


# Prevalence of hearing protection device non-use among noise-exposed US workers in 2007 and 2014

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## Abstract

**Background:** This study estimated the prevalence of hearing protection device (HPD) non-use among US workers exposed to hazardous workplace noise and provided risk estimates.

**Methods:** Self-reported data from the National Health Interview Survey in 2007 (15,852 workers) and 2014 (23,656 workers) were examined. Weighted prevalence and adjusted prevalence ratios of HPD non-use (using HPDs half the time or less when exposed to hazardous noise) were estimated by demographic, industry, and occupation. Differences in the prevalences of non-use were estimated and compared.

**Results:** The prevalence of HPD non-use was 53% among all noise-exposed workers in 2014. Workers in the Accommodation and Food Services industry had the highest prevalence (90%) and risk (PR: 2.47, 95% confidence interval: 1.54–3.96) of HPD non-use. The industries with the lowest prevalences of noise exposure, including Finance and Insurance (2%) and Health Care and Social Assistance (4%), had some of the highest prevalences of HPD non-use (80% and 83%, respectively). There were no statistically significant changes in HPD non-use among industries between 2007 and 2014. Among occupations, HPD non-use increased 37% in Arts, Design, Entertainment, Sports and Media, and decreased 39% in Architecture and Engineering.

**Conclusion:** The prevalence of HPD non-use remains high; especially within industries and occupations with fewer noise-exposed workers. These groups need targeted attention to increase awareness and compliance. Employers should require HPD use and trainings among noise-exposed workers and provide an assortment of HPDs tailored to noise level and type, workplace environment, communication and audibility needs, and individual comfort and convenience.

## KEYWORDS

hazardous noise, hearing protection, occupational noise exposure, prevalence, surveillance

## 1 | INTRODUCTION

In the United States, 22 million workers (14%) are exposed to hazardous noise on the job each year. Fifty-eight percent of self-reported hearing difficulty among workers is attributable to

occupational noise exposure.<sup>1</sup> In addition to causing hearing loss, noise exposure is associated with tinnitus and psychological and cardiovascular health effects such as depression and hypertension.<sup>1–4</sup>

To control exposures to occupational hazards including noise, the National Institute for Occupational Safety and Health (NIOSH)

recommends utilization of the Hierarchy of Controls.<sup>5</sup> Elimination of the noise, substitution of a quieter process, or engineering controls to reduce sound levels are considered the most effective methods of noise control because they remove or reduce the hazard for all affected workers.<sup>6</sup> When these options are insufficient to reduce noise to safe levels, hearing protection devices (HPDs) are to be utilized. However, to be effective, HPDs must be worn consistently and correctly by each noise-exposed worker. Several factors affect HPD non-use, including challenges with communication, reduced ability to monitor important sounds, discomfort, and worker attitudes.<sup>7-10</sup>

Davis and Sieber<sup>11</sup> analyzed data from the 1981-1983 NIOSH National Occupational Exposure Survey (NOES) to determine whether workers exposed to hazardous noise utilized hearing protection. Of the 4.1 million industrial workers exposed to measured noise levels  $\geq 85$  decibels, A-weighted (dBA), lasting at least 30 min a week, only 41% were observed wearing some form of hearing protection. Tak et al. analyzed National Health and Nutrition Examination Survey (NHANES) data from 1999 to 2004 and found that 34% of the estimated 22 million workers with self-reported hazardous noise exposure at work never used HPDs.<sup>12</sup> However, no recent studies with national estimates of HPD non-use are available.

The National Health Interview Survey (NHIS) has not been previously used to examine the prevalence of HPD usage. Using data from the 2007 and 2014 NHIS, the objectives of this study were to (1) provide current prevalence and adjusted risk estimates of HPD non-use by demographic, industry and occupation among noise-exposed U.S. workers in 2007 and 2014; (2) examine any differences in the prevalence of HPD non-use between study years; and (3) examine the relationship between prevalence of occupational noise exposure and the prevalence of HPD non-use in 2014.

## 2 | METHODS

### 2.1 | Study design and population

This was a cross-sectional study examining HPD non-use among noise-exposed workers using publicly available data from the 2007 and 2014 NHIS Adult Samples ( $\geq 18$  years). The NHIS is an annual, cross-sectional survey conducted by the National Center for Health Statistics (NCHS) to monitor the health of the US civilian, noninstitutionalized population through in-person household interviews.<sup>13,14</sup> The survey contains four main modules: household, family, sample child, and sample adult. A representative sample of households is selected using a multistage cluster sample design. The adult samples, which were used for this study, are based on the responses from one randomly selected adult aged 18 years or older.

The survey years 2007 and 2014 were chosen since these were the latest available years with sponsored hearing supplements. The hearing supplements collected more detailed hearing data, including information on the impact of hearing impairment on children and adults, associated symptoms such as tinnitus and imbalance, use of

hearing aids, occupation and leisure-time noise exposures, and use of hearing protection when exposed to hazardous noise.

The current study included 15,852 participants from the 2007 NHIS survey and 23,656 participants from the 2014 NHIS survey (in 2007, the NHIS sample was reduced due to a budget shortfall<sup>15</sup>). Males and females aged 18 or older who were employed during the 12 months preceding their interviews were included (i.e., current workers). The 2007 and 2014 NHIS were approved by the NCHS Research Ethics Review Board and the US Office of Management and Budget. All NHIS respondents provided oral consent before participating.

### 2.2 | Measures

#### 2.2.1 | Hearing protection device usage and non-usage

The main outcome of interest for this study was hearing protection device (HPD) non-use among persons reporting occupational noise exposure (defined below under Occupational Noise Exposure). HPD non-use was derived from HPD use. HPD use was determined based on the participant's response to the following questions in 2007 and 2014:

2007: "In the past 12 months, how often did you wear ear plugs or ear muffs when exposed to loud sounds or noise at work?"

2014 (1): "During the past 12 months, how often did you wear hearing protection, such as ear plugs or ear muffs when exposed to VERY LOUD sounds or noise at work?"; and (2) "During the past 12 months, how often did you wear hearing protection, such as ear plugs or ear muffs when exposed to LOUD sounds or noise at work?"

Responses were categorized as "use" if participants answered "always" or "usually," and "non-use" if participants reported "about half the time," "seldom," or "never." Response categorizations were based on the sharp drop in effective attenuation when HPDs are not worn for even short periods of time. For example, a hearing protector which provides 30 dB of sound reduction effectively provides only 10 dB of protection if the device is removed for 10% of the workday; a hearing protector which provides 15 dB of sound reduction has an effective attenuation of less than 6 dB if removed for two hours of an eight-hour shift.<sup>16</sup> Hence, any use less than "usually" could not be assumed to provide adequate protection.

#### 2.2.2 | Occupational noise exposure

Occupational noise exposure was assessed using the following questions:

2007: "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." A followup question asked "Was any of this exposure to loud sounds or noise in the past 12 months?" Workers reporting exposure to loud noise in the past 12 months were identified as having occupational noise exposure.

2014 (1): "Have you ever had a job, or combination of jobs, where you were exposed to VERY LOUD sounds or noise for four or more hours a day, several days a week? Very loud means so loud that you must SHOUT to be understood by someone standing three feet (arm's length) away." (2) "Have you ever had a job, or combination of jobs, where you were exposed to LOUD sounds or noise for four or more hours a day, several days a week? Loud means so loud that you must SPEAK IN A RAISED VOICE to be heard." The questions regarding noise exposure were asked in this order, and only those who answered "no" to the first question were asked the second question. Participants were categorized as being exposed to occupational noise if they answered "yes" to the first or second question.

Followup questions asked (1) "When were you exposed to VERY LOUD sounds or noise at work...during last 12 months, before then, or both during and before the last 12 months?" and/or (2) "When were you exposed to LOUD sounds or noise at work...during last 12 months, before then, or both during and before the last 12 months?" Workers with either loud or very loud noise in the past 12 months were combined and identified as having occupational noise exposure.

The NHIS questions on noise exposure utilize a longstanding "rule of thumb" based on vocal effort in various noise environments. Speaking in a "raised voice" is necessary when noise levels approach 85 dBA and a "shout" is necessary to be heard as noise levels approach 90 dBA.<sup>17</sup>

### 2.2.3 | Employment, industry, and occupation

Study participants were "current workers," meaning they reported working at any time in the 12 months preceding the survey interview. Industry refers to type of business (where a person works) and occupation refers to type of work (what a person does). Industry and occupation were collected via verbatim responses to questions regarding the participants' industry and occupation. The responses were then reviewed by US Census Bureau coding specialists who assigned codes based on the 2002 North American Industry

Classification System (NAICS) and 2000 Standard Occupational Classification (SOC) system in 2007, and the 2012 NAICS and 2010 SOC systems in 2014. For this study, to ensure adequate sample size for examination of industries and occupations, codes were collapsed into 2-digit industry and occupation recodes that included 21 industry categories and 23 occupation categories. The Management of Companies and Enterprises industry (NAICS 55) and the Legal occupation (SOC 23) were excluded from all analyses due to insufficient sample size. The 2007 analyses also excluded the Utilities (NAICS 22) industry and the Community and Social Services (SOC 21) and Computer and Mathematical (SOC 15) occupations due to insufficient sample size.

## 2.3 | Statistical analysis

The primary independent variables were industry and occupation, and occupational noise exposure. The primary dependent variable was HPD non-use. The covariates of interest in this analysis were age, gender, race/ethnicity, education, and smoking. Age was grouped into seven categories: 18–25, 26–35, 36–45, 46–55, 56–65, 66–75, and 76 and above. Race/ethnicity was stratified as non-Hispanic white, non-Hispanic black, non-Hispanic Asian, non-Hispanic other, or Hispanic. Education was stratified as less than a high school diploma, a high school diploma, some college, or a college degree. Lastly, smoking status was defined as current smoker, former smoker, or never smoker.

Prevalence estimates for HPD usage by industry, occupation, and demographic were calculated using the SAS surveyfreq procedure and weighted using the NHIS individual sample adult record weights. Records are weighted by NHIS to ensure they are a representative sample, and results are not to be generalized beyond the sample in the absence of weighting. Relative standard errors (RSE) were calculated to ensure the stability of the estimates—to assess sampling error and how far survey estimates may likely deviate from the population parameter. Prevalence estimates with RSE > 30% and < 50% are noted and estimates with RSE > 50% are not reported. Weighted adjusted prevalence ratios (PRs) and associated 95% confidence intervals for HPD non-use by each covariate were estimated utilizing the SUDAAN procedure rlogist. The PRs were adjusted for age, gender, race/ethnicity, education, and smoking status. The reference industry assigned for the analysis of HPD non-use was Mining. Mining was designated as the reference industry in a previous analysis of HPD non-use and has been shown to have the lowest proportion of workers who report non-use of HPDs.<sup>12</sup> For occupation, the reference was designated as the prevalence among all other occupations, rather than a specific occupation, because no prior research has indicated which occupation has the lowest risk for HPD non-use. Reference groups for each covariate are designated in Table 1.

The differences in HPD non-use between the 2007 and 2014 surveys by industry, occupation, and demographic were calculated and compared using *t* tests. To prevent Type I Error due to the number of statistical comparisons, the False Discovery Rate approach

**TABLE 1** Prevalence of hearing protection device (HPD) non-use by demographic among noise-exposed US Workers in 2007 and 2014<sup>a</sup>

Demographic	2007			2014			2007 vs. 2014	
	Unweighted n (%)	Weighted N	Weighted prevalence of HPD non-use (%)	Unweighted n (%)	Weighted N	Weighted prevalence of HPD non-use (%)	PR <sup>b</sup> (95% CI)	Difference in HPD non-use prevalence
All	2057	22,309,159	55.5	3380	22,708,625	52.65		-2.85
Gender								
Male	1588 (77.20)	18,027,770	51.43	2571 (76.07)	17,887,631	47.06	ref	-4.37
Female	469 (22.80)	4,281,389	71.10	809 (23.93)	4,820,994	73.39	<b>1.56 (1.43-1.70)</b>	+2.29
Age group (years)								
18-25	308 (14.97)	3,800,660	65.97	502 (14.85)	4,016,916	63.77	<b>1.30 (1.14-1.50)</b>	-2.20
26-35	463 (22.51)	4,913,889	58.57	791 (23.40)	5,066,716	51.69	1.06 (0.92-1.21)	-6.88
36-45	518 (25.18)	5,676,237	48.62	709 (20.98)	4,780,473	47.15	0.96 (0.83-1.13)	-1.47
46-55	484 (23.53)	5,121,358	48.76	759 (22.46)	5,045,554	48.88	ref	+0.11
56-65	238 (11.57)	2,356,790	55.92	479 (14.17)	2,993,337	52.97	1.08 (0.93-1.26)	-2.95
66-75	37 (1.80)	351,693	85.06	122 (3.61)	703,017	58.00	<b>1.74 (1.46-2.09)</b>	-27.06
76 and above	9 (0.44)	88,532	63.87	18 (0.53)	102,612	60.64	1.24 (0.69-2.23)	-3.23
Race/ethnicity								
White, non-Hispanic	1,282 (62.32)	15,752,498	56.05	2146 (63.49)	14,859,808	51.66	ref	-4.39
Black, non-Hispanic	274 (13.32)	2,216,939	53.83	405 (11.98)	2,644,264	53.15	1.03 (0.91-1.17)	-0.68
Asian, non-Hispanic	47 (2.28)	509,780	55.49	92 (2.72)	500,462	60.32	1.17 (0.93-1.47)	+4.82
Hispanic	393 (19.11)	3,037,976	53.95	636 (18.82)	4,160,509	53.86	1.04 (0.93-1.16)	-0.09
Other, non-Hispanic	61 (2.97)	791,966	46.93	101 (2.99)	543,582	61.03	1.18 (0.93-1.50)	+14.10
Education								
<High School Diploma	244 (11.86)	1,883,945	58.17	327 (9.67)	1,690,160	55.38	ref	-2.79
High School Diploma	612 (29.75)	6,294,945	53.20	876 (25.92)	5,652,931	51.65	0.93 (0.80-1.09)	-1.56

(Continues)

TABLE 1 (Continued)

Demographic	2007			2014			2007 vs. 2014		
	Unweighted n (%)	Weighted N	Weighted prevalence of HPD non-use (%)	Unweighted n (%)	Weighted N	Weighted prevalence of HPD non-use (%)	PR <sup>b</sup> (95% CI)	Difference in HPD non-use prevalence	p value <sup>c</sup>
Some College	504 (24.50)	5,731,850	56.80	796 (23.55)	5,236,631	59.91	1.08 (0.94–1.25)	+3.11	0.648
College Degree	693 (33.69)	8,370,846	54.92	1380 (40.83)	10,123,091	49.03	0.89 (0.76–1.03)	–5.90	0.146
Smoking Status									
Current Smoker	642 (31.21)	7,226,303	61.06	866 (25.62)	5,666,561	57.69	<b>1.12 (1.01–1.24)</b>	–3.38	0.449
Former Smoker	480 (23.33)	5,198,676	54.48	731 (21.63)	5,151,239	49.39	0.96 (0.85–1.08)	–5.09	0.449
Never Smoker	908 (44.14)	9,611,408	50.93	1764 (52.19)	11,737,227	51.56	ref	+0.64	0.804

Note: ISS, insufficient sample size—these estimates have a relative standard error >50% and do not meet the standards of reliability/precision. Bold font indicates statistical significance.

Abbreviations: CI, confidence interval; NAICS, North American Industry Classification System; PR, prevalence ratio.

<sup>a</sup>Data are from the National Health Interview Survey 2007 and 2014 adult samples.

<sup>b</sup>Prevalence ratio (adjusted for gender, age, race/ethnicity, education, smoking status)

<sup>c</sup>Corrected using False Discovery Rate (FDR).

was employed using the SAS procedure multtest to adjust the comparison *p*-values.<sup>18–20</sup> Statistical significance was defined as *p* < 0.05.

Data analyses were conducted using survey procedures in SAS, version 9.4 (SAS Institute Inc.) and SUDAAN version 11 (RTI International).

### 3 | RESULTS

Data were available for 15,852 currently employed persons in 2007 and 23,656 currently employed persons in 2014. Of these workers, 2057 reported exposure to occupational noise during the preceding 12 months in 2007 and 3380 in 2014. HPD non-use prevalence estimates are provided for both years, with the study focusing on the 2014 results and the 2007 results provided for comparison. HPD non-use is only measured/reported for noise-exposed workers, and this will not be explicitly re-stated each time.

As shown in Table 1, noise-exposed workers in 2014 were predominantly male (76%), white, non-Hispanic (63%), and had a college degree (41%). This is compared to 49% male, 62% non-Hispanic, and 55% with a college degree among all workers in 2014 (data not shown). Overall prevalence of HPD non-use among noise-exposed workers was 53%. The highest prevalence of HPD non-use in each demographic category was among females (73%), those aged 18–25 (64%), classified as other non-Hispanic race/ethnicity (61%), having some college (60%), and current smokers (58%). Female gender (PR: 1.56, 95% CI: 1.43–1.70), ages 18–25 years (PR: 1.30, 95% CI: 1.14–1.50), and current smoking (PR: 1.12, 95% CI: 1.01–1.24) were significantly associated with HPD non-use.

Overall, the prevalence of HPD non-use was 56% in 2007 and 53% in 2014, but this change was not statistically significant (*p* > 0.05). However, the prevalence of HPD non-use did significantly decrease among males (*p* < 0.05) and those aged 66–75 years (*p* < 0.05).

#### 3.1 | Industry

In 2014, HPD non-use among noise-exposed workers ranged from approximately 40% to 80% across most industries, regardless of noise exposure prevalence (Table 2 and Figure 1). Workers in the Manufacturing (28%), Mining (28%), and Utilities (38%) industries had the lowest proportions of HPD non-use. The industries with the highest prevalence of HPD non-use were Accommodation and Food Services (90%), Health Care and Social Assistance (83%), and Education Services (82%). Some of the highest proportions of HPD non-use were seen among industries with lower prevalences of occupational noise exposure such as Finance and Insurance (80%), Health Care and Social Assistance (83%), and Education Services (82%). However, among some industries with higher prevalences of reported occupational noise exposure, such as (1) Arts, Entertainment, and Recreation and (2) Agriculture, Forestry, Fishing, and Hunting, HPD non-use was relatively high (64% and 74%, respectively).

TABLE 2 Prevalence of hearing protection device (HPD) non-use by industry among noise-exposed US workers in 2007 and 2014<sup>a</sup>

Industry (NAICS)	2007			2014			2007 vs. 2014				
	Unweighted n	Weighted N	Weighted prevalence of HPD non-use (%)	Unweighted n	Weighted N	Weighted prevalence of HPD non-use (%)	PR <sup>b</sup> (95% CI)	Weighted N	PR <sup>b</sup> (95% CI)	Difference in HPD non-use prevalence	p value <sup>c</sup>
Accommodation and Food Services (72)	77	784,009	80.09	199	1,511,161	89.88	<b>1.70 (1.10–2.63)</b>	89.88	<b>2.47 (1.54–3.96)</b>	+9.79	0.526
Administrative and Support and Waste Management and Remediation (56)	152	1,569,079	55.97	204	1,466,960	44.92	1.13 (0.71–1.80)	44.92	1.29 (0.79–2.1)	–11.06	0.526
Agriculture, Forestry, Fishing, and Hunting (11)	60	653,255	61.70	133	660,794	74.18	1.32 (0.83–2.10)	74.18	<b>2.16 (1.34–3.47)</b>	+12.48	0.397
Arts, Entertainment, and Recreation (71)	58	592,634	56.69	88	597,172	64.29	1.20 (0.72–1.99)	64.29	<b>1.80 (1.08–3.00)</b>	+7.60	0.593
Construction (23)	359	4,024,744	61.44	528	3,808,165	52.18	1.41 (0.92–2.16)	52.18	1.60 (1.00–2.55)	–9.27	0.397
Education Services (61)	77	791,080	73.38	126	761,096	81.70	<b>1.58 (1.01–2.47)</b>	81.70	<b>2.28 (1.41–3.69)</b>	+8.32	0.526
Finance and Insurance (52)	12	165,224	64.30	19	121,537	79.51	1.37 (0.74–2.54)	79.51	<b>2.37 (1.42–3.96)</b>	+15.21	0.526
Health Care and Social Assistance (62)	69	621,155	81.04	126	782,001	82.89	1.52 (0.94–2.45)	82.89	<b>2.22 (1.38–3.58)</b>	+1.85	0.526
Information (51)	32	313,374	58.66	38	240,392	49.88	1.24 (0.71–2.16)	49.88	1.47 (0.83–2.62)	–8.78	0.674
Manufacturing (31–33)	551	5,983,334	32.75	770	5,367,583	27.53	0.72 (0.46–1.14)	27.53	0.77 (0.47–1.25)	–5.22	0.397
Mining (21)	34	374,538	42.76	120	487,565	28.36	ref	28.36	ref	–14.41	0.397
Other Services (except Public Administration) (81)	88	1,147,161	73.46	166	1,061,365	69.76	<b>1.64 (1.05–2.56)</b>	69.76	<b>1.98 (1.21–3.22)</b>	–3.71	0.526
Professional, Scientific, and Technical Services (54)	35	427,131	42.94	89	644,226	61.99	0.90 (0.47–1.70)	61.99	1.26 (0.69–2.32)	+19.04	0.526
Public Administration (92)	72	789,240	48.09	169	1,085,782	41.10	1.12 (0.68–1.86)	41.10	<b>1.82 (1.12–2.96)</b>	–6.99	0.397
Real Estate and Rental and Leasing (53)	17	172,399	74.09	31	234,396	62.85	<b>1.68 (1.02–2.75)</b>	62.85	1.29 (0.79–2.12)	–11.24	0.526
Retail Trade (44–45)	111	1,287,711	81.87	169	1,085,782	73.96	<b>1.73 (1.12–2.69)</b>	73.96	<b>2.01 (1.23–3.26)</b>	–7.92	0.657
Transportation and Warehousing (48–49)	142	1,292,069	62.59	222	1,559,468	59.49	1.39 (0.91–2.13)	59.49	<b>2.09 (1.30–3.35)</b>	–3.10	0.526

(Continues)

TABLE 2 (Continued)

Industry (NAICS)	2007			2014			2007 vs. 2014			
	Unweighted n	Weighted N	Weighted prevalence of HPD non-use (%) <sup>a</sup>	Unweighted n	Weighted N	Weighted prevalence of HPD non-use (%) <sup>a</sup>	PR <sup>b</sup> (95% CI)	PR <sup>b</sup> (95% CI)	Difference in HPD non-use prevalence	p value <sup>c</sup>
Utilities (22)	25	240,477	ISS	56	387,657	37.62	ISS	<b>1.73 (1.08-2.78)</b>	ISS	ISS
Wholesale Trade (42)	52	690,128	69.58	78	522,966	50.73	1.53 (0.95-2.48)	1.54 (0.89-2.64)	-18.85	0.397

Note: ISS, Insufficient sample size—these estimates have a relative standard error >50% and do not meet the standards of reliability/precision. Bold font indicates statistical significance.

Abbreviations: CI, confidence interval; NAICS, North American Industry Classification System; PR, prevalence ratio.

<sup>a</sup>Data are from the National Health Interview Survey 2007 and 2014 adult samples.

<sup>b</sup>Prevalence ratio (adjusted for gender, age, race/ethnicity, education, smoking status).

<sup>c</sup>Corrected using False Discovery Rate (FDR).

Among those exposed to occupational noise, the risk for HPD non-use was more than two times greater than the reference industry for workers in: Accommodation and Food Services (PR: 2.47, 95% CI: 1.54-3.96); Agriculture, Forestry, Fishing and Hunting (PR: 2.16, 95% CI: 1.34-3.47); Education Services (PR: 2.28, 95% CI: 1.41-3.69); Finance and Insurance (PR: 2.37, 95% CI: 1.42-3.96); Health Care and Social Assistance (PR: 2.22, 95% CI: 1.38-3.58); Retail Trade (PR: 2.01, 95% CI: 1.23-3.26); and Transportation and Warehousing (PR: 2.09, 95% CI: 1.30-3.35) (Table 2). The prevalence of HPD non-use did not change significantly between 2007 and 2014 in any industry (Table 2).

### 3.2 | Occupation

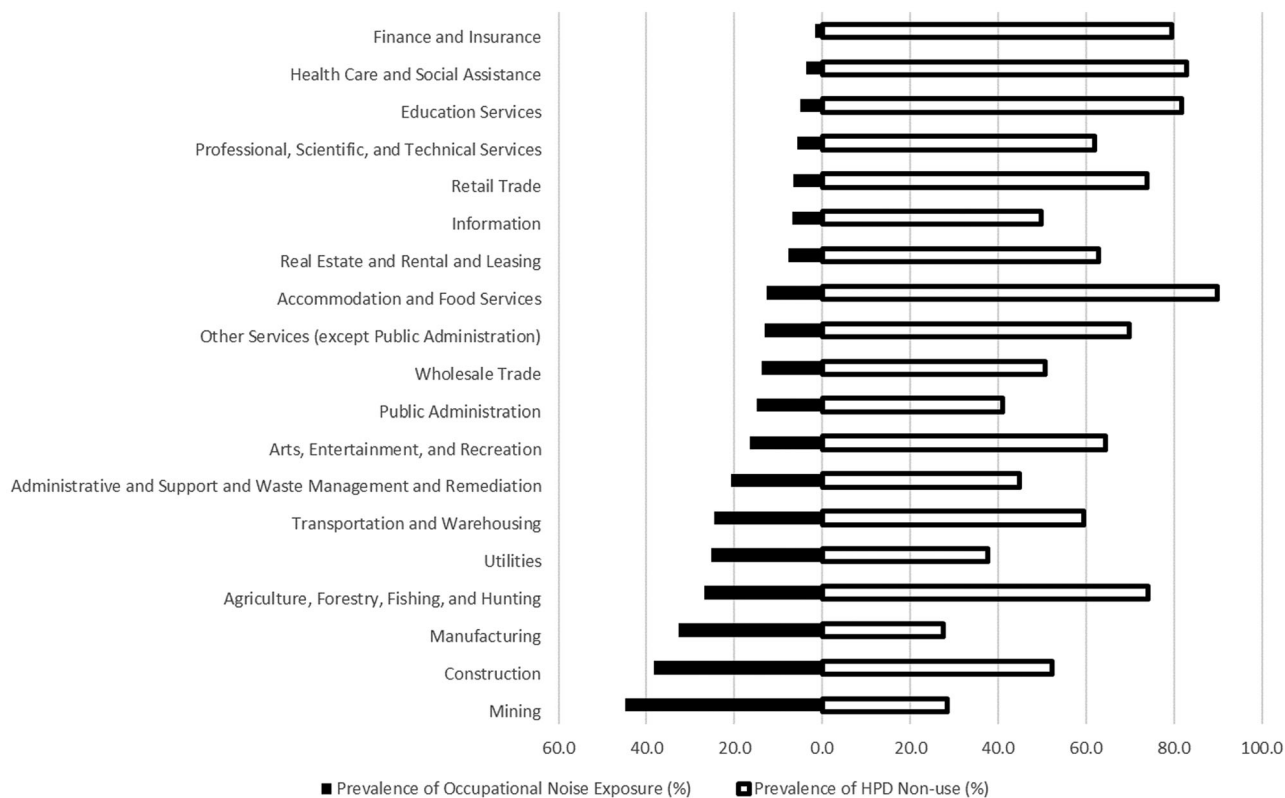
In 2014, the prevalence of HPD non-use among noise-exposed workers was more variable across occupations, ranging from 17% to 94% in 2014 (Table 3). The lowest prevalence of HPD non-use was among workers in Architecture and Engineering (17%) and Production (27%) occupations. The occupations with the highest prevalence of HPD non-use included Healthcare Support (94%) and Education, Training and Library (87%). About half of the occupations had significantly higher risks of HPD non-use individually, when compared with all other occupations (reference). Healthcare Support had the highest risk of HPD non-use (PR: 1.67, CI: 1.41-1.99), followed by Food Preparation and Serving-Related occupations (PR: 1.65, CI: 1.46-1.87).

Similar to industry, some of the highest proportions of HPD non-use were among those occupations that had low prevalence of occupational noise exposure (Figure 2). However, even among the occupations in which occupational noise exposure prevalence was 20% or higher, all but production workers had a percentage of HPD non-use greater than 45%.

The prevalence of HPD non-use significantly increased between 2007 and 2014 among workers in Arts, Design, Entertainment, Sports and Media (37% increase;  $p < 0.01$ ) and Building and Grounds Cleaning and Maintenance (22% increase;  $p < 0.05$ ). Among workers in Architecture and Engineering, the prevalence of HPD non-use significantly decreased (39% decrease;  $p < 0.01$ ). No other occupation showed a significant change in HPD non-use between the 2007 and 2014 surveys.

## 4 | DISCUSSION

This is the first study to provide nationally representative estimates of HPD non-use among noise-exposed workers since 2004, and the first to provide estimates by each occupation (not restricted to selected industries). Current study results indicated that 53% of US noise-exposed workers did not always or usually use HPDs when they were exposed to hazardous noise in 2014. This is a small, statistically nonsignificant decrease (improvement) in HPD non-use compared to 2007 (56%). HPD non-use varied by



**FIGURE 1** Prevalence of occupational noise exposure in comparison to the prevalence of HPD non-use among noise-exposed U.S. workers by industry in 2014.<sup>a,b</sup> <sup>a</sup>Data are from the National Health Interview Survey 2014 adult sample. <sup>b</sup>Included occupational noise exposures and HPD non-use reported for the 12 months prior to each worker's survey interview

worker demographic, industry, and occupation; however, there was little change within categories between the 2007 and 2014 survey years.

Comparisons with earlier national estimates are difficult to make due to differences in methodology and definitions of HPD non-use. Tak et al.<sup>12</sup> found that HPD non-use among noise-exposed workers in the 1999–2004 NHANES was 34%. However, response options in that survey only allowed categorizing HPD usage as ever/never, so the results cannot be directly compared to this study which defined HPD non-use as 50% or less. Davis and Sieber<sup>11</sup> observed HPD non-use of 59% among noise-exposed workers during the 1981–1983 NOES. Again, comparisons are difficult as estimates in that study were based on a single observation.

#### 4.1 | HPD non-use by demographic

The current study found a significantly higher prevalence of HPD non-use among females, workers aged 18–25, and current smokers. The findings regarding gender have been reported in several previous studies. Tak et al.<sup>12</sup> found that women were less likely to report using hearing protection than men. They speculated that—as their study drew a nationally representative sample which included noise-exposed workers in nonindustrial jobs—women may have been more

likely to be employed in jobs in which HPD use was less prevalent. Meira et al.<sup>21</sup> also found that fewer women (21%) than men (59%) reported using hearing protection when exposed to loud noise at work in their population-based cohort of workers in northeastern Brazil. They commented that occupational safety programs have historically been developed from a male perspective and may not generalize well to women. Not all studies have found this gender difference, however. McCullagh et al.<sup>22</sup> found no significant difference in HPD use by gender in a study of farm operators, but noted that women often lack appropriate role models for hearing protection use.

The findings regarding HPD non-use and age are also consistent with the results of some previous studies. Tak et al.<sup>12</sup> reported that non-use of HPDs was highest in the youngest age group (16–24 years). In a study of nearly 1600 Israeli blue-collar males in Manufacturing aged 20–64 years, Melamed et al.<sup>23</sup> found that use of hearing protection increased with increasing age. Younger workers may have less experience and/or familiarity with workplace hearing loss prevention strategies,<sup>6</sup> may be more willing to take risks, or be less aware of the consequences of noise-induced hearing loss. However, not all research has found the same relationship between HPD non-use and age. A large cohort study of over 13,000 lumbermill workers in Canada found that use of hearing protection was higher among younger workers.<sup>24</sup> In this case, the authors surmised

TABLE 3 Prevalence of Hearing Protection Device (HPD) non-use by occupation among noise-exposed US Workers in 2017 and 2014<sup>a</sup>

Occupation	2007			2014			2007 vs. 2014			
	Unweighted n	Weighted N	Weighted prevalence of HPD non-use (%)	Unweighted n	Weighted N	Weighted prevalence of HPD non-use (%)	PR <sup>b</sup> (95% CI)	PR <sup>b</sup> (95% CI)	Difference in HPD non-use prevalence	p value <sup>c</sup>
Architecture and Engineering	39	436,205	55.5	69	515,456	16.55	1.13 (0.84–1.53)	0.37 (0.20–0.69) <sup>d</sup>	-38.95	0.001
Arts, Design, Entertainment, Sports and Media	32	288,761	43.65	47	316,584	81.02	0.66 (0.41–1.04)	1.53 (1.30–1.81)	+37.37	0.001
Building and Grounds Cleaning and Maintenance	114	1,203,796	61.26	180	1,258,294	39.07	1.08 (0.90–1.30)	0.77 (0.62–0.96)	+22.19	0.047
Business and Financial Operations	23	312,235	44.62	43	255,490	53.71	0.79 (0.42–1.47)	0.96 (0.66–1.41)	+9.09	0.957
Community and Social Services	7	69,362	ISS	12	84,581	83.21	ISS	1.58 (1.14–2.20)	ISS	ISS
Computer and Mathematical	7	92,714	ISS	28	228,824	42.62	ISS	0.88 (0.58–1.36)	ISS	ISS
Construction and Extraction	333	3,634,712	57.17	507	3,438,120	47.57	1.11 (0.99–1.26)	1.00 (0.88–1.12)	+9.60	0.291
Education, Training, and Library	40	398,272	87.24	75	470,895	87.15	1.54 (1.31–1.81)	1.59 (1.35–1.88)	+0.09	0.966
Farming, Fishing, and Forestry	27	295,023	65.48	65	386,525	52.63	1.14 (0.85–1.53)	0.94 (0.62–1.43)	+12.85	0.536
Food Preparation and Serving Related	66	683,495	81.37	164	1,207,728	90.16	1.33 (1.07–1.66)	1.65 (1.46–1.87)	+8.79	0.445
Healthcare Practitioners and Technical	28	251,085	75.52	62	420,386	82.49	1.20 (0.88–1.64)	1.49 (1.23–1.80)	+6.97	0.554
Healthcare Support	12	107,882	79.33	22	124,181	93.69	1.10 (0.57–2.12)	1.67 (1.41–1.99)	+14.36	0.445
Installation, Maintenance, and Repair	169	1,917,709	56.78	303	1,988,649	51.24	1.10 (0.95–1.27)	1.06 (0.91–1.23)	+5.53	0.536
Legal	3	22,343	ISS	3	7,800	ISS	ISS	ISS	ISS	ISS
Life, Physical, and Social Science	14	146,316	46.55	27	171,769	38.91	0.83 (0.40–1.69) <sup>d</sup>	0.78 (0.41–1.46) <sup>d</sup>	+7.64	ISS

TABLE 3 (Continued)

Occupation	2007			2014			2007 vs. 2014			
	Unweighted n	Weighted N	Weighted prevalence of HPD non-use (%)	PR <sup>b</sup> (95% CI)	Unweighted n	Weighted N	Weighted prevalence of HPD non-use (%)	PR <sup>b</sup> (95% CI)	Difference in HPD non-use prevalence	p value <sup>c</sup>
Management	138	1,554,258	63.08	<b>1.22 (1.06–1.40)</b>	247	1,770,392	63.82	<b>1.30 (1.14–1.48)</b>	+0.73	0.966
Office and Administrative Support	127	1,312,402	66.26	1.09 (0.91–1.32)	196	1,259,540	63.33	1.14 (0.95–1.36)	+2.94	0.994
Personal Care and Service	44	500,173	84.03	<b>1.37 (1.10–1.71)</b>	77	480,914	81.72	<b>1.40 (1.13–1.73)</b>	+2.31	0.966
Production	454	4,963,449	34.90	0.56 (0.47–0.66)	585	3,810,028	27.41	0.45 (0.37–0.55)	+7.49	0.235
Protective Service	50	483,727	44.89	0.86 (0.62–1.18)	105	664,697	57.46	1.09 (0.88–1.35)	+12.57	0.450
Sales and Related	84	883,445	82.49	<b>1.47 (1.29–1.67)</b>	131	853,505	73.55	<b>1.32 (1.15–1.52)</b>	+8.94	0.291
Transportation and Material Moving	218	2,437,915	54.82	1.03 (0.88–1.19)	384	2,705,495	55.03	1.07 (0.95–1.20)	+0.21	0.994

Note: ISS, insufficient sample size—these estimates have a relative standard error > 50% and do not meet the standards of reliability/precision. Bold font indicates statistical significance.

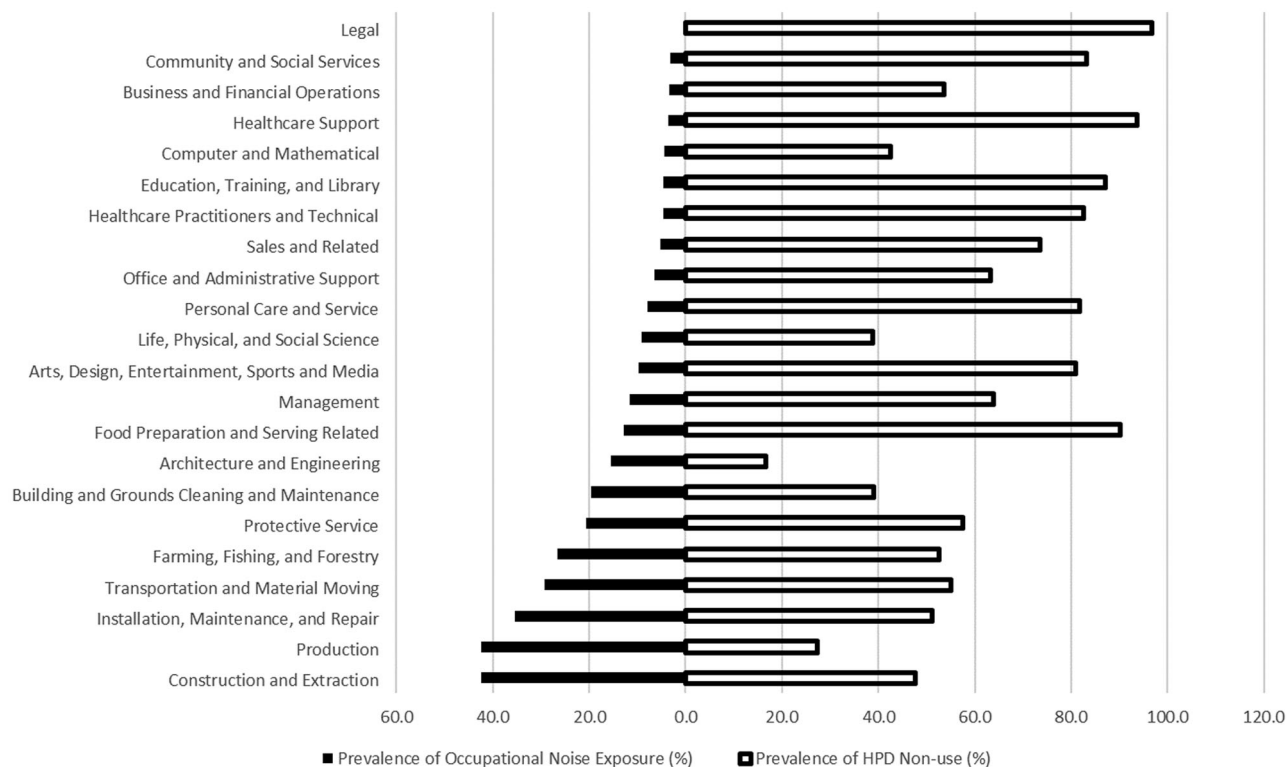
Abbreviations: CI, confidence interval; PR, prevalence ratio.

<sup>a</sup>Data are from the National Health Interview Survey 2007 and 2014 adult samples.

<sup>b</sup>Prevalence ratio (adjusted for gender, age, race/ethnicity, education, smoking status).

<sup>c</sup>Corrected using False Discovery Rate (FDR).

<sup>d</sup>These estimates have a relative standard error ≥30% and ≤50% and should be used with caution as they do not meet the standards of reliability/precision.



**FIGURE 2** Prevalence of occupational noise exposure in comparison to the prevalence of HPD non-use by occupation among noise-exposed U.S. workers in 2014.<sup>a,b</sup> <sup>a</sup>Data are from the National Health Interview Survey 2014 adult sample. <sup>b</sup>Included occupational noise exposures and HPD non-use reported for the 12 months prior to each worker's survey interview

that good safety practices are more easily inculcated in younger employees. In a study of 434 manufacturing workers across multiple industries in Portugal, Arezes and Miguel<sup>25</sup> similarly found that never using HPDs increased with increasing age and always using HPDs decreased with increasing age. They related their findings to the fact that regulatory requirements for use of hearing protection were relatively new in that country, and older workers would therefore be less knowledgeable and experienced in their use.

This study found a significant association between current smoking and HPD non-use. While there is an established association between smoking and hearing loss,<sup>26,27</sup> and between smoking and occupational noise exposure,<sup>28</sup> no prior relationship between smoking and HPD non-use has been reported. Prior studies have found that HPD non-use is independently and inversely associated with education,<sup>12</sup> which may be related to smoking status, with less educated workers more likely to smoke.<sup>29,30</sup> In a cross-sectional study of over 1500 manufacturing workers, Emmons and colleagues found that workers who smoke were more likely to engage in other poor health habits in general.<sup>31</sup> Smoking should be taken into account in future analyses of HPD non-use.

## 4.2 | HPD non-use by industry and occupation

The industries in which this study found the lowest rates of HPD non-use were Manufacturing, Mining, and Utilities—industries in which noise

exposure is a long-standing, highly prevalent hazard. Industries with a high prevalence of noise exposure are likely to have well-established occupational hearing loss prevention programs. The Agriculture, Forestry Fishing, and Hunting and the Construction industries also have high prevalences of noise exposure, but were found to have high proportions of HPD non-use (74% and 52%, respectively) in this study. These industries have unique challenges for hearing conservation, including less stringent or non-existent regulations and a substantial proportion of mobile, temporary, and/or nonnative English speaking workers.<sup>6</sup> Workers in these industries often work independently or in small groups with little or no oversight. Innovative approaches are needed to improve HPD use in these industries.

HPD non-use was most prevalent in the Accommodation and Food Service, Health Care and Social Assistance, and Education Services industries and they had some of the highest increased risks for HPD non-use compared to workers in Mining (147%, 122%, and 128%, respectively). The Finance and Insurance Industry also had a 137% higher risk of HPD non-use. Only a small proportion of workers in these industries are exposed to hazardous occupational noise. Results of this study are consistent with earlier analyses<sup>11,12</sup> in suggesting an inverse relationship between HPD non-use and noise exposure prevalence. Other analyses examining audiometric data for noise-exposed workers by industry also found higher than expected prevalences of hearing loss and shifts in hearing in similar industries.<sup>32,33</sup>

Occupations with the lowest prevalence of HPD non-use were Architecture and Engineering and Production. The Production occupation, at least, has many jobs in which noise exposures are well-documented and hearing conservation strategies are firmly in place. The highest prevalences and risks of HPD non-use were found in the occupations of Healthcare Support, Food Preparation and Serving Related, and Education, Training, and Library, with 67%, 65%, and 59% higher risks for HPD non-use, respectively, than all other occupations combined.

Similar to industries, nearly all occupations with low prevalences of occupational noise exposure (<20%) had high risks for HPD non-use among noise-exposed workers. This association between noise exposure prevalence and HPD non-use among occupations is consistent with that reported by Tak et al.<sup>12</sup>

Within industries and occupations with small percentages of noise-exposed workers, and likely lower awareness of the hazards of noise, hearing conservation programs may be less likely to be instituted or more poorly funded. Further, efforts to reduce noise exposures, whether through engineering controls or HPDs, may receive lower priority compared to controlling other hazards that are more prevalent, visible, and perceived to cause more catastrophic injury or illness. Better education is needed to raise awareness about the potentially dramatic impact on quality of life, which result from hearing loss, tinnitus, and other conditions caused by or associated with noise exposure, and the importance of prevention. The referenced studies have also called for additional research to identify noise sources and better protect workers in similar industries and occupations. To our knowledge, no such studies have yet been conducted.

### 4.3 | Trends

The overall prevalence of HPD non-use did not change significantly between the 2007 and 2014 NHIS surveys. No significant changes occurred in any category of gender, race/ethnicity, education, or smoking status between the surveys. However, HPD non-use declined significantly among 66–75 year olds, from 85% in 2007 to 58% in 2014. The reasons for this are unclear. Participants aged 66–75 years in 2007 were born between 1932 and 1941 and would have entered the workforce mostly in the 1950s to early 1960s. Participants in this age category in 2014 were born between 1939 and 1948 and would likely have entered the workforce in the late 1950s and 1960s. Occupational noise exposure regulations were implemented for general industry in the United States in 1970, so it is possible that workers in the later sample were more likely to be provided and trained in HPD use earlier in their careers and carry that habit through their working lifetime. However, data on when participants first held a noisy job were not collected in the NHIS, so this cannot be evaluated. Additional studies are needed to confirm this trend.

No significant changes in HPD non-use occurred in any industry between 2007 and 2014. There were no regulatory changes regarding HPD use during the time between the surveys. Increasing use

of HPDs requires industry-specific interventions to address real and/or perceived barriers, and these results indicate that the five critical barriers to HPD use have not been adequately addressed. These are discussed in the next section. However, there were significant changes in HPD non-use in three occupations. HPD non-use consistently decreased in Architecture and Engineering occupations by 39%, but increased in Arts, Design, Entertainment, Sports and Media by 37% and in Building and Grounds Cleaning and Maintenance by 22%. No additional information is available to explain these changes and more research is needed.

## 4.4 | Barriers to HPD use

Although less effective than noise mitigation measures such as elimination and engineering controls, HPDs can effectively protect workers from the adverse effects of noise if worn correctly and consistently.<sup>34</sup> As this analysis shows, however, HPDs are frequently not worn when needed. A complex mix of factors influence HPD non-use. Stephenson<sup>35</sup> summarizes these barriers into categories called the “5 Cs”—Communication, Comfort, Convenience, Climate, and Cost. The information about HPD non-use obtained in this study provides insights into how these barriers might be overcome.

### 4.4.1 | Communication

Perhaps the most common barrier to HPD use is worker perception that HPDs will negatively affect essential job functions, especially communication. This belief may explain the elevated rates of HPD non-use in industries and occupations where communication with others is a core job function. For example, this study found that 83% of noise-exposed workers in the Health Care and Social Assistance industry did not use HPDs when exposed to loud noise, perhaps because they are concerned about their ability to obtain critical health information from patients. Perception and localization of other workplace sounds can be vitally important as well. For example, this study found that 53% of noise-exposed workers within the Protective Services occupation did not wear hearing protection when exposed to loud noise. This occupation includes firefighters and police officers, who have reported concern that HPDs could hamper the audibility of alarms and other crucial signals.<sup>36</sup>

For workers with normal hearing, HPDs actually improve perception of speech and warning sounds in high levels of background noise by reducing signal distortion. This is not the case for workers who have hearing loss.<sup>3</sup> HPDs that maximize the ability to hear and localize speech and other crucial workplace sounds, such as flat attenuation or active noise reduction hearing protectors, are readily available but perhaps underutilized among workers who could benefit from them. These kinds of protectors may need additional training and a period of adjustment to maximize their utility. In addition, HPDs should be carefully selected to avoid overprotection (i.e., reducing sound to <70 dBA), which can cause workers to remove their HPDs

to hear critical sounds. Selecting devices that offer the highest listed noise reduction rating (NRR) when only a few decibels of attenuation are needed may increase the prevalence of HPD non-use in industries and occupations where communication is essential.<sup>37,38</sup> A recent fit-testing study among metal manufacturing workers found that 84% of participants were overprotected (i.e., had protected noise exposures below 70 dBA).<sup>39</sup>

#### 4.4.2 | Comfort

Typically, HPD selection focuses almost exclusively on the noise reduction rating of the hearing protector with little or no consideration of other factors which influence use. Comfort is essential for any device which must be worn for long periods of time. Davis<sup>40</sup> reviewed the scant literature on HPD comfort and reported that workers can reliably rate HPD comfort and that short-term ratings predict long-term comfort assessments. Arezes and Miguel<sup>16</sup> suggest that providing workers a more personalized choice among a variety of HPD sizes and configurations will ultimately improve their HPD use. In focus groups with apprentice carpenters, Stephenson<sup>35</sup> found that these workers were not aware of the breadth of HPDs available, and that nearly half did not believe that HPDs could be comfortable when properly worn. Employers can select from nearly 400 different hearing protectors currently available on the US market. As Stephenson noted, no one would choose to go barefoot because the first pair of shoes they tried was uncomfortable, yet many workers choose to forego wearing HPDs because they have not found a comfortable solution.<sup>35</sup> Among farmers, providing an assortment of HPDs (muffs, foam plugs, pre-molded plugs, and semi-aurals) has been shown to improve the use of HPDs over time.<sup>22</sup>

#### 4.4.3 | Convenience

Consistent HPD use is critical to successfully preventing hearing loss. Removing a hearing protector in noisy areas for just a few minutes a day drastically reduces its effective noise reduction. HPDs must be convenient so that they are worn every time the worker is exposed to hazardous noise. Convenience encompasses a wide range of considerations. HPDs must be compatible with other required safety equipment. Safety glasses (and even some eyeglasses), hardhats, and respirators may be incompatible with earmuffs and canal caps.<sup>38</sup> Hearing protection must also be suitable for the work environment. Earmuffs may be uncomfortable in very warm work environments, ineffective in very cold environments, and too cumbersome in confined spaces. Earplugs may be inconvenient to continually remove and replace in workplaces with intermittent noise exposure.<sup>38</sup> This could be one reason for the prevalence of HPD non-use in occupations such as Building and Grounds Cleaning and Maintenance (39%), in which workers may frequently have dirty hands which prevent them from re-inserting their HPDs. Earmuffs and canal caps are easier to don and doff, and pre-formed earplugs can be removed and

replaced without touching the part of the device which is inserted into the ear canal. Level dependent or sound restoration HPDs, which reduce sound levels only when noise exceeds a certain level, can be another solution when noise exposures are intermittent.

Convenience also includes considerations such as availability, replacement, and care and use. HPDs should be readily available in noisy areas and highly visible signage should remind workers and visitors that hearing protection is required. Workers should know where to get replacement HPDs and when the HPD should be replaced. Sometimes a trade-off between comfort and convenience may exist.<sup>11</sup> Workers may have different priorities in choosing the best HPD, which should be considered in selecting appropriate HPDs for a workplace.

#### 4.4.4 | Climate

The safety climate of a company is defined by workers' perceptions of management commitment to safety as shown both in policy and practice.<sup>35</sup> Company safety culture has been linked to improved safety outcomes, including more consistent HPD use.<sup>41</sup> Safety climate also includes workers' interpersonal perceptions and workplace norms.<sup>36,42,43</sup> Worker beliefs that hazardous noise exposures are part of the job, that exposures are short and will not affect individual hearing in the long term, and that no one else is using HPDs and therefore they are not necessary can increase the prevalence of HPD non-use. These perceptions could partially explain the elevated prevalence of HPD non-use (64%) among workers in the Arts, Entertainment, and Recreation industry.

Effective worker training is another aspect of the safety climate that has been shown to be strongly correlated with HPD use. Consistent use of HPDs requires active participation by the worker and therefore requires strategies that help motivate and encourage their use. Targeted interventions tailored to specific worksite factors and worker characteristics have shown to increase HPD use significantly among construction workers,<sup>44,45</sup> factory workers,<sup>46</sup> and operating engineers.<sup>47</sup> However, despite the short-term success of many of these interventions in reducing HPD non-use, the long-term effects have been less favorable,<sup>45,48</sup> suggesting repeated interventions and/or combinations of interventions are needed.

#### 4.4.5 | Cost

As with any business expense, HPD costs must be evaluated. However, HPDs are a small part of overall hearing conservation program costs and can prevent much larger expenditures for worker compensation claims. Though data are scarce, one recent study reported that the average annual cost for HPDs across a company's fourteen metal manufacturing sites was \$64 per worker.<sup>49</sup> Workers' compensation costs for noise-induced hearing loss vary, as compensation programs in the United States are governed by differing federal, state, and territorial statutes.<sup>3</sup> Nonetheless, claims expenditures are typically much higher. The average compensation settlement for occupational hearing loss in Washington State was \$7180 per claim in 1998<sup>50</sup> and \$6705.<sup>34</sup>

per claim in Oregon between 1990 and 1998.<sup>51</sup> Individual claims at a global health care products company ranged from \$44 to \$20,157 across its US locations from 2001 to 2004.<sup>52</sup>

Sayler and colleagues found that HPD costs were higher at sites with higher prevalences of worker hearing loss. One explanation for this could be that workers who have sustained a hearing loss may require more expensive HPDs to hear important signals while still being protected from high noise levels.<sup>49</sup> This possibility highlights the advantage of ensuring that workers are properly protected and consistently using HPDs to prevent work-related hearing loss.

## 4.5 | Limitations

While the NHIS is a representative sample of the US civilian, non-institutionalized population, it may not be representative of each industry and occupation group. Industry and occupation are coded for the most recent job, but noise exposure was reported for any job held in the past 12 months and in rare cases may have occurred in a different industry/occupation. All data, including the main outcome of the study (HPD non-use), were obtained via self-report, and no workplace measurements or observations were completed to ensure accuracy. The NHIS questions on noise exposure have been validated for accuracy, and the recall of noise exposure has been found to be typically valid.<sup>53</sup> Prior research has also indicated that self-report is an appropriate measure of HPD use and that self-report and workplace observations are highly correlated.<sup>8</sup> However, research has found that the accuracy of self-reported HPD use is dependent on noise variability within worksites, with higher accuracy among workers in steady noise.<sup>54</sup> The type of noise exposure could not be assessed with the data available in this study. The accuracy of self-reported HPD use also declines over time, and trends toward the over-reporting of HPD use.<sup>54</sup> The NHIS survey questions were limited to HPD non-use over the previous 12 months, but the prevalence of HPD non-use may be higher than reported in this study.

## 5 | CONCLUSIONS

Occupational noise exposure remains a concern in the United States. An estimated 22 million workers, representing 14% of the workforce, are exposed to hazardous noise levels on the job.<sup>1</sup> The prevalence of HPD non-use also remains high. Among noise-exposed workers, the majority (53%) do not wear hearing protection consistently. Hearing protection is the least effective method for reducing hazardous noise exposure.<sup>5,55</sup> However, correct and consistent use of HPDs can successfully protect workers from the deleterious effects of hazardous noise when other prevention techniques cannot be effectively implemented. This study has shown that HPD use differs by demographic, industry, and occupation. HPD non-use was significantly higher among females, workers aged 18–25 years, and current smokers. HPD non-use exceeded 80% in three industries and eight occupations. Little improvement in reducing HPD non-use occurred between 2007 and 2014.

Interventions which could reduce HPD non-use include: increasing awareness in industries with smaller proportions of exposed workers; repeated trainings on the risks of noise and proper HPD use; providing a variety of appropriate HPDs for workers; fit-testing HPDs for proper fit and to increase self-efficacy; and management support for compliance.

Employers should consider multiple factors when purchasing HPDs to reduce non-use. These include: the amount of noise reduction necessary (particularly with the goal of avoiding over-attenuating sound); workplace characteristics (e.g., environment, temperature, type of work); comfort and convenience; potential interference with other PPE (e.g., helmets); type of noise (continuous, impulse, mixed); how long the HPD will be worn; whether HPDs need to be removed and replaced frequently; and the need to hear speech and other auditory signals.

Although personal protective equipment such as HPDs are the least effective hazard control, HPDs continue to be employed as the first, and often only, prevention tool for minimizing hazardous noise exposures at US worksites. Where feasible, engineering and administrative controls should be implemented. However, when every attempt has been made and HPDs are the only option, ensuring high compliance is critical to prevent harmful noise exposure and preserve worker quality of life.

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## CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

## DISCLOSURE BY AJIM EDITOR OF RECORD

John Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

## AUTHOR CONTRIBUTIONS

Deirdre R. Green and Elizabeth A. Masterson participated in the conception and design, acquisition, analysis, and interpretation of data, drafting and critically revising for important intellectual content, final approval of version to be published, and the agreement to be accountable for all aspects in ensuring that questions related to the accuracy and integrity of any part are appropriately investigated and resolved of the work. Christa L. Themann participated in drafting and critically revising for important intellectual content, final approval of version to be published, and the agreement to be accountable for all aspects in ensuring that questions related to the accuracy and integrity of any part are appropriately investigated and resolved of the work.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study were accessed from the National Health Interview Survey, which has been made openly available to all by the Centers for Disease Control and Prevention: <https://www.cdc.gov/nchs/nhis/1997-2018.htm>, reference number 14.

## ETHICS APPROVAL AND INFORMED CONSENT

The 2007 and 2014 NHIS were approved by the National Center for Health Statistics Research Ethics Review Board and the U.S. Office of Management and Budget. All National Health Interview Survey respondents provided oral consent before participating.

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