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Prevalence of Hearing Loss Among Noise-Exposed US Workers Within the Utilities Sector, 2010–2019

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Abstract

Objective: This study's objective was to estimate hearing loss prevalence for noise-exposed US Utilities workers.

Methods: In this cross-sectional study of a retrospective cohort, audiograms were examined for 1.3 million workers (13,595 within utilities) from 2010–2019. Hearing loss prevalence and adjusted risk as compared with a reference industry were estimated.

Results: The hearing loss prevalence for noise-exposed Utilities workers (25%) was higher than for noise-exposed workers in all industries combined (20%). Some subsectors surpassed the prevalence for all industries combined and/or had adjusted risks significantly higher than the reference industry. The highest prevalence subsectors were Hydroelectric Power Generation (37%) and steam and Air-Conditioning Supply (29%).

Conclusions: While often overlooked, noise-exposed workers in this sector have among the highest prevalences of hearing loss and significantly higher risks. Increased attention and better hearing conservation strategies are needed.

Keywords

occupational hearing loss; hazardous noise; hydroelectric power generation; electric power generation; power distribution; natural gas distribution; surveillance

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Conflicts of Interest Statement: None declared.

Ethical Considerations: This activity was reviewed by the Centers for Disease Control and Prevention, deemed not research, and was conducted consistent with applicable federal law and Centers for Disease Control and Prevention policy (see e.g., 45 C.F.R. part 46.102(l)(2), 21 C.F.R. part 56; 42 U.S.C. §241 (d); 5 U.S.C. §552a; 44 U.S.C. §3501 et seq.)

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Hearing loss is a significant public health burden in the United States. It is the third most common chronic physical condition among adults after hypertension and arthritis, and is more prevalent than diabetes, vision trouble, or cancer.[1,2] Hearing loss is one of the most common work-related illnesses.[3] In addition to being prevalent, hearing loss can have a dramatic impact on quality of life. Communication deteriorates and relationships can suffer. Hearing loss is associated with cognitive decline, including thinking skills and memory.[4,5] It is also associated with hypertension and coronary heart disease.[3] It is strongly associated with depressive symptoms and depression.[6–9] Often co-occurring with hearing loss, tinnitus is associated with anxiety and depression and can disrupt concentration and sleep.[10]

Occupational hearing loss (OHL) is caused predominantly by loud noise, but also by chemicals that damage hearing or make the ears more susceptible to the damaging effects of noise (ototoxic).[11] The Utilities sector is often overlooked as a high-risk industry for OHL. About 27% of all workers in the Utilities sector report hearing difficulty, the highest of any sector, and more than double the prevalence for all industries combined (12%).[12] The Utilities sector also has the fourth highest prevalence of a history of occupational noise exposure (43%).[12] Few studies cover hearing loss within Utilities. The most recent hearing loss estimates available for noise-exposed workers in this sector are based on audiometric data from 2000–2008, with 26% of workers experiencing a material hearing impairment.[13] This means that the hearing loss was severe enough that these workers had difficulty understanding speech.

The purpose of this study was to identify the highest risk groups for targeting interventions, and to provide updated hearing loss estimates among noise-exposed workers in the Utilities sector and subsectors, and all industries combined. Audiograms from the National Institute for Occupational Safety and Health (NIOSH) OHL Surveillance Program from 2010–2019 were examined.

METHODS

Study Design and Population

This cross-sectional study using a retrospective cohort of deidentified audiograms for noise-exposed workers examined hearing loss prevalence and risk in the Utilities sector. The study adhered to “Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)” guidelines (Supplemental Digital Content, https://links.lww.com/JOM/B589). Adjusted risks were estimated using probability ratios (PRs). The PRs compared hearing loss risk among noise-exposed tested Utilities workers to the hearing loss risk among noise-exposed tested workers in the Couriers and Messengers industry (the reference industry). NIOSH OHL Surveillance Program audiograms were examined and have been characterized in more detail elsewhere.[13] Briefly, audiograms came from a convenience sample of companies including audiometric service providers, occupational health clinics, and others (hereby labeled as “providers”). Providers performed audiometric testing for noise-exposed workers (generally ≥85 dBA time-weighted average) to comply with regulations. They shared deidentified audiograms with NIOSH, and workers were assigned arbitrary employee IDs. Workers aged 18–75 years with at least one audiogram from 2010–2019 were included in the study. Males and females were included. Within the period, the most recent audiogram

was examined. The years 2010–2019 were selected since 2019 was the most recent year with complete data available. It was also chosen to ensure the sample size was substantial enough to examine smaller subsectors within Utilities. This activity was reviewed by the Centers for Disease Control and Prevention, deemed not research, and was conducted consistent with applicable federal law and Centers for Disease Control and Prevention policy (see, eg, 45 C.F.R. part 46.102(l)(2), 21 C.F.R. part 56; 42 U.S.C. §241(d); 5 U.S.C. §552a; 44 U.S.C. §3501 et seq.)

Materials

Study audiograms contained hearing thresholds (frequencies 0.5, 1, 2, 3, 4, 6, and 8 kHz included), gender, birthdate, state where the worker was employed, and industry code (North American Industry Classification System [NAICS] code).[14,15] Data that were not available included hire date, race, occupation, income, smoking status, hearing protection device use, and information on exposure to ototoxic chemicals. Individual and area measurements of noise exposure were also not attainable. However, noise exposures of ≥85 dBA can be assumed for all workers because testing was performed as part of US regulatory requirements for occupational noise exposure.

Inclusion and Exclusion Criteria

Since the audiometric testing for workers in the study was not originally collected for research purposes, the audiograms may contain errors or be incomplete.[16] Unless otherwise stated in the results, an audiogram was excluded from the regression analyses if it was missing gender, birth year, or NAICS code. Only audiograms within the age range of 18–75 years were included to eliminate unlikely birth years. Audiograms missing birth month or birth day were imputed as July and 15, respectively. If both birth day and month were missing, July 1 was imputed. If hearing thresholds at frequencies required for identifying hearing loss were missing (1, 2, 3, and 4 kHz), the audiogram for the affected ear was also excluded.

Senior NIOSH audiologists developed standards (described in Masterson et al) to identify and exclude audiograms that did not meet other standards of quality nor had characteristics signaling a nonoccupational etiology.[13] Audiograms that were excluded had the following: substantial (≥40 dB) interaural differences indicating a potential medical etiology; threshold values indicating negative slope in either ear, indicative of middle ear pathology or contamination by background noise during audiometric testing[17]; threshold values that are “unlikely” (improbable) and thus suggesting a testing error; or “no response at maximum value/output” consistent with a nonoccupational etiology.

Beginning with 4,602,436 audiograms for 1,591,411 US workers aged 18–75 years from 2010–2019, 1,123,930 audiograms were removed due to inadequate quality and 2,279,135 audiograms were eliminated as they were not the most recent audiogram for each worker (Table 1). The final study sample was comprised of 1,321,980 workers at 11,967 US companies. This included 13,595 Utilities workers at 441 companies.

Statistical Analysis

The Utilities sector falls under NAICS code 22[14,15] and is categorized as such in this study. Industry was the independent variable and based on the NAICS code. Material hearing impairment, hereby denoted as "hearing loss," was the study outcome. It was based closely on the NIOSH definition[18] and specified in this study as a pure-tone average threshold of 25 dB or more in either ear across frequencies 1, 2, 3, and 4 kHz. States where the workers were employed were grouped into six geographical regions based on US Embassy regions,[19] and age was ordered into six groups. The statistical software used was SAS version 9.4 (SAS Institute, Inc, Cary, NC).

Hearing loss prevalence percentages and 95% confidence intervals (CIs) were estimated for the Utilities sector, subsectors within Utilities, all industries combined, and the reference industry, which was Couriers and messengers (NAICS 492). The reference industry was selected based on a number of factors. These included the industry's low prevalence of hearing loss, statistical considerations such as group size, an investigation of the literature, and consistency with prior studies' methodology for comparison. These are explained in detail in prior studies.[13,20] Workers not exposed to noise rarely receive audiometric testing in workplace hearing conservation programs. Therefore, all or nearly all of the audiograms in this study were from noise-exposed workers. Reference groups were 18–25 years for age group and female for gender. Hearing loss becomes more prevalent as age increases and is more common in men than in women.[21,22]

PRs were generated for the utilities sector and its subsectors as compared with the reference industry using the genmod procedure for log-binomial regression within SAS.[23,24] If the log-binomial regression method failed to converge, the copy method was used to calculate the PR.[24] PRs were adjusted for age group and gender, with the exception of one industry. Hydroelectric Power Generation was only adjusted for age group as no gender information was available. Adjusted risk and prevalence estimates were not reported for subsectors or groups with inadequate sample size and cell characteristics (case and noncase configuration). Adjusted risks for geographical region were also not reported due to the uneven distribution of industries among regions and large amount of missing data.

RESULTS

The Utilities sector had a higher prevalence of males (91%) (Table 2) than all industries combined (78%) (data not shown). Utilities sector workers also tended to be older, with 11% fewer workers aged 18–35 years compared with all industries combined (data not shown). Males in the Utilities sector were three times more likely than females to have hearing loss, with prevalences of 26% and 9%, respectively. The adjusted risk of hearing loss increased dramatically with age.

The hearing loss prevalence for noise-exposed workers in the Utilities sector (25%) was higher than the prevalence for noise-exposed workers in all industries combined (20%) (Table 3). Utilities subsector prevalences (at six-digit NAICS code specificity) ranged from 13% to 37%. Focusing on subsector results at the highest NAICS code specificity (six-digit), the subsectors with the highest prevalences were as follows: Hydroelectric Power Generation

(37%), Steam and Air-Conditioning supply (29%), Other Electric Power Generation (24%), and Natural Gas Distribution (24%).

The adjusted risk (PR) for hearing loss was 31% higher in the Utilities sector than in the reference industry. The subsectors with the highest adjusted risks were Hydroelectric Power Generation, Electric Power Distribution, and Other Electric Power Generation, with risks 118%, 41%, and 32% significantly higher than the reference industry, respectively. Two subsectors, Water Supply and Irrigation Supply as well as Sewage Treatment Facilities, had adjusted risks significantly lower than the reference industry. The adjusted risk in The Steam and Air-Conditioning Supply subsector was not significantly different from the reference industry.

DISCUSSION

Over 550,000 workers are employed in the US Utilities sector.[25] Utilities subsector industries "provide electric power, natural gas, steam supply, water supply, and sewage removal" and exclude waste management.[15] This study showed that the prevalence of hearing loss in Utilities (25%) was notably higher than for all industries combined (20%) and a number of Utilities subsectors had hearing loss risks significantly higher than in the reference industry. Prior estimates using similar data from 2000–2008 indicated a slightly higher prevalence for Utilities (26%) and a lower prevalence for all industries combined (18%).[13] There has been little decrease in the prevalence in Utilities over time, and a 5% discrepancy remains with all industries combined. Since most of the risk for OHL originates from loud noise on the job, identifying high-risk workers, the sources of their noise exposure, and how to mitigate the exposure is important, especially when 38% of US noise-exposed Utilities workers report not wearing their hearing protection.[26]

The Hydroelectric Power Generation subsector stood out with the highest prevalence of hearing loss (37%) and more than double the adjusted risk compared with the reference industry. Studies of noise in the Utilities sector are very limited, and only two studies were found that focused on hydroelectric power. Celik et al[27] measured noise levels in a hydroelectric power plant in Turkey and found that noise levels from continuous turbines ranged from 95–110 dBA in work areas and 75–85 dBA in "resting" areas. They also measured hearing thresholds for 126 noise-exposed plant workers under age 50 years, and 56% were diagnosed with hearing impairment. Another study also measured hearing thresholds in groups of noise-exposed Turkish hydroelectric plant workers.[28] Workers in the turbine areas (95–110 dBA) and machinery maintenance areas in the generator or machine rooms (75–85 dBA) of the plant had significantly higher mean hearing thresholds (worse hearing) than plant workers stationed outdoors (<75 dBA) and nonutility controls. None of the plant workers wore hearing protection.[28]

The Steam and Air-Conditioning Supply subsector, which is composed of establishments that provide heated air, steam, or cooled air,[15] also stood out with a 29% prevalence, although the risk was not significantly different from the reference industry. No studies were found related to noise in this subsector. Other Electric Power Generation had a high prevalence (24%) and 32% higher risk of hearing loss than the reference industry. This

sector includes converting solar, wind, or tidal power into electricity.[15] While no noise-related studies were found for solar or tidal power generation, there was limited literature related to wind power generation. A review of health effects of wind turbines in working environments indicated that noise exposures vary by occupation and possibly by location (on-shore, off-shore) and stage in the life cycle of the wind farm.[29] Among included studies with noise exposure measurements, all on-shore from Iran or Poland, mechanics had higher noise exposures (75–84 dBA) than other workers such as security (66 dBA), office personnel (60 dBA), or nonutility workers within 2 miles from the wind turbine (30–52 dBA).[29]

This study sample had insufficient data to generate estimates for fossil fuel or nuclear electric power generation. It is unknown if this is because the NIOSH OHL Surveillance Program does not have partners who test workers in these subsectors, or if audiometric testing is lacking in these subsectors, such that data are not available. There are a few available studies on these subsectors. Noise assessments across five US coal-fueled power plants found that exposures exceeded the Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) of 90 dBA over 8 hours for 3% of sampled workers.[30] The OSHA action level of 85 dBA over 8 hours was also exceeded for 19% of workers. Job categories with the highest prevalences of exposures exceeding the action level were mechanics (range among plants of 23%–46%) and operations (range among plants of 13%–50%).[30] Three NIOSH health hazard evaluations conducted in 2003 and 1984 also examined noise exposures in coal-fired plants. They found time weighted exposure levels ranged from 73 to 99 dBA, depending on location and occupation.[31–33] Another study reconstructed worker noise exposure from historical records for two nuclear power plants in England from 1965 to 1999.[34] With the assumption that workers effectively wore hearing protection, it found that the median exposure across all jobs, plants, and years was 86 dBA with a range of 60–97 dBA.[34]

Hearing risk in Utilities may be high due to the presence of impulsive noise at some power plants. McBride and Williams[35] reported that air blast noise created to extinguish electrical arcs when high tension electrical circuits are interrupted/broken produced median peak levels of 146 dBA at operator locations. Workers at electricity transmission plants who reported exposure to such air blasts had increased odds of hearing loss, regardless of whether they reported using hearing protection.[35] Steam release valves are another potential source of impulsive noise in power plants, with reported sound levels of 140–150 dBA at 1 meter (3.3 feet).[36]

In regard to trends, a review of OSHA full-shift dosimetry measurements for PEL and action levels during regulatory site visits between 1979 and 2013 found that PEL noise measurements in the Utilities sector remained stable over time, and action levels fluctuated with an increase during 2000–2013.[37] This is despite the expansion of occupational noise control regulations [29 CFR § 1910.95] and technology development during this 34-year period.

Most of the very limited information available on potential noise controls specific to this sector focuses on power plants, where primary noise sources include combustion turbines or diesel engines, and steam bursts used to release waste heat.[38] The top tiers of the hierarchy

of controls are recommended to reduce the noise at the source by using quieter equipment, encasing noise sources in acoustic enclosures, and using duct silencers, barrier walls, and other similar treatments to interrupt the path of the noise.[38] It is also recommended to group smaller sources together so that a common noise barrier or enclosure can be used. In some cases, a facility upgrade may be needed to achieve sufficient noise control. For new plants, it is important to place the loudest equipment far from designated quieter areas.[38] A NIOSH health hazard evaluation report also recommended replacing manually controlled generators with remote-controlled generators to reduce the exposure time near the equipment with noise levels at 95–114 dBA.[39]

Limitations and Strengths

There were study limitations. Study data were part of a convenience sample from providers that agreed to participate in the NIOSH OHL Surveillance Program and share deidentified information. As such, the data might not be representative of all noise-exposed Utilities workers. There were Utilities subsectors with zero or an insufficient number of audiograms to develop estimates. This might reflect a lack of providers who test workers in these subsectors sharing their data with NIOSH, or a general lack of audiometric testing in these subsectors.

The work-relatedness of the hearing losses was inferred since no employment or medical records were available. In order to strengthen this inference of work-relatedness, audiograms with characteristics suggesting other etiologies were excluded. It is possible that some hearing losses were temporary. Because only the most recent audiogram was examined for each worker, hearing losses were not confirmed with a subsequent audiogram. However, temporary shifts are a sign of overexposure to noise and useful for identifying high risk workers.[3]

All or nearly all of the workers in this study were exposed to noise, and this included workers in the reference industry. This likely reduced the observed differences between industries and the available reference industry than what could have been observed between industries and the ideal reference group (unexposed). Therefore, the “true” risk may be higher than reported in this study since the risk estimates may trend toward the null. NAICS codes may not group together workers with equivalent exposures. No noise exposure information was available for individual workers, and these exposures likely varied across subsectors. Finally, for the relatively few audiograms where the NAICS code was supplied by the provider rather than NIOSH, there was a possibility for misclassification or inconsistent classification.

However, this study also had important strengths. This is the only US study elucidating hearing loss risks for the noise-exposed across the Utilities sector. Rather than depending on self-reported hearing level, this study analyzed worker audiograms. While a convenience sample, it included workers from a wide variety of workplaces and with a sufficient sample size to examine most subsectors within Utilities at the six-digit NAICS specificity, including 13,595 workers at 441 companies. It also included data from 1.3 million workers from all industries for comparison. In addition, the sample size allowed for the exclusion of poor

quality audiograms and audiograms suggesting characteristics likely due to nonoccupational factors, improving the accuracy.

CONCLUSIONS

This study identified subsectors within Utilities with elevated hearing loss prevalences and risks. Most OHL risk is due to noise exposure, although ototoxic chemical exposures, such as second-hand smoke, may play a role. OHL is preventable using the appropriate hearing conservation strategies and technologies.[3] NIOSH recommends using the hierarchy of controls to reduce or eliminate noise exposures.[18,40] When noise cannot be otherwise eliminated or controlled, interventions to increase the consistent use of hearing protection are needed. Finally, additional surveillance is needed for subsectors where there is a lack of hearing data. Workers in this sector need not lose their hearing because of where they work.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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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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LEARNING OUTCOMES

Upon completion of this learning activity, the learner will be better able to:

- Discuss the impact of occupational hearing loss and recognize the high prevalence of hearing loss among noise-exposed workers in the Utilities sector.
- Identify groups of workers at high risk for hearing loss within the Utilities sector.
- Discuss the potential sources of noise exposure and mitigation strategies to help prevent hearing loss within Utilities.

TABLE 1.

Audiograms Excluded From Analysis

Reason for Exclusion	Number With Characteristic	Total Excluded in Grouping[a]
Quality deficiencies:		1,123,930
Missing value for independent variable[b]	441,865	
Missing value for dependent variable[c]	3024	
Unlikely threshold values for left ear	2219	
Unlikely threshold values for right ear	2253	
Large interaural difference[d]	348,527	
Negative slope[e]	326,042	
Not the most recent valid audiogram in the time period		2,279,135
All exclusions		3,403,065[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/output” threshold values.

[d] Audiograms with large (≥40 dB) interaural differences, with possible inaccurate testing of the poorer 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 1,321,980 audiograms/workers included in the final sample.

TABLE 2.

Utilities Sector Demographics for Noise-Exposed Workers,[a] With Estimated Prevalence and Adjusted Probability Ratios (PRs) for Hearing Loss (HL), 2010–2019 (N = 13,595)

Demographic	n	(%)	Prevalence of HL (%)	Prevalence 95% CI[b]	PR[c]	PR 95% CI
HL (outcome)						
Yes	3379	24.86				
No	10,216	75.15				
Missing	0					
Gender						
Male	12,012	90.66	26.47	25.68–27.26	3.03	2.54–3.63
Female (ref)	1237	9.34	8.65	7.08–10.22	ref	
Missing	346					
Age group (years)						
18–25 (ref)	866	6.37	2.77	1.68–3.87	ref	
26–35	2806	20.64	5.56	4.71–6.41	2.01	1.31–3.10
36–45	3209	23.60	14.43	13.21–15.64	5.20	3.44–7.85
46–55	3767	27.71	30.71	29.24–32.19	11.19	7.46–16.79
56–65	2803	20.62	53.02	51.17–54.86	18.92	12.63–28.35
66–75	144	1.06	64.58	56.77–72.40	ISS	
Missing	0					
Geographical region						
Mid-Atlantic[d]	971	8.74	28.63	25.79–31.47	*k*	
Midwest[e]	3149	28.33	25.60	24.07–27.12	*k*	
New England[f]	101	0.91	ISS[j]		*k*	
South[g]	4920	44.27	24.61	23.41–25.82	*k*	
Southwest[h]	0	0	ISS		*k*	
West[i]	1974	17.76	24.67	22.77–26.57	*k*	
Missing	2480					

[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, DC.

[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]ISS = not estimated due to insufficient sample size and cell characteristics (configuration of cases and noncases).

[k]PRs not estimated for geographical region due to the uneven distribution of industries and large percent of missing data.

TABLE 3.

Estimated Prevalence and Adjusted Probability Ratios (PRs) for Hearing Loss (HL) by Subsector within Utilities, 2010–2019 (N = 13,595)

Industry (NAICS[a] 2007 Code)	n	Prevalence of HL (%)	Prevalence 95% CI[b]	PR[c]	PR 95% CI
All industries	1,321,980	19.84	19.77–19.91		
All industries except couriers and messengers (492)	1,268,666	20.23	20.16–20.30	1.41	1.38–1.44
Utilities (22 and 221)	13,595	24.86	24.13–25.58	1.31	1.26–1.35
Electric power generation, transmission and distribution (2211)	9841	24.28	23.43–25.12	1.34	1.29–1.39
Electric power generation (22111)	7326	24.80	23.81–25.79	1.32	1.27–1.38
Hydroelectric power generation (221111)	187	36.90	29.98–43.82	2.18	1.90–2.49
Fossil fuel electric power generation (221112)	101	ISS[d]		ISS	
Nuclear electric power generation (221113)	0	ISS		ISS	
Other electric power generation (221119)	7038	24.44	23.44–25.44	1.32	1.27–1.38
Electric power transmission, control, and distribution (22112)	2515	22.74	21.12–24.38	1.41	1.33–1.50
Electric bulk power transmission and control (221121)	124	ISS		ISS	
Electric power distribution (221122)	2391	22.88	21.19–24.56	1.41	1.33–1.51
Natural gas distribution (2212 and 22121 and 221210)	1529	24.13	21.99–26.28	1.17	1.08–1.27
Water, sewage, and other systems (2213)	2159	14.60	13.12–16.08	0.69	0.62–0.76
Water supply and irrigation systems (22131 and 221310)	1749	13.32	11.73–14.92	0.63	0.56–0.70
Sewage treatment facilities (22132 and 221320)	298	15.10	11.04–19.17	0.75	0.59–0.97
Steam and air-conditioning supply (22133 and 221330)	145	28.97	21.58–36.35	1.19	0.96–1.48
Couriers and messengers (492) (reference)	53,314	10.57	10.31–10.83	ref	

[a] NAICS = North American Industry Classification System.

[b] CI = 95% confidence interval.

[c] PRs were adjusted for age-group and gender, except for 221111, which was only adjusted for age-group as no gender information were available.

[d] ISS = not estimated due to insufficient sample size and cell characteristics (configuration of cases and noncases).