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Prevalence of hearing loss among noise-exposed workers within the agriculture, forestry, fishing, and hunting sector, 2003–2012

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Abstract

Background—The purpose of this study was to estimate the prevalence of hearing loss among noise-exposed US workers within the Agriculture, Forestry, Fishing, and Hunting (AFFH) sector.

Methods—Audiograms for 1.4 million workers (17 299 within AFFH) from 2003 to 2012 were examined. Prevalence, and the adjusted risk for hearing loss as compared with the reference industry (Couriers and Messengers), were estimated.

Results—The overall AFFH sector prevalence was 15% compared to 19% for all industries combined, but many of the AFFH sub-sectors exceeded the overall prevalence. Forestry sub-sector prevalences were highest with Forest Nurseries and Gathering of Forest Products at 36% and Timber Tract Operations at 22%. The Aquaculture sub-sector had the highest adjusted risk of all AFFH sub-sectors (PR = 1.70; CI = 1.42–2.04).

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AUTHORS' CONTRIBUTIONS

Elizabeth Masterson participated in the design of the work; the acquisition, analysis, and interpretation of the data; drafting the work and revising it critically for important intellectual content; final approval of the version to be published; and agreement to be accountable for all aspects of the work. Christa Themann participated in the design of the work; the interpretation of data for the work; critically revising the work for important intellectual content; final approval of the version to be published; and agreement to be accountable for all aspects of the work. Geoffrey Calvert participated in the design of the work; the interpretation of data for the work; critically revising the work for important intellectual content; final approval of the version to be published; and agreement to be accountable for all aspects of the work.

ETHICS APPROVAL AND INFORMED CONSENT

Since all audiograms were de-identified, the NIOSH Institutional Review Board determined this program to be research not involving human subjects.

DISCLOSURE (AUTHORS)

The authors report no conflicts of interest.

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DISCLAIMER

The findings and conclusions in this article have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

Institution at which the work was performed: NIOSH, Centers for Disease Control and Prevention, Cincinnati, Ohio.

Conclusions—High risk industries within the AFFH sector need continued hearing conservation efforts. Barriers to hearing loss prevention and early detection of hearing loss need to be recognized and addressed.

Keywords

aquaculture; fishing; forestry; hazardous noise; material hearing impairment; noise-induced hearing loss; occupational hearing loss; prevalence; surveillance

1 | INTRODUCTION

Hazardous noise is one of the most ubiquitous occupational exposures, affecting an estimated 22 million workers in the United States.[1] Over time, continued high noise exposure results in occupational hearing loss (OHL) and other auditory sequelae, including tinnitus (ringing in the ears), difficulty understanding speech in background noise, and the inability to localize sound sources.[2] Noise exposure has also been associated with cardiovascular disease, stress, and performance decrements, including absenteeism and an increased risk of accidents.[3] In addition to noise, ototoxic chemicals such as heavy metals, organic solvents, and asphyxiants (eg, exhaust), can also cause OHL or increase the ear's sensitivity to noise.[3]

Some studies have indicated the Agriculture, Forestry, Fishing, and Hunting (AFFH) sector has high noise exposures and an increased risk of OHL. Using self-reported, nationally representative data from the National Health and Nutrition Examination Survey (NHANES), Tak et al[1] placed Agriculture, Forestry, and Fishing among the top industry sectors with a high prevalence of hazardous noise exposure (43%). Twenty-seven percent of these workers also reported not wearing hearing protection when exposed to loud noise at work.[1] An analysis that used National Health Interview Survey (NHIS) data, which is entirely self-reported and nationally representative, found that among AFFH workers, 20% had hearing difficulty, 13% had tinnitus, and 2% had both conditions; the highest of any industry sector.[4]

Trend analyses of audiograms for noise-exposed tested workers from the National Institute for Occupational Safety and Health (NIOSH) OHL Surveillance Project[5] indicated a dramatic drop in the AFFH sector prevalence of hearing loss from 1981 to 2005 (33% to 13%) followed by an increase to 14% in the 2006–2010 time period.[6] The same analysis also showed reductions in the incidence during 1986–2010 (11% to 6%) and adjusted risk for incident hearing loss (41%).[6] Despite these reductions, AFFH still had the third highest adjusted risk for hearing loss after the Mining and Healthcare and Social Assistance sectors.

Although some overall estimates are available, there is limited research available identifying the prevalences and risks for the sub-sectors within the AFFH sector. There are also limited studies available related to hearing loss within the Forestry and Hunting sub-sectors. The few studies related to Fishing are mostly non-US studies.[7–9] There are several studies on noise and hearing loss among US farmers; most based on small, family farms.[3] The purpose of this study was to estimate the prevalence of hearing loss among noise-exposed US workers within the AFFH sub-sectors using audiograms collected through the NIOSH OHL

Surveillance Project. The adjusted risks for hearing loss as compared with a reference industry were also estimated.

2 | MATERIALS AND METHODS

2.1 | Study design and population

This cross-sectional study using a retrospective cohort estimated and compared the prevalence and adjusted risk of worker hearing loss within the US AFFH sector. Worker audiograms and related information from the NIOSH OHL Surveillance Project were used and are described in Masterson et al.[10] In brief, a convenience sample of audiometric service providers, occupational health clinics, hospitals, and others (hereafter denoted as providers) previously conducted audiometric tests for workers exposed to high noise (≥85 dBA) and shared them in de-identified format with NIOSH. Arbitrary employee IDs were assigned. Workers aged 18–75 years with at least one audiogram during 2003–2012 that met study quality standards (described below) were included. The latest year with complete data was 2012 and multiple years were needed to increase sample size for smaller subsectors within the AFFH sector. The most recent quality audiogram for each worker was used to determine worker age and hearing status and was the only audiogram retained for the analyses. In total, 1 491 729 workers were included with 17 299 from the AFFH sector. Since all audiograms were de-identified, the Institutional Review Board determined this to be research not involving human subjects.

2.2 | Materials

Worker audiogram results were used to identify hearing loss, and included threshold values at frequencies 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz, date of birth, gender, employer state and employer North American Industry Classification System (NAICS) code.[11,12] Date of hire, occupation, education, race, income, smoking status, and ototoxic chemical exposure information were not available for most or all workers. Workers received audiometric testing to comply with US regulatory requirements for noise-exposed workers. As such, although specific noise exposure levels were not available, ≥85 dBA exposures can be presumed for all or nearly all workers.

2.3 | Audiogram inclusion and exclusion criteria

The study audiograms could contain incomplete or inaccurate information as they were originally collected for non-research purposes.[13] The entire audiogram was excluded if the year of birth, gender, geographical region, or NAICS code was missing and this information could not be ascertained from another audiogram for the same worker. July and 15, respectively, were imputed for missing birth months and days. July 1 was imputed if month and day were both missing. Restricting the age range to 18–75 excluded audiograms with unlikely birth years. Audiometric results for the affected ear were excluded if data were missing at frequencies necessary for evaluation of quality or calculation of hearing loss.

Using methods developed by senior NIOSH audiologists (described in Ref.[10]) audiograms were excluded that did not meet additional quality standards or displayed attributes indicating that hearing loss may be due to non-occupational factors or pathology. In short,

audiograms with large (≥40 dB) inter-aural differences indicating possible medical etiology, or depicting negative slope in either ear indicating possible threshold contamination by background noise, were excluded. If the threshold values suggested the presence of testing errors or there was "no response at maximum value," results were also excluded for the affected ear.

Starting with 5 736 082 US audiograms for 1 660 013 workers aged 18–75 during 2003–2012, 1 098 361 audiograms (19%) were eliminated due to the quality deficiencies identified in Table 1. Then, only the most recent audiogram for each worker was retained (eliminating 3 145 992 audiograms). The final study sample contained 1 491 729 workers employed at 26 191 US companies, including 17 299 workers at 458 companies in the AFFH sector.

2.4 | Statistical analysis

Industry was the independent variable and based on the NAICS code. The AFFH sector included all audiograms with NAICS codes beginning with 11 (ie, two-digit NAICS code specificity). Sub-sectors were identified at greater levels of NAICS specificity (eg, three, four). Material hearing impairment as defined by NIOSH (denoted "hearing loss") was the outcome: a pure-tone average threshold across frequencies 1000, 2000, 3000, and 4000 Hz of 25 dB or more in either ear.[14] Six categories were used for worker age and US states of worker employment were placed into six geographical regions based on US Embassy groupings.[15] The sample did not include any AFFH workers from the New England region (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont). SAS version 9.3 statistical software was used for analyses (SAS Institute, Inc., Cary, NC).

Hearing loss prevalence percentages with 95% confidence intervals were estimated for all industries combined, the AFFH sector and its sub-sectors, and the reference industry (Couriers and Messengers). The reference industry is the reference group to which each industry is compared and typically has lower risks for the outcome of interest (eg, hearing loss). Couriers and Messengers (NAICS 492) was designated "a priori" as the reference group for the hearing loss risk estimates (probability ratios [PRs]) for the industry analyses, similar to previous analyses comparing risks among industries.[10,16] The rationale is provided elsewhere[10,16] and was determined by an examination of the literature, preliminary data analyses related to the prevalence of hearing loss and demographics within this industry and others, and statistical considerations, such as robust sample size for producing stable estimates. The hearing loss prevalence in the reference industry has been consistently the lowest or one of the lowest in analyses using the NIOSH dataset and is close to the prevalence of hearing difficulty among non-noise-exposed workers (7%).[4] Audiometric data for non-noise-exposed workers would be a preferable reference group but these data are not available. Typically only noise-exposed workers receive audiometric testing.

PRs were estimated using the SAS® genmod procedure for log-binomial regression.[17] The PRs characterize the risk in each group as compared with the reference group. PRs were calculated rather than odds ratios because (1) odds ratios should only be used for rare outcomes and some prevalences were expected to exceed 10%[18] and (2) for ease of interpretation. PRs were estimated using the copy method because the log-binomial regression models did not converge.[18] Reference groups for the covariates were designated

as 18–25 years for age group, female for gender, and West for region. The prevalence of hearing loss increases as age increases and more men experience hearing loss than women.[10,19] The regions were not expected to be significantly different from each other, and the West was chosen due to good sample size while not placing 50% of the sample in the reference group.

Demographic variable PRs were adjusted by gender, age-group and region, as appropriate. PRs for the AFFH sector and sub-sectors were adjusted by age-group and gender. Ninety-five percent confidence intervals were calculated for all PRs. When the risk was higher in an industry/demographic category than in the reference group, then the PR > 1. When the risk was lower in the industry/demographic category than in the reference group, then the PR < 1.

Due to insufficient or zero sample size (insufficient number of cases and non-cases per cell), the prevalence and adjusted risk could not be accurately estimated for the New England Region, and eight of the 19 sub-sectors at the four-digit NAICS code level of specificity: Oilseed and Grain Farming (NAICS 1111); Fruit and Tree Nut Farming (NAICS 1113); Greenhouse, Nursery and Floriculture Production (NAICS 1114); Hog and Pig Farming (NAICS 1122); Sheep and Goat Farming (NAICS 1124); Other Animal Production (NAICS 1129); Hunting and Trapping (NAICS 1142); and Support Activities for Animal Production (NAICS 1152).

3 | RESULTS

Among the 17 299 noise-exposed workers in the AFFH sector, most were male (72%) and employed in the Southwest (51%) (Table 2), while among workers in all industries combined, 78% were male and 46% were employed in the Midwest (data not shown). The AFFH sector age group distribution was younger than for all industries combined. Specifically, there were 13% more workers in the 18–35 age-groups and 11% fewer workers in 46–65 age-groups (data not shown). Males were nearly three times more likely to have hearing loss than females, with hearing loss prevalences of 19% and 6%, respectively. The risk of hearing loss also increased substantially as workers aged. There was twice the risk of workers having hearing loss in the 26–35 age-group than in the 18–25 age-group. This jumped to almost 24 times the risk in the 66–75 age-group as compared with the 18–25 age-group.

The prevalence of hearing loss for noise-exposed workers in the AFFH sector (15%) was lower than the prevalence for all industries combined (19%) (Table 3). However, many of the individual AFFH sub-sector prevalences exceeded the overall AFFH prevalence. Forestry and Logging (NAICS 113) and two of its sub-sectors exceeded the prevalence for all industries combined. These sub-sectors were Forest Nurseries and Gathering of Forest Products (NAICS 1132) with a 36% prevalence and Timber Tract Operations (NAICS 1131) with a 22% prevalence. The Fishing, Hunting, and Trapping (NAICS 114) sub-sector, almost entirely comprised of Fishing (NAICS 1141) in this sample, had a prevalence of 20%. Other hearing loss prevalence rates of note included Aquaculture (NAICS 1125) (19%) and Cattle Ranching and Farming (NAICS 1121) (19%). The sub-sectors with the lowest prevalences

were Support Activities for Forestry (NAICS 1153) (7%) and Vegetable and Melon Farming (NAICS 1112) (7%).

All but two sub-sectors (Cattle Ranching and Farming; and Support Activities for Forestry) had adjusted risks for hearing loss significantly higher than the reference industry. Sub-sectors with the highest risks compared with the reference industry were: Aquaculture (NAICS 1125) (PR = 1.70; CI = 1.42–2.04); Forest Nurseries and Gathering of Forest Products (NAICS 1132) (PR = 1.60; CI = 1.53–1.68); and Fishing (NAICS 1141) (PR = 1.46; CI = 1.31–1.64). While the Vegetable and Melon Farming sub-sector had a lower prevalence than the reference industry, the adjusted risk was significantly higher (PR = 1.32; CI = 1.07–1.62).

4 | DISCUSSION

This is the first known study to estimate and compare the prevalence of worker hearing loss by AFFH sub-sector. Our study results indicate that while the overall prevalence of hearing loss is lower in the AFFH sector than in all industries combined (although the adjusted risk is slightly higher), there are sub-sectors within AFFH that have an elevated prevalence and risk of hearing loss. These sub-sectors included: Forest Nurseries and Gathering of Forest Products; Timber Tract Operations; Fishing; and Aquaculture. We also discuss the Logging sub-sector, which had an elevated risk of hearing loss. We did not discuss the Agricultural sub-sectors in detail. They did not have higher prevalences, although a few had risks significantly higher than the reference industry. It is possible that our study's sample of agricultural workers, tested to comply with regulatory requirements, primarily includes workers from larger farming operations where hearing conservation programs are in place and audiometric testing is required.

4.1 | Forestry and logging workers

NAICS 1131 and 1132 are the Forestry sub-sectors and NAICS 1133 is the Logging sub-sector, however, we will discuss Forestry and Logging together as many of the activities and available research overlap. All of our sample's workers in Timber Tract Operations (NAICS 1131) worked in Timber Tract Operations (NAICS 113110). A timber tract is a specified area of land on which there are standing trees that may be harvested to make timber (also known as a forested tract). Timber Tract Operations workers were employed by establishments in the operation of timber tracts with the intention to sell standing timber.

All of the workers in Forest Nurseries and Gathering of Forest Products (NAICS 1132) worked in Forest Nurseries and Gathering of Forest Products (NAICS 113210). These workers were employed by establishments that grow trees for reforestation and/or gather forest products such as barks, gums, balsam needles, fibers, rhizomes, Spanish moss, truffles and ginseng. Finally, all of the workers in Logging (NAICS 1133) worked in a sub-sector with the same name (Logging) with NAICS code 113310.

Some noise exposure values for forestry operations can be found in the literature. Pyykkö et al[20] reported noise levels ranging from 97 to 102 dBA in a study of 199 forest workers. Neitzel and Yost[21] obtained 44 full-shift dosimetry measures on forestry workers

representing six trades: fellers, vehicle operators, rigging slingers, chokermen, landing men, and hooktenders. Overall, 83% of the measures exceeded the time-weighted average (TWA) of 85 dBA and 48% exceeded the TWA of 90 dBA using NIOSH criteria.[21] Tree fellers and hooktenders had the highest mean noise exposures at 98 and 97 dBA, respectively. The highest noise exposure task was unbelling chokers on landings, which is unlatching the cables that hold logs when the logs are moved (92 dBA), and the highest exposure tool was chain saws (91 dBA).[21] These workers self-reported using hearing protection 84% of the time.[21]

Vibration exposure may also increase the risk of hearing loss. The mechanism is not known, but suspected to be related to vaso-constriction within the cochlea.[20] Iki et al[22] found greater hearing shifts over time among forestry workers who also sustained vibration-induced white finger disease (VWF), than among those who did not. Pyykkö et al[20] also reported that VWF was associated with hearing loss, but could not confirm that VWF caused more hearing loss than noise alone, as the exposures were concomitant. Neitzel and Yost[21] reported that for all but tree shoveling (0%) and tree felling (unreported), 11–80% (depending on operation) of whole body vibration measures among forestry workers exceeded the 8-h Commission of European Communities (CEC) exposure limit (1.15 m/s^2). Workers performing log processing had the most overexposures (80%). They also reported that, overall, 33–53% of hand arm vibration measures exceeded the American Conference of Governmental Industrial Hygienists (ACGIH) 8-h threshold limit value (TLV), with the tree felling operation and tree feller job title having the most overexposures.[21] The TLV ranges from 4 to 12 m/s^2 depending on duration.

4.2 | Fishing workers

All of our sample's workers in Fishing (NAICS 1141) worked in Finfish Fishing (NAICS 114111). Finfish Fishing includes establishments engaged in commercial catching or taking of finfish from their natural habitat; not farm raising. Finfish include tuna, trout, salmon, and bluefish. Few studies are available on hearing hazards in fishing workers. Casson et al[7] found that 63% of Italian fishermen had hearing loss. Ergonomic case studies of Massachusetts fishing vessels recorded 8-hour TWA noise measurements ranging from 87 to 90 dBA, depending on the vessel, with maximum values ranging from 102 to 124 dBA.[23] A study by Paini et al[9] found that 72–97% of fishermen on small-scale Brazilian fishery boats with engines had high frequency hearing loss (3000, 4000, 6000 Hz frequencies) compared to 36% of fishermen who worked on boats without engines. Paini et al[9] also found that among coastal Brazil small-fisheries, equivalent continuous noise levels ranged from 90 to 108 dBA depending on the type of fishing vessel, with maximum levels up to 112 dBA. Neitzel et al[8] measured noise levels on larger catcher/processor fishing vessels and reported an average equivalent continuous noise level of 95.3 dBA. About half of the studied workers had 24-h exposures above the Coast Guard recommended limit, which is equivalent to the Occupational Safety and Health Administration (OSHA) permissible exposure limit for 24 h (82 dBA).[8] Fishermen have highly variable work shifts and routines, and frequently work shifts exceeding eight hours and sometimes lasting 24 h.[7,9] During peak seasons, work continues 7 days a week.[9] When the work day is longer, noise exposures must be reduced to comply with limits based on an 8-h shift[14] (29 CFR 1910.95),[24] and to improve the

opportunity for auditory recovery. No fishermen in the Brazil study used hearing protection, even though they were aware of the risks of hearing loss,[9] which suggests that a lack of knowledge was not the barrier to safety compliance in this case and that other barriers were present. All the workers in the Neitzel et al[8] study reported using hearing protection during most of their work shifts (averaging 70 min less than shift length). Fishermen are also exposed to weather conditions, vibration, and chemical exposures (carbon monoxide) which can pose a risk to hearing.[9] Casson et al[7] also reported that Italian fishery workers had a high rate of smoking (58%), increasing the risk of hearing loss.

4.3 | Aquaculture workers

Workers in Aquaculture (NAICS 1125) in our sample all worked in Finfish Farming and Fish Hatcheries (NAICS 112511). This includes establishments engaged in "(1) farm raising finfish (eg, catfish, trout, goldfish, tropical fish, minnows) and/or (2) hatching fish of any kind."[12] Very few studies were available related to noise. A study by Barnes et al[25] measured noise levels in two rearing facilities at a production fish hatchery in South Dakota. This study found that noise exposures ranged from 64 to 68 dBA, depending on rearing facility, for routine tasks and from 73 to 77 dBA for intermittent activities in absence of engineering controls for noise.[25] While these exposures may not cause hearing loss directly, they may lead to risky behaviors such as amplifying headset volumes for music or phones to hazardous noise levels, as workers have done in other environments with elevated background noise[26] and can happen in any industry. The authors also suggested that the noise level could be higher in hatcheries with more fish tanks, or vary based on building construction (eg, higher noise with "more open air construction of uninsulated steel and wire mesh" or deeper and larger standpipes which control tank water levels).[25] A review by Quandt et al[27] also identified chemical exposures in this sub-sector, including pesticides, which may be ototoxic. Examples of pesticides that are ototoxic include organophosphates, paraquat, pyrethroids, and hexachlorobenzene.[28]

4.4 | AFFH sector workers overall

The AFFH sectoras a whole has additional challengesto the critical tasks of (1) hearing loss prevention and (2) early detection of hearing loss by consistent annual audiometric testing so that timely interventions may occur to stop additional hearing loss. Regular testing is complicated, in part due to the mobile nature of many of the occupations. Regularly measuring noise exposures and monitoring hearing sensitivity is difficult when workers are temporary, seasonal, or move from site to site, as is common among workers in this sector.[8,27,29]

There is at least some evidence that regulations are protective,[30] however, workers in the AFFH sector are impacted unevenly by regulatory coverage. Forestry workers are protected by the OSHA noise regulation and hearing conservation amendment.[31] However, much of the agriculture industry is exempt from OSHA regulations. Small farming operations with ≤10 employees are exempt from OSHA enforcement unless the operation maintains a temporary labor camp.[32] Immediate family members of farmers are not considered employees.[32] Workers in the fishing industry may be covered by one of several regulations, depending on whether they are crew or non-crew, on land or at sea, and private sector or

government.[32,33] In general, OSHA standards apply within three miles of shore, beyond which the US Coast Guard has jurisdiction.[8,33] The US Coast Guard provides voluntary guidelines (rather than requirements) for noise exposure similar to OSHA regulatory limits normalized to a 24-h exposure time,[34] and their recommendations for a hearing conservation program for overexposed workers are similar to OSHA requirements.[35]

It is also estimated that immigrant workers account for 37% of the AFFH sector[26] and many of these workers speak limited English.[27,29,36,37,38] Disproportionately more foreign-born workers are employed in some noisy jobs, and workers with limited English-language skills are often at higher risk for hearing loss due, in part, to not understanding safety training materials or instruction.[39] The unofficial working status of many immigrants may also preclude them from receiving any hearing loss prevention training or screenings.[39] Immigrant workers may also be reluctant to voice any complaints in spite of poor or illegal working conditions or practices, or request protective equipment such as ear plugs, fearing job loss and deportation.[39,40]

This study had several limitations. The NIOSH dataset is a convenience sample from providers willing to share their data and may not be representative of all noise-exposed AFFH workers. No noise-exposure measurements were available and we could not control for exposure duration, which may have varied across industries. Within agriculture, tested workers are more likely to be employed on larger, corporate farms, which may have different exposure levels and patterns than smaller family farms. Larger corporate farms may also have a better safety culture, access to modern equipment with better noise controls (eg, tractor cabs), and a greater likelihood of OSHA enforcement activities. Our estimates from these tested agriculture workers may be lower than if workers from smaller establishments were included. It is unknown if the industries in this sample for which there were no audiograms were missing due to lack of providers who service these industries, or if noise-exposed workers are not being tested in these industries. Without medical and other records, the work-relatedness of hearing loss can only be inferred. To strengthen this inference, audiograms with attributes unlikely to be related to OHL were excluded. In a few cases, the industry coding was performed by the provider (not by NIOSH), with the potential for inconsistencies or misclassification. Without a confirmation audiogram, it is possible that a few hearing losses were temporary shifts in hearing. However, even temporary threshold shifts can indicate over-exposure to noise. The risk estimates in this study represent the risk for worker hearing loss in an industry as compared with the reference industry, all of whom were noise-exposed workers. As such, the risk estimates might be biased towards the null and the true risks might be higher. Finally, NAICS is an economic classification system and may not group workers with similar exposures together.

Although not a limitation, it is possible to have a lower prevalence of hearing loss than the reference industry and a risk estimate significantly higher than the reference industry; or a higher prevalence of hearing loss than the reference industry and a risk estimate not significantly different than the reference industry. The risk estimates are adjusted for gender and age group. A significant (or non-significant) difference in risk from the reference industry may indicate that gender or age in a particular sub-sector is accounting for less (or more) of the hearing loss than other risk factors such as occupational noise. For example, in

this study, the Vegetable and Melon Farming sub-sector had a lower prevalence of hearing loss than the reference industry, yet had a significantly higher adjusted risk. This indicated that the distributions of age and gender in this sub-sector lowered the prevalence, but when these demographics were controlled, the risk for hearing loss was significantly higher than in the reference industry. The percent of females in this sub-sector was 50%, the highest of any sub-sector and substantially higher than most sub-sectors (including the reference group). This likely explains the lower prevalence, and adjusting for gender allowed the risk from other factors to become apparent.

5 | CONCLUSIONS

Although there are significant challenges to hearing loss prevention efforts in this sector, they can be overcome. OHL is entirely preventable with the right strategies and technology.[3,39] There are well-established methods for controlling noise to safe levels, protecting employees through personal protective equipment, and monitoring workers for changes in their hearing levels[14,41] (29 CFR 1910.95).[24] Within Forestry, strategies include applying acoustic treatment (absorbent material used to reduce sound reverberation), enclosing engines and heavy equipment workstations, installing silencers and mufflers, reducing exposure time for workers operating noisy equipment, performing timely maintenance of hand tools and vehicle systems to reduce noise and vibration, and using anti-vibration (AV) chain saws and gloves.[21] Fishing workers can benefit from regular maintenance to boat engines and equipment (often the primary sources of noise), acoustic enclosures and other engineering controls, and shorter work shifts since exposure predominantly occurs during work time rather than non-work time on the vessel.[8] Within Aquaculture, a study found that simple, relatively inexpensive engineering control solutions significantly reduced worker noise exposures. These included at least partially covering the fish tanks and using standpipe covers.[25] Finally, addressing gaps in regulatory coverage, and providing hearing loss prevention information in a language the worker understands and from trusted sources such as advocacy groups or agricultural extension services, are also critical steps in reducing hearing loss within the AFFH sector.

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TABLE 1

Audiograms excluded from analysis

Reason for exclusion	Number with characteristic	Total Excluded in grouping[a]
Missing value for independent variable[b]	284 064	1 098 361
Missing value for dependent variable[c]	5064	1 098 361
Unlikely threshold values for left ear	3893	1 098 361
Unlikely threshold values for right ear	4338	1 098 361
Large inter-aural difference	510 766	1 098 361
Negative slope[d]	415 595	1 098 361
Not the most recent valid audiogram in time period		3 145 992
All exclusions		4 244 353

[a] Some audiograms were eliminated for more than one reason within groupings.

[b] Industry (NAICS code).

[c] Includes eliminations of affected ear results due to “no response at maximum value” threshold values.

[d] Audiograms depicting negative slope in either ear indicate possible threshold contamination by background noise.

TABLE 2

Agriculture, forestry, fishing, and hunting sector demographics for noise-exposed workers, with estimated prevalence and adjusted probability ratios (PRs) for hearing loss (HL), 2003–2012 (N = 17 299)

Demographic	*n*	(%)	Prevalence of HL (%)	Prevalence 95%CI[a]	PR[b]	95%CI
HL (outcome)						
Yes	2658		15.37	14.00–16.74		
No	14 641		84.63	84.05–85.21		
Missing	0					
Gender						
Male	12 482	72.19	18.84	18.15–19.53	2.81	2.51–3.14
Female (ref)	4808	27.81	6.32	5.63–7.01	Ref	
Missing	9					
Age group (years)						
18–25 (ref)	4180	24.16	2.73	2.24–3.22	Ref	
26–35	5003	28.92	6.30	5.63–6.97	2.32	1.88–2.87
36–45	3824	22.11	15.17	14.03–16.31	5.59	4.59–6.81
46–55	2939	16.99	30.86	29.19–32.53	11.49	9.51–13.88
56–65	1217	7.04	53.25	50.45–56.05	18.95	15.69–22.88
66–75	136	0.79	69.12	61.36–76.89	23.74	19.31–29.20
Missing	0					
Geographical region						
Mid-Atlantic[c]	768	4.48	14.19	11.72–16.66	1.15	1.02–1.30
Midwest[d]	802	4.68	19.70	16.95–22.45	0.93	0.80–1.09
New England[e]	0		ISS[i]		ISS	
South[f]	3279	19.14	17.11	15.82–18.40	0.99	0.90–1.08
Southwest[g]	8674	50.63	13.78	13.06–14.51	1.06	0.98–1.14
West[h] (ref)	3608	21.06	15.69	14.50–16.88	Ref	
Missing	168					

[a] CI = 95% confidence interval.

[b] PRs were adjusted for gender and age-group.

[c] Mid-Atlantic: Delaware, Maryland, New Jersey, New York, Pennsylvania, Washington, D.C.

[d] Midwest: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin.

[e] New England: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont.

[f] South: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, West Virginia.

[g] Southwest: Arizona, New Mexico, Oklahoma, Texas.

[h] West: Alaska, California, Colorado, Hawaii, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming.

[i] ISS, insufficient sample size.

TABLE 3

Estimated prevalence and adjusted probability ratios (PRs) for hearing loss (HL) by industry for noise-exposed workers within agriculture, forestry, fishing, and hunting, 2003–2012 (N = 1 491 729)

Industry (NAICS 2007 Code)	*n*	Prevalence of HL (%)	Prevalence 95%CI[b]	PR[a]	95%CI
All Industries	**1 491 729**	18.95	18.89–19.01		
All industries EXCEPT couriers and messengers (492)	**1 381 759**	19.74	19.67–19.81	1.38	1.36–1.41
Agriculture, forestry, fishing, and hunting (11)	**17 299**	15.37	14.83–15.91	1.40	1.36–1.45
Crop products (111)	**9878**	13.18	12.51–13.85	1.43	1.38–1.50
Oilseed and grain farming (1111)	0	ISS[c]		ISS[c]	
Vegetable and melon farming (1112)	921	7.60	5.89–9.31	1.32	1.07–1.62
Fruit and tree nut farming (1113)	16	ISS[c]		ISS[c]	
Greenhouse, nursery, and floriculture production (1114)	24	ISS[c]		ISS[c]	
Other crop farming (1119)	8917	13.64	12.93–14.35	1.44	1.38–1.50
Animal production (112)	**2973**	16.55	15.21–17.89	1.34	1.25–1.43
Cattle ranching and farming (1121)	421	18.76	15.03–22.49	1.13	0.96–1.33
Hog and pig farming (1122)	12	ISS[c]		ISS[c]	
Poultry and egg production (1123)	2237	15.78	14.27–17.29	1.37	1.27–1.47
Sheep and goat farming (1124)	0	ISS[c]		ISS[c]	
Aquaculture (1125)	303	18.81	14.41–23.21	1.70	1.42–2.04
Other animal production (1129)	0	ISS[c]		ISS[c]	
Forestry and logging (113)	**2204**	21.23	19.52–22.94	1.43	1.35–1.52
Timber tract operations (1131)	1584	21.91	19.87–23.95	1.42	1.32–1.52
Forest nurseries and gathering of forest products (1132)	86	36.05	25.90–46.20	1.60	1.53–1.68
Logging (1133)	534	16.85	13.68–20.03	1.40	1.22–1.62
Fishing, hunting, and trapping (114)	**605**	19.50	16.34–22.66	1.47	1.31–1.64
Fishing (1141)	601	19.47	16.30–22.64	1.46	1.31–1.64
Hunting and trapping (1142)	4	ISS[c]		ISS[c]	
Support activities for agriculture and forestry (115)	**1473**	14.26	12.47–16.05	1.18	1.06–1.31

Industry (NAICS 2007 Code)	*n*	Prevalence of HL (%)	Prevalence 95%CI[b]	PR[a]	95%CI
Support activities for crop production (1151)	1133	16.33	14.18–18.48	1.21	1.08–1.35
Support activities for animal production (1152)	0	ISS[c]		ISS[c]	
Support activities for forestry (1153)	340	7.35	4.58–10.12	1.01	0.73–1.39
Couriers and messengers (492) (ref)	**109 970**	9.08	8.91–9.25	ref	

Bolded values represent a higher level of NAICS.

[a]PRs were adjusted for gender and age-group.

[b]CI, 95% confidence interval.

[c]ISS, insufficient sample size.