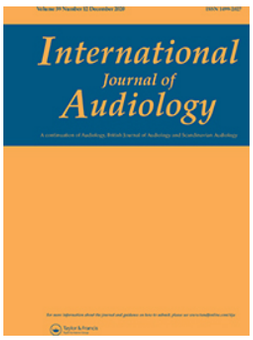

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ORIGINAL ARTICLE

Prevalence of hearing loss among noise-exposed workers within the services sector, 2006–2015

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ABSTRACT

Objective: The purpose of this study is to estimate the prevalence of hearing loss among noise-exposed U.S. workers within the Services sector.

Methods: Audiograms for 1.9 million workers (158,436 within Services) from 2006 to 2015 were examined. Prevalence and adjusted risk for hearing loss as compared with a reference industry were estimated for the Services sector/sub-sectors, and all industries combined.

Results: The prevalence of hearing loss within Services was 17 compared to 16% for all industries combined. However, many sub-sectors greatly exceeded the overall prevalence (10–33% higher) and/or had adjusted risks significantly higher than the reference industry. Workers in Administration of Urban Planning and Community and Rural Development had the highest prevalence (50%), and workers in Solid Waste Combustors and Incinerators had more than double the risk, the highest of any sub-sector. Some sub-sectors traditionally viewed as 'low-risk' also had high prevalences and risks.

Conclusions: Large numbers of workers within Services have an elevated risk of hearing loss and need immediate hearing conservation efforts. Additional research and surveillance are needed for sub-sectors for which there is low awareness of hearing hazards or a lack of hearing data.

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Introduction

Hearing loss is the third most prevalent chronic physical condition after hypertension and arthritis among adults in the United States (Bogardus, Yueh, and Shekelle 2003; Blackwell, Lucas, and Clarke 2014). Exposure to hazardous noise (≥85 dBA), or ototoxic chemicals such as solvents (e.g., styrene), heavy metals (e.g., mercury), asphyxiants (e.g., exhaust) and certain pharmaceuticals (e.g., neoplastic agents) can result in occupational hearing loss (OHL) (Themann, Suter, and Stephenson 2013a). Twenty-five percent of workers in the United States have a history of occupational noise exposure, with 14% exposed in the last year (Kerns et al. 2018). Twelve percent of U.S. workers report hearing difficulty, with 58% of the cases due to occupational noise exposure (Kerns et al. 2018). Hearing loss often co-occurs with tinnitus (ringing in the ears) (Themann, Suter, and Stephenson 2013a) and is associated with depression and cognitive decline (Lin et al. 2013; Li et al. 2014).

Industries such as Mining, Construction and Manufacturing have been recognized as having a high prevalence of noise exposure (Kerns et al. 2018) and hearing loss (Tak and Calvert 2008; Masterson et al. 2013). However, a recent analysis found elevated prevalences of hearing loss among some groups of noise-exposed workers in presumed "low risk" industries, and in sectors with a low to moderate overall prevalence of hearing loss or noise exposure (Masterson et al. 2013, 2014). The Services sector meets both of these criteria (Mrena et al. 2007; Masterson et al. 2013). The Services sector (as defined by the National Institute for Occupational Safety and Health (NIOSH) – National Occupational Research Agenda (NORA)) is the largest U.S. industry sector, employing 77 million workers, and consists of a wide variety of services, also known as intangible goods (NORA 2018; Kerns et al. 2018). These include: newspaper, music and software publishing; renting and leasing; financial transactions; legal advice and representation; overseeing and managing governmental programs; security and surveillance; educational training; entertainment and recreation; accommodations and food service; machinery repairing; dry cleaning and laundry; and landscaping (U.S. Census Bureau 2011).

Several previous studies have estimated the prevalence of hearing loss among the Services sector and sub-sectors (Tak and Calvert 2008; Tak, Davis, and Calvert 2009; Masterson et al. 2013; Masterson et al. 2016; Kerns et al. 2018). Ten percent of all Services sector workers have hearing difficulty (Kerns et al. 2018). A study using NIOSH Occupational Hearing Loss (OHL) Surveillance Project data found that the prevalence of hearing loss among noise-exposed Services sector workers was 20%, very close to the prevalence for all industries combined (19%) (Masterson et al. 2015). However, some Services sub-sectors with presumed 'low risk' (and therefore presumed low prevalence) had a higher than expected prevalence among noise-exposed workers: 23% in Educational Services, 21% in Finance and Insurance and 20% in Professional, Scientific and Technical Services. Within Finance and Insurance, the Depository Credit Intermediation sub-sector had a prevalence of 36% (Masterson et al. 2013).

Some studies have characterised noise exposures within Services sub-sectors. Kerns et al. (2018), using 2014 National Health Interview Survey (NHIS) data, estimated that 21% of all Services sector workers have been exposed to hazardous noise. Musicians can be exposed to dangerously high levels of noise (94–103 dBA) while performing (McIlvaine, Stewart, and Anderson 2012). Ringing

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bells, classroom noise, slamming lockers and announcements over the public address (PA) system expose classroom teachers to noise without any protection (Martins et al. 2007). Music teachers are exposed to high sound levels from instruments and singing and gym teachers are also exposed to loud background music during their classes (Cutietta et al. 1994; Behar et al. 2004; Palma et al. 2009; Isaac et al. 2017). High noise levels have been reported among disc jockeys in night clubs (93.2–109.7 dBA), drivers of stock racing cars (114 dBA), amusements ride operators (83–92.4 dBA) and restaurant workers (74–102 dBA) (Santos et al. 2007; Kardous and Morata 2010; Lao et al. 2013; Gilbertson, Thies, and Vosburgh 2017). The majority of the tools and equipment used by groundskeepers and landscaping workers (e.g., lawn mowers, leaf blowers, hedge trimmers, grass trimmers) expose them to noise levels >85dBA (Hanidza et al. 2013; Balanay, Kearney, and Mannarino 2016; Jaafar et al. 2017).

Although some overall prevalence and risk estimates are available, no known study has performed an in-depth analysis within the Services sub-sectors. The purpose of this study was to further investigate and compare the prevalence of hearing loss for noise-exposed U.S. workers within the Services sector and sub-sectors using audiograms collected through the NIOSH OHL Surveillance Project. Prevalence and adjusted risks of hearing loss as compared with a reference industry were also estimated to identify additional at-risk groups for targeted intervention.

Materials and methods

Study design and population

This was a cross-sectional study that estimated and compared the prevalence and adjusted risk of hearing loss among noise-exposed workers within the Services sector using a retrospective cohort of de-identified audiograms. Adjusted risks were calculated via probability ratios (PRs). In general, a PR is the ratio of the estimated probability of an event (e.g., hearing loss) occurring in an exposed group versus the estimated probability of the same event occurring in an unexposed or lesser-exposed group or reference group. In this study, the risk of hearing loss among noise-exposed tested workers in the Services sector was compared to the risk of hearing loss among noise-exposed tested workers in the reference industry (Couriers and Messengers). Worker audiograms from the NIOSH OHL Surveillance Project were used and are described in more detail by Masterson et al. (2013). In brief, audiograms were collected from a convenience sample of audiometric service providers, occupational health clinics, hospitals and others (hereby denoted as providers) that conducted audiometric tests for workers exposed to high noise levels (≥85 dBA) for regulatory purposes. These providers shared the audiograms and related information in a de-identified format with NIOSH. Each audiogram was assigned an arbitrary employee ID. Male and female workers with at least one audiogram from 2006 to 2015 and aged 18–75 years were included in the study. This time period was selected because 2015 was the latest year with complete audiometric data available and also to ensure that the sample size was large enough to perform in-depth analysis for smaller sub-sectors within the Services sector. Audiograms that did not meet quality standards (described below) were excluded. Only the latest quality audiogram per worker was included in the analyses and was used to determine the age and hearing status of the noise-exposed worker. This Project was determined by the NIOSH Institutional Review Board to be non-human subjects research, as all audiograms were de-identified.

Materials

Worker audiograms included thresholds at frequencies 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz, date of birth, gender, employer state, and North American Industry Classification System (NAICS) code (U.S. Census Bureau 2011). These audiograms did not include date of hire, occupation, race, income, smoking status, hearing protection device (HPD) use or ototoxic chemical exposure information. Specific noise exposure levels were not available for each worker. However, ≥85 dBA exposures can be assumed for all workers, given that the data were collected as part of U.S. regulatory requirements for noise-exposed workers. The results of the audiograms were used to identify workers with hearing loss.

Inclusion and exclusion criteria

Audiograms may contain incomplete or inaccurate information as they were not originally collected for research purposes (Laurikkala et al. 2000). If the audiogram was missing year of birth, gender, geographical region, or NAICS code and this information could not be imputed from another audiogram of the same worker, it was excluded from the analysis. To eliminate unlikely birth years, audiograms were restricted to the age range of 18–75. Audiograms missing birth month or birth day were imputed as July and 15, respectively. If both month and day were missing, July 1 was imputed. Audiograms missing thresholds at frequencies necessary for the determination of hearing loss for the affected ear were also excluded (1000, 2000, 3000 and 4000 Hz).

Using standards developed by senior NIOSH audiologists and described in detail in Masterson et al. (2013), audiograms that did not meet additional quality standards were excluded from the study. Audiograms that displayed attributes indicating a non-occupational factor or pathology was likely responsible for hearing loss were excluded. Audiograms with large (≥40 dB) inter-aural differences (suggesting a possible medical etiology) and with threshold values depicting negative slope in either ear (indicating likely contamination by the background noise during testing or middle ear pathology) (Suter 2002) were excluded. Audiograms with unlikely threshold values (suggesting a testing error) or with "no response at maximum value" (indicating an etiology different from or in addition to noise exposure) were also excluded.

The study began with 7,289,570 audiograms for 2,167,493 workers aged 18–75 from 2006 to 2015. 1,388,969 audiograms were eliminated due to quality deficiencies as shown in Table 1. Next, only the most recent audiogram for each worker was selected, eliminating an additional 3,989,634 audiograms (only one audiogram was examined for each worker). The final study sample included 1,908,218 workers at 22,100 U.S. companies, including 158,436 workers at 3412 companies in the Services sector.

Statistical analysis

Based on the NAICS code, industry was the independent variable. The outcome variable was material hearing impairment (hereby denoted as hearing loss) based closely on the NIOSH definition (NIOSH (National Institute for Occupational Safety and Health) 1998): a pure-tone average threshold across frequencies 1000, 2000, 3000 and 4000 Hz of 25 dB or more in either ear. Worker age was stratified into six categories and U.S. states of worker employment were condensed into six geographical regions based on U.S. Embassy groupings (U.S. Embassy 2008). The Services

Table 1. Audiograms excluded from analysis.

Reason for exclusion	Number with characteristic	Total excluded in grouping[a]
Quality deficiencies:		1,388,969
Missing value for independent variable[b]	414,879	
Missing value for dependent variable[c]	5,441	
Unlikely threshold values for left ear	3,811	
Unlikely threshold values for right ear	3,913	
Large inter-aural difference[d]	579,675	
Negative slope[e]	539,017	
Not the most recent valid audiogram in the time period		3,989,634
All exclusions		5,378,603[f]

[a]Some audiograms were eliminated for more than one reason within groupings.
[b]Industry [North American Industry Classification System (NAICS) code].
[c]Hearing loss. Includes eliminations of affected ear results due to "no response at maximum value" threshold values.
[d]Audiograms with large (≥ 40 dB) interaural differences, with likely inaccurate testing of the better ear, or suggesting medical etiology.
[e]Audiograms with negative slope in either ear indicating possible threshold contamination by background noise.
[f]Number of audiograms excluded, leaving 1,908,218 audiograms/workers included in the final sample.

sector (and this study) includes all audiograms with NAICS codes 51–56, 61, 71–72, 81 and 92 (excluding 92212, 92214 and 92216) (U.S. Census Bureau 2011). SAS version 9.4 statistical software was used for all analyses (SAS Institute, Inc., Cary, NC).

Prevalence percentages of hearing loss with 95% confidence intervals (CIs) were estimated for all industries combined, the Services sector and its sub-sectors at two- and three-digit NAICS specificity and for the reference industry (Couriers and Messengers – NAICS 492). Based on results at the two- and three-digit levels, select sub-sectors were examined at greater levels of specificity. Pre-determined sub-sectors were also targeted for analysis, based on noise levels reported in the scientific literature and the experience of the authors. These included Landscaping Services (NAICS 561730), Amusement and Theme Parks (NAICS 713110), Food Services such as Drinking Places (Alcoholic Beverages) (NAICS 722410), Full-Service Restaurants (NAICS 722110) and Limited-Service Restaurants (NAICS 722211). Musical Groups and Artists (NAICS 711130), Sports Teams and Clubs (NAICS 711211), Amusement Arcades (NAICS 713120), Bowling Centers (NAICS 713950) and Casino Hotels (721120) were also of interest but had insufficient sample sizes for analysis.

The rationale for selection of the reference industry was based on an examination of literature, low hearing loss prevalence, consistency with prior studies and statistical considerations (Masterson et al. 2013; Masterson et al. 2014). The prevalence of hearing loss in the Couriers and Messengers industry (10%) is close to the prevalence of hearing loss among non-noise-exposed workers (7%) (Masterson et al. 2016), which would be an ideal reference group. However, only audiograms for noise-exposed workers were available in this study as non-exposed workers are rarely tested in workplace hearing conservation programs. Reference groups for the covariates were female for gender and 18–25 years for age group. Hearing loss is more prevalent in men as compared to women and hearing loss increases with age (Tak and Calvert 2008; Masterson et al. 2013).

PRs were estimated for the industry analyses as compared to the reference industry. The log-binomial regression method with PROC GENMOD and the log link was used to calculate the PRs (Spiegelman and Hertzmark 2005; Deddens and Petersen 2008). PRs were selected over odds ratios because odds ratios should only be used for rare outcomes and some prevalences were expected to exceed 10% (Deddens and Petersen 2008). The copy method was used to determine PRs if the log-binomial regression method failed to converge (Deddens and Petersen 2008). PRs were adjusted for gender and age group. A PR greater than 1 indicates an increased risk and a PR less than 1 indicates a decreased risk when compared to the reference industry or group. Prevalence and adjusted risk estimates were not reported for industries with zero or insufficient sample size, identified by insufficient numbers of cases and non-cases per cell and/or with relative standard error (RSE) ≥50%. Adjusted risks were also not reported for geographical region because the industries were unevenly distributed.

Results

Most of the Services sector workers in this study were male (81%) and employed in the Midwest (57%) (Table 2), compared to workers in all industries combined, where 77% were male and 58% were employed in the Midwest (data not shown). The distribution of the worker age groups was similar to all industries combined. Males were 2.5 times more likely to have hearing loss than females, with hearing loss prevalences of 20% and 8%, respectively. The risk of hearing loss increased with age.

The prevalence of hearing loss for noise-exposed workers in the Services sector (17%) was very close to the prevalence of all industries combined (16%). Most of the Services sub-sector prevalence estimates (at six-digit NAICS code specificity) ranged from 11 to 20% (some data not shown). Table 3 depicts Services sub-sector prevalences at two- and three-digit NAICS code specificity. All of the sub-sector prevalences at two-digit NAICS code specificity exceeded the overall prevalence for all industries combined except Information (NAICS 51) (15%), Administrative and Support and Waste Management and Remediation Services (NAICS 56) (15%), and Accommodation and Food Services (NAICS 72) (14%). All adjusted risks were significantly higher than the reference industry, except in Educational Services (NAICS 61) (PR 0.89, CI 0.85–0.94). Workers in the Administration of Housing Programs, Urban Planning and Community Development (NAICS 925) had the highest prevalence (50%) of hearing loss and risk compared to the reference industry (PR 1.65, CI 1.43–1.89). Credit Intermediation and Related Activities (NAICS 522) had the second highest prevalence (33%) of hearing loss followed by Administration of Economic Programs (NAICS 926) (28%) and Administration of Human Resource Programmes (NAICS 923) (28%). The following sub-sectors were selected for examination at greater NAICS code specificity due to high prevalences and risks of hearing loss: (1) Real Estate and Rental and Leasing (NAICS 53), (2) Other Services (Except Public Administration) (NAICS 81) and (3) Public Administration (NAICS 92).

Table 4 presents prevalences and adjusted risks for Real Estate and Rental and Leasing (NAICS 53) at six-digit NAICS code specificity. With the exception of one sub-sector (Other Commercial and Industrial Machinery and Equipment Rental and Leasing [NAICS 532490]), the sub-sectors with the highest prevalences also had the highest adjusted risks. Workers in Other Commercial and Industrial Machinery and Equipment Rental and Leasing had a moderate prevalence of 16%, but a significantly higher risk (PR 1.43, CI 1.30–1.5712) as compared to the reference industry. Truck, Utility Trailer and Recreational Vehicle (RV) Rental and Leasing (NAICS 532120) had a moderately elevated prevalence (21%) and a significantly higher adjusted risk (PR 1.73, CI 1.35–2.22) than the reference industry.

The prevalences of hearing loss for most of the sub-sectors in Other Services (Except Public Administration) (NAICS 81) at

Table 2. Services sector demographics for noise-exposed workers[a], with estimated prevalence and adjusted prevalence ratios (PRs) for hearing loss (HL), 2006–2015 ($N = 158,436$).

Demographic	*n*	(%)	Prevalence of HL (%)	Prevalence 95% CI[b]	PR[c]	PR 95% CI
HL (outcome)						
Yes	26,743	16.88				
No	131,693	83.12				
Missing	0					
Gender						
Male	120,042	81.03	19.57	19.35–19.79	2.44	2.34–2.54
Female (ref)	28,109	18.97	8.01		Ref	
Missing	10,285					
Age group (years)						
18–25 (ref)	23,028	14.53	2.74	2.53–2.95	ref	
26–35	37,333	23.56	4.95	4.73–5.17	1.71	1.56–1.88
36–45	37,943	23.95	12.10	11.77–12.43	4.23	3.88–4.60
46–55	37,812	23.87	25.66	25.22–26.10	8.96	8.25–9.74
56–65	20,513	12.95	43.59	42.91–44.27	15.00	13.80–16.29
66–75	1,807	1.14	57.00	54.72–59.28	19.27	17.61–21.08
Missing	0					
Geographical region						
Mid-Atlantic[d]	2,886	2.40	23.18	21.64–24.72	[j]	
Midwest[e]	68,553	57.11	20.66	20.36–20.96	[j]	
New England[f]	1,753	1.46	12.44	10.90–13.99	[j]	
South[g]	25,508	21.25	15.84	15.39–16.29	[j]	
Southwest[h]	1,221	1.02	6.39	5.02–7.76	[j]	
West[i]	20,111	16.75	18.28	17.75–18.81	[j]	
Missing	38,404					

[a]One audiogram was examined for each worker.
[b]CI = 95% confidence interval.
[c]PRs were adjusted for age group and gender.
[d]Mid-Atlantic: Delaware, Maryland, New Jersey, New York, Pennsylvania, Washington, D.C.
[e]Midwest: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin.
[f]New England: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont.
[g]South: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Tennessee, Virginia, West Virginia.
[h]Southwest: Arizona, New Mexico, Oklahoma, Texas.
[i]West: Alaska, California, Colorado, Hawaii, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming.
[j]PRs not estimated for geographical region due to the uneven distribution of industries.

six-digit NAICS code specificity were higher than all industries combined (Table 5). Adjusted risks for all the sub-sectors were also significantly higher than the reference industry. Labor Unions and Similar Labor Organizations (NAICS 813930) and Business Associations (NAICS 813910) had the highest prevalences of hearing loss (45% and 43%, respectively) and risks 74% and 78% higher, respectively, than the reference industry. Commercial and Industrial Machinery and Equipment (Except Automotive and Electronic) Repair and Maintenance (NAICS 811310) had a moderate prevalence of hearing loss (17%) but a high adjusted risk (PR 1.40, CI 1.32–1.48).

Table 6 contains prevalences and adjusted risks for Public Administration (NAICS 92) up to six-digit NAICS specificity. The prevalence of hearing loss for all the sub-sectors was higher than all industries combined except in Other Justice, Public Order and Safety Activities (NAICS 922190) (14%) and National Security (NAICS 928110) (8%). Sub-sectors with the highest prevalences and adjusted risks were: Courts (NAICS 922110) with prevalence (41%) and adjusted risk (PR 1.78, CI 1.68–1.88), Administration of Urban Planning and Community and Rural Development (NAICS 925120) with prevalence (50%) and adjusted risk (PR 1.65, CI 1.44–1.90) and Legislative Bodies (NAICS 921120) with prevalence (26%) and adjusted risk (PR 1.50, CI 1.35–1.66). Although Public Finance Activities (NAICS 921130) had a moderately elevated prevalence (23%), the risk was not significantly different than in the reference industry.

Among targeted sub-sectors, Landscaping Services (NAICS 561730) had a moderate-to-low prevalence (15%) and risk (PR 1.16, CI 1.04–1.31). Amusement and Theme Parks (NAICS 713110) also had a moderate prevalence (20%) and fairly low risk (PR 1.10, CI 0.94–1.27). Food Services such as Drinking Places (Alcoholic Beverages) (NAICS 722410) and Full-Service Restaurants (NAICS 722110) had low or fairly low prevalences (6% and 13%, respectively) and the risks were not significantly higher than the reference industry. Limited-Service Restaurants (NAICS 722211) had a moderate prevalence of 14% and a 31% higher risk of hearing loss.

Table 7 lists miscellaneous sub-sectors within the Services sector at six-digit NAICS specificity not previously presented that had prevalences ≥25% and/or adjusted risks ≥30% significantly higher than the reference industry. Within Solid Waste Combustors and Incinerators (NAICS 562213), 44% of workers had hearing loss and more than double the risk (PR 2.35, CI 2.30–2.41), the highest of any sub-sector. Other sub-sectors with high prevalences and adjusted risks include Software Publishers (NAICS 511210), Custom Computer Programming Services (NAICS 541511), and Marinas (NAICS 713930) with prevalences of 33%, 35% and 27% and adjusted risks 78%, 73% and 112% higher than the reference industry, respectively. Also of note, Credit Unions (NAICS 522130) had a 33% prevalence and risk 27% higher than the reference industry. Some sub-sectors had moderate prevalences of hearing loss, but had high adjusted risks. These included Telecommunications Resellers (NAICS 517911) (16%), Other Services Related to Advertising (NAICS 541890) (14%) and Employment Placement Agencies (NAICS 561311) (14%), with risks 60%, 49% and 42% higher than the reference industry, respectively.

Table 3. Estimated prevalence and adjusted probability ratios (PRs) for hearing loss (HL) by sub-sector within Services at two- and three-digit NAICS[a] code specificity, 2006–2015 ($N = 158,436$).

Industry (NAICS 2007 Code)	*n*	Prevalence of HL (%)	Prevalence 95% CI[b]	PR[c]	PR 95% CI
All Industries	1,908,218	16.20	16.15–16.25		
All Industries Except Couriers and Messengers (492)	1,804,945	16.58	16.53–16.63	1.18	1.16–1.20
Services (51–56, 61, 71–72, 81, 92)	158,436	16.88	16.70–17.06	1.18	1.15–1.20
Information (51)	19,937	14.99	14.49–15.49	1.07	1.04–1.11
Publishing Industries (Except Internet) (511)	7,639	18.64	17.77–19.51	1.00	0.95–1.04
Motion Picture and Sound Recording Industries (512)	1,842	10.69	9.28–12.10	1.18	1.05–1.33
Broadcasting (Except Internet) (515)	1,874	11.58	10.13–13.03	0.89	0.79–1.01
Telecommunications (517)	6,051	16.31	15.38–17.24	1.58	1.50–1.66
Data Processing, Hosting, and Related Services (518)	2,488	6.43	5.47–7.39	0.55	0.48–0.64
Other Information Services (519)	43	9.30	0.62–17.98	0.50	0.17–1.42
Finance and Insurance (52)	1,178	20.80	18.48–23.12	1.17	1.06–1.29
Monetary Authorities – Central Bank (521)	0				
Credit Intermediation and Related Activities (522)	119	32.77	24.34–41.20	1.26	1.01–1.58
Securities, Commodity Contracts and Other Financial Investments, and Related Activities (523)	752	21.68	18.73–24.63	1.16	1.03–1.31
Insurance Carriers and Related Activities (524)	249	14.46	10.09–18.83	1.24	0.94–1.64
Funds, Trusts, and Other Financial Vehicles (525)	58	12.07	3.69–20.45	0.69	0.36–1.33
Real Estate and Rental and Leasing (53)	3,161	17.27	15.95–18.59	1.32	1.24–1.41
Real Estate (531)	1,163	20.12	17.82–22.42	1.56	1.44–1.69
Rental and Leasing Services (532)	1,998	15.57	13.98–17.16	1.18	1.08–1.29
Lessors of Nonfinancial Intangible Assets (Except Copyrighted Works) (533)	0				
Professional, Scientific and Technical Services (54)	18,728	16.53	16.0–17.06	1.14	1.11–1.18
Professional, Scientific, and Technical Services (541)	18,728	16.53	16.0–17.06	1.14	1.11–1.18
Management of Companies and Enterprises (55)	1,558	21.69	19.64–23.74	1.33	1.23–1.45
Management of Companies and Enterprises (551)	1,558	21.69	19.64–23.74	1.33	1.23–1.45
Administrative and Support and Waste Management and Remediation Services (56)	42,250	15.29	14.95–15.63	1.14	1.11–1.17
Administrative and Support Services (561)	32,714	14.50	14.12–14.88	1.13	1.09–1.16
Waste Management and Remediation Services (562)	9,535	18.01	17.24–18.78	1.18	1.13–1.22
Educational Services (61)	6,898	17.73	16.83–18.63	0.89	0.85–0.94
Educational Services (611)	6,898	17.73	16.83–18.63	0.89	0.85–0.94
Arts, Entertainment and Recreation (71)	4,415	16.72	15.62–17.82	1.14	1.07–1.21
Performing Arts, Spectator Sports, and Related Industries (711)	1,834	15.27	13.62–16.92	1.10	1.00–1.21
Museums, Historical Sites, and Similar Institutions (712)	458	16.59	13.18–20.0	1.15	0.96–1.38
Amusement, Gambling, and Recreation Industries (713)	2,123	17.99	16.36–19.62	1.16	1.07–1.26
Accommodation and Food Services (72)	3,670	14.11	12.98–15.24	1.20	1.12–1.29
Accommodation (721)	577	15.60	12.64–18.56	1.30	1.11–1.53
Food Services and Drinking Places (722)	3,093	13.84	12.62–15.06	1.18	1.09–1.28
Other Services (Except Public Administration) (81)	21,798	18.42	17.91–18.93	1.31	1.27–1.35
Repair and Maintenance (811)	19,247	18.36	17.81–18.91	1.30	1.26–1.34
Personal and Laundry Services (812)	1,372	18.66	16.60–20.72	1.36	1.24–1.50
Religious, Grantmaking, Civic, Professional, and Similar Organizations (813)	1,088	19.39	17.04–21.74	1.40	1.26–1.55
Private Households (814)	0				
Public Administration (92)	34,843	18.87	18.46–19.28	1.28	1.25–1.32
Executive, Legislative, and Other General Government Support (921)	14,158	21.78	21.10–22.46	1.22	1.18–1.26
Justice, Public Order, and Safety Activities (922)	275	21.45	16.60–26.30	1.36	1.11–1.65
Administration of Human Resource Programs (923)	1,977	27.52	25.55–29.49	1.30	1.22–1.38
Administration of Environmental Quality Programs (924)	1,522	18.13	16.19–20.07	1.16	1.05–1.28
Administration of Housing Programs, Urban Planning, and Community Development (925)	40	50	34.50–65.50	1.65	1.43–1.89
Administration of Economic Programs (926)	6,118	27.53	26.41–28.65	1.41	1.35–1.46
Space Research and Technology (927)	0				
National Security and International Affairs (928)	10,588	8.31	7.78–8.84	0.84	0.64–1.12
Couriers and Messengers (492) (ref)	103,273	9.52	9.34–9.70	ref	

[a]NAICS = North American Industry Classification System.
[b]CI = 95% confidence interval.
[c]PRs were adjusted for age group and gender.

Discussion

This is the first known study to estimate and compare the prevalence of hearing loss among most sub-sectors within the Services sector using noise-exposed worker audiograms. More than 77 million workers were employed in the Services sector in 2014, making it the largest industry sector in the U.S. Twenty-one percent of these workers had a history of occupational noise exposure and 10% reported hearing difficulty (Kerns et al. 2018). Study results indicated that workers in nearly all the sub-sectors within the Services sector had high prevalences of hearing loss and higher adjusted risks than workers in the reference industry.

This discussion will focus on sectors and sub-sectors that had the highest prevalences and adjusted risks, and also on targeted sub-sectors found to be of significance based on the literature. Whenever possible, results will be discussed at the highest level of NAICS specificity (6-digit). As such, the discussion will begin with the sub-sectors grouped under Real Estate and Rental and Leasing (NAICS 53), Other Services (Except Public Administration) (NAICS 81) and Public Administration (NAICS 92). This will be

Table 4. Estimated prevalence and adjusted probability ratios (PRs) for hearing loss (HL) by sub-sector within Real Estate and Rental and Leasing, 2006–2015 ($N = 3,161$).

Industry (NAICS 2007 Code)	*n*	Prevalence of HL (%)	Prevalence 95% CI[a]	PR[b]	PR 95% CI
Real Estate and Rental and Leasing (53)	3161	17.27	15.95–18.59	1.32	1.24–1.41
Real Estate (531)	1163	20.12	17.82–22.42	1.56	1.44–1.69
Lessors of Real Estate (5311)	754	20.29	17.42–23.16	1.58	1.44–1.72
Lessors of Residential Buildings and Dwellings (531110)	0				
Lessors of Nonresidential Buildings (Except Miniwarehouses) (531120)	742	19.95	17.07–22.83	1.58	1.44–1.73
Lessors of Miniwarehouses and Self-Storage Units (531130)	12	ISS[c]		ISS	
Lessors of Other Real Estate Property (531190)	0				
Offices of Real Estate Agents and Brokers (5312 and 531210)	383	19.84	15.85–23.83	1.47	1.25–1.72
Activities Related to Real Estate (5313)	26	ISS		ISS	
Residential Property Managers (531311)	2	ISS		ISS	
Nonresidential Property Managers (531312)	24	ISS		ISS	
Offices of Real Estate Appraisers (531320)	0				
Other Activities Related to Real Estate (531390)	0				
Rental and Leasing Services (532)	1,998	15.57	13.98–17.16	1.18	1.08–1.29
Automotive Equipment Rental and Leasing (5321)	141	20.57	13.90–27.24	1.73	1.34–2.22
Passenger Car Rental (532111)	2	ISS		ISS	
Passenger Car Leasing (532112)	0				
Truck, Utility Trailer, and RV (Recreational Vehicle) Rental and Leasing (532120)	139	20.86	14.11–27.61	1.73	1.35–2.22
Consumer Goods Rental (5322)	83	7.23	1.66–12.80	ISS	
Consumer Electronics and Appliances Rental (532210)	0				
Formal Wear and Costume Rental (532220)	0				
Video Tape and Disc Rental (532230)	0				
Home Health Equipment Rental (532291)	0				
Recreational Goods Rental (532292)	0				
All Other Consumer Goods Rental (532299)	83	7.23	1.66–12.80	ISS	
General Rental Centers (5323)	0				
General Rental Centers (532310)	0				
Commercial and Industrial Machinery and Equipment Rental and Leasing (5324)	1,774	15.56	13.87–17.25	1.16	1.06–1.27
Commercial Air, Rail, and Water Transportation Equipment Rental and Leasing (532411)	363	16.25	12.45–20.05	1.06	0.85–1.31
Construction, Mining, and Forestry Machinery and Equipment Rental and Leasing (532412)	116	6.90	2.29–11.51	ISS	
Office Machinery and Equipment Rental and Leasing (532420)	0				
Other Commercial and Industrial Machinery and Equipment Rental and Leasing (532490)	1,295	16.14	14.14–18.14	1.43	1.30–1.57
Lessors of Nonfinancial Intangible Assets (Except Copyrighted Works (533)	0				
Lessors of Nonfinancial Intangible Assets (Except Copyrighted Works) (5331)	0				
Lessors of Nonfinancial Intangible Assets (Except Copyrighted Works) (533110)	0				
Couriers and Messengers (492) (ref)	103,273	9.52	9.34–9.70	ref	

[a]CI = 95% confidence interval.
[b]PRs were adjusted for age-group and gender.
[c]ISS = insufficient sample size.

followed by a discussion of sub-sectors that were targeted a priori for analysis. Lastly, other more disparate sub-sectors found to have high prevalences and/or adjusted risks will be discussed.

Real Estate and Rental and Leasing (NAICS 53)

Within the Real Estate and Rental and Leasing sub-sector, workers within Automotive Equipment Rental and Leasing had the highest prevalence and adjusted risk of hearing loss. In this study, nearly all of the workers in this sub-sector worked in Truck, Utility Trailer and RV Rental and Leasing (NAICS 532120). One might anticipate a higher risk of hearing loss among these workers as they spend ample time inspecting and managing vehicles and utility trailers and may be exposed to noise from engines, horns, tires and tools, in addition to exhaust, an ototoxicant. No known studies have examined the noise levels in this sub-sector and further research is needed.

Other Commercial and Industrial Machinery and Equipment Rental and Leasing (NAICS 532490) had a moderate prevalence (16%), but a 43% higher risk than the reference industry. However, 88% of the workers in this sub-sector were at or below the age of 55 (data not shown). More younger workers may lower the prevalence and mask the impact of noise or ototoxicant exposures when examining prevalence alone. After controlling for age and gender, the high risk suggests that the age distribution among these workers may have influenced the low prevalence.

Realtors work in an environment similar to call centers and have heavy cell phone usage, often with the phone volume adjusted higher due to background noise in the office and in vehicles as discussed in Masterson et al. (2013). Sources of background noise might be noise from radios, conversations among co-workers, noise from ventilation systems, telephones ringing, fax machines and printers. Health hazards associated with high noise levels at call centers have been previously documented (NIOSH (National Institute for Occupational Safety and Health) 2011b). Typical volume levels during a phone call range from 68 to 91 dBA, with maximum noise levels between 88 and 102 dBA (Smagowska 2010). OSHA recommends the use of acoustic limiting devices in headsets to protect hearing from damage caused by acoustic shock, which is a sudden and unexpected burst of high frequency noise—for example, from feedback in the headset

Table 5. Estimated prevalence and adjusted probability ratios (PRs) for hearing loss (HL) by sub-sector within Other Services (Except Public Administration), 2006–2015 ($N = 21{,}798$).

Industry (NAICS 2007 Code)	*n*	Prevalence of HL (%)	Prevalence 95% CI[a]	PR[b]	PR 95% CI
Other Services (Except Public Administration) (81)	21,798	18.42	17.91–18.93	1.31	1.27–1.35
Repair and Maintenance (811)	19,247	18.36	17.81–18.91	1.30	1.26–1.34
Automotive Repair and Maintenance (8111)	9,465	16.13	15.39–16.87	1.19	1.14–1.24
General Automotive Repair (811111)	2,262	17.29	15.73–18.85	1.32	1.22–1.43
Automotive Exhaust System Repair (811112)	0				
Automotive Transmission Repair (811113)	55	34.55	21.98–47.12	1.61	1.20–2.14
Other Automotive Mechanical and Electrical Repair and Maintenance (811118)	4,451	13.82	12.81–14.83	1.02	0.96–1.10
Automotive Body, Paint, and Interior Repair and Maintenance (811121)	801	26.47	23.41–29.53	1.46	1.33–1.60
Automotive Glass Replacement Shops (811122)	0				
Automotive Oil Change and Lubrication Shops (811191)	0				
Car Washes (811192)	967	13.65	11.49–15.81	1.15	1.01–1.32
All Other Automotive Repair and Maintenance (811198)	929	17.01	14.59–19.43	1.32	1.16–1.49
Electronic and Precision Equipment Repair and Maintenance (8112)	189	23.28	17.25–29.31	1.45	1.19–1.77
Consumer Electronics Repair and Maintenance (811211)	0				
Computer and Office Machine Repair and Maintenance (811212)	0				
Communication Equipment Repair and Maintenance (811213)	0				
Other Electronic and Precision Equipment Repair and Maintenance (811219)	189	23.28	17.25–29.31	1.45	1.19–1.77
Commercial and Industrial Machinery and Equipment (Except Automotive and Electronic) Repair and Maintenance (8113)	4,333	16.87	15.75–17.99	1.40	1.32–1.48
Commercial and Industrial Machinery and Equipment (Except Automotive and Electronic) Repair and Maintenance (811310)	4,333	16.87	15.75–17.99	1.40	1.32–1.48
Personal and Household Goods Repair and Maintenance (8114)	5,260	23.42	22.28–24.56	1.37	1.31–1.44
Home and Garden Equipment Repair and Maintenance (811411)	74	21.62	12.24–31.00	1.17	0.80–1.71
Appliance Repair and Maintenance (811412)	3,766	25.52	24.13–26.91	1.45	1.38–1.52
Reupholstery and Furniture Repair (811420)	30	23.33	8.20–38.46	ISS[c]	
Footwear and Leather Goods Repair (811430)	0				
Other Personal and Household Goods Repair and Maintenance (811490)	1,390	17.84	15.83–19.85	1.15	1.04–1.27
Personal and Laundry Services (812)	1,372	18.66	16.60–20.72	1.36	1.24–1.50
Personal Care Services (8121)	114	19.30	12.06–26.54	1.03	0.74–1.44
Barber Shops (812111)	0				
Beauty Salons (812112)	114	19.30	12.06–26.54	1.03	0.74–1.44
Nail Salons (812113)	0				
Diet and Weight Reducing Centers (812191)	0				
Other Personal Care Services (812199)	0				
Death Care Services (8122)	14	ISS		ISS	
Funeral Homes and Funeral Services (812210)	14	ISS		ISS	
Cemeteries and Crematories (812220)	0				
Drycleaning and Laundry Services (8123)	408	17.65	13.95–21.35	1.30	1.09–1.56
Coin-Operated Laundries and Drycleaners (812310)	31	22.58	7.86–37.30	ISS	
Dry Cleaning and Laundry Services (Except Coin-Operated) (812320)	168	15.48	10.01–20.95	1.13	0.83–1.54
Linen Supply (812331)	97	14.43	7.44–21.42	1.23	0.79–1.92
Industrial Launderers (812332)	112	22.32	14.61–30.03	1.64	1.22–2.19
Other Personal Services (8129)	836	18.90	16.25–21.55	1.46	1.30–1.64
Pet Care (Except Veterinary) Services (812910)	4	ISS		ISS	
Photofinishing Laboratories (Except One-Hour) (812921)	0				
One-Hour Photofinishing (812922)	0				
Parking Lots and Garages (812930)	832	18.99	16.32–21.66	1.46	1.30–1.65
All Other Personal Services (812990)	0				
Religious, Grantmaking, Civic, Professional and Similar Organizations (813)	1,088	19.39	17.04–21.74	1.40	1.26–1.55
Religious Organizations (8131)	751	17.71	14.98–20.44	1.35	1.18–1.55
Religious Organizations (813110)	751	17.71	14.98–20.44	1.35	1.18–1.55
Grantmaking and Giving Services (8132)	0				
Grantmaking Foundations (813211)	0				
Voluntary Health Organizations (813212)	0				
Other Grantmaking and Giving Services (813219)	0				
Social Advocacy Organizations (8133)	2	ISS		ISS	
Human Rights Organizations (813311)	0				
Environment, Conservation and Wildlife Organizations (813312)	0				
Other Social Advocacy Organizations (813319)	2	ISS		ISS	
Civic and Social Organizations (8134)	94	10.64	4.41–16.87	ISS	
Civic and Social Organizations (813410)	94	10.64	4.41–16.87	ISS	
Business, Professional, Labor, Political, and Similar Organizations (8139)	241	28.22	22.54–33.90	1.73	1.48–2.03
Business Associations (813910)	37	43.24	27.28–59.20	1.78	1.72–1.84
Professional Organizations (813920)	0				
Labor Unions and Similar Labor Organizations (813930)	44	45.45	30.74–60.16	1.74	1.30–2.32
Political Organizations (813940)	0				
Other Similar Organizations (Except Business, Professional, Labor, and Political Organizations) (813990)	160	20	13.80–26.20	1.53	1.16–2.00
Private Households (814)	0				

(*continued*)

Table 5. Continued.

Industry (NAICS 2007 Code)	*n*	Prevalence of HL (%)	Prevalence 95% CI[a]	PR[b]	PR 95% CI
Private Households (8141)	0				
Private Households (814110)	0				
Couriers and Messengers (492) (ref)	103,273	9.52	9.34–9.70	ref	

[a]CI = 95% confidence interval.
[b]PRs were adjusted for age group and gender.
[c]ISS = insufficient sample size.

Table 6. Estimated prevalence and adjusted probability ratios (PRs) for hearing loss (HL) by sub-sector within Public Administration, 2006–2015 ($N = 34,843$).

Industry (NAICS 2007 Code)	*n*	Prevalence of HL (%)	Prevalence 95% CI[a]	PR[b]	PR 95% CI
Public Administration (92)	34,843	18.87	18.46–19.28	1.28	1.25–1.32
Executive, Legislative and Other General Government Support (921)	14,158	21.78	21.10–22.46	1.22	1.18–1.26
Executive Offices (921110)	9,500	21.65	20.82–22.48	1.23	1.19–1.28
Legislative Bodies (921120)	745	26.44	23.27–29.61	1.50	1.35–1.66
Public Finance Activities (921130)	73	23.29	13.59–32.99	0.38	0.06–2.50
Executive and Legislative Offices, Combined (921140)	31	19.35	5.44–33.26	ISS[c]	
American Indian and Alaska Native Tribal Governments (921150)	8	ISS		ISS	
Other General Government Support (921190)	3,801	21.20	19.90–22.50	1.15	1.09–1.22
Justice, Public Order, and Safety Activities (922)	275	21.45	16.60–26.30	1.36	1.11–1.65
Courts (922110)	78	41.03	30.11–51.95	1.78	1.68–1.88
Legal Counsel and Protection (922130)	0				
Parole Offices and Probation Offices (922150)	0				
Other Justice, Public Order, and Safety Activities (922190)	196	13.78	8.95–18.61	0.98	0.71–1.37
Administration of Human Resource Programs (923)	1,977	27.52	25.55–29.49	1.30	1.22–1.38
Administration of Education Programs (923110)	78	28.21	18.22–38.2	1.32	0.98–1.77
Administration of Public Health Programs (923120)	1,898	27.45	25.44–29.46	1.29	1.21–1.38
Administration of Human Resource Programs (except Education, Public Health, and Veterans Affairs Programs) (923130)	1	ISS		ISS	
Administration of Veterans Affairs (923140)	0				
Administration of Environmental Quality Programs (924)	1,522	18.13	16.19–20.07	1.16	1.05–1.28
Administration of Air and Water Resource and Solid Waste Management Programs (924110)	271	19.19	14.50–23.88	0.93	0.74–1.18
Administration of Conservation Programs (924120)	1,251	17.91	15.79–20.03	1.24	1.11–1.38
Administration of Housing Programs, Urban Planning and Community Development (925)	40	50	34.50–65.50	1.65	1.43–1.89
Administration of Housing Programs (925110)	0				
Administration of Urban Planning and Community and Rural Development (925120)	40	50	34.50–65.50	1.65	1.44–1.90
Administration of Economic Programs (926)	6,118	27.53	26.41–28.65	1.41	1.35–1.46
Administration of General Economic Programs (926110)	24	ISS		ISS	
Regulation and Administration of Transportation Programs (926120)	5,631	27.56	26.39–28.73	1.42	1.36–1.48
Regulation and Administration of Communications, Electric, Gas, and Other Utilities (926130)	2	ISS		ISS	
Regulation of Agricultural Marketing and Commodities (926140)	6	ISS		ISS	
Regulation, Licencing, and Inspection of Miscellaneous Commercial Sectors (926150)	455	28.57	24.42–32.72	1.28	1.12–1.46
Space Research and Technology (927)	0				
Space Research and Technology (927110)	0				
National Security and International Affairs (928)	10,588	8.31	7.78–8.84	0.84	0.64–1.12
National Security (928110)	10,588	8.31	7.78–8.84	0.84	0.64–1.12
International Affairs (928120)	0				
Couriers and Messengers (492) (ref)	103,273	9.52	9.34–9.70	ref	

[a]CI = 95% confidence interval.
[b]PRs were adjusted for age group and gender.
[c]ISS = insufficient sample size.

or an unexpected increase in volume (NIOSH (National Institute for Occupational Safety and Health) 2011b; U.S. Department of Labor 2013).

Other Services (Except Public Administration) (NAICS 81)

The Other Services (Except Public Administration) sub-sector encompasses a diverse range of industries. Business Associations (NAICS 813910) and Labour Unions and Similar Labour Organizations (NAICS 813930) had the highest adjusted risks among workers in this sub-sector (78% and 74% higher than the reference industry, respectively) with prevalences in excess of 40%. It is possible that some workers in labour unions and organizations previously worked in the trades they represent and their current hearing loss may be representative, at least in part, of the exposures they received previous to their current industry. Also, workers within all these sub-sectors work in environments such as large open offices/areas, use microphones and PA systems to address large audiences and attend meetings/conferences in large halls. No known noise study was found focusing on hearing loss within these sub-sectors. Poor room acoustics due to hard surfaces may contribute to the level of background noise by reflecting the sound and allowing it to persist in the space for a longer duration (e.g., reverberation from vaulted ceilings, hard

Table 7. Estimated prevalence and adjusted probability ratios (PRs) for hearing loss (HL) for sub-sectors not previously reported within Services with ≥25% prevalence and/or ≥30% significantly greater risk than the reference industry, at six-digit NAICS[a] code specificity, 2006–2015 ($N = 158,436$).

Industry (NAICS 2007 Code)	*n*	Prevalence of HL (%)	Prevalence 95% CI[b]	PR[c]	PR 95% CI
Services (51–56, 61, 71–72, 81, 92)	158,436	16.88	16.70–17.06	1.18	1.15–1.20
Software Publishers (511210)	199	33.17	26.63–39.71	1.78	1.72–1.84
Telecommunications Resellers (517911)	5,670	16.35	15.39–17.31	1.60	1.52–1.68
Credit Unions (522130)	119	32.77	24.34–41.20	1.26	1.01–1.58
Building Inspection Services (541350)	53	37.74	24.69–50.79	1.38	1.00–1.89
Surveying and Mapping (Except Geophysical) Services (541370)	469	22.60	18.81–26.39	1.67	1.45–1.92
Testing Laboratories (541380)	279	22.94	18.01–27.87	1.40	1.18–1.67
Custom Computer Programming Services (541511)	119	35.29	26.70–43.88	1.73	1.43–2.09
Human Resources Consulting Services (541612)	280	26.79	21.60–31.98	1.57	1.37–1.81
Other Services Related to Advertising (541890)	296	13.51	9.62–17.40	1.49	1.17–1.90
All Other Professional, Scientific and Technical Services (541990)	2,759	19.35	17.88–20.82	1.38	1.29–1.47
Offices of Other Holding Companies (551112)	1,557	21.71	19.66–23.76	1.33	1.23–1.44
Employment Placement Agencies (561311)	165	13.94	8.65–19.23	1.42	1.02–1.98
All Other Business Support Services (561499)	3,667	18.33	17.08–19.58	1.46	1.38–1.55
Security Guards and Patrol Services (561612)	684	32.75	29.23–36.26	1.53	1.39–1.68
Janitorial Services (561720)	6,660	11.65	10.88–12.42	1.31	1.24–1.39
Carpet and Upholstery Cleaning Services (561740)	186	20.43	14.64–26.22	1.78	1.72–1.84
All Other Support Services (561990)	6,005	19.60	18.60–20.60	1.37	1.31–1.43
Solid Waste Combustors and Incinerators (562213)	71	43.66	32.12–55.20	2.35	2.30–2.41
Other Nonhazardous Waste Treatment and Disposal (562219)	720	27.64	24.37–30.91	1.40	1.26–1.55
Elementary and Secondary Schools (611110)	2,621	25.83	24.15–27.51	1.25	1.17–1.32
Sports and Recreation Instruction (611620)	463	19.65	16.03–23.27	1.57	1.37–1.79
Marinas (713930)	113	26.55	18.41–34.69	2.12	1.78–2.53
Hotels (Except Casino Hotels) and Motels (721110)	577	15.60	12.64–18.56	1.30	1.11–1.53
Limited-Service Restaurants (722211)	1,823	14.21	12.61–15.81	1.31	1.19–1.44
Couriers and Messengers (492) (ref)	103,273	9.52	9.34–9.70	ref	

[a]NAICS = North American Industry Classification System.
[b]CI = 95% confidence interval.
[c]PRs were adjusted for age group and gender.

surfaces, lack of carpeting). The recommended sound level for offices, courtrooms and private work rooms is between 40 and 45 dBA and for corridors, open offices, reception spaces, lobbies, it is between 45 and 55 dBA (ANSI 2008). These standards are designed to facilitate clear communication and they recommend sound levels well below the point of being hazardous (ANSI 2008). Room acoustics could potentially be improved by installing carpet and drop ceilings, hanging curtains over windows, and in non-public areas, using acoustic foam over walls (Passero and Zannin 2012). When making changes in room acoustics, however, care should be taken to ensure that necessary signals (wanted sounds) are still audible throughout the space.

Industrial Launderers (NAICS 812332) also had a high prevalence (22%) and 64% higher risk of hearing loss than the reference industry. These workers are primarily engaged in supplying and cleaning work uniforms and related clothing (e.g., protective apparel) and room cleaning materials (e.g., mops, rugs, wiping towels) to restaurants, medical facilities, hotels, schools and spas. Workers in this profession operate heavy machinery such as dryers, washing machines and delivery trucks. They might be exposed to loud noise at the washing area, drying area or linen squeezing area. A study conducted in a hospital laundry room found that laundry workers are exposed to noise levels between 77 and 99 dBA and that the spin-drying area was the loudest location (Fontoura et al. 2014). Another study found a noise level of 101 dBA in a hospital laundry room and a low level of HPD usage (Elias, Ijaduola, and Sofola 2004). The authors recommended reducing noise through engineering controls and upgrading to quieter machines, as well as educating employees concerning the use of HPDs (Elias, Ijaduola, and Sofola 2004).

Several Automotive Repair and Maintenance sub-sectors also appear to be at high risk of hearing loss. Automotive Transmission Repair (NAICS 811113) and Automotive Body, Paint and Interior Repair and Maintenance (NAICS 811121) had prevalences of 35% and 26% and risks of hearing loss 61% and 46% significantly higher than the reference industry, respectively. An older study reported noise doses in excess of 160% among workers in a small automotive body shop, with major noise sources being pneumatic chippers and grinders, sanders and air hoses. These body shop workers were also exposed to ototoxic solvents from the paints (Jayjock and Levin 1984). A more recent study by Loupa (2013) of workers in an automotive repair shop found noise doses well below occupational exposure limits, but reported sporadic sounds that reached hazardous levels from hammers (75–94 dBA), compressed air wrenches (74–89 dBA), banging car doors and hoods (67–87 dBA) and revving up engines (71–88 dBA). Spectral analysis found that most of the sound energy occurred in the 1000–4000 Hertz bands, which are the frequencies at which the ear is most sensitive and at which the resonance of the ear canal amplifies the acoustic signal (Loupa 2013).

Public Administration (NAICS 92)

Although Public Administration ranked among the three Services sub-sectors with the highest prevalences and adjusted risk of hearing loss, no data were found describing noise sources for this industry group. Legislative bodies (NAICS 921120), Courts (NAICS 922110) and Administration of Urban Planning and Community and Rural Development (NAICS 925120) all had hearing loss prevalences of more than 25%. They also had risks 50%, 78% and 65% significantly higher than the reference industry, respectively. As with the Business Associations and Labor Unions and Similar Labor Organizations sub-sectors described earlier, Public Administration employees may work in heavily reverberant office and meeting spaces and attend conferences and public gatherings that could create hazardous exposure levels. Research is needed to identify and remediate

the noise sources that are contributing to the high risks of hearing loss in this sub-sector.

Sub-sectors targeted for analysis

It was expected that Landscaping Services (NAICS 561730) workers would have a higher prevalence and risk, but this analysis showed only a moderate-to-low prevalence of 15% and a 16% higher risk of hearing loss. Having a much younger workforce can lower the prevalence as hearing loss risk increases dramatically with age. Workers in this sub-sector were only slightly younger than among all industry sectors, with 5% more workers in the 26–35 age group and 5% fewer workers in the 46–55 age group (data not shown). So, the age distribution likely did not significantly reduce the prevalence, and the risk was adjusted for age group. However, the seasonal nature of the work in many areas may protect workers in these industries from developing hearing loss as quickly as workers in sectors whose noise exposures occur year-round. Noise exposure levels are potentially substantial enough to cause concern. Landscaping workers use motorized machines with high noise levels, including lawn mowers (88–96 dBA), wood chippers (106 dBA), chainsaws (109 dBA) and leaf blowers (106 dBA) (Balanay, Kearney, and Mannarino 2016; Jaafar et al. 2017). Grass trimming machines produce 100–105 dBA of noise and operators working nearby might further increase the noise level (Mallick et al. 2009). In view of the seasonal and sometimes temporary nature of the work, establishing effective hearing loss prevention programs may be difficult. A review of workplace inspection data from Washington State found that more than two-thirds of inspected businesses in landscaping, lawn care and tree service did not have adequate training, audiometric testing or noise monitoring programs in place (Lofgren 2008). Engineering controls such as regular equipment maintenance, use of less noisy tools, and administrative controls such as limiting the duration of exposure and/or taking breaks between tasks have been recommended (Balanay, Kearney, and Mannarino 2016). Positioning operators at least 15 m apart could also help to reduce the noise level (Mallick et al. 2009). Jaafar et al. (2017) also recommended the use of HPDs to limit noise exposure.

In this study, Drinking Places (Alcoholic Beverages) (NAICS 722410) and Full-Service Restaurants (NAICS 722110) had low or fairly low prevalences and risks, although Limited-Service Restaurants (NAICS 722211) did have a moderate prevalence and a 31% higher risk of hearing loss. These numbers were expected to be higher. However, workers in Drinking Places (Alcoholic Beverages) and Limited-Service Restaurants were much younger than among all industry sectors, with 25% and 10% more workers under age 36, respectively (data not shown). This likely reduced the prevalence of hearing loss in these sub-sectors to some extent. Also, noise regulations are not enforced in these venues and audiometric testing is not required, so it is unknown which types of workers in these industries are being tested and analyzed in this sample. It is possible that servers, cooks and bussing staff are not being tested, and these numbers may not be representative of their hearing loss prevalences/risks; rather other occupations within these industries.

These sub-sectors deserve further attention. Hazardous noise levels $\geq$85 dBA have been recorded in these venues (Sadhra et al. 2002; Kelly et al. 2012; Spira-Cohen, Caffarelli, and Fung 2017). A study reported that the mean L_{Aeq} for nightclubs and lounges (97 dBA) was higher than restaurants and bars (91 dBA) (Spira-Cohen, Caffarelli, and Fung 2017), but both levels are in the hazardous range. The main sources of noise were music (live or recorded), stoves in the kitchen and people talking in the dining area. Another study of cooks, bartenders, counter attendants and servers at full-service restaurants found that only 8% of 8-hour time-weighted average exposures exceeded the NIOSH 85 dBA limit. However, exposures varied by time of year, day of week, restaurant type and job type. Noise exposures were higher in the fall, on weekends, for full-service compared to limited service restaurants, and for cooks (Green and Anthony 2015). Most or all of the employees in these venues do not wear hearing protection. This may be due to lack of noise control regulations, belief that HPDs may impair communication between patron and employee, and lack of awareness of noise as a hazard. A study conducted in restaurant workers in China estimated that 47% of workers were exposed to noise levels above 85 dBA and the noise level of 87 dBA was recorded in the kitchen during cooking. Pressurized gas stoves were recognized as a major source of noise (Lao et al. 2013).

Unfortunately, no audiometric data were available for Musical Groups and Artists (NAICS 711130), Sports Teams and Clubs (NAICS 711211), Amusement Arcades (NAICS 713120), Bowling Centers (NAICS 713950), or Casino Hotels (NAICS 721120). This may again be due to the lack of noise regulations and a requirement for audiometric testing in these industries, in addition to a lack of awareness of noise hazards (Ghent 2013). Hearing loss risk has been associated with recreational events, such as live sporting events, concerts, movie theaters and orchestras. The maximum (L_{max}) and peak sound pressure levels (L_{peak}) measured during an indoor hockey event were 116 dBA and 134 dB, respectively (Adams and Brazile 2017). The main sources of noise were: whistle blowing, impact noise from hockey sticks, background music and people cheering. Similar measurements were recorded during concerts (120 dBA), college basketball events (98–115 dBA), video arcades (115 dBA) and bowling centers (88–94 dBA) (Rabinowitz and Kernodle 2014). Most of the time background music is amplified to attract more customers. Most or all of the employees in these venues do not wear hearing protection, due to the unavailability of HPDs, concern that HPDs might affect customer service or the quality of the music, and a lack of knowledge (Bogoch, House, and Kudla 2005; Adams and Brazile 2017).

Other sectors with high prevalences and/or adjusted risks

In this study, workers in Solid Waste Combustors and Incinerators (NAICS 562213) had the highest adjusted risk and Other Nonhazardous Waste Treatment and Disposal (NAICS 562219) had a significantly elevated risk of hearing loss. A study conducted by Liu et al. among workers from municipal solid waste landfills in China found that workers had exposures to noise and total volatile organic compounds (TVOCs) such as toluene, xylene and trichloroethylene (Liu et al. 2015). TVOCs have ototoxic and neurotoxic effects, and continuous exposure can lead to permanent hearing loss (Gopal 2008). These workers use glass crushers, can compactors, grinders, trommels, paper choppers, combustors and other equipment to dig, transport and compact landfills, all of which can generate excessive noise. The overall prevalence of hearing loss was 24% among these workers with more than triple the risk of hearing loss. Despite frequent exposure to noise levels $\geq$85 dBA, only 1% of workers reported using HPDs (Liu et al. 2015). Continuous noise exposure to $\geq$85 dBA combined with exposure to TVOCs could intensify hearing loss, especially at high frequencies (Mohammadi, Labbafinejad, and Attarchi 2010).

Ncube, Ncube, and Voyi (2017) found noise exposure just under the 85 dBA limit among solid waste handlers in South Africa, but noted that waste collection often occurs near other noise sources such as high traffic areas and construction. In addition to the risk to hearing, the authors pointed out possible safety risks such as the inability to hear warning signals. Burns and colleagues reported on noise exposures among electronic waste recycling workers in Ghana. Average time-weighted average exposures were 78 ± 6 dBA. Fifteen percent of the exposure measurements exceeded the 85 dBA 8-h exposure limit. Noisy tasks included loading/sorting scrap, collecting/burning iron and other rubbish, and dismantling recycled objects such as vehicles and appliances. These workers in Ghana also reported frequently working long days, which would increase hearing loss risk (Burns et al. 2016; Burns, Sayler, and Neitzel 2019). Hearing conservation programs should be implemented to help workers in waste and recycling-related industries protect their hearing (Liu et al. 2015).

Some financial sub-sectors, such as Credit Unions (NAICS 522130) showed higher than expected prevalences of hearing loss (Credit Unions at 33%). One recent study conducted full-shift dosimetry on financial services workers and reported time-weighted average exposures below 70 dBA (Stokholm et al. 2013). However, like realtors, finance and insurance agents spend much of their time either talking on the phone or travelling to meet clients. Patel and Broughton (2002) conducted a study involving call centers across various industry sectors such as financial services (e.g., banks), hotels, telecommunications and IT in which background noise levels and noise levels generated by the telephonic headsets were recorded. The background noise levels ranged from 57 to 66 dBA and headset noise levels were between 65 and 88 dBA. When the background noise level is below 85 dBA, it may still influence behaviors contributing to hearing loss, such as raising voices and turning up the phone volume. Operators at call centers should receive regular training to properly use headsets and other telephone equipment (Patel and Broughton 2002).

Sub-sectors within Professional, Scientific and Technical Services (NAICS 54) had risks significantly higher than the reference industry, including Custom Computer Programming Services (NAICS 541511) (73% higher), Surveying and Mapping (except Geophysical) Services (NAICS 541370) (67% higher), Human Resources Consulting Services (NAICS 541612) (57% higher), Other Services Related to Advertising (NAICS 541890) (49% higher), Testing Laboratories (NAICS 541380) (40% higher) and Building Inspection Services (NAICS 541350) (38% higher). Building inspectors inspect buildings and may also monitor construction sites to ensure overall compliance, exposing them to construction noise. Surveyors and mappers record measurements of the land and may work for construction and mining industries. Industries and occupations within professional and scientific services have been previously identified as having higher than expected risks for hearing loss (Tak and Calvert 2008; Masterson et al. 2013), but no research is available related to the source(s) of these risks. More focused research is needed to determine the reason behind high risks within these sub-sectors.

Music teachers, physical education teachers, dance teachers and coaches may be at risk, as much of their time is spent in noisy environments such as classrooms, playgrounds, gyms and stadiums during games. Some common sources of noise in the classroom are ringing bells, musical instruments, marching bands and announcements over the PA system, exposing both teachers and students to potentially high sound levels (Martins et al. 2007; Cutietta et al. 1994; Behar et al. 2004; Palma et al. 2009; Isaac et al. 2017). The prevalence of non-use of HPDs among workers in Educational Services (NAICS 61) has been previously reported as 56% (Tak, Davis, and Calvert 2009). Barriers to the use of HPDs may be low access and availability, lack of knowledge of how to properly use them, and belief that HPDs may impair ability to communicate. Hearing loss risk at educational institutions could be minimized by overcoming these barriers and by adopting certain policies and procedures such as: setting noise level standards for school events like dance competitions, installing noise absorbing ceiling tiles in classrooms, reducing or eliminating construction activities during school hours, and ensuring that students and staff members are using HPDs during activities like marching band, music classes and technology education classes (CDC Healthy Schools 2015). It is also important to use the appropriate type of HPD for these activities.

The Marinas sub-sector (NAICS 713930) includes dock hands, forklift drivers, marine mechanics, maintenance workers and office administrators, mainly involved in operating docks and/or repairing, maintaining or renting pleasure boats. Forklift drivers can be exposed to a high volume of noise (85–88.5 dBA) on a regular basis from horns, beeper noise during reversing, or engine noise while driving forklifts (U.S. Department of Labor 2013). The primary sources of noise during loading and unloading at docks are truck engines and brakes with peak noise levels of 80–82 dBA (Hildebrand 2004). This, in combination with other background noises at marinas such as wind, sea waves, power generating wind mills, and commercial ships and cranes, may have contributed to an elevated risk of hearing loss.

Limitations

This study had limitations. First, the dataset was part of a convenience sample that NIOSH obtained from providers that were willing to share de-identified information. As such, the data may not be representative of all noise-exposed workers within the Services sector or have equal representation across regions (e.g., there is heavy representation from the Midwest). Second, audiograms were used to identify hearing loss, but work-relatedness can only be inferred, as no medical records were available. To strengthen this inference, audiograms with patterns likely indicating other etiologies were excluded. Third, in some cases, the NAICS code was assigned by the provider rather than NIOSH, with the potential for inconsistencies in the coding and misclassification. No information was available on the noise exposures of individual workers, which may have varied across industries. Fourth, only one audiogram (the latest) was examined for each worker, without a confirmation audiogram. A few hearing losses might represent temporary shifts in hearing. However, a temporary shift is still a sign of over-exposure to noise. Fifth, in this study, the adjusted risk estimates represent the risk of worker hearing loss in an industry or group as compared with the risk in the reference industry or group. The workers in this study were all or nearly all exposed to noise, including the reference industry workers, suggesting that the risk estimates may trend towards the null and the actual risk may be higher than reported here. Sixth, some industries in this sample had no available audiometric data. It is unknown if the audiograms were missing due to a lack of providers who service these industries and share data with NIOSH, or if workers were not being adequately tested in these industries. Finally, NAICS codes may not necessarily group together workers with similar exposures.

Conclusions and recommendations

This study identified sub-sectors within the Services sector at higher risk for hearing loss. OHL continues to be one of the most prevalent work-related conditions and occurs across a wide spectrum of industries (Bogardus, Yueh, and Shekelle 2003). Large numbers of workers within the Services sector have an elevated risk of hearing loss, making it very important to identify these at-risk workers and protect their hearing, with the help of targeted interventions. OHL is preventable with appropriate technologies and hearing conservation strategies (Themann, Suter, and Stephenson 2013a; Themann, Suter, and Stephenson 2013b).

Sound is an important part of everyday life, but noise can negatively affect our mental and physical health. Along with hearing loss, noise exposure has been associated with other health effects such as hypertension, arteriosclerosis, elevated cholesterol and coronary heart disease (Themann, Suter, and Stephenson 2013a; Kerns et al. 2018). NIOSH recommends following the hierarchy of controls—in which more effective preventive measures are implemented insofar as possible—to minimize or eliminate hazardous noise exposure and protect workers from its adverse effects (NIOSH 1978).

The most effective means of reducing noise exposures is through elimination or substitution. For example, electric- or battery-powered landscaping equipment is usually quieter than gas-powered tools (Blomberg and Sawchuck 2017). When the noise source cannot be eliminated or substituted with a quieter process or piece of equipment, employing engineering controls is the best alternative to reduce the amount of noise. This is typically accomplished by modifying the noise source (e.g., turning down headset volume), blocking noise transmission (e.g., installing barriers between call center operator workstations), or absorbing sound energy to reduce reflections and reverberations (e.g., adding carpeting, acoustic tiles and curtains to a room). Other examples of engineering controls include adding silencers or mufflers to exhaust systems, applying acoustic shielding to the noise source and using dampening pads to reduce vibration (Suter 2012).

Administrative controls can also effectively reduce noise exposures. For example, limiting the time a worker is exposed, allowing longer breaks between exposure periods, and performing noisy activities when fewer people are present all reduce exposure (Balanay, Kearney, and Mannarino 2016).

Even though engineering and administrative controls are the most effective measures, HPDs can be an important temporary tool until other effective controls are instituted. Workers should be educated on the effects of the excessive noise exposure and properly trained how to correctly wear HPDs (Groenewold et al. 2014). It is also important to identify and address the barriers of non-usage of HPDs.

The findings of this study further strengthen the need for better comprehensive hearing conservation programs (HCPs), audiometric monitoring of worker hearing, appropriate use of HPDs, education for workers, and also program evaluation. This study also identified many sub-sectors with no available worker hearing loss data. Additional surveillance and research efforts are needed to identify the risk factors in some sub-sectors, including taking noise measurements, and conducting audiometric testing.

Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

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Declaration of interest

No potential conflict of interest was reported by the author(s).

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