the worker reported having the condition. Survey respondent ages from variable AGE_P were condensed into seven descriptive categories. The race/ethnicity variables (RACERPI2 and HISPAN_I) were combined into one variable to capture both race and ethnicity. American Indian, Alaska Native, race group not releasable, and multiple race were combined into an Other race/ethnicity category. The smoking variable (SMKSTAT2) was also recoded into a new variable with levels Current Smoker, Former Smoker and Never Smoked.

A work status variable was created with three levels (Currently Working, Formerly Working or Seeking Work, and Never Worked) in order to be able to adjust the demographic risk estimates of the overall population for any inherent differences among individuals with dissimilar working statuses. Individuals were designated as Currently Working and Never Worked as defined in the previous section. Individuals were designated Formerly Working or Seeking Work if their current employment status responses were "looking for work" or "not working at a job or business and not looking for work," **and** their lifetime employment status responses indicated "Yes."

NHIS data were collected using a complex, multistage sample design that involves stratification, clustering, and oversampling of specific population subgroups. In this study, SAS survey procedures and SUDAAN were used for the analyses to produce weighted point estimates for the U.S. population as well as variance estimates that properly account for the complex sample design. All analyses were performed using SAS version 9.3 (SAS Institute Inc., Cary, NC) and SUDAAN version 11 (RTI International, Research Triangle Park, NC) statistical software.

Weighted prevalence percentages for each dichotomous outcome by each demographic for all 2007 Sample Adults (the overall population) were estimated using SAS. Weighted adjusted prevalence ratios (PRs) with 95% confidence intervals for each dichotomous outcome by each demographic were also estimated utilizing SUDAAN. The SUDAAN rlogist procedure can produce PRs in addition to odds ratios and these can be interpreted as relative risk estimates. PRs for the demographic variables (gender, age group, race/ethnicity, smoking status, and region) were adjusted for all of the other demographic variables and work status. Reference groups for the covariates were designated as female for gender, ages 18–25 for age group, Asian for race/ethnicity, never smoked for smoking status, and Northeast for region.

Weighted prevalence percentages for hearing difficulty, tinnitus, and the co-occurrence of the two dichotomous outcomes were estimated for four groups: (i) those who were currently working who reported loud noise exposure at work; and (ii) those who were currently working who did not report loud noise exposure at work; (iii) those who had ever worked and reported loud noise exposure at work; and (iv) those who had ever worked but did not report loud noise exposure at work. Rao-Scott $\chi^2$ Tests [SAS, 2013] were performed to compare the weighted prevalence of hearing difficulty, tinnitus and their co-occurrence for noise-exposed versus non-noise-exposed individuals who were currently working. The dichotomous variables for hearing difficulty and tinnitus were used. Similar analyses were performed for individuals who had ever worked. A $P$-value of 0.05 or less was considered statistically significant.

Weighted prevalence percentages for each dichotomous outcome by each industry and occupation for individuals

currently working were estimated using SAS. Weighted adjusted PRs with 95% confidence intervals for each dichotomous outcome by each industry and occupation were also estimated utilizing SUDAAN. Estimates for the Management of Companies and Enterprises industry (NAICS 55) were not reported due to insufficient group size. The risk of developing hearing difficulty, tinnitus or both for each industry was compared with the risk of developing that outcome for all other industries combined. The risk of developing each outcome for each occupation was assessed in a similar manner. A PR $> 1$ indicates that the risk in a particular industry or occupation is higher than the risk for all other industries or occupations combined. PRs were adjusted by gender, age group, race/ethnicity, smoking status, and region.

The relative standard error (RSE) was calculated for each weighted prevalence estimate and weighted adjusted PR by dividing the standard error by the point estimate. RSE is used to assess sampling error and how far a survey estimate may likely deviate from the population parameter [Australian Bureau of Labor Statistics, 2010]. Point estimates with an RSE $\geq 50\%$ were not reported. Point estimates with an RSE $< 50\%$ but $\geq 30\%$ are identified as such in the tables; however, these point estimates do not meet the NCHS standards of reliability and precision and must be viewed with caution.

## RESULTS

### Overall Adult Population Demographics and Prevalence

Overall adult population demographics and weighted prevalence estimates and PRs are provided in Table I. About 15% of adults reported hearing difficulty, 10% reported tinnitus, and 5% reported having both conditions. The prevalence of hearing difficulty, tinnitus, and their co-occurrence was higher for males, respondents of Other and White race/ethnicity, and former smokers. The prevalence of each outcome also increased with age, with a slight decrease for tinnitus and both conditions in the oldest age group. The prevalence of hearing difficulty, tinnitus and their co-occurrence was lowest among females, respondents of Asian race/ethnicity and those who had never smoked. The risk estimates (PRs) indicate that males were significantly more likely than females to report one of the outcomes (hearing difficulty, tinnitus, or both conditions), and that risk increased with age compared to the 18–25 age group. The risk of having hearing difficulty was three times higher for respondents of Other race/ethnicity than the reference (PR = 3.05, CI = 2.21–4.20) and was five times higher for having both hearing difficulty and tinnitus (PR = 5.01, CI = 2.62–9.56). Other race/ethnicity included American Indian, Alaska Native, race group not releasable, and multiple race. Current and former smokers were significantly more likely to have hearing difficulty, tinnitus, or both conditions than individuals who had never smoked. For example, 25% of former smokers had hearing difficulty, 16% had tinnitus, and 9% had both conditions as compared with those who had never smoked (11%, 7%, and 3%, respectively).

### Prevalence for Noise-Exposed and Non-Noise Exposed Workers

Weighted prevalence estimates for each outcome for workers who did and did not report loud noise exposure at work are presented in Table II. Estimates are presented for those currently working and those who had ever worked. Currently working individuals who reported exposure to loud noise at work had a 23% prevalence of hearing difficulty compared with 7% for those not exposed ($P < 0.0001$). Similarly, individuals who had ever worked and reported exposure to loud noise at work had a 30% prevalence of hearing difficulty compared with 10% for those not exposed ($P < 0.0001$). This pattern remained consistent for tinnitus and the co-occurrence of both outcomes. All Rao-Scott $\chi^2$ Test comparisons of noise-exposed and non-noise-exposed workers were statistically significantly different ($P < 0.0001$). The prevalence of tinnitus and or a co-occurrence of both conditions among noise-exposed workers was 15% and 9%, respectively, for those currently working and 19% and 12% for those who had ever worked. The prevalence of constant tinnitus symptoms ("almost always") among noise-exposed workers was 5% for those currently working and 8% for those who had ever worked compared with 2% for non-noised-exposed workers.

### Prevalence and Risk Within Industries

Overall, among individuals currently working, the prevalence of hearing difficulty was 11%, the prevalence of tinnitus was 8%, and the prevalence of their co-occurrence was 4% (Table III). When examined separately, only a few industries had risks significantly different than all other industries combined. Agriculture, Forestry, Fishing, and Hunting had a significantly higher risk for hearing difficulty (PR = 1.51, CI = 1.09–2.08), tinnitus (PR = 1.47, CI = 1.03–2.11) and their co-occurrence (PR = 1.89, CI = 1.16–3.09) with prevalences 20%, 13%, and 8%, respectively. Manufacturing also had a significantly higher risk of tinnitus (PR = 1.27, CI = 1.04–1.56) and the co-occurrence of both conditions (PR = 1.40, CI = 1.06–1.85) with prevalences 11% and 6%, respectively. The Information industry had a significantly lower risk of hearing difficulty (PR = 0.49, CI = 0.29–0.82) with a prevalence of 5% and

**TABLE I.** Adult Sample Demographics With Weighted Prevalence and Weighted Adjusted Prevalence Ratios (PRs) for Self-Reported Hearing Difficulty (HD), Tinnitus, and Their Co-Occurence, 2007, (N = 23,393)[a]

| Demographic | Unweighted n | Unweighted (%) | Prevalence of HD (%) | PR[b] | 95% CI[c] | Prevalence of tinnitus (%) | PR | 95%CI | Prevalence of co-occurence (%) | PR | 95%CI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| All demographics | | | 14.94 | | | 9.59 | | | 4.98 | | |
| Gender | | | | | | | | | | | |
| Male | 10,375 | 44.35 | 17.91 | 1.56 | 1.44–1.68 | 10.49 | 1.20 | 1.09–1.31 | 5.97 | 1.46 | 1.27–1.67 |
| Female (ref) | 13,018 | 55.65 | 12.17 | Ref | | 8.74 | Ref | | 4.06 | Ref | |
| Age group (years) | | | | | | | | | | | |
| 18–25 (ref) | 2,908 | 12.43 | 4.16 | Ref | | 4.71 | Ref | | 1.34 | Ref | |
| 26–35 | 4,230 | 18.08 | 5.07 | 1.25 | 0.96–1.62 | 5.25 | 1.14 | 0.87–1.49 | 1.75 | 1.32 | 0.85–2.07 |
| 36–45 | 4,338 | 18.54 | 8.74 | 2.14 | 1.69–2.71 | 7.22 | 1.54 | 1.20–1.97 | 2.98 | 2.22 | 1.43–3.45 |
| 46–55 | 4,303 | 18.39 | 15.62 | 3.52 | 2.78–4.46 | 11.32 | 2.21 | 1.74–2.79 | 6.12 | 4.10 | 2.72–6.19 |
| 56–65 | 3,358 | 14.35 | 21.80 | 4.49 | 3.54–5.70 | 15.25 | 2.57 | 2.00–3.31 | 8.59 | 5.01 | 3.29–7.63 |
| 66–75 | 2,308 | 9.87 | 31.42 | 5.95 | 4.74–7.46 | 15.81 | 2.24 | 1.75–2.87 | 10.17 | 4.94 | 3.30–7.39 |
| 76 and above | 1,948 | 8.33 | 45.69 | 9.12 | 7.31–11.37 | 14.01 | 2.04 | 1.58–2.64 | 10.08 | 5.21 | 3.44–7.89 |
| Race/ethnicity | | | | | | | | | | | |
| White | 13,913 | 59.48 | 17.95 | 2.05 | 1.60-2.62 | 11.04 | 1.90 | 1.39–2.60 | 5.99 | 2.64 | 1.59–4.38 |
| Black/African-American | 3,626 | 15.50 | 7.35 | 1.08 | 0.82–1.43 | 6.12 | 1.20 | 0.84–1.70 | 2.40 | 1.26 | 0.71–2.21 |
| Asian (ref) | 450 | 1.92 | 6.26 | Ref | | 4.60 | Ref | | 1.64 | Ref | |
| Hispanic | 1,208 | 5.16 | 7.67 | 1.32 | 1.01–1.74 | 5.90 | 1.34 | 0.95–1.91 | 2.33 | 1.52 | 0.88–2.63 |
| Other race/ethnicity | 4,196 | 17.94 | 23.52 | 3.05 | 2.21–4.20 | 15.75 | 2.79 | 1.82–4.29 | 10.56 | 5.01[d] | 2.62–9.56 |
| Smoking status | | | | | | | | | | | |
| Current smoker | 4,372 | 19.02 | 15.82 | 1.44 | 1.31–1.59 | 12.16 | 1.68 | 1.48–1.90 | 6.22 | 1.83 | 1.53–2.18 |
| Former smoker | 4,929 | 21.44 | 24.58 | 1.33 | 1.22–1.45 | 15.51 | 1.69 | 1.48–1.92 | 8.94 | 1.73 | 1.46–2.05 |
| Never smoked (ref) | 13,689 | 59.54 | 11.15 | Ref | | 6.65 | Ref | | 3.15 | Ref | |
| Unknown/missing | 403 | | | | | | | | | | |
| Region | | | | | | | | | | | |
| Northeast (ref) | 3,921 | 16.76 | 14.06 | Ref | | 8.97 | Ref | | 4.46 | Ref | |
| Midwest | 5,222 | 22.32 | 16.37 | 1.14 | 1.04–1.26 | 10.03 | 1.09 | 0.92–1.28 | 5.24 | 1.12 | 0.92–1.37 |
| South | 8,717 | 37.26 | 14.02 | 1.07 | 0.97–1.18 | 9.48 | 1.11 | 0.93–1.32 | 4.92 | 1.18 | 0.96–1.44 |
| West | 5,533 | 23.65 | 15.58 | 1.19 | 1.07–1.32 | 9.76 | 1.15 | 0.96–1.37 | 5.22 | 1.25 | 1.01–1.54 |

[a]Data from the National Health Interview Survey, 2007 adult sample.
[b]PRs were adjusted for gender, age group, race, smoking status, work status, and geographical region.
[c]CI = 95% confidence limits.
[d]This estimate has a relative standard error $\geq$30% and $<$50% and should be used with caution as it does not meet standards of reliability/precision.

**TABLE II.** Comparisons of Weighted Prevalences and Percentages of Self-Reported Hearing Difficulty, Tinnitus, and Their Co-Occurrence for Current/Former Workers Who Did and Did Not Report Loud Noise Exposure at Work, 2007[a]

| | Currently working with history of loud noise exposure at work[b] | | Currently working with no history of loud noise exposure at work | | Ever worked[c] with history of loud noise exposure at work[b] | | Ever worked with no history of loud noise exposure at work | |
|---|---|---|---|---|---|---|---|---|
| **Outcome** | **Unweighted n** | **Prevalence** | **Unweighted n** | **Prevalence** | **Unweighted n** | **Prevalence** | **Unweighted n** | **Prevalence** |
| Group total | 3,329 | | 11,072 | | 5,197 | | 16,539 | |
| Hearing difficulty | | | | | | | | |
| No difficulty (excellent/good hearing) | 2,595 | 77.46 | 10,364 | 93.46 | 3,649 | 70.21 | 14,781 | 89.83 |
| Yes (has difficulty) | 734 | 22.55 | 704 | 6.54 | 1,548 | 29.79 | 1,751 | 10.17 |
| Don't know/missing | 0 | | 4 | | 0 | | 7 | |
| Hearing description breakdown: | | | | | | | | |
| Excellent | 1,463 | 43.21 | 7,418 | 66.68 | 1,963 | 37.91 | 10,094 | 61.52 |
| Good | 1,132 | 34.25 | 2,946 | 26.76 | 1,686 | 32.30 | 4,687 | 28.28 |
| A little trouble hearing | 499 | 15.00 | 533 | 4.94 | 899 | 17.26 | 1,177 | 6.89 |
| Moderate trouble | 164 | 5.37 | 127 | 1.27 | 384 | 7.58 | 355 | 2.09 |
| A lot of trouble | 67 | 2.09 | 35 | 0.26 | 248 | 4.63 | 194 | 1.05 |
| Deaf | 4 | [d] | 9 | 0.07[e] | 17 | 0.33 | 25 | 0.15 |
| Refused/don't know | 0 | | 4 | | 0 | | 7 | |
| Tinnitus | | | | | | | | |
| No ringing, roaring, or buzzing | 2,826 | 84.62 | 10,520 | 94.93 | 4,186 | 80.60 | 15,396 | 93.12 |
| Yes (has ringing, roaring or buzzing) | 500 | 15.29 | 550 | 5.05 | 996 | 19.11 | 1,128 | 6.76 |
| Refused/don't know | 3 | | 2 | | 15 | | 15 | |
| Tinnitus frequency breakdown: | | | | | | | | |
| Almost always | 182 | 5.47 | 166 | 1.66 | 401 | 7.64 | 355 | 2.21 |
| At least once a day | 71 | 2.40 | 68 | 0.69 | 139 | 2.86 | 155 | 0.95 |
| At least once a week | 71 | 2.20 | 82 | 0.64 | 144 | 2.71 | 176 | 0.99 |
| At least once a month | 57 | 1.81 | 88 | 0.75 | 118 | 2.35 | 170 | 1.02 |
| Less frequently than once a month | 115 | 3.34 | 138 | 1.24 | 184 | 3.48 | 255 | 1.51 |
| No ringing, roaring or buzzing | 2,826 | 84.62 | 10,520 | 94.93 | 4,186 | 80.60 | 15,396 | 93.12 |
| Refused/don't know | 4 | | 8 | | 10 | | 17 | |
| Co-occurrence of hearing difficulty and tinnitus | | | | | | | | |
| No | 3,047 | 91.26 | 10,852 | 98.04 | 4,567 | 88.05 | 16,031 | 97.15 |
| Yes | 279 | 8.75 | 215 | 1.96 | 615 | 11.95 | 487 | 2.85 |
| Missing | 3 | | 5 | | 15 | | 21 | |

[a]Data from the National Health Interview Survey, 2007 adult sample.
[b]All Rao-Scott $\chi^2$ Test comparisons of dichotomous outcomes for noise-exposed and non-noise-exposed workers were statistically significantly different ($P < 0.0001$).
[c]Ever worked includes individuals currently working.
[d]Estimate not shown as it has a relative standard error $\geq$50% and does not meet standards of reliability/precision.
[e]This estimate has a relative standard error $\geq$30% and $<$50% and should be used with caution as it does not meet standards of reliability/precision.

**TABLE III.** Weighted Prevalence of Self-Reported Hearing Difficulty (HD), Tinnitus, and Their Co-Occurence, for Individuals Currently Working, by Industry, and Weighted Adjusted Prevalence Ratios (PRs) for Each Industry Compared With All Other Industries, 2007 (N = 14,453)[a]

| Industry sector (NAICS 2007 code) | Unweighted n | Prevalence of HD (%) | PR[b] | 95%CI[c] | Prevalence of tinnitus (%) | PR | 95%CI | Prevalence of co-occurence (%) | PR | 95%CI |
|---|---|---|---|---|---|---|---|---|---|---|
| All industries | 14,453 | 10.50 | | | 7.57 | | | 3.65 | | |
| Agriculture, forestry, fishing, and hunting (11) | 200 | 20.19 | 1.51 | 1.09–2.08 | 12.73 | 1.47 | 1.03–2.11 | 8.21 | 1.89 | 1.16–3.09 |
| Mining (21) | 66 | 11.75[d] | 0.91[d] | 0.46–1.80 | 10.97[d] | 1.27[d] | 0.70–2.32 | [e] | [e] | |
| Utilities (22) | 114 | 12.86 | 0.96 | 0.57–1.60 | 11.96[d] | 1.30 | 0.73–2.31 | 8.30[d] | 1.72[d] | 0.82–3.63 |
| Construction (23) | 1,010 | 12.81 | 1.09 | 0.89–1.33 | 6.61 | 0.77 | 0.58–1.04 | 3.35 | 0.80 | 0.52–1.24 |
| Manufacturing (31–33) | 1,474 | 13.80 | 1.10 | 0.92–1.32 | 10.57 | 1.27 | 1.04–1.56 | 5.58 | 1.40 | 1.06–1.85 |
| Wholesale trade (42) | 371 | 11.78 | 0.98 | 0.70–1.37 | 6.13 | 0.73 | 0.46–1.14 | 2.98[d] | 0.72[d] | 0.34–1.54 |
| Retail trade (44–45) | 1,371 | 9.86 | 0.95 | 0.77–1.17 | 7.04 | 0.94 | 0.76–1.17 | 2.73 | 0.75 | 0.53–1.07 |
| Transportation, warehousing (48–49) | 606 | 12.36 | 1.01 | 0.78–1.31 | 6.67 | 0.74 | 0.53–1.03 | 2.81 | 0.63 | 0.38–1.05 |
| Information (51) | 351 | 5.15 | 0.49 | 0.29–0.82 | 7.56 | 1.07 | 0.69–1.65 | 1.57[d] | 0.49[d] | 0.19–1.30 |
| Finance and insurance (52) | 674 | 7.84 | 0.83 | 0.62–1.10 | 5.53 | 0.78 | 0.54–1.14 | 2.37[d] | 0.74 | 0.41–1.34 |
| Real estate and rental and leasing (53) | 301 | 10.07 | 0.77 | 0.52–1.14 | 8.28 | 0.92 | 0.61–1.38 | 1.92[d] | 0.41[d] | 0.18–0.93 |
| Professional, scientific, and technical services (54) | 837 | 12.01 | 1.10 | 0.89–1.35 | 9.66 | 1.28 | 0.92–1.78 | 4.92 | 1.38 | 0.95–2.01 |
| Administrative and support and waste Mgt and remediation services (56) | 676 | 11.59 | 1.08 | 0.81–1.44 | 7.87 | 1.03 | 0.75–1.40 | 4.90 | 1.35 | 0.88–2.06 |
| Educational services (61) | 1,354 | 8.06 | 0.79 | 0.62–1.01 | 6.38 | 0.84 | 0.62–1.13 | 2.95 | 0.80[d] | 0.44–1.44 |
| Healthcare and social assistance (62) | 1,884 | 10.10 | 1.17 | 0.98–1.39 | 7.30 | 1.06 | 0.85–1.32 | 3.45 | 1.09 | 0.78–1.52 |
| Arts, entertainment, and recreation (71) | 296 | 10.18 | 1.00 | 0.63–1.60 | 7.39 | 1.02 | 0.62–1.69 | 2.98[d] | 0.88[d] | 0.37–2.07 |
| Accommodation and food services (72) | 848 | 7.57 | 1.03 | 0.78–1.35 | 6.89 | 1.16 | 0.85–1.57 | 3.32 | 1.34 | 0.83–2.18 |
| Other services (except public administration) (81) | 709 | 10.41 | 0.95 | 0.73–1.25 | 7.40 | 0.94 | 0.68–1.30 | 3.91 | 1.03 | 0.62–1.71 |
| Public administration (92) | 687 | 10.99 | 0.98 | 0.74–1.29 | 7.90 | 0.94 | 0.68–1.30 | 3.89 | 0.94 | 0.61–1.45 |
| Refused/not ascertained/ unknown | 604 | | | | | | | | | |

[a]Data from the National Health Interview Survey, 2007 adult sample.
[b]PRs were adjusted for gender, age group, race, smoking status, and geographical region. Each industry sector was compared to all other industries combined.
[c]CI = 95% confidence limits.
[d]These estimates have a relative standard error ≥30% and <50% and should be used with caution as they do not meet standards of reliability/precision.
[e]Estimates not shown as they have a relative standard error ≥50% and do not meet standards of reliability/precision.

Real Estate and Rental and Leasing had a significantly lower risk of the co-occurrence of both conditions (PR = 0.41, CI = 0.18–0.93) with a 2% prevalence.

## Prevalence and Risk Within Occupations

Only a few occupations had risks significantly different than all other occupations combined (Table IV). The Life, Physical, and Social Science (PR = 1.69, CI = 1.18–2.42), Production (PR = 1.25, CI = 1.05–1.50), and Personal Care and Service Occupations (PR = 1.42, CI = 1.09–1.84) had significantly higher risks for hearing difficulty with prevalences 20%, 14%, and 13%, respectively. The Arts, Design, Entertainment, Sports, and Media (PR = 0.56, CI = 0.37–0.85) and Sales and Related (PR = 0.73, CI = 0.59–0.91) occupations had significantly lower risks with prevalences 6% and 8%. The Architecture and

**TABLE IV.** Weighted Prevalence of Self-Reported Hearing Difficulty (HD), Tinnitus, and Their Co-Occurence, for Individuals Currently Working, by Occupation, and Weighted Adjusted Prevalence Ratios (PRs) for Each Occupation Compared With All Other Occupations, 2007 (N = 14,453)[a]

| Occupation | Unweighted n | Prevalence of HD (%) | PR[b] | 95%CI[c] | Prevalence of tinnitus (%) | PR | 95%CI | Prevalence of co-occurence (%) | PR | 95%CI |
|---|---|---|---|---|---|---|---|---|---|---|
| All occupations | 14,453 | 10.50 | | | 7.57 | | | 3.65 | | |
| Management | 1,286 | 12.65 | 0.96 | 0.77–1.17 | 7.24 | 0.79 | 0.62–1.00 | 3.79 | 0.84 | 0.56–1.25 |
| Business and financial operations | 595 | 10.99 | 1.03 | 0.78–1.36 | 8.66 | 1.09 | 0.78–1.52 | 3.70 | 0.97 | 0.56–1.66 |
| Computer and mathematical | 359 | 9.15 | 0.92 | 0.58–1.44 | 7.84 | 1.11 | 0.70–1.74 | 2.41[d] | 0.74[d] | 0.33–1.66 |
| Architecture and engineering | 249 | 9.99 | 0.82 | 0.53–1.27 | 12.99 | 1.64 | 1.02–2.63 | 4.18[d] | 1.08[d] | 0.58–2.01 |
| Life, physical, and social science | 129 | 20.44 | 1.69 | 1.18–2.42 | 11.01 | 1.26 | 0.73–2.18 | 6.80[d] | 1.52[d] | 0.79–2.94 |
| Community and social services | 255 | 12.20[d] | 1.22 | 0.69–2.16 | 9.32[d] | 1.20[d] | 0.58–2.48 | [e] | [e] | |
| Legal | 146 | 9.52[d] | 0.87[d] | 0.42–1.81 | 4.97[d] | 0.68[d] | 0.31–1.46 | 2.92[d] | 0.87[d] | 0.36–2.12 |
| Education, training, and library | 906 | 7.36 | 0.78 | 0.60–1.01 | 6.36 | 0.90 | 0.67–1.22 | 2.46 | 0.75 | 0.44–1.30 |
| Arts, design, entertainment, sports, and media | 294 | 6.14 | 0.56 | 0.37–0.85 | 11.58 | 1.50 | 0.98–2.30 | 2.83[d] | 0.76[d] | 0.37–1.60 |
| Healthcare practitioners and technical | 759 | 8.90 | 0.96 | 0.74–1.25 | 7.60 | 1.06 | 0.78–1.45 | 3.69 | 1.12 | 0.69–1.80 |
| Healthcare support | 330 | 5.66 | 0.80 | 0.50–1.27 | 6.37 | 1.03 | 0.66–1.61 | 3.15 | 1.14[d] | 0.56–2.30 |
| Protective service | 310 | 11.24 | 1.04 | 0.74–1.47 | 6.68 | 0.85 | 0.50–1.43 | 3.84[d] | 1.03[d] | 0.52–2.03 |
| Food preparation and serving related | 672 | 8.79 | 1.16 | 0.88–1.51 | 7.29 | 1.15 | 0.85–1.56 | 4.10 | 1.54 | 0.95–2.48 |
| Building and grounds cleaning and maintenance | 653 | 9.61 | 0.93 | 0.69–1.24 | 6.30 | 0.85 | 0.60–1.19 | 2.84 | 0.80 | 0.50–1.29 |
| Personal care and service occupations | 462 | 12.56 | 1.42 | 1.09–1.84 | 7.15 | 1.00 | 0.66–1.52 | 4.54 | 1.45 | 0.85–2.47 |
| Sales and related | 1,395 | 8.45 | 0.73 | 0.59–0.91 | 6.14 | 0.76 | 0.59–0.98 | 2.21 | 0.55 | 0.36–0.83 |
| Office and administrative support | 1,888 | 9.94 | 1.08 | 0.91–1.28 | 7.43 | 1.02 | 0.82–1.26 | 3.41 | 1.00 | 0.71–1.42 |
| Farming, fishing, and forestry | 113 | 13.13[d] | 1.35[d] | 0.73–2.49 | 7.80[d] | 1.14[d] | 0.50–2.58 | [e] | [e] | |
| Construction and extraction | 781 | 11.38 | 1.01 | 0.80–1.27 | 6.79 | 0.84 | 0.61–1.17 | 3.31 | 0.86 | 0.51–1.43 |
| Installation, maintenance, and repair | 489 | 15.48 | 1.15 | 0.88–1.51 | 10.34 | 1.15 | 0.85–1.56 | 5.78 | 1.27 | 0.82–1.99 |
| Production | 972 | 14.17 | 1.25 | 1.05–1.50 | 9.29 | 1.17 | 0.93–1.48 | 4.61 | 1.22 | 0.87–1.72 |
| Transportation and material moving | 784 | 13.70 | 1.08 | 0.87–1.34 | 9.59 | 1.09 | 0.81–1.45 | 5.75 | 1.32 | 0.88–1.99 |
| Refused/not ascertained/unknown | 615 | | | | | | | | | |

[a]Data from the National Health Interview Survey, 2007 adult sample.
[b]PRs were adjusted for gender, age group, race, smoking status, and geographical region. Each occupation was compared to all other occupations combined.
[c]CI = 95% confidence limits.
[d]These estimates have a relative standard error ≥30% and <50% and should be used with caution as they do not meet standards of reliability/precision.
[e]Estimates not shown as they have a relative standard error ≥50% and do not meet standards of reliability/precision.

Engineering occupations also had a significantly higher risk of tinnitus (PR = 1.64, CI = 1.02–2.63) while Sales and Related had a significantly lower risk (PR = 0.76, CI = 0.59–0.98).

## DISCUSSION

This study used data from the NHIS to produce nationally representative estimates [CDC, 2008] of the prevalence of hearing difficulty, tinnitus and their co-occurrence among working groups and the overall U.S. adult population. To our knowledge, this is the first reporting of prevalence estimates for tinnitus by U.S. industry and occupation, and also the first study to provide these estimates side-by-side with prevalence estimates of hearing difficulty.

Our study results indicated that hearing difficulty, tinnitus and their co-occurrence are fairly prevalent in the U.S. adult population; affecting 15%, 10%, and 5%, respectively. Among chronic physical conditions, the prevalence of hearing difficulty is surpassed only by hypertension (24%) and arthritis (21%), and hearing difficulty and tinnitus are more prevalent than vision trouble

(9%), diabetes (9%), or cancer (8%) [Blackwell et al., 2014]. The patterns of hearing difficulty prevalence among genders, age groups, race/ethnicities, and noise exposure groups were consistent with the available literature [Stanbury et al., 2008; Tak and Calvert 2008; Masterson et al., 2013], as were the patterns for tinnitus [Shargorodsky et al., 2010; Folmer et al., 2011]. Tinnitus prevalence estimates can vary based on the definition used. Heller [2003] reported an overall prevalence of 10–15% for "prolonged" tinnitus, Shargorodsky et al. [2010] reported 25% overall for any tinnitus, while Folmer et al. [2011] reported 7% for "chronic tinnitus" in males. Palmer et al. [2001] reported a 26% prevalence of "occasional tinnitus" and a 4% prevalence of "persistent tinnitus" in Britain.

In our sample, the prevalence of hearing difficulty, tinnitus, and their co-occurence was lower for those currently working than the general population, possibly reflecting the younger age of the working population and the increasing risk of tinnitus and hearing difficulty with age progression. However, the risks were much higher for those currently working who reported exposure to loud noise at work (23%, 15%, and 9%), consistent with the known effects of noise on auditory function. The prevalence increased even further for the noise-exposed when we included all adults who had ever worked at a job or business (30%, 20%, and 12%). About 5% of current workers and 8% of those who had ever worked reported constant tinnitus symptoms ("almost always").

Our analyses indicated that in most cases, industries and occupations with a higher (or lower) prevalence/risk of hearing difficulty also had a higher (or lower) prevalence/risk of tinnitus and the co-occurrence of these conditions. This is not unexpected, as both hearing difficulty and tinnitus reflect underlying damage to the auditory system and share many of the same risk factors. While the pathophysiology of hearing loss is better understood than that of tinnitus, the association between the two indicates that they likely share at least some causal etiologies [Tan et al., 2013]. Hearing damage from noise exposure can occur through multiple pathways, but primarily results through a series of metabolic processes which create free radicals and cause the death of the tiny sensory hair cells within the cochlea [Henderson et al., 2006]. Tinnitus may also result through damage to a variety of sites. Its frequent association with noise exposure suggests a peripheral etiology. However, the continued perception of tinnitus in cases following complete destruction of the peripheral auditory system suggests a central component. One current theory suggests that the changes within the cochlea trigger changes within the central auditory system, leading to tinnitus—though what specific changes are the trigger and how they translate into a centrally perceived sound is not understood [Tan et al., 2013]. Those who report hearing difficulty but not tinnitus may not have initiated the process by which peripheral hearing damage leads to tinnitus. However, those who report tinnitus but not hearing difficulty have probably sustained sub-clinical auditory damage, as several recent studies have demonstrated [Schaette and McAlpine, 2011; Tan et al., 2013].

Also as expected, the industries and occupations with a higher prevalence of hearing difficulty and/or tinnitus were generally those for which an increased prevalence of noise exposure has been reported. No previous tinnitus estimates by U.S. industry or occupation were found in the literature, although the prevalence of tinnitus among British workers by occupation is available [Palmer et al., 2001]. Palmer and colleagues [2001] found that the occupations with the highest prevalence of "persistent tinnitus" included: Electricians and Electrical Maintenance Fitters; Farming, Fishing, and Forestry occupations; and Other Transport & Machinery Operatives. Only men were studied in these occupations. We did find that Installation, Maintenance, and Repair occupations, as well as Transportation and Material Moving had high prevalences in our sample, although not the highest.

Manufacturing had a significantly higher risk of tinnitus and its co-occurrence with hearing difficulty. Elevated risk for hearing loss in this industry is consistent with prior research [Tak and Calvert, 2008; Masterson et al., 2013], although no specific tinnitus studies were found. Although no industry-wide studies of tinnitus in manufacturing are available, isolated studies of drop-forge operators [Sulkowski et al., 1999] and meat-packers [Steinmetz et al., 2009] reported prevalences of 70% and 22%, respectively.

There is also support for the Agriculture, Forestry, Fishing, and Hunting industry prevalence and risk elevation. A higher risk for shifts in hearing, which are measurable losses in hearing used to identify workers for intervention, was found for noise-exposed workers in this industry [Masterson et al., 2014]. It was also estimated that 43% of Agriculture, Forestry, Fishing, and Hunting workers are exposed to hazardous noise on the job [Tak et al., 2009] and large proportions of the industry (many agricultural workers) are not regulated for noise exposure or regularly tested for hearing loss [OSHA, 2014]. Occupations within this industry have also been found to have a high prevalence and risk for hearing difficulty [Neitzel et al., 2006; Alterman et al., 2008; Tak and Calvert, 2008].

Among occupations, the Sales and Related occupations had significantly lower risks for all three outcomes, which is fairly consistent with other research [Palmer et al., 2001; Tak and Calvert, 2008]. However, Life, Physical and Social Science had an elevated risk of hearing difficulty and Architecture and Engineering had an elevated risk of tinnitus. Prior research has indicated that some professional, technical, and scientific occupations have only a moderate prevalence/risk for hearing difficulty and tinnitus [Palmer et al., 2001; Tak and Calvert, 2008]. The occupations included in the Life, Physical, and Social Science grouping were: (i) life scientists; (ii) physical scientists; (iii) social scientists and related workers; and (iv) life, physical, and

social science technicians. More in-depth studies of these occupations may be necessary to identify the specific populations and risk factors involved. Some prior research does indicate a higher than expected risk of hearing loss for noise-exposed workers within industries associated with these occupations. Masterson et al. [2014] found that workers in the Professional, Scientific, and Technical Service industries had the third highest prevalence and fourth highest risk of shifts in hearing. These are occupations where small proportions of workers are exposed to noise and large proportions (>40%) of the exposed report not wearing hearing protection [Tak et al., 2009]. Hearing loss is likely not a well-recognized problem. Research has indicated that the prevalence of workers using hearing protection when they should increases with the prevalence of workers exposed to noise [Tak et al., 2009].

This study had several limitations. The study information was based entirely on self-reported survey responses. While the question used to identify hearing difficulty was adapted from a question previously validated against audiometric threshold measurements [Schein et al., 1970], studies have shown that individuals sometimes under-report hearing difficulty, particularly when the hearing impairment is mild or primarily affecting the higher frequencies [Nondahl et al., 1998; Sindhusake et al., 2001; Valete-Rosalino and Rozenfeld, 2005]. Tinnitus is a personal and subjective condition that requires self-report for diagnosis [Heller, 2003]. However, questionnaire items used to identify tinnitus vary widely across surveys and are difficult to validate [Baguley et al., 2013]. Research does indicate that self-report is a valid measure of occupational noise exposure [Neitzel et al., 2009; Schlaefer et al., 2009]. We could not differentiate cases of hearing difficulty due to noise exposure, ototoxic chemical exposure or a combination of exposures. A larger sample size may have improved the power and stability of the estimates in some of the smaller industry and occupation groups, and allowed us to examine all industry groups. Finally, NAICS and SOC are economic classification systems and may not group together workers with similar noise and ototoxic chemical exposures.

Nonetheless, these results highlight important areas for more detailed investigation. Hearing difficulty, tinnitus, and their co-occurrence are prevalent in the U.S., but especially among noise-exposed workers. These conditions, while potentially debilitating on their own, are strongly associated with a number of other negative health outcomes [Shargorodsky et al., 2010], impacting quality of life [Hetu et al., 1995]. This study identifies industries and occupations in which prevention efforts need to be focused. The problem of hearing loss is well-recognized in the Manufacturing, Construction, and Mining industries and occupations, but may have been overlooked in Agriculture and the Life, Physical, and Social Sciences occupations. The problem of tinnitus has received little attention in any industry and deserves further investigation and intervention. Increased awareness of these problems, targeted interventions, better implementation of current best practices for hearing conservation in the workplace, improving/innovating these strategies, and stronger regulations are needed to safeguard workers' quality of life.

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## AUTHORS' CONTRIBUTIONS

All authors made substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work. All authors approved the version to be published and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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