Noise Exposure and Hearing Loss: Data from U.S. Health Surveys

Christa L. Themann, MA, CCC-A
National Institute for Occupational Safety and Health (NIOSH), CDC, Cincinnati OH

Edward Krieg, PhD
National Institute for Occupational Safety and Health (NIOSH), CDC, Cincinnati OH

Howard J. Hoffman, MA
National Institute on Deafness and Other Communication Disorders (NIDCD), NIH, Bethesda MD

Abstract

Although exposure to hazardous noise is generally considered the major cause of preventable hearing loss among adults, the U.S. does not have a measurement-based surveillance system to track noise exposure. However, several national health survey systems collect self-reported noise exposure information as well as self-rated and/or audiometrically-measured hearing data from nationally-representative samples of U.S. adults. The National Health Interview Survey (NHIS) and the National Health and Nutrition Examination Survey (NHANES) collect data describing exposure to loud workplace noise, very loud workplace noise, non-work noise, and firearm noise. Both surveys also collect data on self-reported hearing impairment, tinnitus, frequency of hearing protector use, and audiometric monitoring. In addition, NHANES conducts pure-tone air-conduction audiometry. Data from these surveys allow calculation of the prevalence of various types of noise exposure and permit examination of how these types and combinations of exposure are related to hearing loss and tinnitus. In the absence of a dedicated noise surveillance system, NHIS and NHANES provide a snapshot of the noise exposure problem in the U.S. and highlight the most significant hearing-related public health needs.

Repeated exposure to hazardous noise is generally considered to be the major cause of preventable hearing loss among adults in the U.S. Despite the risk that noise poses to hearing, the U.S. does not have a measurement-based surveillance system to track noise exposure levels. However, several national health survey systems collect self-reported noise exposure information as well as self-rated and/or audiometrically measured hearing data. These surveys provide valuable insight into the extent of the noise problem in this country and can serve as a tool for targeting interventions, evaluating impact, and tracking progress in reducing the burden of noise exposure over time.

The National Health Interview Survey (NHIS) and the National Health and Nutrition Examination Survey (NHANES) were established in the late 1950s and assess the health status of the non-institutionalized U.S. civilian population. Both surveys are cross-sectional and are designed to provide nationally-representative estimates of health conditions and related risk factors. They are the current gold standard for U.S. health data and are used extensively to monitor progress towards national health objectives and to provide a basis for health policies and programs.

The NHIS collects data via in-person interviews of approximately 87,500 persons in 35,000 households across all 50 states each year. Data are released annually. The survey includes a set of core questions that are asked each year as well as supplemental questions which collect more detailed information on various topics that change from year to year. The data reported herein are from the NHIS hearing supplement in 2014, which asked adults aged 18 and older about exposure to noise from various sources, hearing problems (including tinnitus), and protective behaviors (n ~ 37,000).

NHANES collects data through examinations and laboratory tests in addition to personal interviews. Data are collected from about 5,000 persons in 15 sampled counties each year and released biennially. Examinations have included pure-tone air-conduction audiometric threshold testing in every survey cycle except 2013-2014, though the age range for audiometry varied across survey cycles. The data reported here were collected from adults aged 20-69 years in the 2011-2012 survey cycle (n ~ 4,400).

Self-reported noise exposure data were collected in both surveys using the following questions (minor differences noted in brackets):

- Have you ever had a job, or combination of jobs, where you were exposed to loud/very loud sounds or noise for 4 or more hours a day, several days a week?
- Have you ever been exposed to loud/very loud sounds or noise [NHANES: noise or music] 10 or more times a year?
- Have you used [NHIS: guns or] firearms for any reason?

NHIS and NHANES define "very loud" noise as noise that would require one to shout to be heard by someone three feet (an arm's length) away and "loud" noise as sound that would require one to speak in a raised voice to be heard. Based on previous research (Miller, 1971), these definitions are assumed to equate "very loud" noise to sound levels of 90 dBA or more and "loud" noise to approximately 85 dBA. Exposure to loud and very loud noise was assessed in separate questions, except for non-occupational noise exposure in NHANES, which assessed exposure to loud and very loud non-work noise in a single question.

In addition to lifetime noise exposure, NHIS 2014 asked about noise exposure history over the past 12 months. Participants who reported each type of noise exposure were asked follow-on questions to further characterize the duration of their exposure and determine hearing protector use. Data from both surveys were weighted to produce nationally-representative estimates.

Table 1 provides estimates of the number and percent of U.S. adults exposed to noise from various sources in the past 12 months (NHIS 2014) and over their lifetime (NHANES 2011-2012). As the table indicates, more than half of U.S. adults report hazardous noise exposure at some point in their lives, and more than one-third report exposure in the past year. The current estimate from the National Institute for Occupational Safety and Health of 22 million workers exposed to noise annually at work is derived from NHIS 2014 data (accounting for workers exposed to both loud and very loud noise on-the-job) (Kerns et al., 2018).

	NHIS 2014 (exposed past year)		NHANES 2011-2012 (ever exposed)	
Any noise exposure	87,422,443	36%	117,443,522	60%
Loud workplace noise	4,151,395	2%	24,418,202	12%
Very loud workplace noise	19,793,521	8%	43,481,233	22%
Non-workplace noise	63,682,294	27%	24,626,458	13%
Firearms noise	34,782,009	15%	86,572,506	44%

Table 1: Noise exposure estimates among U.S. adults from NHIS 2014 (age 18+ years) and NHANES 2011-2012 (age 20-69 years). For purposes of this research loud noise was presumed to equal approximately 85 dBA, and very loud noise to 90 dBA.

Audiometric thresholds collected in NHANES 2011-2012 allow examination of the association between various types of noise exposure and hearing levels (see Figure 1). Mean pure-tone thresholds across all ages, genders, and race/ethnicities are shown for each type of noise exposure (note that individuals in each category may have reported exposure to other noise categories as well). As is typically reported, thresholds are slightly poorer in the left ear than the right ear across all noise sources (as well as among individuals who report no exposure to any type of noise).

In both ears, individuals who report exposure to very loud noise at work show the poorest thresholds. Due to the increased hazard posed by impulsive noises, individuals who reported firearms use had been expected to show the poorest thresholds. Firearms exposure in this analysis includes individuals who have ever fired even a single round. Nearly half of those respondents who reported firearms use reported firing less than 100 lifetime rounds, and over two-thirds reported firing less than 1000 rounds; the small number of rounds fired by a majority of those exposed could explain the better-than-expected thresholds. Among those exposed to firearms noise, hearing thresholds increase with increasing number of rounds fired (see Figure 2).

The best hearing thresholds are observed among individuals who reported exposure to non-occupational noise. Further analyses are underway to investigate the reason these individuals appear to have better hearing than those who report no noise exposure; possible explanations include variations in age, gender, and race across noise exposure groups or unreported exposures in the no noise group.

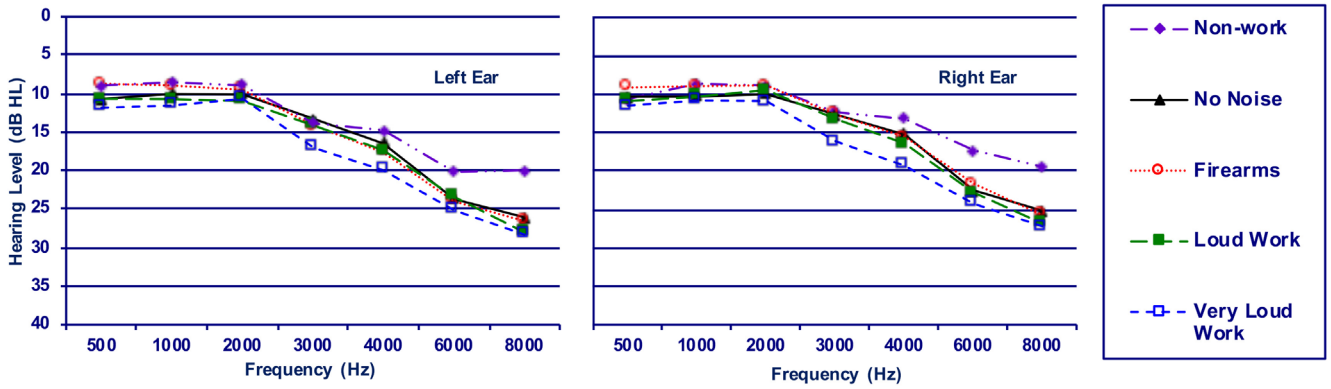

Figure 1: Mean weighted audiometric thresholds in the left and right ears among U.S. adults (age 20-69 years) reporting lifetime exposure to noise from various sources (NHANES 2011-2012).

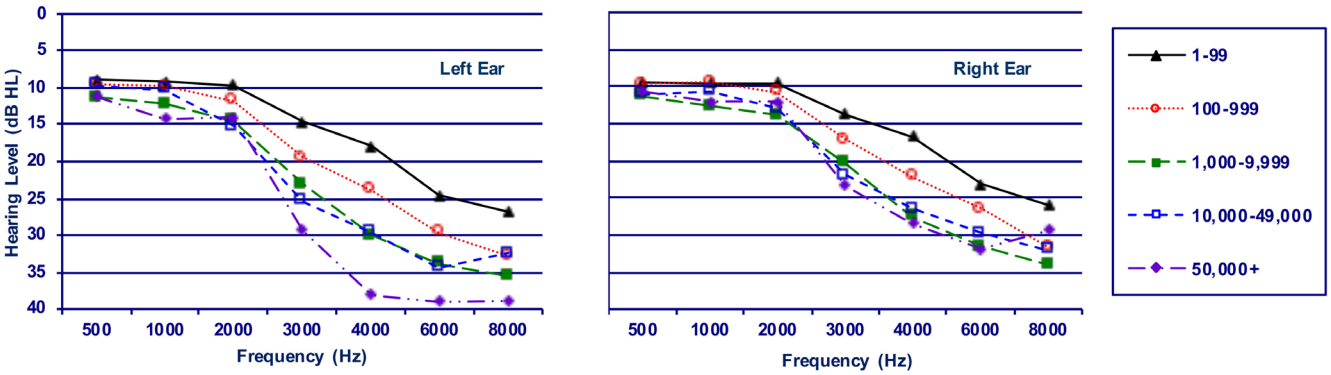

Figure 2: Mean weighted audiometric thresholds in the left and right ears among U.S. adults (age 20-69 years) reporting firearms use based on total lifetime rounds fired (NHANES 2011-2012).

Due to the larger sample size, NHIS allows examination of different combinations of noise exposure. Although this survey cannot measure audiometric thresholds, NHIS 2014 participants were asked to self-rate their hearing as "excellent," "good," "a little trouble," "moderate trouble," "a lot of trouble," or "deaf" (across both ears, unaided). Participants were also asked whether they had been "bothered" by tinnitus ("ringing, roaring, or buzzing in your ears or head that lasts for five minutes or more") in the last 12 months. Figure 3 shows the association between hearing complaints and various types and combinations of lifetime noise exposure in terms of odds ratios (the ratio of the likelihood of having the hearing complaint among those with the exposure to those without the exposure). An odds ratio of 1.0 indicates no difference in risk due to exposure; odds ratios significantly greater than 1.0 indicate increased risk among those with the exposure, with risk increasing as the odds ratio increases. Risk estimates were adjusted for age, race/ethnicity, socio-economic status (education or income), smoking history, and relevant medically-diagnosed illnesses (coronary heart disease, hypertension, diabetes, or asthma). Data were analyzed separately for males and females; results for males are shown in the figures; results for females showed similar patterns with overall less prevalence of noise exposure and reported hearing trouble.

Among participants reporting only a single source of noise exposure, risk of any hearing trouble (i.e., "little trouble" or worse) was greatest among those who reported very loud workplace noise exposure for five years or more. As expected, risk of hearing trouble increases with multiple sources of noise exposure. Among two-way combined exposures, combinations including very loud workplace noise for at least five years also showed the highest risk. The three-way combined exposure of very loud workplace noise for 5+ years, non-work noise, and firearms exposure showed the highest risk of self-reported hearing trouble, with more than eight times the risk as those who reported no noise exposure. All odds ratios except that for loud noise exposure alone were statistically significant (Hoffman et al., 2019).

Similar patterns were seen for self-reported tinnitus in the past 12 months. In general, exposures which included occupational exposure to noise for five years or more showed the highest risk. The odds ratio was greatest for the three-way combined exposure of 5+ years of very loud

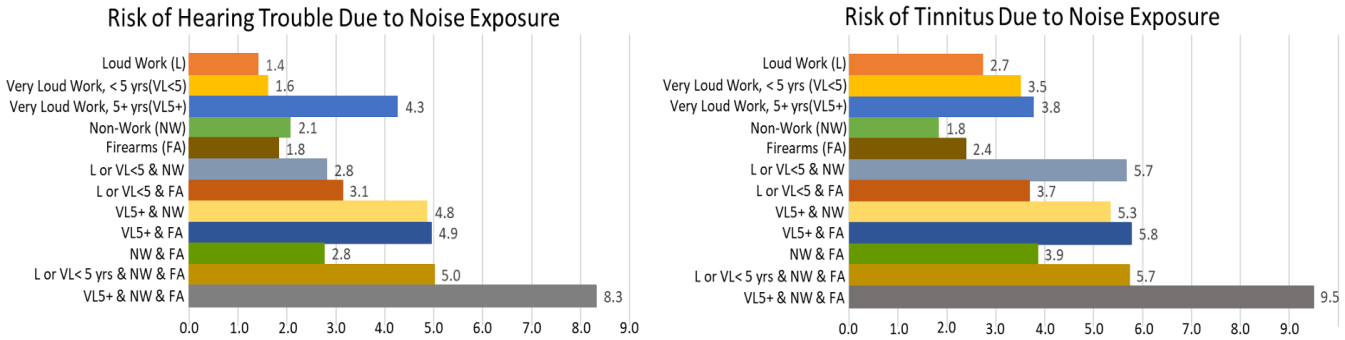

Figure 3: Odds ratios indicating risk of self-reported hearing trouble (left chart) and tinnitus in the past 12 months (right chart) due to lifetime exposure to various types and combinations of noise. (Males, NHIS 2014). Odds ratios of 1.0 indicate no difference in risk due to exposure. All odds ratios for hearing trouble except loud noise alone and all odds ratios for tinnitus were statistically significant.

workplace noise, non-work noise, and firearms exposure, with those individuals approaching 10 times the risk of tinnitus as individuals with no reported exposure. All of the odds ratios for tinnitus were statistically significant.

Pure-tone thresholds alone may not always capture the full scope of hearing difficulties caused by noise exposure (Hetu et al., 1995). Noise-induced auditory damage can also result in difficulty on more complex listening tasks such as understanding speech in the presence of background noise. In view of this, NHANES 2011-2012 also asked participants how often they found it "difficult to follow a conversation if there is background noise, for example, when other people are talking, TV or radio is on, or children are playing close by." Responses to this question by lifetime noise exposure status are shown in Figure 4 and show similar patterns to those described above. Among those who reported only a single source of noise exposure, participants exposed to very loud workplace noise had the highest prevalence of "always" have trouble understanding speech in noise and the lowest prevalence of "never" have trouble. Among those with multiple noise exposure sources, exposure combinations which included very loud occupational noise showed the same pattern.

Considering the continued high prevalence of noise exposure in the U.S., use of hearing protection devices could reduce the effects of noise on hearing. NHIS 2014 survey participants were asked how frequently they used hearing

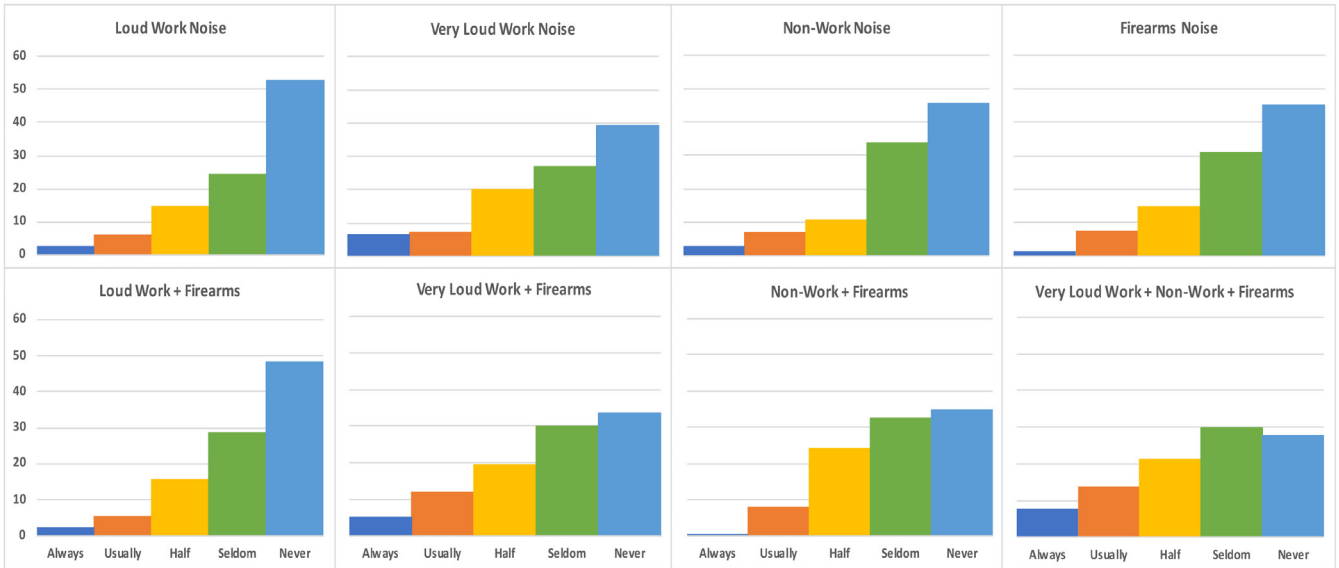

Figure 4: Frequency of difficulty understanding speech in background noise by various types and combinations of self-reported noise exposure (NHIS 2014).

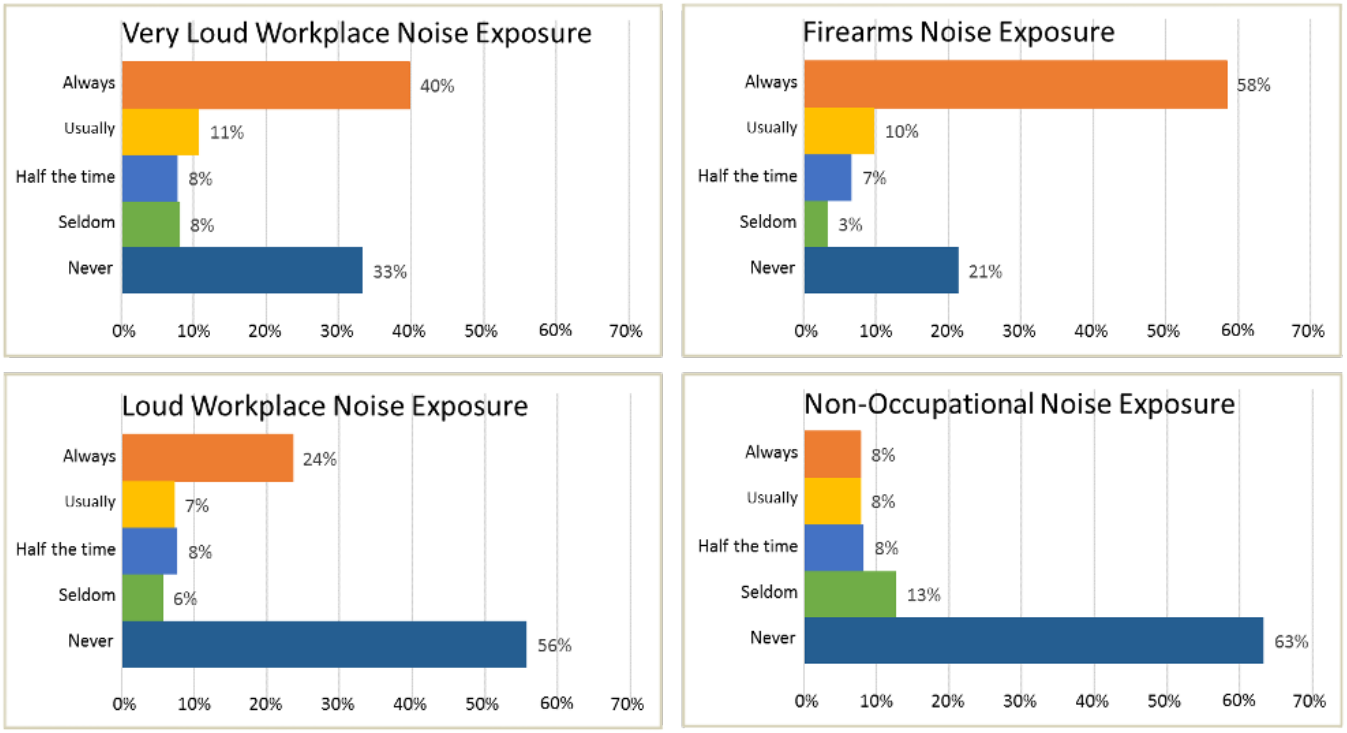

Figure 5: Self-reported hearing protector use among individuals exposed to various types of noise in the past 12 months (NHIS 2014).

protection devices when exposed to different noise sources in the past 12 months. As Figure 5 shows, consistent use of hearing protection is poor. A little more than half of those respondents who reported firearms exposure in the past year reported always using hearing protection when exposed to firearms noise. Less than half of participants reporting other types of noise exposure reported always using hearing protection. This is particularly disconcerting among those who report exposure to very loud noise on-the-job, as regulations in most industries mandate the use of hearing protection at this level. Across all occupational exposures, 64% of respondents reported using hearing protection at least half the time when exposed to loud or very loud noise at work. This is essentially unchanged from the rate of hearing protector use on-the-job a decade ago. Tak et al. (2009) analyzed similar data from NHANES 1999-2004 and found that only 66% of noise-exposed workers reported using hearing protection at least half the time. Berger (2000) reported similarly low rates of hearing protector utilization in both occupational and non-occupational sectors based on a meta-analysis of data from over 100 studies in the U.S. and 18 other countries.

Data from NHIS and NHANES possess a number of strengths. They are nationally representative and collected using strict protocols developed specifically for research purposes. The data are useful for answering broad questions and generating hypotheses that can be further studied in more detailed investigations. Although cross-sectional, the continuous design of NHIS and NHANES permit tracking noise exposure and hearing difficulty over time. However, the data also are subject to several limitations. Noise exposure history is based on self-report. In addition, because these surveys collect data on a wide range of topics, only a few questions about noise exposure history are included, resulting in broad categorizations of exposure.

As the data presented here indicate, very loud workplace noise exposures appear to pose more risk to hearing than loud workplace noise, non-work noise, or firearms noise. Poorer hearing increases with multiple sources of exposure. Self-reported use of hearing protection is inconsistent for all noise types, including very loud workplace noise for which hearing protection is mandated in nearly all industries. Hearing protection is used most frequently for firearms exposures. Further analyses of NHANES data adjusting for age, gender, race/ethnicity and other variables are planned to better model hearing risk from reported noise exposures. However, this initial look at national survey data indicates that better interventions to prevent noise-induced hearing loss are needed in both occupational and non-occupational settings.

Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent official positions of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention or the National Institute on Deafness and Other Communication Disorders, National Institutes of Health.

References

Berger, E. H. (2000). "Hearing Protection Device Utilization Around the World," Spectrum Suppl. 1, 17, p. 18.

Hetu, R., Getty, L., and Quoc, H. T. (1995). "Impact of occupational hearing loss on the lives of workers," Occup. Med. 10, 495-512.

Hoffman, H. J., Dobie, R. A., Losonczy, K. G., Themann, C. L., and Flamme, G. A. (2019). "Hearing impairment and other health effects associated with loud and very loud occupational, firearms, and other noise exposures." Presentation accepted for the 23rd International Congress on Acoustics, Aachen, Germany.

Kerns, E., Masterson, E. A., Themann, C. L., and Calvert, G. M. (2018). "Cardiovascular conditions, hearing difficulty, and occupational noise exposure within U.S. industries and occupations," Am. J. Ind. Med. 61, 477-491. doi: 10.1002/ajim.22833.

Miller, J. D. (1971). Effects of Noise on People. U.S. Environmental Protection Agency, NTID 300.7, NTIS Document No. PB-206723.

Tak, S., Davis, R. R., and Calvert, G. M. (2009). "Exposure to hazardous workplace noise and use of hearing protection devices among US workers – NHANES, 1999–2004," Am. J. Ind. Med. 52(5), 358-371. doi: 10.1002/ajim.20690.