Final Progress Report

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Abstract

Washington State experienced a large increase in workers' compensation claims for occupational hearing loss (OHL) during the 1990s, continuing to the present. The findings of studies of these claims, and studies elsewhere, indicate that a substantial segment of the contemporary work force still faces a significant risk for developing OHL. There is a need for actions to address the underlying problems. There is also a critical need for information to guide any actions in a constructive and efficient manner.

This study included two main projects: 1) a telephone survey of people with recent OHL claims, and 2) field evaluation of noise exposures and hearing loss prevention practices at 76 companies in eight industries with higher than average rates of OHL claims. The study also analyzed previously collected pilot data from field evaluations in ten foundries, and incidentally yielded a descriptive study of OHL claims filed during 1984-1998. The overall study had four specific aims.

Aim 1: *To identify the major pathways and influential factors by which individuals with OHL are identified and reported to the workers' compensation system*.

The telephone survey found that the decision by a current or former worker to file an OHL claim is commonly influenced by a number of factors. The most important influence on decisions to file an OHL claim was social contacts, especially family members, but also friends and coworkers.

Several types of health care providers were identified as important or very important influences on decisions to file a claim. Most subjects said a screening program conducted outside of work had an important influence on their decision to file an OHL claim, but they generally described this as less important than other influences, particularly family members and friends.

Only about a quarter of subjects said an advertisement or other media source of information was an important influence, and most did not say it was a very important influence.

There was a relative lack of influence by workplace representatives on decisions to file an OHL claim. This raises concern about the completeness or adequacy with which audiometry findings are communicated to workers when they are tested in workplace annual monitoring programs.

Aim 2: *To identify factors that may have contributed to the increased reporting of OHL in Washington State*.

The telephone survey of did not identify any factors – "smoking guns" – that clearly accounted for why so many more current and former workers chose to file an OHL claim in recent years, than in the past. As noted, most of the surveyed claimants said that a screening program conducted outside of work had an important influence on their decision to file an OHL claim, but they generally described this as less important than other influences, particularly family and friends. It is possible, however, this study underestimated the direct or indirect influence of screening programs, advertisements, and media information on decisions to file a claim.

Aim 3: *To determine whether there is any substantial work-related risk at the present time for OHL in industries with high numbers and/or rates of OHL claims*.

The information provided by the telephone survey subjects about conditions at their most recent noisy job – most of which occurred since OSHA/WISHA hearing conservation regulations were implemented – suggested that many employers are not optimally compliant with regulations. Based on the subject reports, employers in some industries, particularly construction and other non-manufacturing industries, are generally less compliant than employers in other industries.

The evaluation of work sites in selected industries found that excessive noise exposure was common in all of the study industries. Nearly all companies had employee exposures that required a hearing loss prevention program, and more than half had employee exposures that required the employer to consider possible noise controls. In general, the possibility of new noise controls received no or low priority in all of the study industries.

Most of the evaluated companies had substantial shortcomings in their hearing loss prevention programs. In general, there was little difference between industries in the use of noise measurements or consideration of noise controls. However, policies and practices related to employee training, hearing protection, and audiometric testing were generally more complete in some industries than others. Within each industry, there were substantial differences between companies in the completeness of hearing loss prevention policies and practices. Every industry included some companies with relatively complete policies and practices and some companies where policies and practices were substantially incomplete.

Hearing protection was commonly underused. Reported use was highest at companies with relatively complete hearing conservation programs, and in industries where excessive noise exposure was most prevalent and least intermittent. Many employees had difficulty estimating how often, and presumably when, their noise exposure was excessive. This can pose a problem in situations where exposure is intermittent and hearing protection is used only during exposure.

Aim 4: *To assess the effectiveness of using workers' compensation claims information to "target" or identify industries and worksites with remediable risk factors for a chronic occupational health problem, using OHL as a case in point*.

The evaluation of work sites in selected industries found little evidence that claims statistics for OHL – and conceivably for other occupational illnesses that manifest many years after first exposure to a hazard – are useful for identifying industries where there is a high risk for developing that condition and where additional preventive measures are most needed.

In general, the reports by OHL claimants in the telephone survey about their most recent noisy workplace also were not an effective source of information for identifying industries that were substantially more in need of intervention than other industries, nor companies that were more in need of intervention than other companies within the same industry.

It is conceivable that claims statistics or claimants' reports could be useful for targeting specific industries, if supplemented with other information about candidate target industries.

The OHL claims statistics for the study industries showed a significant correlation with the average prevalence of hearing loss on audiometry records in each industry. In industries where OHL claims were more common, monitored employees were more likely to have hearing loss. Claims statistics for OHL – and conceivably other occupational illnesses – may be useful for targeting initiatives to identify workers who have that condition and who may not be aware they have the condition.

Information about the usual extent of noise in an industry is probably a better source of information for targeting interventions to reduce risk for developing OHL, than is information about hearing loss claims, although the two may be useful when considered together. In general, the average completeness of hearing loss prevention policies and practices at work sites in a study industry was strongly associated with the extent of noise overexposure in that industry. Furthermore, the intuitive response to information about noise levels would not necessarily be the best response. The industries with greatest margin for improving hearing loss prevention efforts are not necessarily the noisiest industries, but may be industries where noise exposure is more moderate or intermittent.

Significant Findings

Washington State experienced a large increase in workers' compensation claims for occupational hearing loss (OHL) during the 1990s, continuing to the present. Almost half of these claims involved persons beyond the usual retirement age, indicating at least part of the increase represents hearing loss caused by noise exposures that occurred many years or decades ago. However, the findings of studies of these claims, and studies elsewhere, indicate that a substantial segment of the contemporary work force still faces a significant risk for developing OHL. There is a need for actions to address and remediate the underlying problems. There is also a critical need for information to guide any actions in a constructive and efficient manner.

This study had four specific aims:

- **Aim 1:** To identify the major pathways and influential factors by which individuals with OHL are identified and reported to the workers' compensation system.
- **Aim 2:** To identify factors that may have contributed to the increased reporting of OHL in Washington State.
- **Aim 3:** To determine whether there is any substantial work-related risk at the present time for OHL in industries with high numbers and/or rates of OHL claims.
- **Aim 4:** To assess the relative effectiveness of using workers' compensation claims information to "target" (i.e., appropriately identify) industries and worksites with remediable risk factors for a chronic occupational health problem, using OHL as a case in point.

This study consisted of three related projects:

- **Project 1** involved analysis of data collected by the pilot project, in which noise exposures and hearing conservation practices were evaluated at ten foundries.
- **Project 2** was a cross-sectional study – using telephone interviews – of individuals with workers' compensation claims that were filed during 1997-1998 and accepted for OHL. In addition, the claims data obtained for this project were combined with OHL claims data from a separate project (1984-1996) to conduct a descriptive analysis of OHL claims.
- **Project 3** was a cross-sectional study – evaluating noise exposures and hearing loss prevention activities – at a representative sample of worksites in each of nine industries with relatively high industry-specific rates of OHL claims.

Aim 1: To identify the major pathways and influential factors by which individuals with OHL are identified and reported to the workers' compensation system.

Project 2 originally planned to characterize the "awareness-healthcare-claim pathways," or sequences of events, by which persons become aware of their hearing condition, receive a diagnosis, and enter the workers' compensation system. However, the pilot telephone survey found that many subjects did not know or recall which provider had filed their claim, or the sequence of provider contacts before and after claim filing. In addition, many subjects did not know or understand differences between different types of hearing professionals. Consequently, characterization of the healthcare pathway focused on: the health care provider who was involved in filing the claim; any referral made by that provider; and the referral source for any non-usual provider who was "important" in the decision to file a claim.

*The **Project 2** telephone survey of OHL claimants found that the decision by a current or former worker to file an OHL claim is commonly influenced by a number of factors. The most important influence on individuals' decisions to file an OHL claim was social contacts, especially family members, but also friends and coworkers.*

Several types of health care providers were identified as important or very important influences on decisions to file a claim. Most subjects said a screening program conducted outside of work had an important influence on their decision to file an OHL claim, but they generally described this as less important than other influences, particularly family members and friends.

Only about a quarter of subjects said an advertisement or other media source of information was an important influence, and most did not say it was a very important influence. It is possible, however, that this study underestimated the direct or indirect influence of screening programs, advertisements, and media information on decisions to file a claim.

There was a relative lack of influence by workplace representatives on decisions to file an OHL claim. This raises concern about the completeness or adequacy with which audiometry findings are communicated to workers when they are tested in workplace annual monitoring programs.

- For the majority of individuals with an OHL claim, the decision to file a claim was not triggered by recent awareness of hearing loss or its possible relationship to noise at work, nor by progressive worsening of hearing loss. However, recent information from a health care provider about their hearing loss, and its possible relationship to noise at work, probably had an important influence on a near majority of the subjects. The survey did not attempt to distinguish which provider, or type of provider, communicated this information.
- Several types of health care providers were identified as important or very important influences on many subjects' decisions to file a claim. About two-thirds of subjects said a hearing tester in a screening program outside of work played an important role in their decision to file an OHL claim, although that role was rarely considered very important. In contrast, one-quarter of subjects said their usual health care provider played an important role; however, more often than not, they considered that role to be very important.
- About one-quarter of subjects said a health care provider other than their usual provider played an important, and often very important role, in their decision to file an OHL claim. Most of those providers were otolaryngologists, audiologists, or other hearing-related professionals. Subjects came under the care of those important other providers through a variety of routes, but most often by self-referral. The next most common route was by referral from the subject's usual health care provider.
- Most of the providers who helped subjects file their OHL claim or evaluated them before they filed their claim were otolaryngologists or a type of hearing specialist the subject could not identify. Subjects' usual providers served this role in less than 20% of claims, but generally also referred subjects to a hearing professional.

Since this survey, the State of Washington implemented a requirement that OHL claims be filed within two years after diagnosis of OHL or cessation of occupational noise exposure (i.e., the "date of injury"), to be fully eligible for potential benefits. Claims filed after two years are still eligible for coverage of medical expenses, including hearing aids, but not disability compensation.

In the absence of such a requirement, about half of the subjects, including about one-third of those who were younger than 65 years of age when they filed their claim, did not file their claim in what would now be considered a timely manner.

- In the absence of a two-year filing requirement, there were some identifiable differences between individuals who filed their claim sooner or later than two years after the "date of injury." However, many of those differences were explainable by the difference in age.
- Among subjects who were younger than usual retirement age, those who filed more than two years after the date of injury were, on average, identical in age to those who filed in more timely manner but had ended their last noisy job about five years earlier. It is possible that age – or age-related phenomena such as retirement or impending retirement, onset of concomitant non-occupational hearing loss, particularly presbycusis, or the development of other health problems – may be a more important stimulus than the recency of final noise exposure for filing an OHL claim, at least in the absence of a two-year filing requirement.

Aim 2: To identify factors that may have contributed to the increased reporting of OHL in Washington State.

*The **Project 2** telephone survey of OHL claimants did not identify any factors – "smoking guns" – that clearly accounted for why so many more current and former workers chose to file an OHL claim in recent years, than in the past. As noted, most of the surveyed claimants said that a screening program conducted outside of work had an important influence on their decision to file an OHL claim, but they generally described this as less important than other influences, particularly family and friends. It is possible, however, this study underestimated the direct or indirect influence of screening programs, advertisements, and media information on decisions to file a claim.*

- A majority of survey subjects said hearing screening programs conducted outside of work were important, but not very important, in their decision to file a claim, and a substantial minority said advertisements and media sources of information were important. Most subjects attributed greater importance to family members and other social contacts, whose presence would not be expected to vary substantially from one period of time to another. Of note, subjects who said a screening program was an important influence were even more likely than those who did not say so, to report that family members and friends were important, and even very important, influences on their decision to file a claim.
- This study could have underestimated the influence of advertisements, media information, and screening programs on subjects' decisions to file an OHL claim. It is possible that publicly disseminated information, including intermediate person-to-person communication of that information, could have had a greater indirect than direct influence on subjects' decisions, by stimulating the people whom subjects considered to be important or more important influences. Similarly, it is plausible that the relative importance of publicly disseminated information and screening programs was under-appreciated by subjects.

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***Project 3**, the evaluation of work sites in selected industries, found that excessive noise exposure was common in all of the study industries. Nearly all companies had employee*

exposures that required a hearing loss prevention program, and more than half had employee exposures that required the employer to consider possible noise controls. In general, the possibility of new noise controls received no or low priority in all of the study industries.

- The percent of employees with excessive noise exposure differed significantly between the study industries. However, excessive exposure was common in all industries. In addition, the percent of employees with excessive noise exposure differed widely between companies within most of the study industries.
- Excessive employee noise exposure would have been 1.5 to 3 times more common if the NIOSH-recommended L_{eq} was used to characterize full-shift noise exposures, rather than the OSHA-specified L_{ave}.
- Employee noise exposures were relatively continuous at lumber mills. However, In all other industries, employee exposures generally were intermittent, and most employees spent at least several hours daily in areas where noise levels were under 85 dBA.
- In general, the possibility of new noise controls received no or low priority in all of the study industries. The study team judged that it would have been feasible for all or nearly all of the participant companies to implement one or more effective noise controls, at reasonable cost, to achieve a meaningful reduction in noise exposures for one or more employees. However, most companies had insufficient information about noise exposures in their workplace, and most had no plans to consider or implement any new noise controls.

Most of the evaluated companies had substantial shortcomings in their hearing loss prevention programs. In general, there was little difference between industries in the use of noise measurements or consideration of noise controls. However, policies and practices related to employee training, hearing protection, and audiometric testing were generally more complete in some industries than others. Within each industry, there were substantial differences between companies in the completeness of hearing loss prevention policies and practices. Every industry included some companies with relatively complete policies and practices and some companies where policies and practices were substantially incomplete.

- Employers are required to provide hearing loss prevention training upon first assignment of a new or relocated employee to a noise exposed position, and at least annually thereafter for all exposed employees. Annual training was not conducted by more than one-third of companies, and training had shortcomings at many other companies. Many employees who had annual training at their present company did not recall ever having such training.
- Employers are required to provide at least two different types of hearing protection for noise exposed employees. At most companies, all or nearly all employees reported that hearing protectors were readily available for them at no personal cost, although this was often limited to only one type of protector. However, at 25% of companies, between 11% and 48% of employees said that no hearing protectors were readily available for them.
- Employers are required to ensure that employees use appropriate hearing protection when noise exposure is excessive. Most company representatives reported no formal company policy or enforcement practices requiring use of hearing protection, either in the entire production area or in specific noisy areas. According to employees, however, hearing protector use policies were more common than reported by company representatives. The findings suggest a need for more enforcement at many companies and improved coordination of enforcement policies at other companies.

Hearing protection was commonly underused. Reported use was highest at companies with

relatively complete hearing conservation programs, and in industries where excessive noise exposure was most prevalent and least intermittent. Many employees had difficulty estimating how often, and presumably when, their noise exposure was excessive. This can pose a problem in situations where exposure is intermittent and hearing protection is used only during exposure.

- Overall, only 62% of interviewed employees said they always or almost always used hearing protection when they were exposed to loud noise. The reported use of hearing protection differed significantly between industries and, in general, was highest in industries where excessive noise exposure was most prevalent and least intermittent. The reported use of hearing protection was also generally highest at companies with relatively complete hearing conservation programs, particularly companies with actively enforced requirements to wear hearing protection. This suggests that greater company effort to ensure hearing protection can, on average, result in better employee hearing protective behavior.
- Overall, 25% of employees said they sometimes used hearing protection when they were exposed to loud noise, and another 13% said they either never (or almost never) used protection or were never exposed. It may be appropriate to consider these distinctions in endeavors to increase the use of hearing protection.
- Employees were often incorrect in estimating how often – and presumably when – they were exposed to loud noise. A commonly taught rule-of-thumb guideline for estimating noise levels was found to have limited reliability. This inaccuracy of employee perception could pose an important problem in industries where noise levels are intermittent and hearing protection may not be needed continuously, unless employees are given more than subjective guidelines for when and when not to wear hearing protection.

Hearing loss was common on existing audiometry for current and recent employees.

- Overall, 15% had enough hearing loss to meet American Medical Association criteria for impairment, and another 11% had moderate or worse high frequency loss without impairment. Among employees 55 years or older, 53% had evidence of impairment, and another 21% had moderate or worse high frequency hearing loss.
- Hearing loss was significantly more common in some industries than others. The difference between industries in the extent of hearing loss was seen in all except the youngest age group of employees, suggesting that the risk of hearing loss continues to the present, in at least six of the study industries.
- Employers are required to inform employees about abnormal findings on audiometry, and such findings can provide an important teaching opportunity, to inspire an employee to improve personal efforts to protect his/her hearing. However, the majority of workers whose audiometry revealed a clinically significant amount of hearing loss had not been informed – or did not recall being informed – that their audiometry showed an abnormality. More than a third had no tell-tale symptoms of hearing loss and were unaware of their hearing loss.
- Employers are required to provide written notification and training to individual employees who have a specified amount of hearing change over time, known as a standard threshold shift (STS). This important early indicator of possible noise effects on hearing was not being used effectively. Most employees whose audiometry showed an STS while they were employed at the present company did not recall ever being informed of that finding, and only about half of those who thought they had an STS had truly experienced one. Employee recollection of this important indicator was essentially no better than a random guess.

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***Project 3**, the evaluation of work sites in selected industries, found little evidence that claims statistics for OHL – and conceivably for other occupational illnesses that manifest many years after first exposure to a hazard – are useful for identifying industries where there is a high risk for developing that condition and where additional preventive measures are most needed.*

*In general, the reports by OHL claimants in the **Project 2** telephone survey about their most recent noisy workplace also were not an effective source of information for identifying industries that were substantially more in need of intervention than other industries, nor companies that were more in need of intervention than other companies within the same industry.*

It is conceivable that claims statistics or claimants' reports could be useful for targeting specific industries, if supplemented with other information about candidate target industries.

- This study evaluated companies in a limited number of industries, mostly in manufacturing, and included only one primary production industry, one construction industry, and no industries within the broad sector of "other" industries. Therefore, the study findings may have limited generalizability, particularly for the industries outside manufacturing sectors.
- The OHL claims statistics for the study industries showed no consistent relationship with either the average extent of employee overexposure to noise or the average completeness of hearing loss prevention policies and practices, at companies evaluated in those industries.
- One study industry, road construction, was an exception to this general conclusion. This industry had a very high incidence rate of OHL claims, and the companies evaluated in this industry tended to have substantially incomplete hearing loss prevention policies and practices. However, the average extent of employee overexposure to noise and completeness of hearing loss prevention policies and practices in this industry were comparable to what this study found in other industries with much lower rates or absolute numbers of OHL claims.
- Information about OHL claims may have limited or no usefulness for identifying specific companies where there is a relatively high need for additional preventive measures. Individual companies were no more likely to have incomplete hearing loss prevention policies or practices, if they had been assigned liability for one or more OHL claims or if an OHL claimant described them as a recent noisy workplace, compared to other companies that were not linked to an OHL claim, in the same industry.

The OHL claims statistics for the study industries showed a significant correlation with the average prevalence of hearing loss on audiometry records in each industry. In industries where OHL claims were more common, monitored employees were more likely to have hearing loss. Claims statistics for OHL – and conceivably other occupational illnesses – may be useful for targeting initiatives to identify workers who have that condition and who may not be aware they have the condition.

Information about the usual extent of noise in an industry is probably a better source of information for targeting interventions to reduce risk for developing OHL, than is information about hearing loss claims, although the two may be useful when considered together. In general, the average completeness of hearing loss prevention policies and practices at work sites in a study industry was strongly associated with the extent of noise overexposure in that industry. Furthermore, the intuitive response to information about noise levels would not necessarily be the best response. The industries with greatest margin for improving hearing loss prevention efforts are not necessarily the noisiest industries, but may be industries where noise exposure is more moderate or intermittent.

Scientific Report

A OVERVIEW

Washington State experienced a large increase in workers' compensation claims for occupational hearing loss (OHL) during the 1990s, continuing to the present.[1] Almost half of these claims involve persons beyond the usual retirement age, indicating at least part of the increase represents hearing loss caused by noise exposures that occurred many years or decades ago. However, the findings of studies of these claims, and studies elsewhere, indicate that a substantial segment of the contemporary work force still faces a significant risk for developing OHL. There is a need for actions to address and remediate the underlying problems. There is also a critical need for information to guide any actions in a constructive and efficient manner.

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  In addition, the claims data obtained for this project were combined with OHL claims data from a separate project (1984-1996) to conduct a descriptive analysis of OHL claims.
- **Project 3** was a cross-sectional study – evaluating noise exposures and hearing loss prevention activities – at a representative sample of worksites in each of nine industries with relatively high industry-specific rates of OHL claims.

  The nine study industries were:
  - Road construction
  - Lumber milling
  - Pulp and paper production
  - Heavy gauge metal fabrication
  - Machine shops
  - Sheet metal fabrication
  - Fruit and vegetable processing (i.e., packing, canning and freezing)
  - Printing
  - Wood product manufacturing

B BACKGROUND

Occupational hearing loss (OHL) provides an excellent model for studying the preventability of chronic occupational illnesses. There are fewer gaps in knowledge about OHL than for virtually all other occupational illnesses, and the primary barriers to prevention lie in implementation of that knowledge. If workers cannot be effectively protected against the development of OHL, then one must question how workers could ever be protected against other, more complex or less well understood hazards.

B.1 Occupational noise induced hearing loss

Noise induced hearing loss is one of the most common, best understood, and readily preventable occupational illnesses. The dose-response relationships between repeated noise exposure and hearing loss are well understood,[2] more so than for almost any other occupational health hazard. Studies in the 1980s concluded more than nine million workers in the U.S. are exposed daily to potentially harmful levels of noise.[2] Fortunately, noise is easily measurable with widely available and affordable instruments. Similarly, the most prevalent health effect of noise, hearing loss, is readily detectable at early stages of development using a commonplace clinical instrument, the audiometer, potentially before symptoms or clinically important dysfunction can manifest. Detection of the hazard or the health effect can occur in time to take actions to prevent development or progression of hearing loss. There are well established noise control strategies and affordable personal protection devices that can, in principle, reduce almost any worker's noise exposure to levels that are widely recognized as safe. Finally, federal and state regulations have been in place since the 1980s, requiring employers to implement noise controls or other hearing loss prevention measures, when noise exposures reach action or permissible levels.

The consequences of occupational noise exposure can be devastating for the affected worker. Hearing loss, which often develops and progresses insidiously, may not reach a level that is bothersome to the worker until decades later in life, when effects of aging on hearing ability can compound any previous injury caused by noise. Unfortunately, personal protective efforts at that point in life generally have much less benefit than if they had been used sooner in life. The progressive onset of hearing loss can impact a worker's life in myriad ways. At work, the inability to hear important production sounds, warning sounds, or communication can predispose a worker to making errors or experiencing an injury. Outside of work, hearing loss may cause or contribute to social withdrawal, strained personal relationships, and inability to appreciate enjoyable sounds such as music, children's voices, and sounds of nature. Tinnitus, or ringing in the ear, is another common consequence of repeated noise exposure.[3] For some, tinnitus can be even more distressing than the loss of hearing.

In spite of its preventability, noise induced hearing loss remains a prevalent occupational health problem. In Washington state, for example, the annual number of workers' compensation claims for hearing loss increased more than ten-fold in a decade, with annual disability compensation costs exceeding $50 million in recent years.[1] Much of this increase occurred among individuals older than the usual retirement age, suggesting the increase is at least partially a reporting phenomenon and not related to contemporary work circumstances. Credible explanations include noisy work conditions that existed in the past but that may no longer exist, and possible changes in clinical service and marketing practices. However, substantial increases in claims also occurred among younger individuals who have more recent or ongoing noise exposures, suggesting that recent or current workplace practices may place contemporary workers at risk for hearing loss. The magnitude of the claims increase and uncertainty make it important to evaluate the current extent of occupational noise exposure and adequacy of hearing loss prevention efforts.

B.2 Hearing loss prevention

In Washington state, when an employee's average noise exposure can reach or exceed 85 dBA (decibels), employers must maintain an effective hearing loss prevention program. The hearing loss prevention rule, formerly the hearing conservation rule, was recently updated and rewritten for clarity and ease of use, but the basic requirements are largely unchanged since 1984.[4] A hearing loss prevention program must include representative noise monitoring, employee training, appropriate hearing protection, audiometric monitoring, and ongoing program evaluation. When employee exposures reach 90 dBA, the employer must utilize feasible noise controls. The Washington rule applies to construction and agriculture, as well as fixed industry.

There are several lines of evidence that hearing conservation efforts can be effective. Longitudinal surveillance in Sweden and British Columbia, Canada, has shown declines in rates of hearing loss after implementing industry-wide, comprehensive hearing conservation programs.[5,6] Large manufacturing companies have reported similar success reducing rates of hearing loss with hearing conservation programs.[7,8] A larger number of studies have examined training and related interventions and found increases in workers' use of hearing protection, at least in the short term.[9] It is reasonable to assume, although it is not clearly established, that increased and continued use of hearing protection will in the long term lead to reductions in hearing loss.

Reducing or eliminating a hazard is generally the preferred strategy for mitigating the associated health risk. However, personal hearing protection devices, rather than noise controls, remain a cornerstone of most contemporary hearing loss prevention programs. Unfortunately, many investigators have found that hearing protectors are commonly underused in noisy industries,[10,11] although studies of temporal trends indicate that usage has increased in recent times.[12]

B.3 Surveillance: Closing the loop

Workplace noise and OHL provide a framework for testing strategies to "close the loop" in surveillance for occupational illness.[13] Closing the loop means making the final, essential steps. One definition of surveillance is, "continuous analysis, interpretation, and *feedback* of systematically collected data.... By observing trends in time, place, and persons, changes can be observed or anticipated, and *appropriate action*, including investigative or control measures, can be taken."[14]

Occupational illnesses, with latency periods that may span years or decades, present extreme challenges for surveillance systems. The most hazardous situations or places that caused cases seen today, may no longer exist, at least not in the same places. With hearing loss, there is a good chance that operations that were noisy enough in the past to cause hearing loss, are still noisy. However, it is now twenty years since hearing conservation regulations came into effect, and historically noisy workplaces and industries may, or may not, have already taken the necessary and required steps to prevent new cases of hearing loss.

There is limited experience with action-oriented surveillance for OHL. At least two state SENSOR (Sentinel Event Notification Systems for Occupational Risks) programs include a focus on hearing loss, but generally more effort has been directed to other conditions.[15] In one study, investigators interviewed 1,378 individuals with a fixed hearing loss, out of 1,477 reported to the state of Michigan during 1992 to 1997.[12] Descriptive statistics were compiled. In addition, based on the interviews plus review of State OSHA reports of past inspections at companies mentioned by interviewees, 43 work sites were identified for inspection: 23 had excessive noise levels, and 17 of those had a deficient or no hearing conservation program. The investigators concluded that the targeted inspections helped to protect 758 noise-exposed workers in those 17 facilities.

The primary goal of the present study was to explore further the use of information from workers' compensation claims for surveillance of OHL.

C INSTITUTIONAL REVIEW

All study procedures were initially reviewed and approved by institutional review boards (IRBs) at the University of Washington (UW) *and* at the State Department of Health (DOH). After the initial review, modifications to study procedures were reviewed and approved only by the UW IRB, as agreed by all parties under the existing UW/DOH cooperative agreement. All transfers of data from DLI to the UW researchers were overseen by Barbara Silverstein or Steven Cant, DLI employees designated in a DLI/UW Memorandum of Understanding to serve as a Data Utilization Supervisor.

D PROJECT 1 – Pilot Project

The goal of the pilot project was to determine, in a noisy industry with high rate of OHL claims, whether contemporary hearing loss prevention practices were sufficient to reduce the risk of hearing loss from noise exposures in that industry. The methods and findings are described in a published journal article,[16] which is included as **Appendix 1**, and are summarized here.

Funds from the present grant were used only to support analysis of data, which had been collected previously. The work site evaluations were conducted by the Washington State OSHA (WISHA) as a special emphasis program, primarily in one region (King County, which includes Seattle). Daniell and Swan collaborated with the WISHA team to develop a systematic protocol for evaluating compliance with the State noise and hearing conservation regulation, at targeted work sites. Swan, working as a student intern at WISHA, had primary responsibility (overseen by DLI inspectors) for conducting the noise component of each inspection.

D.1 Methods

D.1.1 Population and study sample

The WISHA team chose **foundries** as the target industry, in part because of the high number and rate of hearing loss claims, but also because of the number of hazards in this industry besides noise. Twenty-nine candidate companies were identified. Ten were selected for inspection based on their larger size, presence on another WISHA targeting list, and/or prior history of a WISHA citation (but not within the preceding two years).

D.1.2 Data collection:

In summary, the work site evaluations included:

- **Dosimetry:** Full-day, personal noise dosimetry was conducted for a representative sample of employees (n=86) in jobs where noise exposures were most likely to exceed 85 dBA.
- **Interviews:** The management representative responsible for hearing loss prevention activities and a sample of employees underwent a structured interview. The employee sample included all employees (except one) who wore a dosimeter, plus a convenience sample of 40 employees in noise-exposed jobs. Interviews were excluded for 33 employees who could not speak English well enough to complete all of the interview. Summary scores were calculated for the 92 employee interviews and the 10 management interviews, using the number of favorable responses on selected, representative, non-duplicated questions.
- **Audiometry:** Existing audiometry records were reviewed for 305 employees who were tested at the most recent annual session, at the eight companies that had conducted any testing. Audiometry was available for 86 interviewed employees. Records were reviewed for the presence of hearing loss and any past occurrence of a "standard threshold shift" (i.e.,

the amount of hearing loss over time that triggers the WISHA requirement for employer actions including written notification of the affected employee).

D.2 Results and Conclusions

In summary, Project 1 found that:

- Employee full-shift noise exposures routinely exceeded 85 dBA, the level at which a hearing loss prevention program is required in Washington.
- All ten foundries had serious, citable deficiencies in their hearing loss prevention programs.
- Employees often were not aware of important findings on their audiograms, including hearing loss or a standard threshold shift.
- There was a strong positive correlation between the management interview score and the average employee interview score at each work site ($r=0.70$, $p=0.02$). This suggests that companies where more effort is put into compliance with hearing loss prevention requirements can achieve a greater favorable impact on employee awareness of noise and efforts to prevent hearing loss.
- Companies with the highest interview scores still had broad deficiencies in their hearing loss prevention programs. This indicates that workers in this industry probably face a continuing substantial risk of OHL.

E PROJECTS 2 AND 3 – Shared methods

E.1 Study population

The study samples for Projects 2 and 3 were drawn from the population of workers and employers whose industrial insurance is provided or regulated by the Washington State Department of Labor and Industries (DLI). The DLI regulates workers' compensation covering nearly all non-federal employers and workers in the state, except for workers covered by special laws or programs, self-employed individuals, corporate officers, and domestic employees. About 400 employers, generally among the largest in the state, have individual self-insured programs, providing coverage for approximately one-third of workers in the DLI jurisdiction. Self-insured programs are regulated by DLI, and limited information about each self-insured claim is reported to DLI. The DLI administers the State Fund, which directly provides industrial insurance for the other two-thirds of workers. The State OSHA program, WISHA, is also based in the DLI.

The study population for Project 3 was restricted to employers listed in one of the nine industry categories chosen as a "target" industry for this study (see below).

E.2 Data sources

The study populations for Projects 2 and 3 were identified using DLI industrial insurance records. The DLI Insurance Services Division maintains computerized databases with administrative data for workers' compensation claims filed in the DLI jurisdiction. The records used for the study were:

- **OHL Claims, 1997-1998:** The primary data source for identifying the claimant population in Project 2 was DLI records for workers' compensation claims that had filing dates during 1997-98 and were accepted for OHL. Information in the DLI records includes: claimant identity, contact information, and demographics; condition reported at claim filing; administrative dates and outcomes; and employer identification. The reported condition was coded by DLI with U.S. Department of Labor Z16.2 codes

  Claims were identified using inclusion criteria adapted from a previous study of OHL claims:[1] (1) the claim was filed during 1/1/97 to 12/31/98; (2) the claim was subsequently accepted for a work-related condition; and (3) Z-16.2 codes for the condition reported at filing were: (a) nature of illness or injury = hearing loss (230), and/or (b) source of illness or injury = noise (4400). There were 10,180 claims that met these criteria.

  Industry was coded by DLI with DLI "risk classes," which are used for industrial insurance premium adjustment purposes. For this study, risk classes were grouped into about 100 larger industry categories using standard and modified DLI classifications.[1,17,18]

- **OHL Claims, 1992-1996:** The study also utilized records for OHL claims filed during 1992-1996, together with the records for 1997-1998 OHL claims, to produce industry-specific summary statistics for selecting the nine "target" industry categories. These claims were identified using the same criteria as above, but with a filing date during 1/1/92 to 12/31/96. There were 12,280 claims that met these criteria.

- **Employment, 1992-1998:** The DLI provided summary data for the total hours of reported employment (i.e., summed for all employers) in all DLI risk classes, for each year during 1992-1998, separately for State Fund and self-insured employers. These data were used to calculate industry-specific incidence rates of OHL claims. By DLI convention, employment hours were divided by 2,000 to estimate the number of "full-time equivalent" (FTE) workers, and that figure was used to calculate industry-specific incidence rates of OHL claims.

- **Employers, 2000:** The primary data source for identifying the employer population in Project 3 was DLI records for all employers who, at the time of data extraction (2000), reported any hours of employment in the nine target industry categories, whether or not the employer was linked to an OHL claim. The records included: employer identity, contact information, and total hours of reported employment, by risk class. The employer records were linked to the 1992-1998 claim files to determine whether the employer was liable for an OHL claim filed during that period.

E.3 Target industries

Industry-specific statistics for OHL claims were used to select nine "target" industries that broadly represented the observed distribution of those statistics across the 106 industry categories, based on claims filed during 1992-1998.

The industries were categorized on the basis of their **prevention index**.[19] The prevention index (PI) is based on the ranked industry-specific number of claims and the ranked industry-specific incidence rate of claims, and is calculated as the average of those ranks in each industry. An industry with a higher number and higher incidence rate of OHL claims has a lower PI. The PI distribution was divided into quartiles, among prevention index values that were lower than the PI median value (PI $\leq$53), and three industries were selected from each of three categories: quartile 1 (ranked PI, 1-13); quartile 2 (14-26); and quartiles 3 and 4 (27-53).

Other **selection criteria**, based on data in the DLI database, were: (1) $\geq$20 employers in the industry with $\geq$10 but <500 employees, and a business address in the extended Puget Sound region, making it feasible to drive from UW to a work site and back in one day; and (2) overall diversity in the types of selected industries. Some industries were excluded or assigned low priority for selection: (1) logging, because work sites are transient and far from UW; and (2) construction, because work sites are transient and often involve more than one employer. Road construction was selected for the study because work sites primarily involve one employer, and the industry has a very high OHL claims incidence rate. The fruit and vegetable processing industry was selected in spite of the distance to work sites, because additional funding became available to cover overnight travel expenses.

The selected target industries and the abbreviations used for them in this report were:

• Road construction	RC
• Lumber milling	LM
• Pulp and paper production	PP
• Heavy gauge metal product manufacturing	HM
• Machine shops	MS
• Sheet or stamped metal product manufacturing	SM
• Fruit and vegetable processing (i.e., packing, canning and freezing)	FV
• Printing	PR
• Wood product manufacturing	WP

The DLI risk classes that defined each industry are listed in **Table E1**.

E.4 Statistical measures of OHL claims

The number, incidence rate, and prevention index of OHL claims in each industry are shown in **Table E2**. In most tables in this report, and in the list above, the target industries are listed in order of the industry-specific incidence rate for OHL claims filed in 1997-1998. Although selection of target industries was primarily based on the OHL claims prevention index, the

incidence rate was chosen as the basis for list order of the industries, because this measure showed a very high correlation with the prevention index (see below), and because incidence rates are generally more widely understood by readers than the prevention index.

It is noteworthy that the annual number of OHL claims increased during the 1992-1998 period. Overall, the statewide average incidence rate increased 1.8-fold, from 1.39 claims per 1,000 FTEs per year in 1992-1996 to 2.56 in 1997-1998. The OHL claims filed in the last two years, 1997-1998, represented 45% of all OHL claims filed during the entire seven year period, 1992-1998. Some industries experienced more change than others. However, all of the selected target industries remained in the same prevention index category throughout the 1992-1998 period, except for one, fruit and vegetable processing (**Figure E1**). The OHL claims incidence rate increased 3.1-fold in that industry, from 1.67 in 1992-1996 to 5.15 in 1997-1998.

There was a high degree of correlation between the three measures of OHL claims within industries, particularly among the target industries. Considering only the claims filed during 1997-1998 and the industries eligible for the study (PI $\leq$53), Pearson correlation coefficients were moderately high between the prevention index and number of claims ($r= -0.71$, $p<.001$) or incidence rate ($r= -0.49$, $p<.001$). In contrast, there was no significant correlation between number of claims and incidence rate ($r = 0.20$, $p=.15$). When only the nine target industries were considered, the amount of correlation was even higher, between all three measures: PI-number, $r= -0.83$ ($p=.005$); PI-incidence, $r= -0.90$ ($p=.001$); and number-incidence, $r= 0.76$ ($p=.02$). Correlation coefficients were very similar for the measures of 1992-1998 claims.

These associations reflect influences of the industry selection criteria. The criteria weighed against smaller industries even if they had a high claims incidence rate. For example, pile driving and dredging had an incidence rate of 66.8 (claims per 1000 per year) but "only" 12 claims per year and 90 FTE workers, during 1997-1998. The criteria also weighed against large industries, particularly those with a small number of large employers. For example, aircraft manufacturing had the seventh highest number of OHL claims (n=398) and a prevention index of 39, but had a below-average claims incidence rate (1.92), and predominantly represented one very large employer.

F PROJECTS 2 AND 3 – Descriptive study of OHL claims, 1984-1998

The claims data obtained for this project were combined with OHL claims data from a separate project (1984-1996) to conduct a descriptive analysis of OHL claims. The results were published in a journal article, included as **Appendix 2**.

F.1 Results

In summary, the analysis of OHL claims found:

- The number of claims increased 12-fold during 1984-1998. The annual incidence reached 2.6 claims per 1,000 workers statewide, and 70/1,000 in the most impacted industry.
- Most claimants (90%) received permanent partial disability compensation. In 1998, the identifiable medical and disability costs exceeded $57 million dollars.
- **Jurisdiction:** The increase in claims and the average amount of associated impairment was higher for claims filed with the State Fund than for claims filed with self-insured employers.
- **Industry:** During 1992-1998, the incidence of OHL claims was highest in primary production and construction industries, averaging nine claims per 1,000 workers per year, and accounting for half (49.5%) of all OHL claims but only 9.5% of the work force covered by DLI. The manufacturing and service sectors each accounted for about 20% of OHL claims. These statistics may point to industries with the greatest risk for hearing loss, at least in the past, but conceivably still at present.
- **Claimant age:** The greatest increase occurred with individuals who were older than 65 years of age when they filed their claim. Retirement-age claimants accounted for almost half of the claims filed in 1998. Therefore, a large share of the OHL claims "epidemic" was undoubtedly caused by noise exposures that must have occurred well in the past. However, the increase in claims was evident among individuals who were as young as their mid 30s. Even though these workers' earliest injurious noise exposures may have occurred a decade earlier, it was likely that those noisy situations had not disappeared in that time. Therefore, claims data, at least for pre-retirement age claimants, may have surveillance utility.
- **Providers:** A small number of providers accounted for a major share of the claims. Among providers who helped file a claim during 1992-1996, 4% of providers accounted for 66% of claims. This finding, and the marketing strategy used by many hearing aid vendors in this state ("If you feel that you have a hearing loss which was caused by a work situation, whether present or in your past history, you may be eligible for compensation...."), suggested that a shift in reporting practices might account for much of the observed rise in claims. If this reporting bias was differential (i.e., if marketing had been focused on people in particular industries), then the relative differences in industry incidence rates might have a very limited relationship to the past or present disease risk.

F.2 Conclusions

The striking increase in OHL claims was probably due in large part to reporting phenomena unrelated to current work circumstances. However, OHL is probably much more common than usually recognized, and contemporary workers may still face substantial risk for hearing loss.

G PROJECT 2 – Telephone Survey of OHL Claimants

G.1 Methods

Project 2 was a cross-sectional study – using telephone interviews – of individuals with workers' compensation claims that were filed during 1997-1998 and accepted for OHL.

G.1.1 Sample selection

The study population included all individuals who had a DLI workers' compensation claim that was filed during 1997-1998 and was accepted for OHL (see section E.2).

The potentially eligible claimants were divided into samples:

- **Sample A** was selected by stratified random sampling from the population of 1997-1998 OHL claimants, excluding claimants who were from one of the target industries and were <65 years old when they filed their claim (see sections E.2 and E.3). The eligible population was categorized by age and jurisdiction (see below), producing eight age-jurisdiction cells, and potential subjects were selected randomly within each cell. Claimants who were selected but not recruited into the study were replaced with another randomly selected claimant until the recruitment goal for each cell was attained. The recruitment goal in each cell approximated the population distribution.

	≤55 yrs	55.1-65 yrs	65.1-75 yrs	>75 yrs	
State fund	75	109	111	75	370 (70%)
Self insured	31	40	40	30	141 (30%)
	106 (20%)	149 (30%)	151 (30%)	105 (20%)	511

An **error** occurred during selection of Sample A. The exclusion of claimants from the target industries was inadvertently extended to *all* claimants in eight of the nine industries (not LM), regardless of age. Consequently, the study sample did not include claimants >65 years old from those eight industries. In view of this, analyses of survey data relative to industry were stratified by subject age (i.e., subjects ≤65 and >65 were analyzed separately).

- **Sample B** was selected in similar manner within the nine targeted industry categories, restricted to claimants who were ≤65 years old when they filed their claim. The recruitment goal of n=30 in each industry category was not achieved in two industries (printing, n=20; wood products manufacturing, n=28). Two extra subjects were recruited in one industry (road construction, n=32), yielding an overall sample size of n=260.

  The recruitment goal of 30 subjects from the population of 1997-1998 OHL claimants was not achieved in six target industries (WP, PR, FV, HM, SM, MS). Therefore, eligibility in those industries was expanded to include individuals with an OHL claim filed in the two previous years (1/1/1995 to 12/31/1996). This yielded 39 subjects in total, ranging from 2 (MS) to 11 (WP) in each target industry.

G.1.2 Subject recruitment

Recruitment was conducted by a private research survey contractor, Gilmore Research. Individuals identified as potential subjects were mailed informational material about the study, describing: reasons for the study; why and how the individual was selected; their right to refuse participation without loss of benefits; content and procedures of the survey; steps taken to protect privacy; and investigator contact information. Individuals were then contacted by

telephone, using the number in DLI records. If no telephone number was listed in DLI records or if it was not valid, public telephone directory records were searched for a new listing, within Washington state and adjoining areas in Oregon and Idaho. Upon contact, the interviewer presented an introductory script, read the mailed material if the individual desired, and answered questions. Interested, eligible individuals provided verbal consent to participate.

G.1.2.a *Eligibility*

Individuals were eligible for the survey if it was confirmed that the individual had a workers' compensation claim that was: in the DLI jurisdiction, as a State Fund or self-insured claim; filed or reopened in 1997 or 1998; and accepted (with no pending review of a protest or appeal) for hearing loss that was attributed at least in part to chronic noise exposure at work.

As noted in section G.1.1, eligibility was modified to include OHL claimants from 1995-1996, to achieve maximum recruitment in six target industries (n=39). Another 5 subjects filed their OHL claim during 1992-1996 but were eligible because their claim was reopened during 1997-1998.

G.1.2.b *Exclusions*

Exclusion criteria were: limited or no English skills; hearing or other impairment that rendered survey completion impossible; or failure or refusal to complete the survey in a satisfactory manner. There were not enough potential study subjects to justify adapting the survey for Spanish language or TDD (Telecommunications Device for the Deaf) administration.

Subject recruitment is outlined in **Figure G1**. Of 1,976 claimants selected as potential subjects, about 15% could not be contacted (i.e., no valid phone number, phone disconnected, or repeated non-answer). In another 18%, a connection was made but pre-connection information was found to be incorrect (i.e., no such person, no DLI claim, no OHL claim, or claim for *acute* OHL). Of 1,334 individuals where a phone connection was made and eligibility was confirmed, 26% chose not to participate, 9% were not available after repeated contacts, 7% were excluded (i.e., non-English speaking, severe hearing problem, or deceased), and 58% participated.

G.1.3 Survey procedure

The survey was conducted by trained, experienced interviewers using computer-assisted telephone interview software. The mean interview duration was 19.7 minutes (SD 6.0).

After a pilot test of the survey and refinement of survey questions, the survey was conducted between October 2000 and May 2001. On average, this was 3.0 years after claim filing (standard deviation, SD, 0.7). Nearly all (97%) of the interviews were conducted within 1.8 to 5.0 years after claim filing (maximum 6.0 years).

The survey consisted of structured statements and questions regarding: study eligibility; hearing status, at the time of the interview and five years earlier; year of first awareness of hearing loss and possible noise relationship; providers involved in filing OHL claim; importance of specific people and things in the decision to file a hearing loss claim; personal background, including military experience and weapons use; and employment information, especially the most recent noisy job. Hearing status was assessed with five questions adapted from the Hearing Handicap Inventories for Adults and Elderly.[20]

Questions about the timing of past events were phrased relative to the time of the interview, rather than the time of claim filing, generally using answer options with 5 to 10 year intervals. This approach made it easier for subjects to answer questions and also minimized focusing subjects' recall efforts on claim filing. Allowing for the average of 3 years between claim filing and the phone survey, events that happened within five years of the survey would generally have been close to the point in time when subjects filed their OHL claim.

Questions about the importance of specific people and things were preceded by the statement, "Some people with hearing loss from work do not file a workers' compensation claim at all, and some people wait a while before they finally decide to file a claim. These next questions are about what people or things were important in your decision to file a claim." The individual questions were phrased, "Was/were [item] important in your decision to file a claim with L&I, even a little important?" Positive answers were followed with a question about degree of importance.

Two CATI programming **errors** were discovered after the survey was completed. First, 154 subjects who reported that a final decision on their OHL claim was still pending were not asked about the health care provider involved in filing the claim nor about referrals by that provider. Second, 42 to 56 subjects who reported having tinnitus for less than five years were not asked about their hearing ability five years ago.

G.1.4 Data analysis

Subjects from samples A and B were weighted equally in data analyses, and no adjustments were made for the over-sampling of subjects from the nine target industries. Most analyses used the overall sample (i.e., Samples A and B combined).

Comparisons were structured around three subject groups, defined by age at time of claim filing and the DLI-determined date of “injury” (also called the date of manifestation, i.e., the date of diagnosis or the date of last injurious exposure, whichever is earlier): subjects who filed within two years after the date of injury (47%; named “timely filers” for this study); and subjects who filed at a later date (“late filers”), divided according to their age at filing, ≤65 years (23%) or >65 years (29%). Only 30 subjects who filed their claim within two years after the date of injury were over age 65; therefore, the first group was not divided by age. The selection of two years after date of injury for categorizing subjects was based in part on State legislation in 2003 that imposed a statute of limitation – “within two years of the date of the worker's last injurious exposure to occupational noise” – for filing an OHL claim and receiving full benefits.[21]

Industries were categorized on the basis of their 1997-1998 OHL claims prevention index (PI), in the manner described in section E.3. The PI distribution was divided into quartiles, among PI values that were lower than the PI median value (PI ≤53). The "very low PI" category consisted of 13 industries with lowest PI values (rank PI, 1-13), and the "low PI" category, 13 industries with next lowest PI values (rank PI, 14-26). All other industries (rank PI, >26) were assigned to the "moderate or higher PI" or "other" category.

Very low PI:
- Logging
- Department of Energy (Hanford site)
- Lumber milling [LM]
- Road construction [RC]
- Miscellaneous construction and erection
- Construction: installation of machines/equipment
- Pulp and paper production [PP]
- Construction: clearing, grading, excavating
- Construction: plumbing, HVAC and sheet metal
- Rolling mills; pipe, tube, wire, wire rope mfg
- Carpentry
- Mining, quarrying, digging, crushing
- Ore dressing, smelting, refining

Low PI:
- Machine shops [MS]
- Truck, bus, auto operation

- Construction: conduits, sewers, tunnels, drilling
- Heavy gauge metal product mfg [HM]
- Construction: electrical
- Construction: rigging, structural and ornamental metal
- Public utilities
- Construction: HVAC
- Sheet or stamped metal product mfg [SM]
- Fruit and vegetable processing [FV]
- Non-state government, not otherwise classified
- Dealers: materials and supplies
- Foundries [PILOT]

The percentage of work-related hearing impairment was not coded in the DLI database. The DLI uses audiometric data and American Medical Association guidelines to calculate impairment.[22,23] After 1995, DLI initiated a policy allowing up to an additional 5% hearing impairment for tinnitus (i.e., in addition to the amount of impairment based on audiometry). In this study, binaural-equivalent hearing impairment was estimated from the disability settlement amount, divided by the DLI scheduled dollar value for total loss of hearing in both ears (based on the date of manifestation, up to $65,023 for dates in 1998). This may overestimate the amount of actual hearing loss for claims filed after 1995, because of the potential additional inclusion of tinnitus in the original calculation of the disability settlement amount.

To facilitate analysis and graphic representation of results, responses to questions about the influence of people or things on the claimant decision to file a claim, were pooled in four categories (social contact, health care, work representative, and other) and coded according to the number of responses given as “important” or “very important” on the 3 or 4 variables comprising each category.

The original proposal was to characterize the "awareness-healthcare-claim pathways," or sequences of events, by which persons become aware of their hearing condition, receive a diagnosis, and enter the workers' compensation system. However, a pilot survey found that many pilot subjects did not know or recall which provider had filed their claim, or the sequence of provider contacts before and after claim filing. In addition, many pilot subjects (and actual survey subjects) did not know or understand differences between different types of hearing-related professionals (e.g., audiometry technician versus audiologist, and audiologist versus ENT physician). Consequently, characterization of the healthcare pathway focused on: 1) the health care provider who was involved in filing the claim (i.e., usual provider, ENT doctor, or other type of provider); 2) any referral made by that provider; and 3) the referral source for any non-usual provider who was "important" in the decision to file a claim.

Because of the error that occurred during selection of Sample A – claimants older than 65 years of age from eight the nine target industries were inadvertently excluded – analyses of survey data relative to industry were stratified by subject age (i.e., subjects $\leq$65 and >65 were analyzed separately.

Statistical methods are otherwise described within the results section.

G.2 Results

G.2.1 Background information

Nearly all of the interviewed subjects were male (97%; **Table G1**). The distribution of age (at time of claim filing) reflected the stratification used in sample selection, and the differences in age between the subject groups reflected the criteria used to define the groups. On average, the "timely-filer" and younger "late-filer" groups were comparable in age, but subjects in the latter group had filed their claim more than ten years later, after the DLI-determined date of injury. The average age in the two late-filer groups differed by 15.5 years, but the difference in time since the date of injury was only 4.7 years.

Late-filer subjects, particularly those older than 65 years of age, were less likely to have completed high school. Subjects older than 65 were more likely to have been in the military, although their exposure to weapons fire beyond basic training was comparable to that of younger subjects. Recreational use of weapons did not differ between the subject groups.

G.2.2 Employment history

Overall, 30% of subjects were still working. Not surprisingly, current employment was lowest and retirement was highest in subjects who were over 65 years of age at the time of claim filing (**Table G2**). The younger late-filer subjects were less likely to be employed, and more likely to be disabled or retired, than the similar age timely-filer subjects.

The percent of subjects in each industry category – categorized according to prevention index – differed significantly between the subject groups (Table G2). However, there was no clear pattern relative to age or timing of filing. Interpretation was complicated by the error in sample selection related to age and industry (see section G.1.1).

For most subjects, their first noisy job had occurred more than 30 years before the survey (Table G2). The time since first and last noisy jobs differed significantly between the subject groups. More than ten years had lapsed since the most recent noisy job for 79% of the older late-filer subjects and 42% of the younger late-filer subjects.

G.2.2.a *Most recent noisy job*

Subjects who were ≤65 years old (timely filers and younger late filers) were asked about conditions at their most recent noisy job (n=515). The median length of time between that employment and the survey was 3.3 years; for 75% of subjects, it was <10 years.

About half of the subjects (n=262; 51%) had their last noisy job in one of the nine target industries. Nineteen subjects identified one of the companies participating in the Project 3 work site evaluations as their last noisy job; 14 of 76 companies, plus the one paper mill, were each mentioned at least once.

Subject survey responses about companies in one of the target industries are compared with findings of the Project 3 work site evaluations in sections H.4.1.d and H.4.2.

G.2.2.b *Noise exposure*

Overall, most subjects (74%) said noise exposure at their most recent job was constant or nearly constant, and nearly all others described noise as intermittent but usually daily (Table G2). Noise exposure was described as constant or nearly constant by 88% of subjects who worked in primary production industries, 82% in manufacturing industries, 69% in construction, and only 55% in other industries (**Table G3**). The percentage ranged from 67% to 93% in the six

targeted manufacturing industries. The percentage was much higher in road construction (88%) than in other construction industries combined (47%).

G.2.2.c *Hearing protection*

Overall, most subjects (77%) said hearing protection was regularly available, although not necessarily when they first started at that job (Table G2). Late-filer subjects, most of whom had not worked in a noisy job for more than ten years, were more likely to say hearing protection was *not* regularly available. The percent of subjects who said protection was not regularly available differed significantly between industries, primarily reflecting the high percentage in road construction (44%) and the broad category of "other" industries (54%).

G.2.2.d *Hearing tests*

Overall, about half of subjects (48%) said hearing tests were provided, although not necessarily when they first started working at that job (Table G2). This differed widely between industries (Table G3). Subjects employed in construction were most likely to say that hearing tests were not provided (84%).

G.2.3 Hearing ability

Most subjects (94%) received disability compensation for their OHL claim (**Table G4**). The average amount of estimated hearing impairment was higher in the older subject group (26.1% binaural loss) than in the two other groups (timely filers, 17.0%; younger late-filers, 19.6%).

Overall, 47% of subjects used a hearing aid on a regular basis, and another 42% used one occasionally (Table G4). Regular use was more common in the older group (60%), intermediate in the younger late-filer group (49%), and lowest in the timely filer group (39%). Only a small fraction of younger subjects had used a hearing aid five years prior to the survey – before filing their OHL claim – but 42% of the older subjects had used one at least occasionally.

Subjects were instructed to describe their hearing ability based on when they wore a hearing aid, if they used one regularly. Overall, 64% reported having one or more of five itemized hearing problems (Table G4); this was significantly more common in both groups of late-filer subjects (each, 69%) than among timely-filer subjects (59%). Overall, 30% reported having three or more of the five hearing problems. There was no significant change in hearing difficulty between the time of the survey and five years earlier, even when analysis was restricted to subjects who either had a hearing aid at both points in time or never had one.

Overall, 27% of subjects said they always or nearly always had tinnitus, and another 27% reported intermittent tinnitus (Table G4). The percentage was slightly lower in the older group. There was no significant difference in subjects' tinnitus between the time of the survey and five years earlier.

G.2.4 Awareness of hearing loss

Most subjects had suspected for a long time before filing their OHL claim that their hearing had been affected by noise at work (**Table G5**). Overall, two-thirds (67%) suspected this more than ten years before the survey, including 33% who suspected this more than twenty years earlier. Only 11% reported no awareness of hearing loss until five years or less before the survey.

About half of the subjects (51%) were first told more than ten years before the survey that they had evidence of hearing loss on a hearing test, including 22% who were told this more than twenty years earlier (Table G5). However, about one third (29%) said they were first told this within five years or less before the survey. As mentioned, allowing for the average 3 years between claim filing and the survey, events within "five years or less" before the survey would

generally have been close to the point in time when subjects filed their OHL claim.

Almost half of the subjects (44%) said that it had been within the past five years that a health care provider first mentioned that their hearing might have been injured by noise at work (Table G5). However, about one-third (35%) said this occurred more than ten years earlier.

These time points of first awareness about hearing loss differed significantly between the groups (Table G5), but approximately paralleled the differences in age between the groups.

G.2.5 Influential people or things

G.2.5.a *Social contacts*

The people or things that were reported most often to be important in the decision to file an OHL claim were social contacts (i.e., 78% of subjects reported one or more social contacts) and health care providers (74%; **Figure G2**). However, the only people or things to be described as very important by a majority of subjects were social contacts (59%).

Family members were the social contact mentioned most often as an important influence (59%), but other social contacts were also mentioned often: friends, 41%; coworkers, 34% (**Figure G3**). Family members were equally important influences for subjects in all of the subject groups, but older subjects were significantly more likely to report that friends were an important influence (**Table G6**). Subjects in the two late-filer groups were less likely to consider coworkers an important influence, which is probably explained at least partially by the longer time since their last employment.

G.2.5.b *Health care providers*

Screening programs: The health care provider reported most often to be important was a hearing tester in a screening program outside of work (65%), although that person's or program's influence was rarely considered very important (7%; Figure G3). Older subjects were more likely than other subjects to describe non-work screening programs as important, but they were also less likely to describe them as very important (Table G6).

Because of the reported importance of screening programs outside work, and because they represented a phenomenon that could vary substantially over time and thus could have contributed to the rise in OHL claims during the 1990s, survey responses were stratified relative to the reported importance or non-importance of non-work screening programs.

Subjects who said a non-work screening program was important in their decision to file an OHL claim were more likely to say that family members and friends, but not coworkers, were also important and even very important influences (**Table G7**). They were also more likely to say their usual doctor or some other doctor or provider were important; in more than half of those cases, the doctor or provider was considered very important.

About a quarter of subjects who said a non-work screening program important also reported an advertisement or other media source of information was important in their decision to file a claim (either, 27%), although this was not much larger than reported by subjects who did not say a screening program was important (either, 20%; p=.02, chi square). There was no substantial difference in the small number of subjects who considered advertisements or media information *very* important, comparing subjects who did or did not say a screening program was important.

Usual doctors and other providers: Subjects' usual doctors or providers and other (non-screening) providers were reported less often to be important (25%, each; 41%, one or both) than testers in screening programs. However, they were more often considered very important

influences (28%, one or both; Table G6).

Of the 195 "other" providers, about half (48%) were otolaryngologists, 14% were audiologists, and 19% were hearing-related professionals in a specialty that the subject was unable to identify (**Figure G4**). Subjects came under the care of those important other providers through a variety of routes, but most often by self-referral (43%). The next most common route was by referral from the subject's usual health care provider (15%).

Subjects identified the following types of providers as the physician or other health care provider who either helped them file their OHL claim or evaluated them before they filed their claim:

• Subject's usual health care provider	101	16.5%
• Otolaryngologist	243	39.6%
• Audiologist	41	6.7%
• Hearing professional; other type or unsure *	121	19.7%
		66.1%
• Other type of provider	16	2.6%
• Unsure	61	10.0%
• No provider	30	4.9%
	613 **	

* Many subjects did not know or understand differences between types of hearing-related professionals.

** 154 subjects who reported that a final decision on their OHL claim was still pending were inadvertently not asked about the health care provider involved in filing the claim nor about referrals by that provider. Several others were unable to answer some questions.

Of the subjects who said their usual health care provider helped file their claim, more than half (55%) were referred by that provider to a hearing professional.

Most subjects (64%) reported eventually having an independent medical examination.

G.2.5.c *Work representatives*

In general, the most important work representative was a person who tested the subject's hearing at work, although only 20% of subjects considered this person to be very important (Figure G3). Other work representatives were mentioned by only 9-12% of subjects. The older subject group was less likely to consider work representatives important (Table G6), which again may be explained at least partially by the longer time since their last employment.

G.2.5.d *Other people or things*

Most of the responses in the "other" category were associated with advertisements or other media information (Table G6), although only 25% of subjects considered one or both of these to be important influences, and only 10%, very important (Figure G3). The older subject group was more likely to say advertisements were an important influence, but only 25% considered them important, and 12%, very important (Table G6). Very few (5%) reported hiring or paying for an attorney to assist with their OHL claim.

Advertisements: Subjects who said an advertisement was an important influence were asked what they recalled about the content of advertisements. Answers were documented in subjects' own words (i.e., not as fixed-choice options) and were categorized later during data analysis. Of the 147 subjects who answered this question, more than half said the advertisement either mentioned possible coverage of costs or disability compensation by industrial insurance (56%)

or mentioned possible "free" hearing aids (3%), without mentioning a source of coverage.

Because advertisements and media information represented phenomena that could vary substantially over time and thus could have contributed to the rise in OHL claims during the 1990s, survey responses were stratified relative to the reported importance or non-importance of advertisements or media information.

Subjects who said an advertisement was important in their decision to file a claim were also more likely to say that other (non-advertisement) media information was also an important, and even very important, influence, although only 19% of them reported this (**Table G8**). They were also more likely to say a non-work screening program was an important, although not necessarily very important, influence; however, the absolute difference between subjects who did or did not ascribe importance to an advertisement was small. They were somewhat less likely to say a friend was important. They also tended more often to describe their usual health care provider as important, although the difference was not statistically significant.

G.2.5.e *Differences between industries*

When industries were categorized according to OHL claim activity – very low PI, low PI, or moderate or higher PI – there were few differences between industries in the percentage of subjects who said specific people or things were important or very important in their decision to file a claim. There was no significant difference in the importance of social contacts, health care providers, or work representatives (**Figures G5 and G6**). However, subjects who were employed in a "very low PI" industry, particularly those older than 65 years of age, were more likely than subjects in other industries or younger subjects to say an advertisement was an important (36%), but not necessarily very important (16%), influence on their decision to file a claim (**Figure G7**).

G.3 Conclusions

Aim 1: To identify the major pathways and influential factors by which individuals with OHL are identified and reported to the workers' compensation system.

*The **Project 2** telephone survey of OHL claimants found that the decision by a current or former worker to file an OHL claim is commonly influenced by a number of factors. The most important influence on individuals' decisions to file an OHL claim was social contacts, especially family members, but also friends and coworkers.*

Several types of health care providers were identified as important or very important influences on decisions to file a claim. Most subjects said a screening program conducted outside of work had an important influence on their decision to file an OHL claim, but they generally described this as less important than other influences, particularly family members and friends.

Only about a quarter of subjects said an advertisement or other media source of information was an important influence, and most did not say it was a very important influence. It is possible, however, that this study underestimated the direct or indirect influence of screening programs, advertisements, and media information on decisions to file a claim.

There was a relative lack of influence by workplace representatives on decisions to file an OHL claim. This raises concern about the completeness or adequacy with which audiometry findings are communicated to workers when they are tested in workplace annual monitoring programs.

- The most important influence on individuals' decisions to file an OHL claim was social contacts, especially family members, but also friends and coworkers. Family members played a very important role for individuals who were older than 65 years of age.
- For the majority of individuals with an OHL claim, the decision to file a claim was not triggered by recent awareness of hearing loss or its possible relationship to noise at work, nor by progressive worsening of hearing loss.

  Most of the survey subjects had been aware of their hearing loss for many years before filing their claim, and most also reported a stable pattern of hearing loss between the time of the survey and five years before the survey. On average, the OHL claims were filed three years before the survey. Although this time window does not directly address the preceding temporal pattern of hearing loss, it is unlikely that hearing loss was substantially more rapidly progressive in a preceding window of time leading up to filing a claim.

  About half of the subjects had first been told by a health care provider that they had audiometric evidence of hearing loss, more than ten years before the survey. In addition about half said a provider had at least mentioned their hearing might have been damaged by noise at work, more than five years before the survey.

- However, recent information from a health care provider about their hearing loss, and its possible relationship to noise at work, probably had an important influence on a near majority of the subjects. The survey did not attempt to distinguish which provider, or type of provider, communicated this specific information.

  Almost one-third of subjects said they were first told about audiometric evidence of hearing loss within the past five years – about the time of claim filing. In addition, almost half of the subjects said that within the past five years was the first time a health care provider had mentioned their hearing might have been damaged by noise at work.

- Several types of providers were identified as important or very important influences on many subjects' decisions to file a claim. About two-thirds of subjects said a hearing tester in a screening program outside of work played an important role in their decision to file an OHL claim, although as mentioned, that role was rarely considered very important. In contrast, one-quarter of subjects said their usual health care provider played an important role; however, more often than not, they considered that role to be very important.
- About one-quarter of subjects said a health care provider other than their usual provider played an important, and often very important role, in their decision to file an OHL claim. Most of those providers were otolaryngologists, audiologists, or other hearing-related professionals. Subjects came under the care of those important other providers through a variety of routes, but most often by self-referral. The next most common route was by referral from the subject's usual health care provider.
- Most of the providers who helped subjects file their OHL claim or evaluated them before they filed their claim were otolaryngologists or a type of hearing specialist the subject could not identify. Subjects' usual providers served this role in less than 20% of claims, but generally also referred subjects to a hearing professional.

Since this survey, the State of Washington implemented a requirement that OHL claims be filed within two years after diagnosis of OHL or cessation of occupational noise exposure (i.e., the "date of injury"), to be fully eligible for potential benefits. Claims filed after two years are still eligible for coverage of medical expenses, including hearing aids, but not disability compensation.

In the absence of such a requirement, about half of the subjects, including about one-third of those who were younger than 65 years of age when they filed their claim, did not file their claim in what would now be considered a timely manner.

- Many subjects filed their claim long after the end of their last noisy job. Similarly, although about half of subjects filed their claim within a timely period of time after a health care provider first mentioned their hearing might have been damaged by noise at work, the other half filed their claim after a longer, and sometimes much longer, period of time. The survey did not ask about definitiveness of the information communicated by the first provider who "mentioned" the possible relationship between the subject's noise exposure and hearing loss. It is possible that a definitive diagnosis was made much later.
- In the absence of a two-year filing requirement, there were some identifiable differences between individuals who filed their claim sooner or later than two years after the "date of injury." However, many of those differences were explainable by the difference in age; for example, the number of years since last occupational noise exposure. The older claimants generally had more hearing loss, but less tinnitus, than younger claimants.
- Among subjects who were younger than usual retirement age, those who filed more than two years after the date of injury were, on average, identical in age to those who filed in more timely manner but had ended their last noisy job about five years earlier. It is possible that age – or age-related phenomena such as retirement or impending retirement, onset of concomitant non-occupational hearing loss, particularly presbycusis, or the development of other health problems – may be a more important stimulus than the recency of final noise exposure for filing an OHL claim, at least in the absence of a two-year filing requirement.

  The young "late-filer" subjects were somewhat more likely than "timely-filer" subjects to be retired or disabled. It is very unlikely that any disability, and possible but still not likely, that these differences were attributable to noise exposure or OHL, suggesting that other factors, including health problems for at least the small percent with disabled status, were active in the late-filer group and not the timely-filer group. The study was not able to characterize these differences.

  The young late-filer subjects also tended to have more hearing difficulty than timely-filer subjects. Although there was no significant difference in the percentage who received disability compensation for OHL, nor in the amount of compensated disability, the late-filer subjects were more likely to use a hearing aid on a regular basis and tended to report more hearing difficulty than the timely-filer subjects, although the difference in reported hearing difficulty was not statistically significant.

There was a relative lack of influence by workplace representatives on decisions to file an OHL claim. This raises concern about the completeness or adequacy with which audiometry findings are communicated to individual workers when they are tested in workplace annual monitoring programs.

- Most of the survey subjects were most recently exposed to workplace noise during a time period after implementation of the hearing conservation amendment to the OSHA/WISHA noise standard, promulgated in the early 1980s. Under that regulation, their hearing ability should have been monitored annually by their employer. Any hearing loss that was truly caused by noise exposure, particularly any hearing loss that was later judged severe enough to meet minimum criteria for disability compensation, should have been evident on workplace audiometry. Yet, hearing testers at work, safety representatives, and other company representatives were not commonly considered important, and were rarely considered very important, in subjects' decisions to file an OHL claim.

- If workers were adequately informed at the time of workplace testing – about the existence of any hearing loss, its possible relationship to workplace noise, and their (potentially time-limited) right to file a workers' compensation claim – it might actually be easier to adjudicate employer liability and the true amount of disability attributable to OHL at that time, if a claim was filed then rather than later. Furthermore, an expectation that employers would notify workers about possible OHL, when detected in the course of workplace monitoring would achieve a balance between employer and employee responsibility for identifying and reporting (possible) OHL. Regulations such as the two-year filing rule in Washington state place the primary burden for recognition and reporting of OHL on affected workers, with essentially no explicit responsibility by employers, whose records presumably include documented but under-recognized or under-reported (possible) OHL.

Occupational hearing loss is clearly a condition that interferes with the daily lives of affected individuals, even when they are provided hearing aids.

- Nearly all of the survey subjects, who were selected to be reasonably representative of OHL claimants, had enough audiometric evidence of hearing loss that DLI judged them to be partially disabled. About half of the subjects used a hearing aid on a regular basis, and most others used one occasionally. About a quarter experienced tinnitus on a continual basis, and more than half experienced tinnitus at least intermittently. Even with hearing aids, two-thirds of subjects reported at least one problem in a social situation, when asked about five problems that commonly affect people with hearing loss, and one-third reported at least three such problems.

Aim 2: To identify factors that may have contributed to the increased reporting of OHL in Washington State.

Project 2 did not identify any factors – "smoking guns" – that clearly accounted for why so many more current and former workers chose to file an OHL claim in recent years, than in the past. Most of the surveyed claimants said that a screening program conducted outside of work had an important influence on their decision to file an OHL claim, but they generally described this as less important than other influences, particularly family and friends. Only about a quarter of subjects said an advertisement or other media source of information was an important influence, and most did not say it was a very important influence. It is possible, however, that this study underestimated the direct or indirect influence of screening programs, advertisements, and media information on decisions to file a claim.

- A majority of survey subjects said hearing screening programs conducted outside of work were important, but not very important, in their decision to file a claim, and a substantial minority said advertisements and media sources of information were important. Most subjects attributed greater importance to family members and other social contacts, whose presence would not be expected to vary substantially from one period of time to another. Of note, subjects who said a screening program was an important influence were even more likely than those who did not say so, to report that family members and friends were important, and even very important, influences on their decision to file a claim.
- This study could have underestimated the influence of advertisements, media information, and screening programs on subjects' decisions to file an OHL claim. It is possible that publicly disseminated information, including intermediate person-to-person communication of that information, could have had a greater indirect than direct influence on subjects' decisions, by stimulating the people whom subjects considered to be important or more important influences. For example, family members and friends might be more inclined to

"nag" a person with hearing difficulties to have their hearing evaluated, and get a potentially costly hearing aid, if they knew about readily available or affordable options for doing so, as well as the possibility of obtaining disability compensation. One would anticipate, however, that advertisements or screening programs would have been considered very important more often, rather than having the observed lesser degree of importance, if profit was a substantial motivation. Similarly, it is plausible that the relative importance of publicly disseminated information and screening programs was under-appreciated by subjects. These factors could have been perceived simply as a readily available and affordable avenue for responding to, and finally escaping, the "nagging" of family members and friends.

- This study was not able to examine these possible mechanisms of influence on decisions to file an OHL claim.

Aim 3: To determine whether there is any substantial work-related risk at the present time for OHL in industries with high numbers and/or rates of OHL claims.

*The information provided by **Project 2** telephone survey subjects about conditions at their most recent noisy job – most of which occurred when OSHA/WISHA hearing conservation regulations were in force – suggested that many employers are not optimally compliant with those regulations. Based on the subject reports, employers in some industries, particularly construction and other non-manufacturing industries, are generally less compliant with regulations than employers in other industries.*

The potential use of claimant reports about their last noisy job for targeting or other surveillance purposes is examined in the companion study, Project 3.

H PROJECT 3 – Using OHL Claims as a Surveillance Tool to Target Industries

H.1 Methods

Project 3 was a cross-sectional study – evaluating noise exposures and hearing loss prevention activities – at a representative sample of companies in each of nine industries.

H.1.1 Study population

The study population included all employers who, at the time of data extraction (2000), reported any hours of employment in the nine target industry categories, whether or not the employer was linked to an OHL claim (see sections E.2 and E.3).

Employers were potentially eligible for the study if they reported ≥10 FTE employees in the target risk classes and had a business location in the extended Puget Sound region (or for fruit/vegetable processing companies, a location in the region between Yakima and the Tri-Cities area). Large employers with ≥500 FTE employees were not eligible, unless employment was reported for more than one business location and the average employment per location was <500 employees. The upper size limit was based on the limited ability of the study team to complete a meaningful evaluation of a large work site in one or two days, and the assumption that large work sites were likely to have maximal access to safety and health resources and relatively more prevalent hearing loss prevention efforts.

H.1.2 Company selection and recruitment

The goal in each industry was to enroll ten companies, with about half (n=4-6) of the companies coming from each of two categories:

- **Company category A:** All companies in a target industry that either: 1) had relatively high numbers of OHL claims filed in 1992-1998; and/or 2) were identified by a surveyed claimant (in Project 2) as their most recent noisy employer during the preceding ten years.
- **Company category B:** All companies in a target industry that: 1) had no or relatively few OHL claims in 1992-1998; and 2) were not identified in the claimant telephone survey.

Recruitment efforts gave priority to employers who reported ≥20 and <250 FTE employees, and had business locations closest to UW.

If an employer had more than one business location, each location was potentially eligible to participate as a "separate" company in the study, if each location separately managed their production and safety & health efforts. Recruitment efforts gave priority to companies with a unique employer.

Informational material was sent by mail. When possible, selected employers were contacted briefly by telephone to confirm the mailing address and identify a person responsible for safety and health efforts. Soon after mailing, a study representative contacted the company by phone to explain the study, and answer questions. If the company was interested, information was collected to confirm eligibility, and an introductory visit to the work site was scheduled.

Participation was voluntary. No incentives were provided other than each participating company was given a formal report that summarized the findings of the evaluation at their company and provided recommendations. Companies were not informed of the identities of employees that participated and were not provided any findings that could be linked to individual employees.

At the introductory visit – if the appropriate company representatives agreed to participate in the study – the study representative gathered general information, made a walk-through assessment

to identify noisy areas and jobs, scheduled subsequent visits, notified employees about the study through printed notices and/or group meetings, and began employee recruitment. In most cases, a second visit was made to recruit employees at a group meeting, usually a company safety meeting, before the evaluation visit.

Study sample: Ten companies were recruited in each of six target industries, and nine in another industry (**Table H1**). Only one paper mill was recruited. To protect confidentiality of that mill, no findings for the PP industry are reported. Recruitment of lumber mills (LM) was also challenging; seven mills were recruited, including three that were part of one corporation but functioned independently. Three pairs of fruit/vegetable processing (FV) companies and one pair of road construction (RC) companies were each part of one corporation but functioned independently.

Overall, about 50% of the companies that were contacted by phone agreed to participate in the study. As noted, participation was lowest in the PP industry; only 1 paper mill participated, out of 6 or 7 in western Washington. Otherwise, participation was lowest in the LM and RC industries, about 30% to 40%; and was highest in the MS, SM, and WP industries, up to about 60%.

The recruited companies were most evenly divided between categories A and B (i.e., 40-60% in each category) in the three metal products industries (HM, MS, and SM; Table H1). Six road construction companies had no OHL claims in a target risk class; however, four of those had OHL claims in a related risk class (e.g., clearing, grading, excavating; sewer construction). Three of the four fruit/vegetable processing companies with "no" OHL claims, had OHL claims assigned to the corporate office, in a target risk class, and it was not possible to determine if any claims were linked to the participating company. Companies in the other three industries were predominantly in one category or the other, reflecting the challenge of identifying and recruiting companies in industries with relatively high incidence (LM) or low incidence (PR and WP) rates of OHL claims.

Fourteen of the 76 (18%) participating companies, plus the one paper mill, were mentioned by at least one OHL claimant (n=19) in the Project 2 telephone survey as their most recent noisy employer. One company was mentioned twice, and another was mentioned four times.

H.1.3 Subject selection and recruitment

Management: The management representative who was most responsible for hearing loss prevention activities was selected for the management interview at each company.

Employees: The employee sample at each company was selected to be as representative as possible of employees who were involved in noisy tasks or who worked in noisy areas. During or after the initial visit, employees were informed about the study in group meetings and/or informational notices distributed at the work site. Participation was voluntary, and no incentives were provided. In general, the employee sample was obtained by first enrolling volunteer employees in noisy jobs and then approaching employees individually, until the enrolment goal was achieved in specific jobs. The refusal rate by employees approached on an individual basis was less than 5% to 10% (estimated). The number of employees participating in personal noise monitoring at each company was dictated by work force size and the number of available dosimeters; the median at each company was 12, ranging from 4 to 45. The median number of employees who completed an interview (nearly all of whom also completed noise monitoring) was 19, ranging from 3 to 56.

H.1.4 Data collection

Between September 2000 and August 2002, 76 companies were evaluated in eight industries (plus one PP company). Data collection at each company usually involved one work shift on one day, but sometimes involved a second shift or a second or third day.

Data collection included: 1) full-shift personal noise dosimetry for a representative sample of employees; 2) one management interview at each company, with the person who was most responsible for work site hearing loss prevention activities; 3) employee interviews, with a representative sample of employees (including all employees who wore a dosimeter); 4) systematic observations of hearing protector use by participating employees; and 5) review of existing audiometry. The collected data are summarized in **Tables H2A and H2B**. A noise map was produced for each company, as a service to the company.

H.1.4.a *Noise exposure*

Area noise level measurements were performed during the walk-through assessment on the initial visit, during observations of hearing protector use on the data collection visit, and during preparation of the noise map. A Type 2 sound level meter was used, usually set for a slow response and A weighting.

Personal noise monitoring utilized a Quest 300 or Quest 400 data-logging noise dosimeter, worn for an entire shift. The median sample duration was 8.1 hours (SD 1.2), and 98% were at least six hours long. The microphone was placed on the shoulder of the dominant arm.

The dosimeters recorded two channels of data, one using OSHA/WISHA parameters (90 dBA criterion, 5 dB exchange rate, 80 dBA threshold, slow response),[24,25] and one using NIOSH/ISO parameters (85 dBA criterion, 3 dB exchange, no threshold, slow response).[26] Dosimetry data were transferred to a personal computer promptly after data collection. Transferred data were processed with QuestSuite software.[27] Dosimetry output included: 1) full-shift L_{ave} (OSHA), L_{eq} (NIOSH), and highest L_{max}; 2) total amounts of time in noise that exceeded certain noise levels (e.g., 80-110 dBA, in 5-10 dB increments); and 3) 1-minute interval values of L_{ave} and L_{eq}. Dosimeters were calibrated before and after each monitoring period.

H.1.4.b *Interviews*

The management and employee interviews were adapted from the pilot project interviews, with questions added to reflect good practices and not just regulatory compliance. Each interview was divided into sections asking about noise monitoring and noise controls, training and hearing protector fitting, hearing protector availability and use, audiometric testing, and background information. The interviewed management representative was allowed to use company records to answer questions, if desired; however, the interviewer did not request or review any records to confirm responses. Most management interviews required 15-30 minutes to complete, and most employee interviews required about five minutes. Employee interviews were conducted individually, usually during a lull in work operations at or near where the worker was stationed. The interview questions and fixed answer options were programmed into handheld personal digital assistant (PDA) devices, using PenDragon Forms™ software. This software presented each question singly for the interviewer, and after the subject's response was entered, presented the next appropriate question. The employee interview was translated into Spanish, primarily for use at fruit/vegetable processing companies.

H.1.4.c *Hearing protection*

Employee use of hearing protection was primarily assessed by the employee interview and, in a limited sample of companies, was also assessed by observation and a brief post-shift interview. The latter were used to evaluate the reliability of subjects' reported noise exposure and use of hearing protection, and not as a primary study outcome.

Interview: The employee interview included two questions:

- At this workplace, how often do you work around noise that is so loud you have to raise your voice for someone to hear you from an arm's length [or 2 to 3 feet] away?
- At this workplace, whenever you work around noise that loud, how often do you wear hearing protection?

The fixed-choice options for these and other such questions were: always, almost always, more than half the time, about half the time, less than half the time, almost never, and never.

Observations: The observations of hearing protector use were conducted at 42 companies, using a protocol more rigorous than originally proposed. This sample represented most or all companies in five industries (RC, LM, MS, SM, and FV). The observations were not continued in the other industries, because of limited staff resources and remaining time to complete company enrollment and evaluation in those industries.

A study team member traversed the entire work site, up to four times during the work shift, and attempted to locate and observe each participating employee on each cycle. Subjects wore a visible number badge. For each observation, the observer noted whether or not: 1) the subject was exposed to noise that was about 85 dBA or louder; 2) the subject was wearing a hearing protector; and 3) if so, a) the protector was placed correctly, by visual criteria (e.g., a self-molded or "roll-down" type of foam ear plug was inserted more than halfway into the ear canal), and b) the type of protector used. The type of task in progress and the subject's study badge number were also recorded. One or more observations were completed for 876 subjects, although data analyses were restricted to 381 subjects who had 3 or 4 observations, at least 1 of which occurred while the subject was exposed to noise $\geq$85 dBA.

When feasible, and particularly until the observer was familiar with noise levels associated with equipment and tasks at the specific site, the observer used a handheld sound level meter to measure the noise level as close as possible to the observed worker's position, on each observation. Actual observation of the hearing protector was conducted as surreptitiously as possible, to maximize blinding of the subject. During recruitment, and when asked thereafter, the observers explained that they were measuring noise levels associated with specific tasks and equipment, which was reinforced by visible use of the sound level meter.

Observations were recorded on a PDA, with PenDragon Forms™ software. The PDA documented the time and date of each observation. The time on each PDA (and each noise dosimeter) was checked relative to a single reliable time source, reset as needed at the start of each day, and checked at the end of each day, to monitor accuracy and allow synchronization of observations with dosimetry records.

Post-shift interview: A brief post-shift interview was conducted in a limited sample of subjects who participated in the observations (n=514). The interview included two questions, analogous to those listed above, about perceived noise exposure and use of hearing protection, during the first and second halves of the shift. The sample was limited because, in the absence of remuneration, most subjects departed quickly at the end of the shift.

H.1.4.d *Existing audiometry*

Each company was asked to provide annual summary reports (since 1998, inclusive) and individual audiometry records for all employees currently covered by the company testing program. Records were usually obtained in electronic format from the audiology contractor. Any identifying information other than company, gender, and age was removed from records for employees who were not study subjects. Records were not obtained from 7 of 51 companies that had conducted testing, including 6 of 7 FV companies, all of whom had out-of-state audiology contractors. Two companies could only provide summary reports for individual

employees, without hearing threshold levels, and were not included in data analysis. Three companies restricted record release to employees who participated as study subjects. Records were obtained for 9,336 current and former employees, including 764 study subjects; however, analysis was restricted to employees whose most recent test was conducted after 1998: 741 participating employees, and 4,486 other current or recent employees (total, n=5,227).

H.1.5 Data transformations

Before any data transformations or data analyses, the major dependent and independent variables were examined descriptively to identify outlying values and skewed, truncated or other non-normal data distributions.

Dosimetry: The noise dosimeters assigned a missing or "zero" value for 1-minute average values when all noise levels in the interval were below the measurement threshold. Dosimetry missing values were "smoothed" by interpolation between temporally adjacent non-missing values, as described by Neitzel et al.[28]

Interviews: Summary scores were derived for the management and employee interviews, to serve as the primary dependent variables in analyses of interview results. The scores were calculated as the unweighted sum of favorable responses on selected, representative non-duplicated, questions from each section of the interview (**Table H3**). Total possible scores were: management interview, 40; employee interview, 25. The questions were selected by Daniell and Swan, after interview content was finalized, and before any data analyses. The scores were analogous but not identical to those in the pilot project, reflecting changes in the interviews.

The fixed-choice response options about exposure to loud noise and use of hearing protection were combined into a smaller number of categories for data analysis. The two options at each extreme were combined for all analyses: always (always plus almost always) and never (never plus almost never). The mid-range response options (less than half, about half, and more than half the time) were preserved for some reliability analyses, but otherwise were combined into one "sometimes" category. In analyses of the reported use of hearing protection as a study outcome, this variable was dichotomized as always or other (never plus sometimes).

Audiometry: Hearing threshold levels (HTLs) in existing audiometry records were used to categorize each tested employee's hearing ability, based on the most recent test since 1998: 1) impairment, using criteria from the *AMA guidelines* (mean HTL >25 dB at 0.5-1-2-3 kHz, in either ear);[23] 2) moderate or worse high frequency hearing loss (mean HTL >40 dB at 3-4-6 kHz, in either ear, without impairment); 3) mild high frequency loss (mean HTL >25 but $\leq$40 dB at 3-4-6 kHz, without impairment); or 4) normal. Individuals with substantial right-left asymmetry (>15 dB average at 0.5-1-2 kHz, or >30 dB average at 3-4-6 kHz)[29] or with a flat or ascending audiometry pattern and impairment were noted but were included in data analysis, to allow comparison with "unscreened" reference databases.

Longitudinal test records were not consistently available for non-subject employees. Therefore, determination whether an employee ever had a "standard threshold shift" (STS) while employed at the present company, was restricted to subject employees. A subject was determined to have had an STS if the difference in mean HTL at 2-3-4 kHz, between the baseline and most recent audiogram, was >10 dB in either ear.

H.1.6 Data analysis

Statistical methods are described within the results sections. The primary study sample unit was the company. In general, data collected from individual employees were aggregated at the level of the company for data analysis, i.e., the percent of subjects or the mean value. Employee data were *not* aggregated in two analyses: reliability analyses, examining the reported frequency of

noise exposure and use of hearing protection; and comparisons of employee-reported and documented audiometry findings.

H.1.7 Technical reports and "guidebooks"

Each company received a detailed report of findings at their work site, including the noise map, with recommendations. In addition, a "technical report and guidebook" has been prepared for selected industries (SM, FV, WP, to date), describing study findings in a readable format and including practical recommendations for company personnel who are responsible for hearing loss prevention activities.

The appendix does not include any of the guidebooks, because each is still in pre-print format and minor changes may be made. The SM and FV guidebooks are available in their pre-print format, upon request and agreement to restrict distribution. The final, printable formats will be available soon.

H.2 Results – Current exposures and practices, and differences between industries

To reiterate, the primary study sample unit was the company. In general, data collected from individual employees were aggregated at the level of the company, i.e., the percent of subjects or the mean value at the company.

H.2.1 Background information

Background information about the participating companies and employees is summarized for each industry in **Tables H4 and H5**. As mentioned, only one paper mill was recruited. To protect confidentiality of that mill, no findings for PP industry are reported.

In most industries, at least 80% of the companies had been owned by the present owner for more than ten years; the exceptions were PR and SM, in which only 60% had been owned this long (Table H4). Companies with relatively small production areas and fewer production employees were most common in the MS and HM industries, and relatively larger companies were most common in the FV, LM, and RC industries. A union was present at 57% or more of companies in the SM, LM, and RC industries, but no more than 33% of companies in the other industries. Overall, 78% of companies had been inspected by WISHA at some point in the past, but only 9% had ever received a citation related to noise exposure or hearing loss prevention.

On average, about 20 employees were interviewed at each company (Table H5). Most of the interviewed employees ($\geq$79%) were men, except in the FV industry were half were men and half were women. There was a broad distribution of employee age and duration of employment. Overall, 71% had been employed at their present company for two years or longer. In general, most of the interviewed employees had completed high school or had some education or vocational training beyond high school. The percentage who had not completed high school was 17% or less in all industries except the FV industry, where it was 44%. The primary spoken language was something other than English for 22% to 35% of interviewed employees in the FV, WP, and PR industries, and no more than 13% of employees in other industries.

The major outcome variables are summarized for each industry in **Table H6**.

H.2.2 Noise exposure

Work shifts and noise sampling periods longer than eight hours were more common in some industries than others (MS, SM, RC, HM, and LM; **Figure H1**). However, the mean duration of personal noise samples did not differ significantly between industries. Therefore, the full-shift L_{ave} (WISHA or OSHA time-weighted average noise exposure) is reported here, and not the eight-hour equivalent value.

Excessive noise exposure was common in all of the study industries. All except three companies (96%) had at least one employee with a full-shift $L_{ave} \geq$85 dBA, and 79% had three or more employees exposed this high. Employers are required to maintain a hearing loss prevention program for employees with such exposures. In addition, 62% of companies had one or more employees with an $L_{ave} \geq$90 dBA, the level at which employers are required to consider implementing noise controls.

There was a significant difference between industries in the prevalence of excessive noise exposure (Table H6 and **Figure H2A**). Full-shift exposures were highest in lumber milling, where on average at each company, 95% of monitored employees had an $L_{ave} \geq$85 dBA. On average, more than 60% of monitored employees in two other industries (HM and FV) had exposures this high, and at least 30% of monitored employees in all other industries.

Within most industries, there was a wide range in the percent of monitored employees with excessive exposure (L_{ave} ≥85 dBA) between companies (**Figure H3**). The difference between the highest and lowest company percentage was narrow within the lumber milling industry (LM, 17%), where excessive exposure was common, but was 63% to 79% in all except one other industries. In one industry, printing, which had the lowest overall prevalence of excessive exposure, the difference between the highest and lowest company percentage was 100%: two companies had no monitored employees with full-shift exposures ≥85 dBA, but at one company, 100% of monitored employees had full-shift exposures this loud. This reflects a particularly wide range in scale of operations within this industry category.

This study used the full-shift L_{ave} to characterize noise exposure, because this measure is prescribed by WISHA and OSHA for judging compliance with noise regulations, and one goal of this study was to judge regulatory compliance. However, if one instead used the L_{eq}, which differs from the L_{ave} primarily by using a 3-dB rather than 5-dB exchange (doubling) rate, then excessive noise exposure would be more prevalent and exposures would generally be higher. This is illustrated in **Figure H2B**. Overall, 74% of monitored employees had an L_{eq} ≥85 dBA, whereas 50% had an L_{ave} ≥85 dBA; and only 14% had an L_{eq} ≥90 dBA, whereas 42% had an L_{ave} ≥90 dBA.

Employee noise exposures were generally intermittent during their work shift, in most industries (**Figures H4A and H4B**). Noise exposures at lumber mills were relatively continuous: as noted, 95% of monitored employees had an excessive full-shift exposure, L_{ave} ≥85 dBA; the median amount of time those employees spent in noise 85 dBA or higher was 435 minutes or about 7.3 hours (IQI 382-538 minutes). However, across all other industries, the average employee with an L_{ave} ≥85 dBA spent a total of 284 minutes or about 4.7 hours in areas where noise levels were 85 dBA or higher (median; interquartile interval, IQI 229-390 minutes).

Nearly all monitored employees with an L_{ave} *under* 85 dBA spent time in areas where noise levels were 85 dBA or higher (Figure H4A). On average, half of them spent 72 minutes or longer in noise this high, and one-quarter spent two hours or longer (IQI 31-119 minutes).

H.2.2.a *Noise sources and controls*

A noise map was produced for each company, as a service. Based on observations during the initial and data collection visits, the study teams concluded it would have been feasible for all or nearly all of the participant companies in each industry to implement one or more effective noise controls, at reasonable cost, to achieve a meaningful reduction in noise exposures for one or more employees. The types of noise sources amenable to controls varied widely across industries. The most common types of identified feasible controls were: 1) machine and tool maintenance programs; 2) alternative machine components, e.g., different cutting or contact surfaces; 3) isolation of major noise sources, including barriers, walls, and physical relocation, and administrative strategies such as relocating employees or limiting the use of unusually loud machines to slow work times, e.g., swing or night shifts; 4) sound absorption materials; and 5) sound deadening surface materials.

H.2.3 Interviews

Analyses of interview scores and responses excluded the three companies where no monitored employees had full-shift exposures ≥85 dBA, because if the sampling was representative, those companies are not required to maintain a hearing loss prevention program. However, each of these companies provided hearing protectors to their employees, and they were included in analyses of hearing protection use.

The overall score for the management interview showed only a marginally significant difference across the eight industries, primarily reflecting differences in the training and hearing protector

subscores (Table H6). The management interview scores varied widely across companies within each industry (**Figure H5A**).

The management interview scores were divided into quartiles (4-16, 17-23, 24-27, and 28-35) to facilitate describing the distribution of interview responses and scores. Every industry included companies with scores in each quartile (**Figure H6**), except lumber milling, in which none of the seven evaluated companies had a score in the lowest quartile.

The employee interview scores, averaged for each company, showed significant differences across industries in the overall score and all subscores except the noise subscore (Table H6 and **Figure H5B**). As in the pilot project, there was a significant correlation between the company-average employee overall score and the management overall score, when considered at the level of individual companies (Pearson r=0.75, p<.001; **Figure H7A**), and when the company-average values were averaged by industry (r=0.93, p<.001; **Figure H7B**).

H.2.3.a *Program coordination*

Most but not all companies (81%) had designated one person to be the hearing loss prevention program coordinator (**Tables H7 and H8**). The management interviews were conducted with the program coordinator or, at other companies, with the person who identified him/herself as the single person most responsible for hearing loss prevention. Only 59% of the interviewed management representatives had ever seen or read a copy of the WISHA noise standard, including 64% of designated program coordinators.

H.2.3.b *Noise monitoring and controls*

Overall, according to the management interviews, 82% of companies had ever measured workplace noise levels, although only 34% retained records of those measurements, as required by the WISHA noise standard (Table H7). Only 11% had made a noise map – noise levels documented on a work site floor plan – which is not required but is a good practice to support training and consideration of noise controls. In general, these practices were more common at companies with higher interview scores.

Half of the companies had ever made a change intended to reduce noise levels; only 7 of those 39 companies measured noise levels afterward to evaluate the changes. Less than half (38%) of companies had plans for changes to reduce noise levels. In general, past and planned efforts to control noise did not differ between companies with higher or lower overall interview scores, and did not differ between industries (Table H8).

H.2.3.c *Training*

Training practices differed substantially between companies with higher and lower interview scores (Table H7). Only 46 companies (63%) reported having annual training. All companies with a median score or higher provided annual training, but only half of companies in the next lowest quartile, and only one company in the lowest quartile. Some training practices were more common in some industries than others (Table H8).

The management reports of annual training were partially confirmed by interviews of employees at the same work site. At companies without an annual training program, more than 90% of employees confirmed they never received any training related to noise at this company. Conversely, at companies that reported conducting annual training, most – but not all – employees said they received training. When analysis was restricted to employees with $\geq$1 year of employment at companies with annual training programs, 60% of those employees (mean; SD 27%) said they had ever received training. The percentage did not differ significantly with length of employment (beyond 1 year), management interview score, or whether or not the

employee had undergone audiometric testing.

The interviewer did not review records to distinguish whether the other 40% of employees failed to receive training or failed to recall training that truly occurred. However, it is noteworthy that 37% of employees who underwent audiometry testing said they had never had any training. Given that nearly all testing was conducted by a contractor, and nearly all contractors presented a training video before or after testing, this indicates at least some failure of recall. An anecdote illustrates this. One interviewed employee stated he never had training but had annual hearing tests at his present company; the interviewer asked questions after completing the interview:

Interviewer: *Did you ever see a video about noise and the ear when they tested your hearing?*
Employee: *Yes, several times.*
Interviewer: *Did you know that video was supposed to be your annual training?*
Employee: *No, really?*
Interviewer: *Yes, really.*
Employee: [after a pause] *Well, then, I guess I've been trained and never knew it.*

Training sessions do not need to be memorable in order to be effective at transmitting knowledge or a skill to a trainee. However, the interviews indicated that the specific content of training was incomplete or ineffectively delivered in many training programs.

When asked about specific training topics, the management representatives reported (or were uncertain) that training did not include one or more topic areas required by WISHA at 21 of the 46 companies with annual training, including 24% of companies in the highest interview score quartile. Annual training was conducted solely by a contractor at 20 of the 46 (43%) companies, and training may have been more complete at those companies than the management representative was aware. Regardless, this could indicate either a lack of appreciation for the importance of some required training topics or a potential deficiency in program coordination. A company is required to ensure that training is complete, even if training is conducted by a specialty contractor.

For example, according to the management interviews, training at most but (possibly) not all companies covered required topics related to hearing protectors, including: when and where to use protectors, ≥90% of companies with training programs; differences between various types of protectors, ≥81%; and how to select, fit, use, and care for hearing protectors, ≥74%. For training of new employees, the management representatives reported that a trained person showed all new employees how to properly insert or wear a protector at only 62% of companies, and checked to see how well the protector fit each new employee at only 25%.

This was confirmed only partially by the employee interviews. At companies that reportedly provided hearing protector training for new employees, only 33% of employees (mean, SD 26%) said they were ever helped to decide what hearing protector to use or were taught the right way to insert their protector, at this company. At companies that reportedly checked hearing protector fit for new employees, only 14% of employees (SD 10%) said this ever occurred for them at this company. These percentages were even lower at other companies. Again, the interviews could not determine whether this was a deficiency in practice or a failure of recall.

H.2.3.d *Hearing protector availability and use*

According to the management representatives, all of the companies provided hearing protectors, although 28% did not provide two or more types, as required (Table H7). In general, this was confirmed by employees. On average, 94% of employees (SD 11%) said hearing protectors were available at no cost whenever they needed one. However, at 11 (15%) companies, 11-20% of employees said hearing protectors were *not* readily available; at five

(7%) companies, 21-35% of employees reported this; and at two (3%) fruit packing companies, 46-48% of employees reported this.

Only 25 (34%) management representatives said their company had a formal policy and/or enforcement practices requiring use of hearing protection, either in the entire production area or in specific noisy areas. According to interviewed employees, however, hearing protector use policies were more common than reported by the management representatives. At 23 (32%) companies, more than 90% of employees said the company had a policy requiring them to wear hearing protection; however, the management representatives at eight of those companies reported no such policy. At another 25 (34%) companies, 51-90% of employees said a company policy applied to them; and at 19 (26%) companies, 25-50% of employees said this.

Availability of two or more types of hearing protection and company enforcement policies were more common in some industries than others (Table H8).

The reported use of hearing protection was included as a variable in calculating the noise subscore (and overall score) for employee interviews. The findings are in section H.2.4.

H.2.3.e *Audiometric testing*

All companies in the two highest interview-score quartiles conducted annual testing, whereas only 37% in the lowest quartile had ever done any testing, annually or less often (Table H7). All companies in the second lowest quartile had conducted testing, but 38% had not done so on an annual basis. Annual testing tended to be more common in some industries than others, although the difference was not statistically significant (Table H8).

Most but not all interviewed employees at companies with annual testing programs said they had been tested at least once. When analysis was restricted to employees with $\geq$1 year of employment at companies with annual testing programs, 79% (mean; SD 30%) said they had been tested annually, and another 8% (SD 11%) had been tested less often. The percentage who reported annual testing was significantly higher at companies in the two highest interview-score quartiles (87%) than in companies in the lower quartiles (64%).

At the 54 companies with annual testing programs, 17 (31%) of the interviewed management representatives did not know what a standard threshold shift (STS) was, before explanation by the interviewer. This was much more common at companies in the two lower interview-score quartiles (65%) than in the two higher quartiles (17%). Nearly all companies (91%) in the two higher quartiles reportedly provided written notification to employees with an STS, but only half (50%) of those in the two lower quartiles. Employee retraining after an STS was provided less often, 67% of companies in the two higher quartiles, and only 11% in the two lower quartiles. The reported company actions after an STS were more thorough in some industries than others but were not complete at all companies in any one industry (Table H8).

H.2.4 Use of hearing protection

Overall, 62% of interviewed employees (mean; SD 29%) said they always or nearly always used hearing protection while exposed to loud noise, i.e., "so loud you have to raise your voice for someone to hear you from an arm's length [or 2 to 3 feet] away." Another 25% (SD 21%) said they sometimes used hearing protection while exposed. The percentage of "always" users was significantly higher at companies with higher management interview scores, up to 77% on average in the two highest quartiles. The percentage of "always" users at a company showed a higher degree of correlation with the percentage of employees who said the company had a policy requiring them to wear hearing protection (Pearson $r = 0.72$, $p<.001$), than with the management interview score ($r = 0.59$, $p<.001$).

The reported use of hearing protection, while exposed to noise, differed significantly between industries (Table H6 and **Figures H8A and H8B**). Usage was highest in the three industries (LM, HM, and FV) where excessive noise exposure was also most prevalent. In the other industries, on average, only about 40% to 60% of employees reported always or nearly always using hearing protection when exposed. The reported use of protection also differed widely between companies within each industry (Figure H8B), although the range tended to be smaller in two industries (HM and LM).

Employees were asked about their use of hearing protection when they spent time around noise outside of work. These results were analyzed for individual employees and were not aggregated by company. Half of the employees (53%) said they were never or almost never exposed to loud noise outside of work. Of the other employees, 44% said they always used hearing protection, and 52% said they sometimes did so. Employees were almost twice as likely to say they always used protection at home if they reported always using protection at work (50% of 456), than were employees who reported only sometimes using protection at work (27% of 157; $p<.001$). Inexplicably, of the 60 employees who reported never using protection at work, 40% said they always used protection outside of work.

H.2.5 Reliability analyses: Self-reported exposure and use of hearing protection

The employee interview questions about personal use of hearing protection were carefully phrased and presented to emphasize the amount of use *while exposed* to loud noise (using the "arm length" guideline), and not the amount of use relative to the entire shift.

The reliability analyses of employee responses separately addressed the reported frequency of exposure and the reported frequency of hearing protector use while exposed. The reliability analyses primarily used responses from the brief post-shift interviews, which asked specifically about the day of evaluation. All other analyses of reported use of hearing protection were based on the standard interviews, which asked about *usual* use of hearing protection, while exposed.

The post-shift interviews asked separately about the first and second halves of the shift. Regrettably, the interview did not ask about the full shift overall, and employee responses about each half had to be combined during analysis, where possible. For example, a response of "never" for one half, and "about half the time" for the other half, was combined as "less than half the time" for the entire shift. In some cases, combinations were not possible; for example, a response of "never" for one half, and "more than half the time" for the other half. Of the 514 employees with post-shift interviews, full-shift responses regarding exposure to loud noise were determined for 494 (96%) employees, and regarding use of hearing protection, for 415 (81%) employees. The latter was lower in part because employees were only asked about protector use while they were exposed to loud noise, and it was necessary to have perceived exposure in both halves of the shift to determine full-shift use of hearing protection: 54 employees said they were never (or almost never) exposed during the shift; another 25 had incongruous responses for the first and second halves of the shift.

H.2.5.a *Exposure*

Exposure data from full-shift personal noise dosimetry and post-shift interviews were available for 335 subjects in five industries (RC, LM, MS, SM, and FV), and three subjects at one company in another industry (WP).

In the post-shift interviews, about two-thirds of interviewed employees said they were exposed to loud noise either always or almost always (30%), or less than half the time (34%). The others were divided between three categories: never or almost never (12%), about half the time (9%), or more than half the time (14%).

The measured percent of time exposed to noise ≥85 dBA was transformed to analogous categories: never or almost never, 0-10% of the noise monitoring period; less than half the time, 11-39%; about half, 40-60%; more than half, 61-89%; and always or almost always, 90-100%. The reported exposures were fully concordant with the measured percent of time for 30% of employees, and agreed within one category for another 49%. This represented a moderate degree of agreement: intra-class r_{ICC}= 0.52; p<.001. The amount of agreement differed significantly between industries (**Figure H9A**; chi-square test, p=.001).

Employees who said they were exposed to loud noise – using the "arm length" guideline – more than half the time tended to over-estimate the amount of time they were exposed to noise ≥85 dBA, and those who said they were never exposed to loud noise tended to under-estimate their exposure (**Figure H10**d). Employees with intermediate reported exposures tended to be correct, relative to a threshold of ≥85 dBA.

Half of the 103 employees who said they were "never" (or "almost never") exposed to loud noise were actually exposed to noise ≥85 dBA for 26% or more of their shift (median; IQI 5-43%; Figure H10d). Their actual exposures to loud noise did not equate to never or almost never exposed unless one used a higher threshold to define noise as loud. Using ≥90 dBA as a threshold, their median duration of exposure was 8% of the shift (IQI 1-18%; Figure H10e). Only by using a threshold of ≥95 dBA did most – but not all – subjects' exposures truly approach never exposed (median 1%; IQI 0-5%; Figure H10f).

Conversely, half of the 42 employees who said they were "always" (or "almost always") exposed to loud noise were actually exposed to noise ≥85 dBA for no more than 80% of their shift (median; IQI 53-87%; Figure H10d). Their actual exposures to loud noise did not equate to always or almost always exposed unless one used a lower threshold to define noise as loud. Using ≥80 dBA as a threshold, their median duration of exposure was still 85% of the shift (IQI 76-91%; Figure H10c). Most, but not all, subjects' exposures truly approached always exposed only if one used a threshold of ≥70 dBA or ≥75 dBA to define loud noise (Figures H10a and H10b).

H.2.5.b *Hearing protector use*

Data about hearing protector use were available from post-shift employee interviews for 415 employees, 410 of whom worked in five industries (RC, LM, MS, SM, and FV; WP, n=5). About three-quarters (74%) of these employees said they always or almost always used hearing protection while exposed, and 17% said they never or almost never used hearing protection while exposed, on that one day. Only small percentages of employees gave other responses: more than half the time, 6%; about half, 1%; less than half, 4%.

An additional 54 interviewed employees said they were not exposed to loud noise in either the first or second half of the shift, and they were not asked about use of hearing protection. In actuality, some of these employees had personal dosimetry that showed exposure ≥85 dBA for part of the shift, and some were observed using hearing protection. However, because they did not perceive themselves as being exposed to loud noise, they could not be asked about use of hearing protection *while exposed* to (perceived) loud noise.

Observations of noise exposure and hearing protector use were made for 876 employees overall, but 31% had only one or two observations. Analysis was restricted to employees who had three or more observations, at least one of which occurred during exposure (n=381). About half (46%) of these employees were observed three or four times during exposure. Because of the limited number of observations for each employee, the observed use of hearing protection was categorized only as never (29% of employees), sometimes (7%), or always (63%).

The reliability analyses examined agreement between reported use of hearing protection on the

day of evaluation (post-shift interview), reported *usual* use of protection (standard interview), and observed use.

H.2.5.c *Hearing protector use – reported usual use vs reported use on one day*

This analysis excluded 20 employees (5%) who reported noise exposure in the post-shift interview but who, in the standard interview, said they usually were never exposed to loud noise. They could not be asked about usual use of protection, while exposed, because they did not perceive themselves as usually having exposure.

Of the remaining 395 employees, responses about usual protector use compared to responses about use on the day of evaluation were fully concordant for 78% of employees and differed by only one category for another 11% of employees (e.g., "always" as one response and "more than half the time" as the other). The measure of agreement was high, r_{ICC}= 0.75 (p<.001).

The amount of agreement was similar when the three mid-range response categories were combined as one "sometimes" category (less than half, about half, and more than half the time): full concordance for 82% of employees; r_{ICC}= 0.71 (p<.001).

H.2.5.d *Hearing protector use – observed use on one day vs reported use on one day*

Post-shift interviews were available for 213 employees with three or more observations. Of note, the percentage of "always" observed use of hearing protection was higher (77%) in this group of 213 employees, and "never" use was lower (16%), than in the larger sample of 381 employees, representing a possible selection bias.

Responses on the post-shift interview were fully concordant with observations for 86% of these employees. As mentioned, the observed use of hearing protection used only three categories: never, sometimes, and always. Another 12% were discordant by only one category (e.g., always by report and sometimes by observation), but only 2% were fully discordant (e.g., always by report and never by observation). The overall measure of agreement was high, r_{ICC}= 0.78 (p<.001). The amount of agreement differed significantly between industries (**Figure H9B**; chi-square test, p=.009).

H.2.5.e *Hearing protector use – observed use on one day vs reported usual use*

Information about *usual* hearing protection use, from the standard employee interview, was available for 357 employees with three or more observations. The amount of full concordance between observed use and reported usual use (69%) was lower than found with reported use on that day, and discordance by one category (23%) and full discordance (8%) were both higher. The measure of agreement was moderately high, r_{ICC}= 0.62 (p<.001).

For most analyses of the reported use of hearing protection as a study outcome, this variable was dichotomized as always or other (never plus sometimes). When this variable was compared with observed use on one day, dichotomously, concordance was higher (82%), and the measure of agreement was unchanged, r_{ICC}= 0.61 (p<.001).

H.2.6 Audiometry

H.2.6.a *Hearing loss*

Hearing loss was common on existing audiometry for current and recent employees. Overall, among the 5,227 employees tested at the most recent testing session (1999 or later) at a study company, 15% had enough hearing loss on the most recent audiogram to meet American Medical Association (AMA) criteria for "impairment," and another 11% had moderate or worse

high frequency loss (average threshold >40 dB at 3, 4, and 6 kHz) without impairment.

The prevalence of hearing loss differed significantly between industries (Table H6 and **Figure H11**). Hearing loss was most common in lumber mill (LM) employees: 22% had evidence of impairment, and another 13% had moderate or worse high frequency hearing loss. Hearing loss was least common in printing (PR) employees: 7% had evidence of impairment, and another 5% had moderate or worse high frequency loss.

Audiometry data were available for only 16 employees at one company in the FV industry. The data were included in Figure H11 but not in subsequent analyses of audiometry data by industry.

All subsequent analyses in this (Audiometry) section used data that were *not* aggregated by company, for several reasons. Occupational hearing loss is generally caused by noise exposures over a person's career, and the proportion of hearing loss attributable to the current employer varies widely between individuals. Comparison of hearing ability with reference databases required data to be in similar format, i.e., unaggregated individual data that can be categorized by gender and age. Finally, the individual was the unit of interest when comparing audiometry findings with interview findings.

H.2.6.b ***Hearing loss, by age and industry***

Two approaches were used to characterize whether the observed amount of hearing loss was more than "normal." First, the study industries were compared to an internal reference group, i.e., the industry with lowest prevalence of hearing loss (PR). Second, the study findings were compared with an external reference group.

To simplify analyses, the industries were categorized according to the overall prevalence of hearing loss: low prevalence, 12% (PR); moderate prevalence, 22-23% (WP, SM, MS); and high prevalence, 29-35% (HM, LM, RC). The analyses included current and former employees with an audiogram performed after 1998. Females were excluded because they represented only 11% of the sample (n=583), and had widely differing presence in each industry. As mentioned, the small number of records from one company in the FV industry were excluded.

The analyses were stratified by age because, not surprisingly, the prevalence of hearing loss increased with age. Overall, 53% of employees older than 55 years had evidence of impairment, and another 21% had moderate or worse high frequency hearing loss.

Internal comparison

Hearing loss was at least 1.5 times more common in the moderate and high prevalence industries, than in the low prevalence industry (PR), in each of three age groups in the 26-55 year age range (**Figure H12**), although the differences were only marginally significant for the 36-45 age group. There was no difference between industry categories in the youngest age group.

Interestingly, the prevalence of hearing loss in the oldest age group was comparably high in the “low” prevalence industry (PR, 79%) and the high prevalence category (81%), but significantly lower in the moderate prevalence category (69%). One conceivable explanation for the relatively high prevalence of hearing loss in older printing employees would be *if* noise exposures in that industry were much higher in the past than at present, while noise exposures in the other study industries changed less over time. On the other hand, the finding could be a chance artifact.

Reference databases

Three reference databases described in ANSI S3.44-1996 were used for external comparison with the study data.[30]

The ANSI **Annex A** database is a compilation of multiple, separate population-based studies. It includes "screened" individuals, i.e., individuals with no symptoms, signs or history of otologic problems and no substantial history of noise exposure.[31] Annex A does not provide an optimal reference for epidemiologic comparison with the present study sample, because the present study sample was unscreened, with no comparable exclusion criteria.

The **Annex B** database is from a US Public Health Survey conducted in 1960-1962, using an "unscreened" population-based sample. However, the Annex B sample included an unknown proportion of individuals with occupational noise exposure.

The **Annex C** database, also known as the NINEP (Non-Industrial Noise Exposed Population) database, includes individuals who were unscreened, excluding only those who reported two or more weeks of industrial noise exposure.[32] Individuals with military, farming, or recreational noise exposure were included.

In principle, the Annex C database provides an optimal reference for epidemiologic comparison with the present study sample, because the major identifiable difference from the present study sample is the presence or absence of industrial noise exposure. However, there are potential limitations to using the Annex C database. The Annex C sample was relatively small, and questionably population-based. Annex C reference values are provided separately for white and black males (and females). There were only 301 white males, of whom only 44 were in the 50 and 60 year age categories combined. The sample was drawn from students at a technical school in a rural area, and visitors to a shopping mall on four Saturday afternoons in an urban area, both in North Carolina. Other than the mentioned exclusion criteria, the recruitment process and rates of participation were not described, and presumably the shopping mall subjects were predominantly self-selected. The degree of participation bias may have been high. The narrow geographic origin of Annex C subjects introduces a possible bias, in that the distribution of otologic disease and non-industrial noise exposure in the sampled North Carolina population might differ substantially from individuals in other regions. Finally, all three of these ANSI databases were derived from studies conducted in the 1960s and 1970s, and patterns of disease and non-industrial exposure may have changed in the subsequent years.

External comparison

Summary values from the Annex A, B, and C databases were compared to the present study sample, with restriction to male subjects. The available data from these databases did not allow creating categories of hearing loss, as for the study sample. Therefore, comparisons utilized the binaural mean hearing thresholds at two sets of frequencies: frequencies used to rate impairment by AMA criteria (0.5, 1, 2, and 3 kHz; HTL_{5123}); and frequencies used in this study to define high frequency hearing loss (3, 4, and 6 kHz; HTL_{346}). Note, these were not mutually exclusive; each included hearing thresholds at 3 kHz. Statistical significance could not be estimated with the summary data readily available for the reference databases, and all comparisons were descriptive.

The Annex B and Annex C databases yielded fairly similar reference values. The HTL_{5123} values differed by only -1.7 to 3.0 dB at the median, 10^{th} percentile, and 90^{th} percentile for each age-specific distribution (Annex C minus Annex B; **Table H9** and **Figure H13A**). The HTL_{346} values differed by only -0.7 to 3.4 dB, other than at the 10^{th} percentile for 60 year old subjects, where the difference was -6.7 dB (**Figure H13B**). In contrast, reference values from Annex B and Annex C were consistently higher than those from Annex A throughout their distribution: age-specific HTL_{5123} values differed by 3.2 to 6.0 dB at the median, and by 6.5 to 11.0 dB at the 10^{th} percentile; and HTL_{346} values differed by 9.4 to 13.4 dB and 10.3 to 28.3 dB, respectively.

If Annex C (or Annex B) was an optimal reference database for epidemiologic comparison with

the present study sample, then Annex C values should generally be the same or lower than respective values in the study sample. Annex C values would only be higher if industrial noise exposure was somehow protective against hearing loss, or if there was a difference in some other risk factor for hearing loss, or by chance occurrence. It is noteworthy that 10th percentile values of HTL_{346} from Annex C were 10.7 to 15.4 dB higher than in the "low prevalence" study industry (PR), for individuals who were 26 to 45 years old, and the median value in the 46-55 year age group was 7.9 dB higher (Figure H13B). In addition, 10th percentile HTL_{5123} values from Annex C were 2.6 to 4.9 dB higher, for all three age groups under 55 years. A similar pattern was seen in relation to Annex B (Figure H13A). It is not likely that printing is protective against hearing loss, and the pattern of differences does not seem random.

These observations suggest that comparison with Annex B or C may under-estimate the true extent of hearing loss in the study sample, beyond what is "normal." On the other hand, comparison with Annex A would probably over-estimate the true extent of hearing loss. Regardless, making the conservative comparison with Annex B or C, the median and 10th percentile values of HTL_{5123} and HTL_{346} in the oldest age group are substantially higher (Figures H13A and H13B), and the 10th percentile values are somewhat higher in the immediately younger age group, at least in the higher prevalence industries.

H.2.6.c *Hearing problems*

Hearing problems were common in the study sample. In the employee interviews, 31% overall said they had a hearing problem (hearing difficulty and/or tinnitus) that interfered with their daily life.

Audiometry findings were reviewed for 741 interviewed employees with an audiometric record at the present company, conducted at least as recently as 1999. Employees were often not aware of hearing loss evident on their audiogram. Of the 517 employees who said they had no hearing problem, 11% had audiometric evidence of impairment or moderate (or worse) high frequency hearing loss, and another 15% had mild high frequency hearing loss (HTL_{346} 26-40 dB).

Conversely, of the 170 employees with audiometric evidence of impairment or moderate (or worse) high frequency hearing loss, 35% reported no hearing problems, and 56% said they were never told by a workplace tester or company representative they had bad hearing.

H.2.6.d *Standard threshold shifts*

Audiometry findings were reviewed for the existence of a standard threshold shift (STS), among the 577 interviewed employees who had audiometric record spanning at least three years. Of the 97 employees with at least one STS at their present company, only 29% recalled ever being informed about this finding, either verbally or in writing. Conversely, of 58 employees who said they had been informed they had an STS, only 48% truly had an STS evident on audiometry.

H.3 **Conclusions – Current exposures and practices, and differences between industries**

Aim 3: To determine whether there is any substantial work-related risk at the present time for OHL in industries with high numbers and/or rates of OHL claims.

H.3.1 **Noise exposure and noise controls**

Excessive noise exposure was common in all of the study industries. Nearly all companies had employee exposures that required a hearing loss prevention program, and more than half had employee exposures that required the employer to consider possible noise controls. In general, the possibility of new noise controls received no or low priority in all of the study industries.

- All except three companies (96%) had at least one employee with a full-shift L_{ave} $\geq$85 dBA, and 79% had three or more employees exposed this high. Employers are required to maintain a hearing loss prevention program for employees with such exposures. Note, this requirement applies to construction employers in Washington State, but not in states where the less stringent OSHA rule applies. In addition, 62% of companies had one or more employees with an L_{ave} $\geq$90 dBA, the level at which employers are required to implement noise controls, if feasible.

- Excessive employee noise exposure would have been 1.5 to 3 times more common if the L_{eq} was used to characterize full-shift noise exposures, rather than the L_{ave}.

  This study used the full-shift L_{ave} to characterize noise exposure, because this measure is prescribed by WISHA and OSHA for judging compliance with noise regulations, and one goal of this study was to judge regulatory compliance. However, the L_{eq} is recommended by NIOSH and is used by most regulatory and advisory bodies outside the United States. Using L_{eq} rather than L_{ave} to characterize exposure, the number of monitored employees with full-shift exposure $\geq$85 dBA would have been 1.5 times higher (74% versus 50%), and the number exposed $\geq$90 dBA would have been 3.0 times higher (42% versus 14%).

- Not surprisingly, the percent of employees with excessive noise exposure differed significantly between the study industries. However, excessive exposure was common in all industries.

  The percentage of monitored employees with full-shift exposures (L_{ave}) $\geq$85 dBA ranged from 95% at lumber mills to 30% at printing companies.

- The percent of employees with excessive noise exposure differed widely between companies within most of the study industries.

  Within each study industry, except one (LM), the company with the highest percent of monitored employees with excessive exposure (L_{ave} $\geq$85 dBA) differed from the company with the lowest percentage in the same industry by at least 63% and up to 100%.

- Employee noise exposures were relatively continuous at lumber mills. However, In all other industries, employee exposures generally were intermittent, and most employees spent at least several hours daily in areas where noise levels were under 85 dBA.

- In general, the possibility of new noise controls received no or low priority in all of the study industries. The study team judged that it would have been feasible for all or nearly all of the participant companies to implement one or more effective noise controls, at reasonable cost, to achieve a meaningful reduction in noise exposures for one or more employees. However, most companies had insufficient information about noise exposures in their workplace, and most had no plans to consider or implement any new noise controls.

  The judgment that noise controls were feasible at nearly all companies was crude and is probably subject to error. The judgment was not based on comprehensive assessment of major noise sources, and was based only on monitoring of employee noise exposures, limited sampling of area noise levels, and the observations and professional opinions of the study team. However, allowing for potential errors in judgment, new noise controls probably would have been feasible at many, if not most, of the participant companies.

  Regardless, more than half of the companies had one or more employees with noise exposures that would require the company at least to consider possible noise controls. However, two-thirds had either never measured noise levels or kept no records of noise measurements, only 11% had mapped noise levels in the workplace, and less than half were considering or had made any plans to reduce noise exposures. Of note, the percentage of companies considering or planning possible new noise controls did not differ substantially

between industries, even though some industries were significantly noisier than others.

H.3.2 Hearing loss prevention programs

Most of the evaluated companies had substantial shortcomings in their hearing loss prevention programs. In general, there was little difference between industries in the use of noise measurements or consideration of noise controls. However, policies and practices related to employee training, hearing protection, and audiometric testing were generally more complete in some industries than others. Within each industry, there were substantial differences between companies in the completeness of hearing loss prevention policies and practices. Every industry included some companies with relatively complete policies and practices and some companies where policies and practices were substantially incomplete.

- The management and employee interview scores, and the responses to individual questions, revealed significant differences between industries in hearing loss prevention practices. There was little difference in the use of noise measurements or consideration of noise controls. However, policies and practices related to employee training, hearing protection, and audiometric testing were generally more complete in some industries than others.
- Within each industry, there were substantial differences between companies in the completeness of hearing loss prevention policies and practices. Every industry included some companies with relatively complete policies and practices and some companies where policies and practices were substantially incomplete.
- The management interview score and the company-average employee interview score were strongly correlated, when considered at the level of individual work companies and when averaged by industry. This suggests that greater company effort is, on average, associated with greater employee awareness and knowledge related to hearing loss prevention activities.
- Employers are required to provide hearing loss prevention training upon first assignment of a new or relocated employee to a noise exposed position, and at least annually thereafter for all exposed employees. Annual training was not conducted by more than one-third of companies, and training had shortcomings at many other companies.
- Many employees who presumably had annual training at their present company did not recall ever having such training. Training sessions do not need to be memorable in order to be effective at transmitting knowledge or a skill to a trainee. However, the management and employee interviews indicated that the content of training was incomplete or ineffectively delivered at many companies where annual training was conducted.
- Employers are required to provide at least two different types of hearing protection for noise exposed employees. At most companies, all or nearly all employees reported that hearing protectors were readily available for them at no personal cost, although this was often limited to only one type of protector. At 25% of companies, between 11% and 48% of employees said that no hearing protectors were readily available for them.
- Employers are required to ensure that employees use appropriate hearing protection when noise exposure is excessive. Most company representatives reported no formal company policy or enforcement practices requiring use of hearing protection, either in the entire production area or in specific noisy areas. According to employees, however, hearing protector use policies were more common than reported by company representatives. The findings suggest a need for more enforcement at many companies and improved coordination of enforcement policies at other companies.

H.3.3 Use of hearing protection

Hearing protection was commonly underused. Reported use was highest at companies with relatively complete hearing conservation programs, and in industries where excessive noise exposure was most prevalent and least intermittent. Many employees had difficulty estimating how often, and presumably when, their noise exposure was excessive. This can pose a problem in situations where exposure is intermittent and hearing protection is used only during exposure.

- Overall, only 62% of interviewed employees said they always or almost always used hearing protection when they were exposed to loud noise. The reported use of hearing protection differed significantly between industries and, in general, was highest in industries where excessive noise exposure was most prevalent and least intermittent.
- The reported use of hearing protection was also generally highest at companies with relatively complete hearing conservation programs, particularly companies with actively enforced requirements to wear hearing protection. This suggests that greater company effort to ensure hearing protection can, on average, result in better employee hearing protective behavior.
- Overall, 25% of employees said they sometimes used hearing protection when they were exposed to loud noise, and another 13% said they either never (or almost never) used protection or were never exposed. It may be appropriate to consider these distinctions in endeavors to increase the use of hearing protection.

  Different solutions may be needed to increase the use of hearing protection, depending on whether the employee uses protectors sometimes or never. We did not ask employees about reasons for not using hearing protection. However, employees who never use protectors may have very different reasons from those who at least use protectors sometimes. They might be especially resistant to changing their behavior or attitudes toward hearing protectors, and might need more attention during training and enforcement. On the other hand, come employees who use protectors sometimes may simply have difficulty judging or anticipating when noise levels are high enough to warrant using protection.
- Employees were often incorrect in estimating how often – and presumably when – they were exposed to loud noise. A commonly taught rule-of-thumb guideline for estimating noise levels was found to have limited reliability. This inaccuracy of employee perception could pose an important problem in industries where noise levels are intermittent and hearing protection may not be needed continuously, unless employees are given more than subjective guidelines for when and when not to wear hearing protection.

  The interviews in this study used a commonly taught rule of thumb to help employees estimate how often they were exposed to noise levels 85 dBA or higher..."noise that is so loud you have to raise your voice for someone to hear you from an arm's length [or 2 to 3 feet] away."

  Employees who reported infrequent or no such exposure tended to under-estimate their actual duration of exposure. In fact, employees who said they were never or almost never exposed to loud noise – on the day their personal exposure was monitored – were not truly never exposed unless one used a threshold of about 95 dBA to define noise as loud.

  In contrast, employees who reported relatively frequent exposure tended to over-estimate their actual exposure. Employees who said they were always or almost always exposed to loud noise were not truly always exposed unless one used a threshold of 70 to 75 dBA to define noise as loud.

- Compared to single-blind observations of hearing protector use, employee self-reported use of hearing protection is a reasonably reliable measure of actual use, if reported use is categorized as never (or almost never), sometimes, or always (or almost always), during exposure to loud noise.

H.3.4 Hearing ability

Hearing loss was common on existing audiometry for current and recent employees.

- Overall, 15% had enough hearing loss to meet American Medical Association criteria for impairment, and another 11% had moderate or worse high frequency loss without impairment. Among employees 55 years or older, 53% had evidence of impairment, and another 21% had moderate or worse high frequency hearing loss.
- Hearing loss was significantly more common in some industries than others. Hearing loss was most common in three study industries (heavy gauge metal manufacturing, lumber milling, and road construction): 29% to 35% of audiograms showed impairment or moderate or worse high frequency hearing loss. The prevalence or extent of hearing loss was intermediate in three other study industries (wood products manufacturing, sheet metal manufacturing, and machine shops; 22-23%), and lowest in the printing industry (12%).
- The difference between industries in the extent of hearing loss was seen in all except the youngest age group of employees, suggesting that the risk of hearing loss continues to the present, in at least six of the study industries.
- The extent of hearing loss was relatively high among printing employees in the oldest age group, suggesting that the risk for hearing loss in this industry may have been higher in the past than in more recent years.
- Hearing ability in the study industries was compared with three "normal" reference databases. The findings indicated that two databases probably under-estimated how much of the hearing loss in the study sample was truly beyond what is "normal," and the other database probably over-estimated the true extent of hearing loss, particularly for individuals younger than 45 or 55 years of age. Within these constraints, the extent of hearing loss was clearly higher than expected for employees older than 55 in all study industries, and for employees 46-55 years old in at least some study industries.
- Hearing problems were reported commonly. Overall, 31% of interviewed employees said they had a hearing problem that interfered with their daily life.
- Employers are required to inform employees about abnormal findings on audiometry, and such findings can provide an important teaching opportunity, to inspire individual employees to improve personal efforts to protect their hearing. However, the majority of workers whose existing audiometry revealed a clinically significant amount of hearing loss had not been informed – or did not recall being informed – that their audiometry showed an abnormality. More than a third had no tell-tale symptoms of hearing loss and were unaware of their documented hearing loss.
- Employers are required to provide written notification and training to individual employees who have a specified amount of hearing change over time, known as a standard threshold shift (STS). This important early indicator of possible noise effects on hearing was not being used effectively. Most employees whose audiometry showed an STS while they were employed at the present company did not recall ever being informed of that finding, and only about half of those who thought they had an STS had truly experienced one. Employee recollection of this important indicator was essentially no better than a random guess.

H.4 Results – Comparison of workplace practices with OHL claims experience

H.4.1 Comparisons between industries

We examined the major outcome variables from the company evaluations, averaged by industry, in comparison to: 1) OHL claims statistics for the respective industry; and 2) OHL claimant reports about their most recent noisy job, from the Project 2 telephone survey, by industry.

H.4.1.a *OHL claims statistics*

In general, the OHL claims statistics showed no significant associations with the major findings of work site evaluations (**Table H10**). However, the prevalence of hearing loss in existing audiometry records showed a significant negative correlation with the prevention index, and marginally significant correlation with the other two claim measures, indicating that the frequency of OHL claims in an industry is somewhat representative of what is found in company surveillance programs. The number of OHL claims in an industry showed modest but only marginally significant correlations with several of the work site findings.

In contrast, the extent of excessive noise exposure at work sites in an industry – indicated by the percent of (monitored) employees with full-shift exposure $\geq$85 dBA – showed relatively strong correlations with all other major findings of the work site evaluations (Table H10). In general, work sites in noisier industries tended to have more complete hearing loss prevention policies and practices, as reported in the management and employee interviews. There was a very high correlation between the extent of excessive noise exposure and the use of hearing protection (Pearson r_p=0.94, p<.001), i.e., employees in noisier industries were more likely to use hearing protection on a regular basis when exposed, than were employees in less noisy industries. Finally, documented hearing loss was generally more common in noisier industries.

H.4.1.b *OHL claims statistics – rank correlation*

Considering that the relative rank of claims measures and evaluation findings might be more important than their numeric value, the comparisons were repeated with Spearman's rank correlation coefficient. This revealed no significant association between the claims measures and the extent of noise exposure, interview scores, or hearing protector usage (each, $|r_s| \leq 0.52$; p>.18). However, the association with prevalence of hearing loss persisted: prevention index, r_s= -0.74 (p=.04); incidence rate, r_s= 0.79 (p=.02); and number of claims, r_s= 0.88 (p=.004).

In general, using rank correlation coefficients, the association between extent of noise exposure and work site findings persisted, but was less strong or not statistically significant for most major findings: management interview score, r_s= 0.81 (p=.02); employee interview score, r_s= 0.52 (p=.18); and prevalence of hearing loss, r_s= 0.67 (p=.07). However, the association with use of hearing protection remained strong, r_s= 0.98 (p<.001).

H.4.1.c *OHL claims statistics – influence of outliers*

Two industries with relatively high incidence rates and absolute numbers of OHL claims had a strong influence on the degree of correlation between claims measures and major findings of work site evaluations (**Figures 14, 15, 16**). One of these industries (LM) had the highest values of all study industries for extent of noise exposure, interview scores, use of hearing protection, and prevalence of hearing loss. In contrast, the other industry (RC) was characterized by relatively low to moderate values for extent of noise exposure and management interview scores, and relatively low values for employee interview scores and use of hearing protection, but relatively high prevalence of hearing loss.

When road construction (RC) was excluded from analysis, the incidence rate of OHL claims showed moderately strong and at least marginally significant correlation with each major work site finding: extent of noise exposure, r_p=0.79 (p=.04); management interview score, r_p=0.76 (p=.05); employee interview score, r_p=0.90 (p=.005); use of hearing protection, r_p=0.720 (p=.07); and prevalence of hearing loss, r_p=0.68 (p=.10). A similar pattern was seen with the prevention index and number of claims, although the degree of correlation was generally less than seen with the claims incidence rate. The correlations between extent of noise exposure and other work site findings were unchanged when RC was excluded, other than an increase in correlation with the prevalence of hearing loss, r_p=0.86 (p=.01).

On the other hand, when lumber milling (LM) was excluded from analysis, none of the claims measures showed a significant correlation with any major findings of the work site evaluations ($|r_p| < 0.30$, $p \geq .51$), other than modest but only marginally significant correlations with the prevalence of hearing loss ($|r_p|$ =0.57 to 0.66, $p \geq .11$). The association between extent of noise exposure and work site findings persisted, but was less strong or not statistically significant for most major findings: management interview score, r_p= 0.67 (p=.10); employee interview score, r_p= 0.52 (p=.23); and prevalence of hearing loss, r_p= 0.70 (p=.08). However, the association with use of hearing protection remained strong, r_p= 0.92 (p=.004).

H.4.1.d *OHL claimant reports (Project 2 telephone survey)*

As described in section G.2.2.a, OHL claimants in the Project 2 telephone survey were asked about conditions at their most recent noisy job; 262 out of 515 were last employed in one of the target industries. The median length of time between that employment and the telephone survey was 4.0 years; it was <10 years for 75% of subjects.

Comparing between the target industries, there was a positive correlation between the percent of OHL claimants who said their noise exposure was constant or nearly constant (at their last noisy job) and what noise monitoring revealed at companies in the same industry (**Figure H18**). In general, the noise monitoring did not affirm the claimant's perspectives that noise exposure was constant, at least not on an absolute scale. The claimant reports about exposures at lumber mills were consistent with the findings of noise monitoring. However, on average, monitored employees in all other industries were exposed to noise levels $\geq$85 dBA for only 24% to 50% of their shift. This may indicate over-reporting of exposure but probably also may reflect the differences between measured and perceived noise (see section H.2.5.a). It is also possible that individuals with OHL were more likely to have constant or relatively constant noise exposures, than other workers in the same industry. When LM was excluded, the positive correlations persisted: percent of time $\geq$85 dBA, r_p= 0.86 (p=.01); percent of full-shift average exposures $\geq$85 dBA, r_p= 0.82 (p=.02).

There was no clear association between what claimants said about the availability of hearing protection and what employees reported in work site evaluations about either availability or use of hearing protection (Figure H18). There was a tendency for hearing tests to be conducted less often in industries where claimants said hearing tests were not provided, but the correlation was not statistically significant (p=.27).

H.4.2 Relationships at the company level

We examined the major outcome variables from the company evaluations according to whether or not: 1) the company was liable for an OHL claim in recent years (1992-1996); and 2) any OHL claimants said their last noisy job was at the company. As described in section H.1.2 and Table H1, all companies in one industry (RC) had liability for an OHL claim in recent years (1992-1998) and/or were mentioned as the most recent noisy employer by an OHL claimant in

the Project 2 phone survey, and nearly all companies in two other industries (PR and WP) had no recent OHL claim experience. Those two industries were excluded from these analyses, and was restricted to the five remaining industries (FV, SM, MS, HM, LM).

In these five industries, 21 (43%) of 49 evaluated companies had liability for an OHL claim in recent years. There was no significant difference in any of the major findings of the work site evaluations, between companies with or without recent OHL claims liability (**Figure H19A**), other than a higher prevalence of employees with hearing loss documented on existing audiometry records at companies with an OHL claim. This association remained statistically significant after adjusting for the differences between industries (analysis of variance, ANOVA, $p<.05$).

In these five industries, 13 (27%) of 49 evaluated companies were mentioned by an OHL claimant in the Project 2 telephone survey as their most recent employer with a noisy work site. All except 2 subjects said noise exposure was constant at that company, and all subjects said hearing protection was available, at least by the end of their employment. Only 2 subjects, referring to 2 different companies, said audiometry was not available. There was no significant difference in any of the major findings of the work site evaluations, between companies that were or were not mentioned in the telephone survey (**Figure H19B**). There was not enough difference in reports about hearing protector or audiometry availability, for meaningful evaluation of the relationships between reports and evaluation findings for those variables.

Using ANOVA to adjust for differences between industries, there was a tendency for mentioned companies to have higher prevalence of excessive noise exposure ($p=.09$) and employees with hearing loss in company audiometry records ($p=.06$), and at least in some industries, lower management interview scores (i.e., industry-survey interaction term, $p=.10$); however, these associations were not statistically significant.

H.4.2.a *Metal fabrication industries*

The three metal fabrication industries (SM, MS, HM) were the only industries in which the evaluated companies were evenly divided between those that did or did not have a connection to an OHL claim, considering either liability assigned by DLI or mention in the Project 2 phone survey. There was no significant difference in any of major findings of the work site evaluations, between companies with or without connection to an OHL claim (**Figure H20**), other than higher prevalence of employees with hearing loss documented on existing audiometry records at companies linked to an OHL claim. This association remained statistically significant after adjusting for differences between industries (ANOVA, $p=.02$).

H.4.2.b *OHL claimant reports about individual companies*

The reports by surveyed OHL claimants about their last noisy job showed limited value for distinguishing individual companies with shortcomings in hearing loss prevention efforts, although this analysis was limited by the small sample of survey subjects (n=15) who last worked in one of the companies (n=14) evaluated in Project 3. As in section H.4.2, all except 2 subjects said noise exposure was constant at that company, and all subjects said hearing protection was available, at least by the end of their employment.

However, 4 subjects, referring to 4 companies, said audiometry was not available, and this was confirmed by the Project 3 evaluation at those companies. Three reports involved the RC (n=2) and MS (n=1) industries. The Project 3 evaluations found audiometric testing was incomplete or absent at most companies in those industries: $\leq$35% of interviewed employees had undergone testing at 6 out of 10 companies in each industry. The company mentioned in the SM industry was, in fact, the only of 10 evaluated companies that conducted no testing; however, testing was incomplete ($\leq$57% of interviewed employees) at most other companies evaluated in that industry.

H.5 Conclusions – Comparison of workplace practices with OHL claims experience

Aim 4: To assess the relative effectiveness of using workers' compensation claims information to "target" (i.e., appropriately identify) industries and worksites with remediable risk factors for a chronic occupational health problem, using OHL as a case in point.

Project 3 *found little evidence that claims statistics for OHL – and conceivably for other occupational illnesses that manifest many years after first exposure to a hazard – are useful for identifying industries where there is a high risk for developing that condition and where additional preventive measures are most needed.*

In general, the reports by OHL claimants in the ***Project 2*** *telephone survey about their most recent noisy workplace also were not an effective source of information for identifying industries that were substantially more in need of intervention than other industries, nor companies that were more in need of intervention than other companies within the same industry.*

- This study evaluated companies in only a limited number of industries, mostly in manufacturing, and included only one primary production industry, one construction industry, and no industries within the broad sector of "other" industries. Therefore, the study findings may have limited generalizability, particularly for the industries outside the manufacturing, production, and construction sectors.

  In view of this, it is noteworthy that reported non-availability of hearing protection was relatively high among OHL claimants from the "other" industry sector (i.e., not primary production, manufacturing, or construction). It probably would not be prudent to forego completely the use of claims statistics or claimant reports to identify potential high-risk industries within that sector, or within other industry sectors. However, the findings of this study indicate such information should be interpreted cautiously and probably should not be relied upon as the primary source of information for decision making.

It is conceivable that claims statistics or claimants' reports could be useful for targeting specific industries, if supplemented with other information about candidate target industries.

- For example, in 2004, WISHA initiated a special enforcement program targeting road construction companies, focusing on noise exposure and hearing loss prevention, and also on work zone traffic control.[33] Selection of road construction as the target was based in part on the high rate of OHL claims in that industry, but also general knowledge that safety and health policies and practices are inherently more difficult to implement, and historically have been less complete, in transient industries like construction than in fixed-location industries. Selection was also influenced by factors not directly related to noise or hearing loss, i.e., the high number of worker fatalities on road projects in recent years.
- The statistical measures of OHL claims for the eight study industries showed no consistent relationship with either the average extent of employee overexposure to noise or the average completeness of hearing loss prevention policies and practices, at companies evaluated in those industries.
- One study industry, road construction, was an exception to this general conclusion. This industry had a very high incidence rate of OHL claims, and the companies evaluated in this industry tended to have substantially incomplete hearing loss prevention policies and practices. However, the average extent of employee overexposure to noise and completeness of hearing loss prevention policies and practices in this industry were comparable to what this study found in other industries with much lower rates or absolute numbers of OHL claims.

- Information about OHL claims may have limited or no usefulness for identifying specific companies where there is a relatively high need for additional preventive measures. Individual companies were no more likely to have incomplete hearing loss prevention policies or practices, if they had been assigned liability for one or more OHL claims or if an OHL claimant described them as a recent noisy workplace, compared to other companies that were not linked to an OHL claim, in the same industry.

The OHL claims statistics for (seven of) the study industries showed a significant correlation with the average prevalence of hearing loss on audiometry records in each industry. In industries where OHL claims were more common, monitored employees were more likely to have hearing loss. Claims statistics for OHL – and conceivably other occupational illnesses – may be useful for targeting initiatives to identify workers who have that condition and who may not be aware they have the condition.

- This correlation between claims statistics and hearing loss prevalence suggests the rise in claims observed in the 1990s was non-differential, relative to industry.

Information about the usual extent of noise in an industry is probably a better source of information for targeting interventions to reduce risk for developing OHL, than is information about hearing loss claims, although the two may be useful when considered together. In general, the average completeness of hearing loss prevention policies and practices at work sites in a study industry was strongly associated with the extent of noise overexposure in that industry. Furthermore, the intuitive response to information about noise levels would not necessarily be the best response. The industries with greatest margin for improving hearing loss prevention efforts are not necessarily the noisiest industries, but may be industries where noise exposure is more moderate or intermittent.

I PUBLICATIONS AND PRESENTATIONS

I.1 Peer-reviewed articles

- Daniell WE, Swan SS, McDaniel MM, Stebbins JG, Seixas NS, Morgan MS. Noise exposure and hearing conservation practices in an industry with high incidence of workers' compensation claims for hearing loss. *Am J Indust Med* 2002; 42:309-17. [see **Appendix 1**].
- Daniell WE, Fulton-Kehoe D, Cohen M, Swan SS, Franklin GM. Increased reporting of occupational hearing loss: Workers' compensation in Washington State, 1984-1998. *Am J Indust Med* 2002; 42:502-10. [see **Appendix 2**].

I.2 Monographs

Three monographs – *Occupational noise exposure and hearing loss prevention: A technical report and guidebook for [industry name] companies* – have been prepared, related to this research. The monographs are nearly ready for printing. The three industries are:

- Sheet metal manufacturing
- Wood products manufacturing
- Fruit and vegetable processing

I.3 Presentations

- Daniell WE: Noise-level color banding for safety signs and simplified recommendations for use of hearing protection. Annual UW-UBC Occupational and Environmental Health Conference. Semiamhoo, WA; January, 2005.
- Daniell WE: Noise exposure and hearing conservation programs in selected industries in Washington State. National Hearing Conservation Association (NHCA) Annual Meeting. Seattle, WA; February, 2004.
- Daniell WE, Swan S, Camp J, McDaniel M, Cohen M, Leo R: Factors associated with the rise in workers' compensation claims for hearing loss in Washington State. Northwest Occupational Health Conference (NOHC). Seattle, WA; October, 2003.
- Daniell WE, Cohen M: Noise exposure and hearing conservation programs in selected industries in Washington state. NOHC. Seattle, WA; October, 2003.
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Miscellaneous

K INCLUSION OF GENDER AND MINORITY STUDY SUBJECTS

The study subjects were selected without direct exclusion based on gender or minority status.

The percentage of women participating in Project 2 (telephone survey of individuals with a workers' compensation claim for hearing loss) was 3.4%. In Project 3 (field evaluations of work sites in noisy industries, including employee interviews), the percentage was 16%. Note, Project 1 simply involved analysis of data collected previously during Washington State OSHA inspections at ten foundries in the greater Seattle area. Because no exclusions were made on the basis of gender, these percentages should be reasonably representative of the population of potential study subjects.

Some minority potential subjects were probably excluded from study participation because they did not meet the study requirement to speak English for Project 2, or to speak English or Spanish for Project 3.

We did not collect information about race or ethnicity for study participants or potential participants, and cannot characterize percentage exclusion or participation relative to minority status. However, within the constraints of language speaking ability, the distribution of minority status among study subjects should parallel the distribution among individuals who filed a workers' compensation claim for hearing loss (Project 2) and/or were employed in a blue collar occupation in the western part of Washington State, particularly the nine study industries.

L INCLUSION OF CHILDREN

The study did not include children. The study samples were restricted to individuals who were old enough to have a hearing loss claim and/or to be employed in one of the studied industries.

Table E1 **Target industries**

Industry	DLI risk class (numeric code and description)	
Road Construction	0101	Street or road construction, NOC
	0210	Asphalt paving roadways
	0214	Concrete paving roadways
Lumber milling	1002	Sawmills: operation and maintenance
	2904	Veneer: mfg
	2904.01	Plywood: mfg
Pulp and paper production	2401	Paper, pulp or wood fiber: mfg
Heavy gauge metal mfg	5208	Iron or steel works shop, structural
	5209	Boilermaking, tank building shop
	5209.01	Metal goods NOC mfg, 9 gauge or heavier
Machine shops	3402.05	Machine shops, NOC
	5109.46	Heavy machinery and equipment: mfg
Sheet metal manufacturing	3404.01	Can: mfg
	3404.07	Metal goods NOC mfg, 9 gauge or lighter
Fruit/vegetable processing	2104.01	Vegetable packing
	2104.02	Fruit packing
	3902	Fruit and vegetable: cannery and freezer operations
	3902.02	Fruit syrup or fruit juice: mfg
Printing	4101	Printing, lithography, engraving, map printing
	4103.01	Newspaper publishing
Wood product manufacturing	2903.08	Sash, door or assembled millwork: mfg
	2905	Furniture and casket: mfg wood
	2907	Cabinet countertop and fixture: mfg wood

NOC = Not otherwise classified. Mfg = Manufacturing.

Table E2 **Selected industries with high numbers and incidence rates of occupational hearing loss claims, (sorted by incidence rate, 1997-1998)**

Industry *	Number of workers **	Number of claims (mean per year)			Claims incidence (per 1000 FTE, per year) **			Prevention index †	
Listed in order of incidence rate, 1997-1998	1997-98	1992-96	1997-98	Rank 1997-98	1992-96	1997-98	Rank 1997-98	1992-96	1997-98
Road construction	**6,199**	**185**	**217**	**6**	**26.0**	**35.0**	**5**	**5.5**	**5.5**
Lumber milling	**15,780**	**224**	**386**	**1**	**19.7**	**24.4**	**9**	**5**	**5**
Pulp and paper production	**8,029**	**406**	**132**	**12**	**17.7**	**16.4**	**15**	**5**	**13.5**
Heavy gauge metal mfg	**4,137**	**44**	**50**	**31**	**8.4**	**12.0**	**17**	**23.5**	**24**
Machine shops	**9,733**	**73**	**92**	**18**	**5.5**	**9.4**	**27**	**25**	**22.5**
Sheet metal mfg	**10,704**	**66**	**74**	**23**	**4.8**	**6.9**	**36**	**27.5**	**29.5**
Fruit/vegetable processing	**20,782**	**27**	**107**	**14**	**3.1**	**5.2**	**45**	**42.5**	**29.5**
Printing	**8,625**	**75**	**39**	**33**	**2.7**	**4.5**	**47**	**35**	**40**
Wood product mfg	**6,906**	**28**	**32**	**36**	**2.4**	**4.6**	**46**	**46**	**41**
(Foundries – Pilot Project)	**4,181**	**32**	**34**	**34.5**	**8.9**	**8.1**	**31**	**25.5**	**32.75**
All industries	**1,985,959**	**4,492**	**5,090**	**(1-106)**	**1.75**	**2.56**	**(1-106)**	**(1-106)**	**(1-106)**

* Mfg = manufacturing

** Full-time equivalent (FTE) employees; mean per year

† Average of $rank_{number}$ and $rank_{incidence}$

Table G1 Background of phone survey participants

	Claim filed <2 years after "date of injury" (n=366)	Claim filed >2 years after "date of injury" *	
		Age ≤65 years (n=179)	Age >65 years (n=226)
Years between "date of injury" and filing claim	0.4 ± 0.5	10.2 ± 6.8 (c)	14.9 ± 7.8 (c)
Years between filing claim and telephone survey	3.2 ± 1.0	3.0 ± 0.7 (b)	2.9 ± 0.6 (c)
Age (years), at filing	58.1 ± 6.5	58.7 ± 5.1	74.2 ± 4.7 (c)
46-55 years	133 36%	49 27% (c)	0 (c)
56-65 years	203 55%	130 73%	0
66-75 years	21 6%	0	130 58%
76-85 years	9 2%	0	96 42%
Gender			
Male	354 97%	170 95%	221 98%
Female	12 3%	9 5%	5 2%
Education			
< 12 years	45 12%	35 20%	54 24% (c)
High school	129 35%	65 36%	83 37%
Voc training	115 31%	41 23%	47 21%
College	76 21%	36 20%	38 17%
Weapons fire, military			
Never in military	110 30%	57 32%	49 22% (a)
Basic training only	127 35%	67 37%	101 45%
< 1 year	18 5%	10 6%	15 7%
1-2 years	53 14%	18 10%	32 14%
3-4 years	43 12%	19 11%	22 10%
> 4 years	15 4%	5 3%	5 2%
Weapons fire, recreational			
Never used weapons	259 71%	118 66%	158 70%
< 1 year	24 7%	10 6%	18 8%
1-5 years	12 3%	9 5%	8 4%
6-20 years	31 8%	13 7%	9 4%
> 20 years	31 8%	23 13%	28 12%

* The "date of injury" is determined by DLI, based on the date of last occupational noise exposure and/or the date of the OHL diagnosis, whichever occurred first.
Letters in parentheses indicate statistical significance of difference between that subject group and the

Table G2 Employment background of phone survey participants

	Claim filed <2 years after "date of injury" (n=366)		Claim filed >2 years after "date of injury" *			
			Age ≤65 years (n=179)		Age >65 years (n=226)	
Emploment status						
Working	162	44%	59	33% (c)	11	5% (c)
Not working	17	5%	1	1%	0	0%
Disabled	21	6%	25	14%	6	3%
Retired	166	45%	94	53%	208	92%
Industry						
Very low PI *	121	45%	143	58%	102	41% (c)
Low PI	75	28%	55	22%	49	19%
Moderate or high PI	76	28%	49	20%	101	40%
First noisy job (years ago)	37.6	± 9.3	38.3	± 8.1	50.3	± 9.2 (c)
≤ 20 years ago	13	4%	3	2%	0	0% (c)
21-30 years ago	56	15%	28	16%	9	4%
31-40 years ago	158	43%	65	36%	19	8%
> 40 years ago	138	38%	79	44%	192	85%
Last noisy job (years ago)	5.6	± 9.2	10.2	± 8.2 (c)	18.3	± 12.1 (c)
At the present time	77	21%	15	8% (c)	2	1% (c)
≤ 5 years ago	170	46%	46	26%	10	4%
6-10 years ago	37	10%	36	20%	35	15%
11-20 years ago	27	7%	50	28%	119	53%
> 20 years ago	22	6%	25	14%	58	26%
• **Noise exposure** †						
Constant	241	72%	140	78%	---	
Intermittent	85	25%	36	20%		
Other	10	3%	3	2%		
• **Hearing protection available** †						
Yes	216	64%	81	45% (c)	---	
Yes, but not at first	61	18%	40	22%		
No	59	18%	58	32%		
• **Hearing tests provided** †						
Yes	137	41%	68	38%	---	
Yes, but not at first	26	8%	18	10%		
No	173	52%	93	52%		

* Letters in parentheses indicate statistical significance of difference between that subject group and the "claim filed <2 years" group, using Pearson chi-square test or Student t-test; p value: a, <.05; b, <.01; c, <.001.

** PI = prevention index = average of $rank_{number}$ and $rank_{incidence}$.
Very low PI = 13 industries with lowest PI values. Low PI = next lowest 13.

† Only subjects ≤65 years old were asked about workplace conditions (n=336 in first data column).

Table G3 **Conditions at most recent noisy job, reported by phone survey participants ***

Industry categories, and Target industries in present study	Noise exposure		Hearing protection available			Hearing tests provided			Total
	Constant (n=381)	Intermittent (n=121)	Yes (n=297)	Yes; not at first (n=101)	No (n=117)	Yes (n=205)	Yes; not at first (n=44)	No (n=266)	n=515
Production	**84 88%**	**9 10%**	**51 54%**	**27 28%**	**17 18%**	**51 54%**	**12 13%**	**32 34%**	**95**
Lumber milling	29 94%	2 7%	18 58%	11 36%	2 7%	19 61%	5 16%	7 23%	31
Pulp and paper production	25 86%	3 10%	21 72%	6 21%	2 7%	23 79%	4 14%	2 7%	29
Manufacturing	**160 82%**	**32 16%**	**114 58%**	**49 25%**	**33 17%**	**97 50%**	**23 12%**	**76 39%**	**196**
Heavy gauge metal mfg	24 92%	2 8%	20 77%	2 8%	4 15%	12 46%	2 8%	12 46%	26
Sheet metal mfg	23 79%	6 21%	20 69%	7 24%	2 7%	16 55%	2 7%	11 38%	29
Machine shops	14 67%	7 33%	13 62%	6 29%	2 10%	4 19%	5 24%	12 57%	21
Fruit/vegetable processing	27 93%	2 7%	12 41%	11 38%	6 21%	9 31%	5 17%	15 52%	29
Printing	14 82%	3 18%	7 41%	7 41%	3 18%	11 65%	3 18%	3 18%	17
Wood products mfg	17 90%	1 5%	9 47%	7 37%	3 16%	8 42%	3 16%	8 42%	19
Construction	**69 69%**	**29 29%**	**65 65%**	**11 11%**	**24 24%**	**13 13%**	**3 3%**	**84 84%**	**100**
Road construction	22 88%	3 12%	12 48%	2 8%	11 44%	3 12%	3 12%	19 76%	25
Other industries	**68 55%**	**51 41%**	**67 54%**	**14 11%**	**43 35%**	**44 36%**	**6 5%**	**74 60%**	**124**

* Table shows row percentages, i.e., the percent within each industry category or target industry. Each of the three variables differed significantly when examined between the major industry categories or between the target industries ($p \leq .002$; chi-square test), except noise exposure versus target industries ($p = .10$).

Table G4 Hearing ability of phone survey participants

	Claim filed <2 years after "date of injury" (n=366)	Claim filed >2 years after "date of injury" *	
		Age ≤65 years (n=179)	Age >65 years (n=226)
Claim outcome			
Received disability compensation	337 92%	167 93%	221 98% (b)
Estimated disability (%binaural loss)	17.0 ± 14.2	19.6 ± 15.7	26.1 ± 16.4 (c)
Hearing aid used now			
Regularly	142 39%	87 49% (a)	136 60% (c)
Occasionally	173 47%	76 42%	73 32%
Hearing aid used five years ago			
Regularly	33 9%	19 11%	66 29% (c)
Occasionally	25 7%	11 6%	29 13%
Difficulty hearing, at the present time… **			
When someone speaks in a whisper	137 37%	77 43%	103 46%
When visiting friends, relatives, or neighbors	103 28%	64 36%	81 36% (a)
In the movies or theater	64 17%	44 25%	53 23%
When listening to TV or radio	80 22%	49 27%	70 31% (a)
When in a restaurant with relatives or friends	148 40%	85 47%	110 49%
One or more difficulties (out of 5)	215 59%	124 69% (a)	156 69% (a)
Three or more difficulties (out of 5)	95 26%	56 31%	83 37% (b)
Compared to five years ago †			
Worse now	78 23%	26 15%	48 22%
Better now	147 43%	74 44%	89 41%
No change (or no difficulty)	116 34%	69 41%	82 37%
Tinnitus, at the present time			
Always or nearly always occurs	126 34%	57 32%	54 24% (c)
Comes and goes	101 28%	58 32%	51 23%
Compared to five years ago			
Worse now	84 23%	36 20%	33 15%
Better now	54 15%	21 12%	31 14%
No change (or no tinnitus)	227 62%	122 68%	162 72%

* Letters in parentheses indicate statistical significance of difference between that subject group and the "claim filed <2 years" group, using Pearson chi-square test or Student t-test; p value: a, <.05; b, <.01; c, <.001.

** Difficulty occurs frequently or always (while wearing hearing aid, if used)

† Some subjects were inadvertently omitted from this part of the survey (n=42-56). The displayed percentages were calculated with the reduced denominators.

Table G5 Awareness of hearing loss, by phone survey participants

	Claim filed <2 years after "date of injury" (n=366) **	Claim filed >2 years after "date of injury" *	
		Age ≤65 years (n=179)	Age >65 years (n=226)
First personally suspected hearing might be injured by noise at work	(n=348)	(n=171)	(n=209)
Years ago	15.2 ± 9.9	17.5 ± 9.4 (a)	21.9 ± 12.0 (c)
≤ 5 years ago	49 14%	20 12% (a)	16 8% (c)
6-10 years ago	96 28%	29 17%	24 12%
11-20 years ago	115 33%	62 36%	65 32%
>20 years ago	87 25%	60 35%	100 49%
Health care provider first mentioned hearing loss on hearing test	(n=358)	(n=172)	(n=214)
Years ago	12.2 ± 9.8	13.7 ± 9.9	15.9 ± 11.4 (c)
≤ 5 years ago	117 33%	54 32% (a)	53 25% (b)
6-10 years ago	80 22%	23 13%	31 15%
11-20 years ago	96 27%	53 31%	65 31%
>20 years ago	63 18%	41 24%	63 30%
Health care provider first mentioned hearing might be injured by noise at work	(n=321)	(n=153)	(n=175)
Years ago	9.4 ± 8.6	10.0 ± 8.4	13.2 ± 12.1 (c)
≤ 5 years ago	148 47%	67 45%	71 41% (b)
6-10 years ago	71 23%	30 20%	23 13%
11-20 years ago	64 20%	34 23%	42 24%
>20 years ago	32 10%	19 13%	38 22%

* Letters in parentheses indicate statistical significance of difference between that subject group and the "claim filed <2 years" group, using Pearson chi-square test or Student t-test; p value: a, <.05; b, <.01; c, <.001.

** Some subjects could not answer these questions (n=32-132). The displayed percentages were calculated with the reduced denominators.

Table G6

People or things cited as important or very important in decision to file an OHL claim, depending on age and how soon claim was filed after "date of injury"

	Important influence			Very important influence		
	Claim filed <2 years after "date of injury"	Claim filed >2 years after "date of injury" *		Claim filed <2 years after "date of injury"	Claim filed >2 years after "date of injury"	
		Age ≤65 years	Age >65 years		Age ≤65 years	Age >65 years
	(n=366)	(n=179)	(n=226)	(n=366)	(n=179)	(n=226)
Social contact						
Family member	215 59%	111 62%	126 56%	168 46%	87 49%	96 42%
Friend outside of work	129 35%	72 40%	116 51% (c)	81 22%	37 21%	65 29%
Coworker	148 40%	50 28% (b)	64 28% (b)	80 22%	23 13% (a)	41 18%
Health care						
Screening program, outside work	223 61%	119 66%	156 69% (a)	36 10%	10 6%	9 4% (b)
Usual doctor	87 24%	44 25%	58 26%	46 13%	26 15%	37 16%
Other doctor or provider	105 29%	36 20% (a)	54 24%	75 20%	28 16%	28 12%
Work representative						
Screening program, at work	91 25%	38 21%	24 11% (c)	36 10%	10 6%	9 4% (b)
Safety representative	50 14%	22 12%	23 10%	18 5%	10 6%	14 6%
Company representative, other	36 10%	14 8%	16 7%	23 6%	8 4%	10 4%
Union representative	40 11%	15 8%	12 5% (a)	24 7%	6 3%	7 3%
Other						
Advertisement	67 18%	33 18%	57 25% (a)	22 6%	15 8%	27 12% (a)
Media information	27 7%	14 8%	22 10%	9 2%	7 4%	7 3%
Attorney	14 4%	4 2%	4 2%	8 2%	3 2%	2 1%

* Letters in parentheses indicate statistical significance of difference between that subject group and the "claim filed <2 years" group, using Pearson chi-square test or Fisher's exact test; p value: a, <.05; b, <.01; c, <.001.

Table G7

People or things cited as important or very important in decision to file an OHL claim, depending on whether a hearing tester or screening program outside work was important or not

	Important influence		Very important influence	
	Screening tester or program described as:		Screening tester or program described as:	
	Not important (n=273)	Important (n=498)	Not important (n=273)	Important (n=498)
Social contact				
Family member	146 53%	306 61% (a)	109 40%	242 49% (a)
Friend outside of work	83 30%	234 47% (c)	49 18%	134 27% (b)
Coworker	99 36%	163 33%	48 18%	96 19%
Health care				
Usual doctor	41 15%	148 30% (c)	22 8%	87 18% (c)
Other doctor or provider	47 17%	148 30% (c)	32 12%	111 22% (c)
Work representative				
Screening program, at work	83 30%	70 14% (c)	0 0%	55 11% (c)
Safety representative	31 11%	64 13%	12 4%	30 6%
Company representative, other	19 7%	47 9%	12 4%	29 6%
Union representative	22 8%	45 9%	8 3%	29 6%
Other				
Advertisement	44 16%	113 23% (a)	23 8%	41 8%
Media information (excluding ads)	15 5%	48 10% (a)	3 1%	20 4% (a)
Attorney	3 1%	19 4% (a)	2 1%	11 2%

* Letters in parentheses indicate statistical significance of difference, using Pearson chi-square test or Fisher's exact test; p value: a, <.05; b, <.01; c, <.001.

Table G8

People or things cited as important or very important in decision to file an OHL claim, depending on whether an advertisement was important or not

	Important influence				Very important influence			
	Advertisement described as:				Advertisement described as:			
	Not important (n=614)		Important (n=157)		Not important (n=614)		Important (n=157)	
Social contact								
Family member	260	42%	98	62%	275	45%	76	48%
Friend outside of work	241	39%	46	29% (a)	141	23%	42	27%
Coworker	213	35%	49	31%	115	19%	29	18%
Health care								
Screening program, outside work	385	63%	113	72% (a)	52	8%	3	2%
Usual doctor	142	23%	47	30%	101	16%	8	5%
Other doctor or provider	153	25%	42	27%	129	21%	14	9%
Work representative								
Screening program, at work	128	21%	25	16%	43	7%	12	8%
Safety representative	73	12%	22	14%	36	6%	6	4%
Company representative, other	53	9%	13	8%	36	6%	5	3%
Union representative	57	9%	10	6%	32	5%	5	3%
Other								
Media information (excluding ads)	33	5%	30	19% (c)	8	1%	15	10% (c)
Attorney	14	2%	8	5%	9	1%	4	3%

* Letters in parentheses indicate statistical significance of difference, using Pearson chi-square test or Fisher's exact test; p value: a, <.05; b, <.01; c, <.001.

Table H1 **Worksite survey: Number of participating companies linked to an OHL claim**

Industry *	Abbrev. in study	Participating companies	OHL claims in target risk class, 1992-98			Mentioned in phone survey **	Category B †
Listed in order of incidence rate, 1997-1998		(n=76)	No claims	1-2 claims	≥3 claims		
Road construction	**RC**	**10**	**6**	**1**	**3**	**3**	**4**
Lumber milling	**LM**	**7**	**1**	**1**	**5**		**1**
Heavy gauge metal mfg	**HM**	**9**	**5**	**2**	**2**	**1**	**5**
Machine shops	**MS**	**10**	**7**	**2**	**1**	**2**	**6**
Sheet metal mfg	**SM**	**10**	**6**	**2**	**2**	**4**	**5**
Fruit/vegetable processing	**FV**	**10**	**4**	**4**	**2**	**3**	**3**
Printing	**PR**	**10**	**9**	**1**			**9**
Wood product mfg	**WP**	**10**	**8**	**2**		**1**	**8**

* Only 1 pulp and paper production company was recruited; not shown. Mfg = manufacturing. Abbrev = abbreviation.

** Phone survey of individuals with OHL claim filed in 1997-1998; company was last noisy employer.

† Companies with no OHL claims in target risk class, 1992-1998, and not mentioned in phone survey.

‡ Related category = related risk class (RC) or related branch of corporation (FV)

Table H2A **Worksite survey: Data collected**

Industry *	Number of companies	Personal dosimetry	Interviewed employees	Existing audiometry records (1999 or more recent)		
				Number of companies	Interviewed employees	Other employees
Road construction	10	158	204	3	60	192
Lumber milling	7	84	170	5	101	1,068
Heavy gauge metal mfg	9	120	169	8	134	864
Machine shops	10	89	160	3	65	224
Sheet metal mfg	10	152	240	8	162	962
Fruit/vegetable processing	10	110	225	1	16	0
Printing	10	108	139	5	62	322
Wood product mfg	10	162	250	8	141	854
All industries	76	983	1,557	41	741	4,486
(Foundries -- Pilot project)	(10)	(86)	(92)	(10)	(86)	(219)

* Only 1 pulp and paper production company was recruited; not shown.

Table H2B **Data collected: observations of hearing protector use, and post-shift interviews**

Industry	Number of companies	Number of employees			
		Observations of task and HPD use			Exit interview
		≥1	≥3	≥3, including ≥1 exposed	
Road construction	6	122	56	36	71
Lumber milling	7	166	100	82	94
Heavy gauge metal mfg	0	---	---	---	---
Machine shops	9	125	122	50	48
Sheet metal mfg	10	233	166	115	113
Fruit/vegetable processing	10	229	158	98	183
Printing	0	---	---	---	---
Wood product manufacturing	(1)	---	---	---	(5)
All industries	42	876	602	381	514

Table H3 Primary questions in management and employee interviews

Interview section	Management interview	Employee interview
Noise monitoring and controls	■ Noise levels ever measured ■ Keep records of measurements ■ Can estimate proportion of employees exposed: o > 85 dBA average o >100 dBA average o ≥115 dBA average (≥15 minutes)	■ Ever seen noise measurements ■ Ever notified of monitoring results ■ Ever told personally overexposed to noise because of work
(noise controls)	■ Have noise map; if so, posted ■ Can identify noisy areas: o ≥ 85 dBA o ≥100 dBA o ≥115 dBA ■ Signs posted: o Loud noise areas requiring HPD use o Areas ≥115 dBA	■ Ever seen noise map
	■ Engineered or administrative changes to reduce noise levels: o Ever made o Planned ■ Measurements repeated after changes	■ Aware of any changes made to reduce noise levels ■ Ever informed or consulted about plans for noise controls
Training and HPD fitting HPD = Hearing Protection Device	■ One person responsible for hearing conservation program ■ Provide training o Annually or more often o Non-English language, if necessary □ Written training program ■ Training content: o OSHA required information o How noise damages hearing o When and where to use HPDs o Differences between HPD types o Select, fit, use, care for HPDs o How and why hearing is tested o Work practices to reduce noise o Right to see records o HPD use outside work	■ Can identify person(s) to ask questions about noise or hearing protection ■ Training is provided: o Annually or more often o By live trainer and/or HPD fitter (with or without video) ■ Training content has included: o When and where to use HPD o When to replace HPD o How to select and wear HPD
	■ HPD fitting: o Trained person shows new employees how to wear HPD o Trained person examines fit of HPD on new employees	■ HPD fitting: o Someone examined personal HPD fit (ie, live trainer and/or fitter)

(continued)

Table H3 (continued)

Interview section	Management interview	Employee interview
HPD availability and use	■ Provide HPDs to all exposed workers ■ Provide ≥2 HPD types ■ Method for choosing HPDs: o Noise measurements o HPD specifications o (not cost or subjective or unknown) ■ Specific policy requiring HPD use ■ Methods for ensuring HPDs are worn o Training o Enforcement	■ HPDs at this company: o Provided at no personal cost o Replacements provided as needed o ≥2 types available ■ Specific policy requiring HPD use ■ Frequency of HPD use when exposed: o At work o Outside work
Audiometry STS = Standard Threshold Shift	■ Conduct testing; annually or more often ■ Method for selecting employees: o Noise measurements, ≥85 dBA o All production areas ■ Know definition or meaning of STS ■ Estimated percent of employees with STS each year ■ When employee has STS: o Written notification o Additional training or HPD fitting ■ Provide noise measurements to hearing tester and/or HPD fitter ■ Keep records of tests for current and/or former employees	■ Ever had testing at this company ■ Had testing annually (approximate) **Not** included in interview score: □ Ever told at this company: o Change in hearing o Change in hearing called STS; written notification, or not o Bad hearing o Should see doctor about hearing □ Ever told elsewhere: Bad hearing □ Problem with hearing in daily life

Table H4 **Background information about studied companies, by industry ***

	Wood prod mfg (n=10)	Printing (n=10)	Fruit/veg processing (n=10)	Sheet metal mfg (n=10)	Machine shops (n=10)	Heavy metal mfg (n=9)	Lumber milling (n=7)	Road construction (n=10)	Total (n=76)
Years under present owner									
≤10	**20%**	**40%**	**10%**	**40%**	**0%**	**22%**	**0%**	**20%**	**20%**
11-25	**40%**	**30%**	**20%**	**10%**	**30%**	**44%**	**29%**	**10%**	**26%**
>25	**40%**	**30%**	**70%**	**50%**	**70%**	**33%**	**71%**	**60%**	**53%**
Size of production area **									
≤25K (SF)	**30%**	**10%**	**0%**	**40%**	**40%**	**44%**	**---**	n/a	**21%**
25-50K	**10%**	**40%**	**0%**	**0%**	**50%**	**22%**	**---**	n/a	**16%**
50-100K	**50%**	**20%**	**20%**	**40%**		**33%**	**---**	n/a	**20%**
>100K	**10%**	**20%**	**80%**	**20%**	**10%**	**0%**	**71%**	n/a	**5%**
Number of employees									
≤50	**20%**	**20%**	**10%**	**30%**	**50%**	**56%**		**10%**	**25%**
50-100	**60%**	**20%**	**30%**	**20%**	**30%**	**11%**	**29%**	**20%**	**28%**
100-200	**10%**	**30%**	**30%**	**30%**	**20%**	**22%**	**29%**	**30%**	**21%**
>200	**10%**	**30%**	**30%**	**20%**		**11%**	**43%**	**40%**	**22%**
Union present	**0%**	**30%**	**30%**	**70%**	**20%**	**33%**	**57%**	**80%**	**39%**
Ever inspected by WISHA	**80%**	**60%**	**70%**	**80%**	**90%**	**100%**	**57%**	**80%**	**78%**
Ever given noise citation	**0%**	**0%**	**0%**	**20%**	**10%**	**0%**	**14%**	**30%**	**9%**

*** Table shows percent of companies within each industry. Information was not available for all companies. Mfg = manufacturing.**

**** K = 1,000; SF = square feet; n/a = not applicable.**

Table H5 **Background information about interviewed employees, by industry ***

	Wood prod mfg (n=250)	Printing (n=139)	Fruit/veg processing (n=225)	Sheet metal mfg (n=240)	Machine shops (n=160)	Heavy metal mfg (n=169)	Lumber milling (n=170)	Road construction (n=204)	Total (n=1,557)
Number of employees interviewed, per company	**25.0** (16.4)	**13.9** (7.7)	**22.5** (8.9)	**24.0** (6.8)	**16.0** (9.0)	**18.8** (9.8)	**24.3** (6.9)	**20.4** (13.8)	**20.5** (10.8)
Gender (male)	**82%** (13%)	**79%** (16%)	**50%** (24%)	**89%** (9%)	**99%** (4%)	**98%** (4%)	**91%** (10%)	**84%** (12%)	**84%** (19%)
Age (years)									
≤25	**14%** (7%)	**4%** (5%)	**5%** (8%)	**12%** (9%)	**10%** (15%)	**14%** (11%)	**4%** (2%)	**11%** (7%)	**10%** (9%)
26-35	**31%** (8%)	**25%** (20%)	**23%** (11%)	**32%** (16%)	**13%** (11%)	**32%** (13%)	**24%** (12%)	**20%** (15%)	**25%** (14%)
36-45	**35%** (15%)	**42%** (14%)	**35%** (10%)	**28%** (13%)	**40%** (12%)	**31%** (5%)	**26%** (9%)	**29%** (15%)	**34%** (13%)
>45	**20%** (9%)	**29%** (20%)	**37%** (13%)	**29%** (18%)	**37%** (18%)	**23%** (13%)	**46%** (14%)	**40%** (19%)	**32%** (17%)
Employment (years)									
<1	**25%** (13%)	**17%** (30%)	**9%** (6%)	**11%** (13%)	**19%** (15%)	**20%** (15%)	**6%** (9%)	**29%** (28%)	**17%** (19%)
1-2	**21%** (7%)	**10%** (13%)	**6%** (9%)	**14%** (8%)	**11%** (10%)	**13%** (9%)	**7%** (9%)	**9%** (14%)	**12%** (11%)
2-5	**27%** (11%)	**17%** (11%)	**14%** (14%)	**26%** (11%)	**24%** (15%)	**25%** (22%)	**10%** (10%)	**17%** (14%)	**20%** (14%)
≥5	**27%** (13%)	**56%** (23%)	**71%** (26%)	**49%** (18%)	**46%** (18%)	**42%** (27%)	**77%** (21%)	**45%** (28%)	**51%** (26%)
Education									
No high school degree	**17%** (10%)	**7%** (8%)	**44%** (18%)	**9%** (8%)	**6%** (7%)	**12%** (14%)	**15%** (7%)	**7%** (9%)	**15%** (16%)
High school degree	**43%** (9%)	**44%** (13%)	**37%** (16%)	**39%** (14%)	**42%** (13%)	**27%** (12%)	**45%** (7%)	**44%** (15%)	**40%** (14%)
College or voc training	**40%** (11%)	**49%** (14%)	**19%** (8%)	**52%** (18%)	**52%** (13%)	**61%** (18%)	**40%** (9%)	**49%** (19%)	**45%** (18%)
Primary language ≠ English	**29%** (24%)	**22%** (27%)	**35%** (27%)	**6%** (11%)	**5%** (8%)	**13%** (12%)	**4%** (4%)	**4%** (7%)	**15%** (21%)
Hearing problem that affects daily life	**18%** (9%)	**35%** (13%)	**27%** (14%)	**36%** (11%)	**30%** (13%)	**24%** (17%)	**39%** (14%)	**42%** (14%)	**31%** (15%)

*** Table shows the mean number or mean percent of employees at each company (and standard deviation), within each industry. Mfg = manufacturing.**

Table H6 **Major findings of work site evaluations, by industry ***

		Wood prod mfg (n=10)	Printing (n=10) **	Fruit/veg processing (n=10)	Sheet metal mfg (n=10)	Machine shops (n=10) **	Heavy metal mfg (n=9)	Lumber milling (n=7)	Road construction (n=10)	Total (n=76) **	Signif (p) *
Noise exposure											
Sample duration (hrs)		8.2 (0.9)	8.0 (1.3)	8.3 (0.6)	8.6 (0.8)	8.3 (0.8)	8.5 (1.0)	8.9 (0.7)	8.4 (1.0)	8.4 (0.9)	---
Lave (dBA)		83.9 (3.0)	80.3 (4.8)	86.4 (3.0)	82.5 (2.8)	81.2 (4.1)	86.7 (2.5)	93.7 (1.8)	84.2 (3.7)	84.5 (4.9)	< .001
Lave ≥85 dBA (%)		47.8 (24.8)	29.9 (33.1)	61.5 (26.7)	37.4 (21.6)	29.3 (24.2)	68.7 (22.8)	94.5 (6.2)	45.4 (28.6)	49.9 (30.9)	< .001
Lave ≥90 dBA (%)		15.1 (9.5)	8.3 (16.3)	27.6 (25.2)	6.2 (12.0)	9.7 (14.2)	23.9 (19.2)	81.2 (12.8)	13.6 (15.0)	20.8 (25.6)	< .001
**Management interview score ** **			(n=8)			(n=9)				(n=73)	
Noise	≤ 12	5.3 (2.1)	5.9 (2.0)	5.7 (2.3)	6.1 (1.4)	5.4 (2.6)	4.6 (1.8)	6.1 (3.2)	6.1 (2.7)	5.6 (2.3)	(.82)
Training	≤ 11	4.3 (3.2)	3.7 (3.5)	5.3 (3.2)	6.4 (2.4)	3.0 (3.2)	7.3 (2.6)	7.9 (1.2)	4.7 (3.5)	5.3 (3.2)	.01
Hrg protectors	≤ 7	3.3 (1.6)	3.0 (1.1)	4.9 (2.0)	4.3 (0.8)	3.8 (1.6)	4.2 (1.3)	5.1 (1.6)	4.4 (1.1)	4.1 (1.5)	.04
Audiometry	≤ 10	5.1 (3.1)	4.4 (3.9)	6.4 (2.5)	6.8 (3.2)	5.2 (3.3)	7.7 (3.0)	8.6 (0.8)	4.8 (3.6)	6.0 (3.2)	(.08)
Overall	≤ 40	18.0 (7.9)	17.0 (9.4)	22.3 (7.7)	23.6 (5.3)	17.4 (8.7)	23.8 (7.6)	27.7 (5.1)	20.0 (9.8)	21.1 (8.2)	(.09)
**Employee interview score ** **			(n=8)			(n=9)				(n=73)	
Noise	≤ 6	0.8 (0.4)	1.4 (0.5)	0.9 (0.4)	1.4 (0.5)	1.2 (0.6)	1.2 (0.8)	1.8 (1.2)	1.3 (0.7)	1.2 (0.7)	(.08)
Training	≤ 8	1.7 (0.9)	2.0 (1.1)	2.6 (1.5)	3.2 (1.2)	2.3 (1.6)	3.3 (1.2)	3.6 (1.2)	2.3 (1.3)	2.6 (1.4)	.008
Hrg protectors	≤ 8	5.0 (1.3)	5.0 (1.1)	5.6 (1.7)	5.4 (0.9)	5.2 (1.3)	6.0 (0.7)	7.0 (0.5)	5.1 (1.1)	5.5 (1.2)	.02
Audiometry	≤ 3	1.7 (1.1)	1.7 (1.4)	2.0 (1.0)	1.9 (0.9)	1.5 (1.3)	2.5 (0.8)	2.9 (0.1)	1.4 (1.0)	1.9 (1.1)	.02
Overall	≤ 25	9.2 (3.3)	10.1 (3.7)	11.1 (4.3)	12.0 (2.9)	10.2 (4.1)	12.9 (2.9)	15.3 (2.8)	10.0 (3.5)	11.2 (3.8)	.02
Employees reported always using HPD when exposed (%)											
At work		57.7 (28.3)	44.9 (26.6)	71.0 (34.0)	56.8 (23.6)	41.6 (24.5)	85.1 (9.8)	92.6 (6.9)	45.1 (25.7)	60.3 (29.1)	< .001
At home		31.0 (24.9)	35.5 (17.4)	53.3 (30.7)	34.0 (21.1)	66.9 (23.1)	34.8 (29.1)	52.4 (17.7)	46.2 (15.4)	44.1 (25.1)	.01
Hearing loss on existing audiogram (%) †		(n=8) 21.7 (3.8)	(n=5) 12.1 (7.2)	(n=1) 31.3 (---)	(n=8) 23.4 (7.8)	(n=3) 23.0 (9.0)	(n=8) 29.5 (9.6)	(n=5) 35.0 (5.6)	(n=3) 32.3 (14.8)	(n=41) 25.1 (9.9)	.003

*** Table shows mean company value, within each industry. Significance determined by oneway ANOVA; p-value >.05 shown in parentheses.**

**** Interview results do not include 3 companies where all monitored workers had LAV (or 8-hour TWA) <85 dBA: machine shops, n=1; printing, n=2.**

† Hearing loss = impairment or moderate (or worse) high frequency hearing loss, on most recent audiogram, using all available company records from 1998-2002.

Table H7 Responses to selected questions on management interview, relative to overall interview score *

	Number and percent of companies where the management interview score was...				Percent of all companies	Signif **
	4-16 (n=19)	17-23 (n=18)	24-27 (n=19)	28-35 (n=17)	(n=73)	
One person is designated to be responsible for hearing loss prevention program	10 (53%)	17 (94%)	18 (95%)	14 (82%)	59 (81%)	.003
Noise monitoring and controls						
Ever measured noise levels	11 (58%)	14 (78%)	18 (95%)	17 (100%)	60 (82%)	.003
Kept records of measurements	2 (11%)	4 (22%)	7 (37%)	12 (71%)	25 (34%)	.001
Has noise map	0 (0%)	1 (6%)	1 (5%)	6 (35%)	8 (11%)	.003
Posts noise warning signs	9 (47%)	10 (56%)	15 (79%)	14 (82%)	48 (66%)	(.06)
Ever made changes to reduce noise	8 (42%)	11 (61%)	7 (37%)	11 (65%)	37 (51%)	(.25)
Ever measured noise after changes	0 (0%)	0 (0%)	1 (5%)	6 (35%)	7 (10%)	.001
Plans changes to reduce noise	6 (32%)	8 (44%)	7 (37%)	7 (41%)	28 (38%)	(.87)
Training and hearing protector fitting						
Training provided annually	1 (5%)	9 (50%)	19 (100%)	17 (100%)	46 (63%)	<.001
Training includes required content	0 (0%)	1 (6%)	11 (58%)	13 (76%)	25 (34%)	<.001
Trained person shows how to insert protector	4 (21%)	8 (44%)	16 (84%)	17 (100%)	45 (62%)	<.001
Trained person checks placement of protector	0 (0%)	4 (22%)	5 (26%)	9 (53%)	18 (25%)	.003
Hearing protector availability and use						
Provide protectors	19 (100%)	18 (100%)	19 (100%)	17 (100%)	73 (100%)	(ns)
Provide two types of protectors	11 (58%)	15 (83%)	18 (95%)	17 (100%)	61 (84%)	.003
Have policy requiring protector use	2 (11%)	4 (22%)	9 (47%)	10 (59%)	25 (34%)	.008
Audiometry						
Conduct testing annually	5 (26%)	13 (72%)	19 (100%)	17 (100%)	54 (74%)	<.001
Provides noise level information to tester	0 (0%)	4 (22%)	2 (11%)	5 (29%)	11 (15%)	(.07)
When an employee has an STS,...†						
Provide written notification	1 (5%)	11 (61%)	17 (89%)	16 (94%)	45 (62%)	<.001
Provide retraining	0 (0%)	3 (17%)	11 (58%)	13 (76%)	27 (37%)	<.001

* Table does not include three companies where all monitored employees had full-shift noise exposure <85 dBA.

** Significance determined by Chi-square test; p-value >.05 shown in parentheses; ns= not significant (not calculable; all values 100%).

† STS = standard threshold shift.

Table H8 Responses to selected questions on management interview, by industry *

	Wood prod mfg (n=10)	Printing (n=8) *	Fruit/veg processing (n=10)	Sheet metal mfg (n=10)	Machine shops (n=9) *	Heavy metal mfg (n=9)	Lumber milling (n=7)	Road construction (n=10)	Signif (p) **
One person is designated to be responsible	7 (70%)	3 (38%)	10 (100%)	10 (100%)	6 (67%)	9 (90%)	5 (71%)	9 (90%)	.002
Noise monitoring and controls									
Ever measured noise levels	7 (70%)	5 (63%)	8 (80%)	10 (100%)	9 (100%)	9 (100%)	7 (100%)	10 (100%)	(.38)
Kept records of measurements	2 (20%)	2 (25%)	3 (30%)	3 (30%)	3 (33%)	4 (44%)	3 (43%)	5 (50%)	(.87)
Has noise map	0 (0%)	1 (13%)	1 (10%)	2 (20%)	0 (0%)	1 (11%)	2 (29%)	n/a	(.45)
Posts noise warning signs	7 (70%)	6 (75%)	8 (80%)	7 (70%)	7 (78%)	6 (67%)	5 (71%)	2 (20%)	(.14)
Ever made changes to reduce noise	4 (40%)	4 (50%)	3 (30%)	4 (40%)	7 (78%)	3 (33%)	4 (57%)	8 (80%)	(.17)
Ever measured noise after changes	0 (0%)	1 (13%)	1 (10%)	0 (0%)	0 (0%)	0 (0%)	2 (29%)	3 (30%)	(.07)
Plans changes to reduce noise	4 (40%)	4 (50%)	5 (50%)	3 (30%)	4 (44%)	1 (11%)	4 (57%)	3 (30%)	(.52)
Training and hearing protector fitting									
Training provided annually	6 (60%)	4 (50%)	6 (60%)	9 (90%)	3 (33%)	7 (78%)	7 (100%)	4 (40%)	.02
Training includes required content	1 (10%)	1 (13%)	3 (30%)	5 (50%)	2 (22%)	5 (56%)	5 (71%)	3 (30%)	(.08)
Trained person shows how to insert protector	5 (50%)	4 (50%)	6 (60%)	5 (50%)	3 (33%)	9 (100%)	6 (86%)	7 (70%)	.03
Trained person checks placement of protector	2 (20%)	2 (25%)	2 (20%)	1 (10%)	0 (0%)	5 (56%)	1 (14%)	5 (50%)	(.05)
Hearing protector availability and use									
Provide protectors	10 (100%)	8 (100%)	10 (100%)	10 (100%)	9 (100%)	9 (100%)	7 (100%)	10 (100%)	ns
Provide two types of protectors	6 (60%)	5 (63%)	7 (70%)	9 (90%)	9 (90%)	8 (89%)	7 (100%)	10 (100%)	.02
Have policy requiring protector use	2 (20%)	0 (0%)	6 (60%)	2 (20%)	2 (22%)	4 (44%)	5 (71%)	4 (40%)	.02
Audiometry									
Conduct testing annually	8 (80%)	5 (63%)	8 (80%)	8 (80%)	5 (56%)	8 (89%)	7 (100%)	5 (50%)	(.16)
Provides noise level information to tester	1 (10%)	1 (13%)	0 (0%)	3 (30%)	3 (33%)	3 (33%)	0 (0%)	0 (0%)	(.05)
When an employee has an STS,...†									
Provide written notification	6 (60%)	3 (38%)	6 (60%)	6 (60%)	3 (33%)	8 (89%)	7 (100%)	6 (60%)	.04
Provide retraining	2 (20%)	1 (13%)	4 (40%)	4 (40%)	3 (33%)	5 (56%)	6 (86%)	2 (20%)	(.06)

* Table does not include three companies where all monitored employees had full-shift noise exposure <85 dBA.

** Significance determined by Chi-square test (likelihood ratio); p-value >.05 shown in parentheses; ns= not significant (not calculable because all values 100%).

† STS = standard threshold shift.

Table H9 **Hearing threshold values in three reference databases (ANSI S3.44-1996)**

Age, in years		Percentile Percent of people with hearing ability that is equal to or worse than specified in right column	Binaural average hearing threshold at 0.5-1-2 kHz (dB)			Binaural average hearing threshold at 3-4-6 kHz (dB)		
			Annex A (males)	Annex B (males)	NINEP (white males)	Annex A (males)	Annex B (males)	NINEP (white males)
Age 60	(>55) *	10%	22.0	30.0	29.7	53.0	70.0	63.3
		50%	8.3	9.3	12.7	26.7	37.3	39.7
		90%	-2.0	0.0	3.7	6.0	14.3	15.0
Age 50	(46-55)	10%	16.3	21.7	23.3	35.7	55.7	57.7
		50%	5.0	7.7	9.7	15.3	25.3	28.7
		90%	-4.0	-1.3	2.3	-0.7	10.0	10.7
Age 40	(35-44)	10%	12.3	17.7	18.7	22.7	51.0	48.7
		50%	2.3	5.0	7.3	7.7	18.0	19.7
		90%	-5.3	-2.3	1.0	-4.7	5.7	6.3
Age 30	(26-34)	10%	9.7	12.7	14.7	14.3	38.7	35.7
		50%	1.0	3.0	5.7	2.3	12.3	11.7
		90%	-6.3	-3.3	-0.7	-7.3	2.0	1.3

* ANSI S3.44-1966 provides reference database values for four specific ages, and does not specify the range.

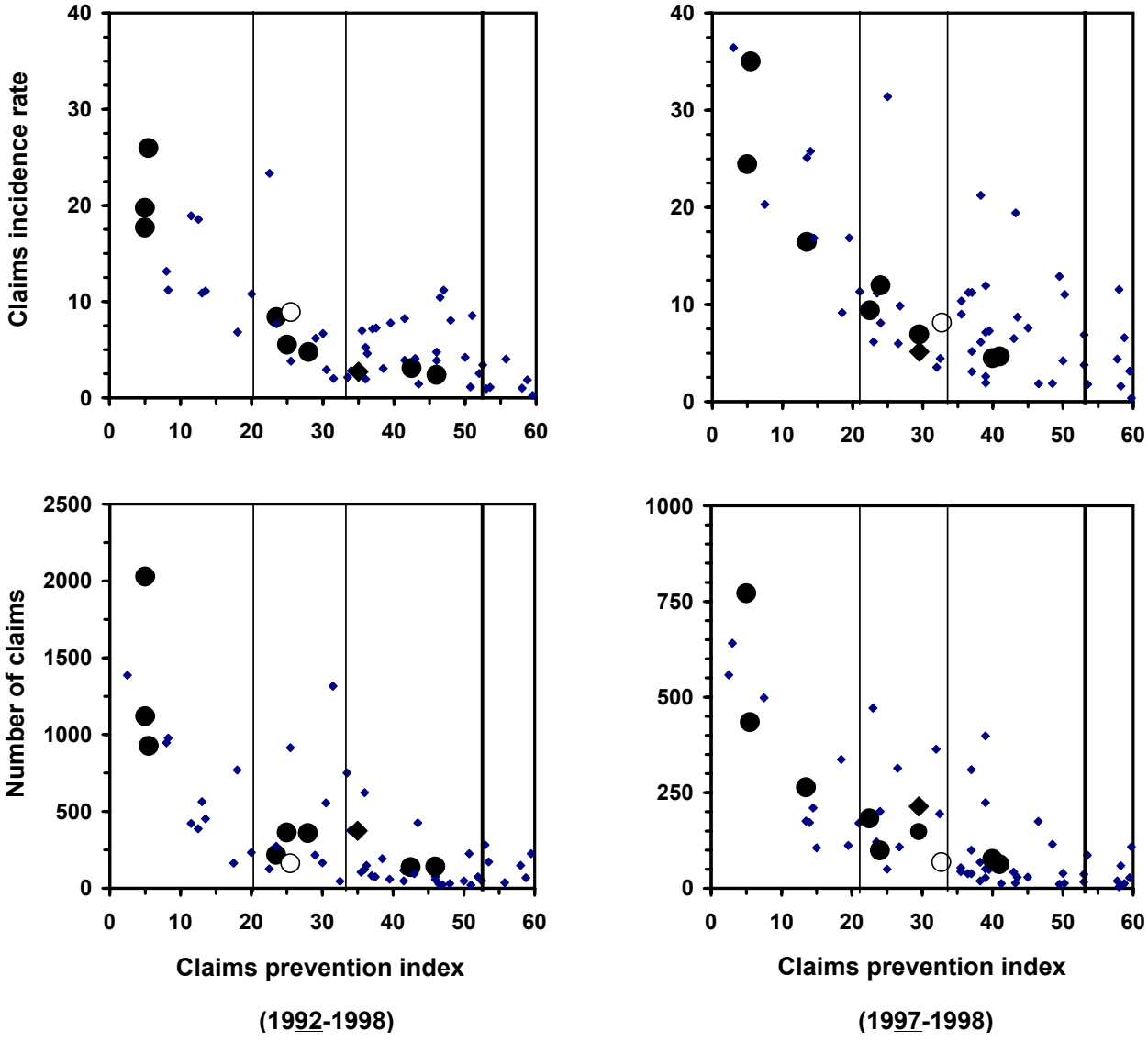
Table H10 **Correlation between annual measures of OHL claims and findings from work site evaluations**

Major findings from work site evaluations	Annual measure of OHL claims, 1997-1998			Percent of employees with full-shift exposure ≥85 dBA
	Prevention index	Incidence rate	Number of claims	
Management interview score	-0.55	0.38	0.64 (*)	0.84 **
Employee interview score	-0.56	0.36	0.66 (*)	0.81 *
Percent of employees...				
with full-shift exposure ≥85 dBA	-0.47	0.42	0.68 (*)	---
who reported "always" using HPD when exposed	-0.28	0.16	0.45	0.94 **
with hearing loss	-0.74 *	0.67 (*)	0.70 (*)	0.76 *

Table shows Pearson correlation coefficient for summary variables from eight industries: (*) p<0.10, * p<0.05, ** p<0.01. Values for major findings were calculated as the average company value within each industry.

Hearing loss = impairment and/or moderate (or worse) high frequency hearing loss, on most recent audiometry performed by company, using available company records from 1999-2002. Data only available for seven industries.

Figure E1 **Industry-specific measures of OHL claims during 1992-1998 and 1997-1998**



Figures show target industries (solid circle), including fruit and vegetable processing (large diamond); the pilot industry, foundries (hollow circle); and non-target industries (small diamond). Vertical grid lines indicate borders of prevention index categories for 1992-98 and 1997-98.

Figure G1 **Subject recruitment for telephone survey**

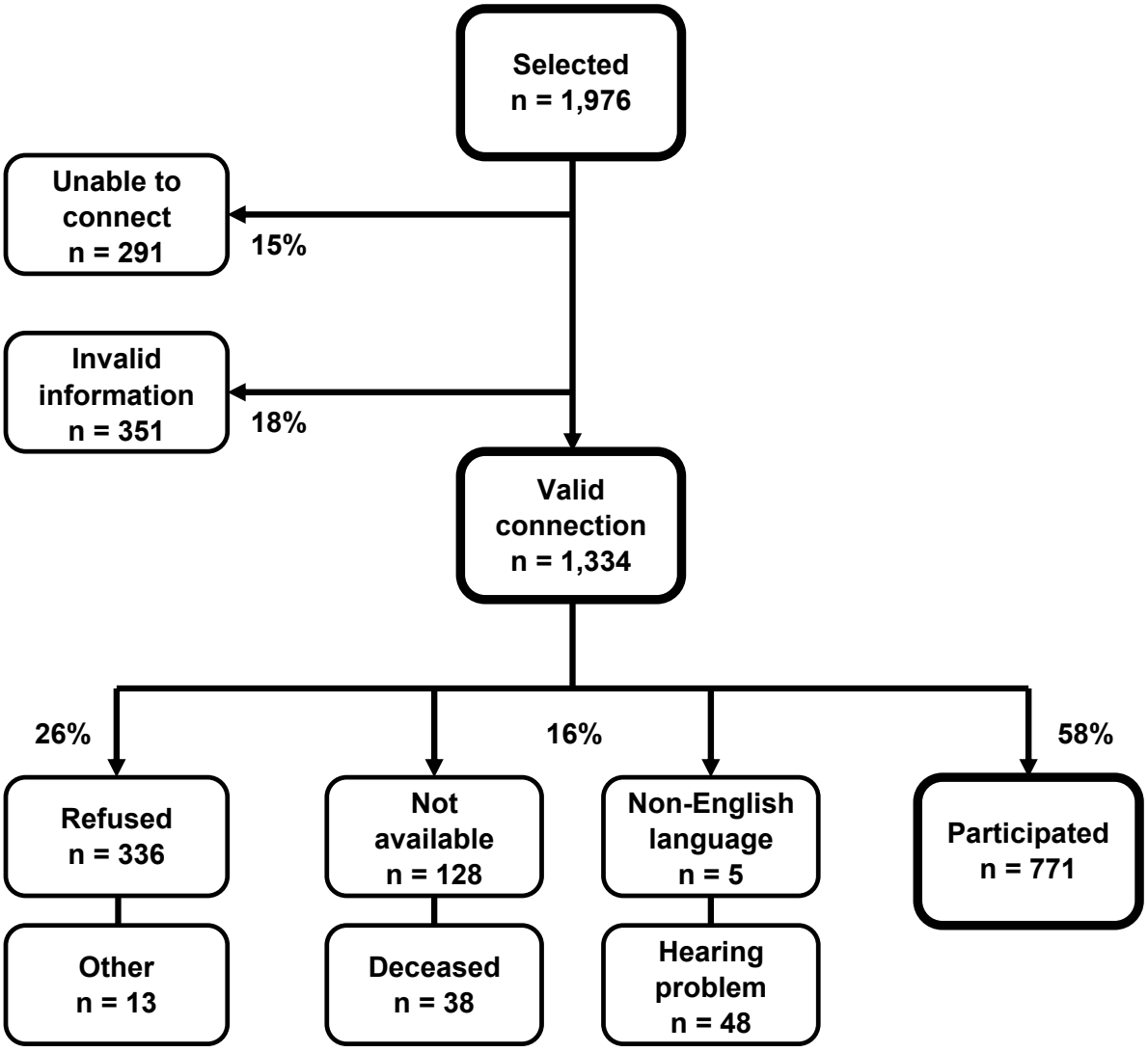


Figure G2 **Percent of subjects who said a person or thing was an important or very important influence in their decision to file a claim (n=771)**

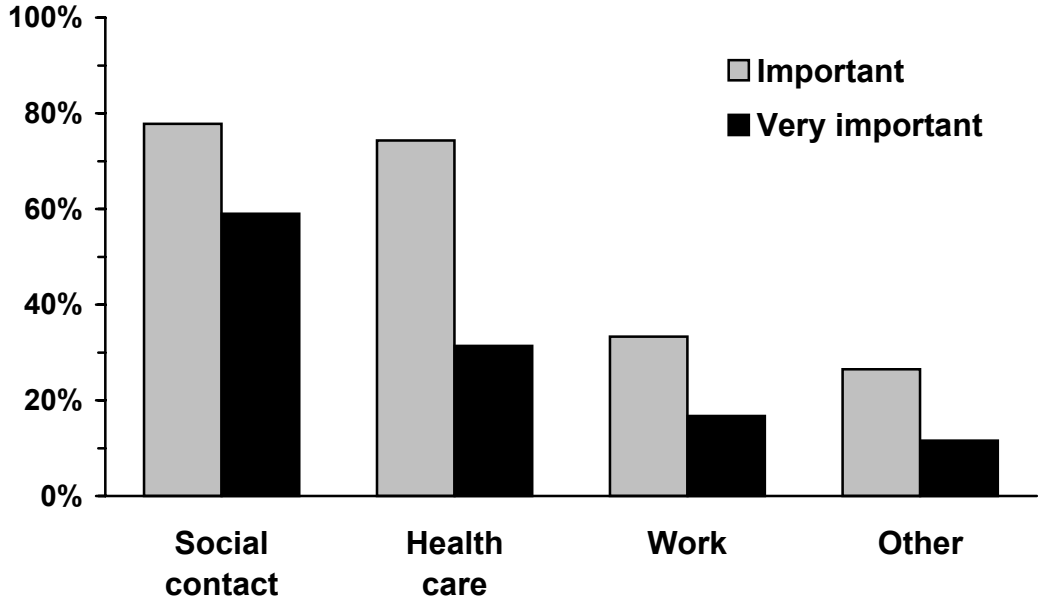


Figure G3 **Percent of subjects who said a person or thing was an important influence in their decision to file a claim (n=771)**

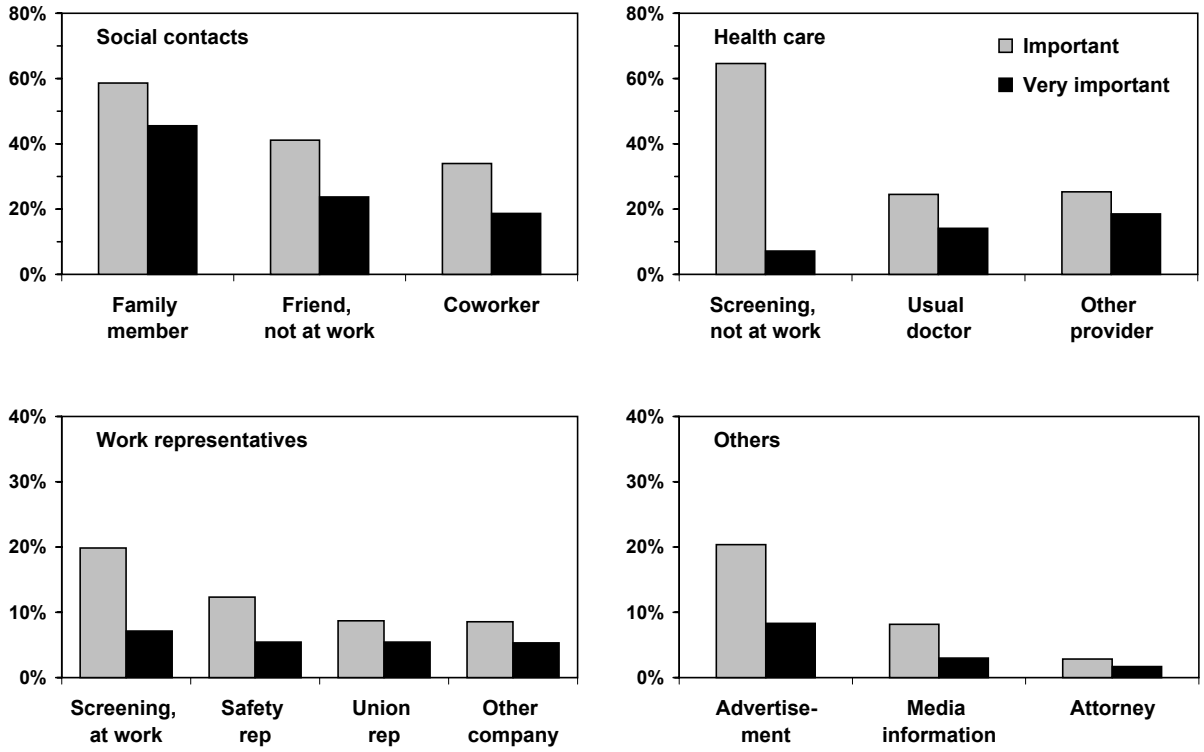


Figure G4 **Referral source and specialty of health care providers (other than the subject's usual provider) reported to be important in the decision to file an OHL claim**

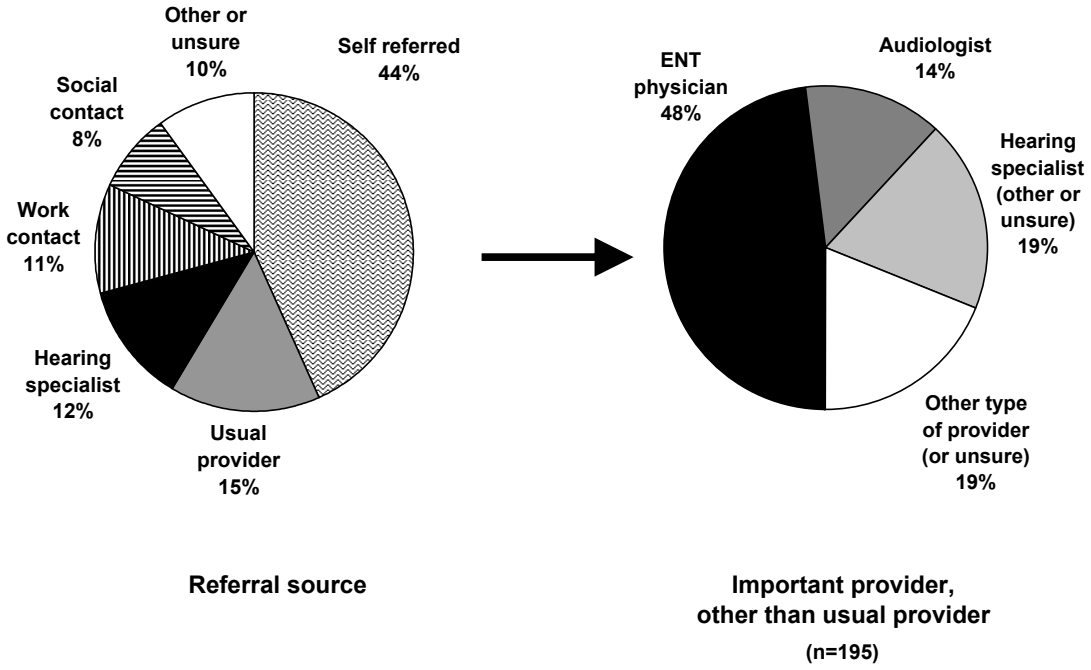
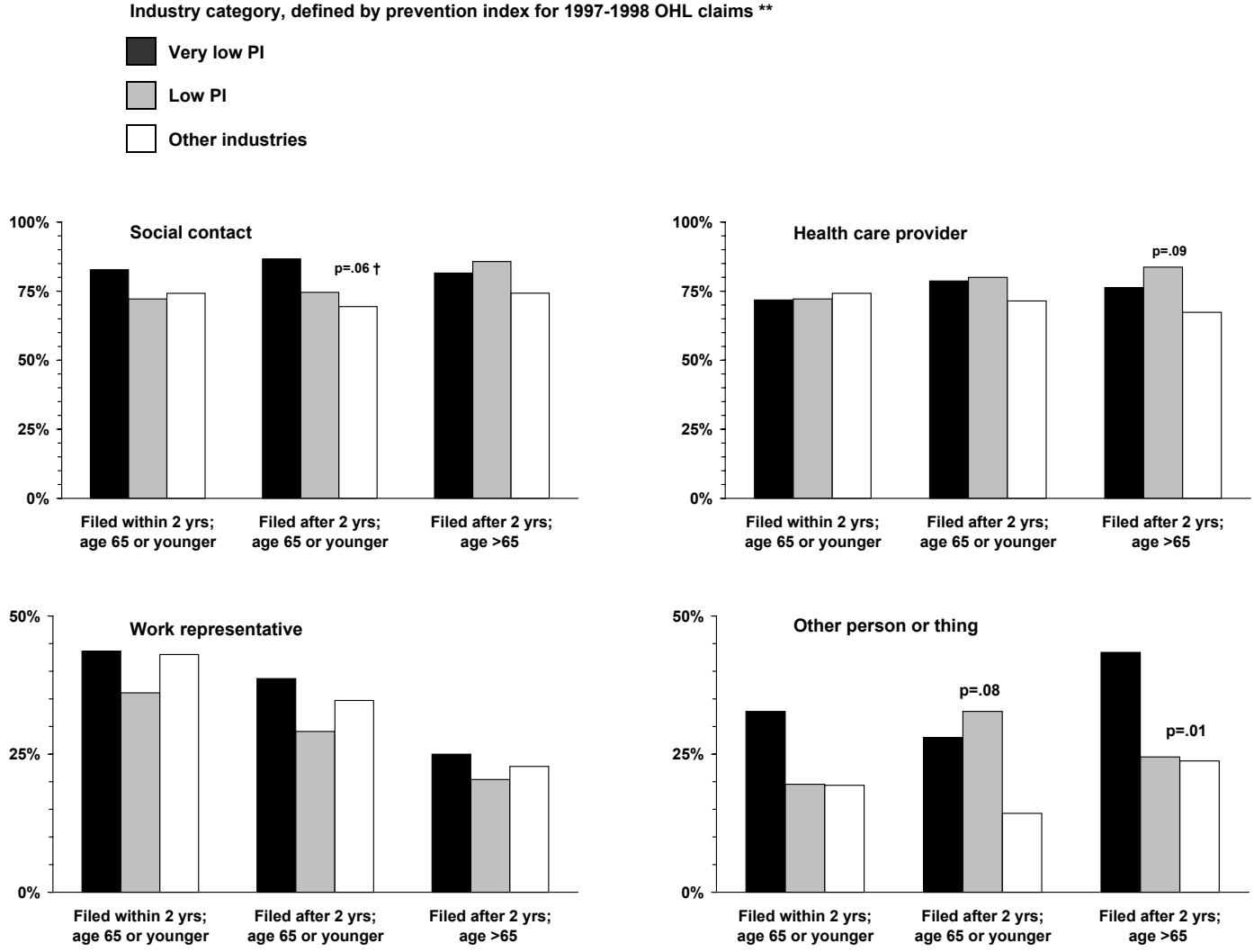


Figure G5 **Percent of subjects who said a person or thing was an important influence in their decision to file an OHL claim, relative to industry category, timing of claim, and subject age (n=741) ***

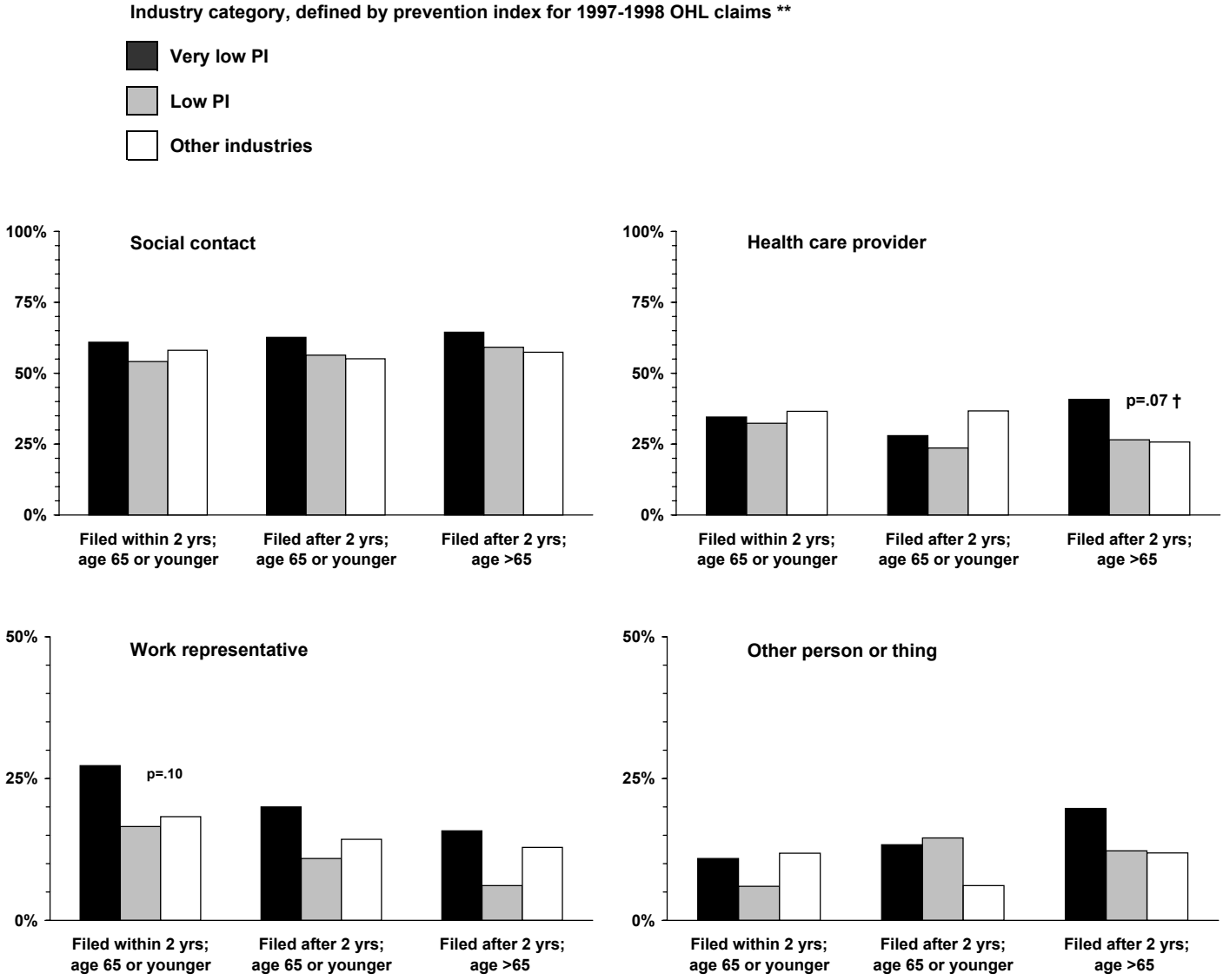


* Timing = claim filed within (or later than) two years after "date of injury."
Figures do not include 30 subjects who filed within two years but were older than 65 years of age.

** Prevention index = average of $rank_{number}$ and $rank_{incidence}$.
Very low PI = 13 industries with lowest PI values. Low PI = next lowest 13.

† Figures show p-value for difference between industry categories, within the timing-age groups, using Pearson chi-square test (p>.10 not shown).

Figure G6 **Percent of subjects who said a person or thing was a very important influence in their decision to file an OHL claim, relative to industry category, timing of claim, and subject age (n=741) ***

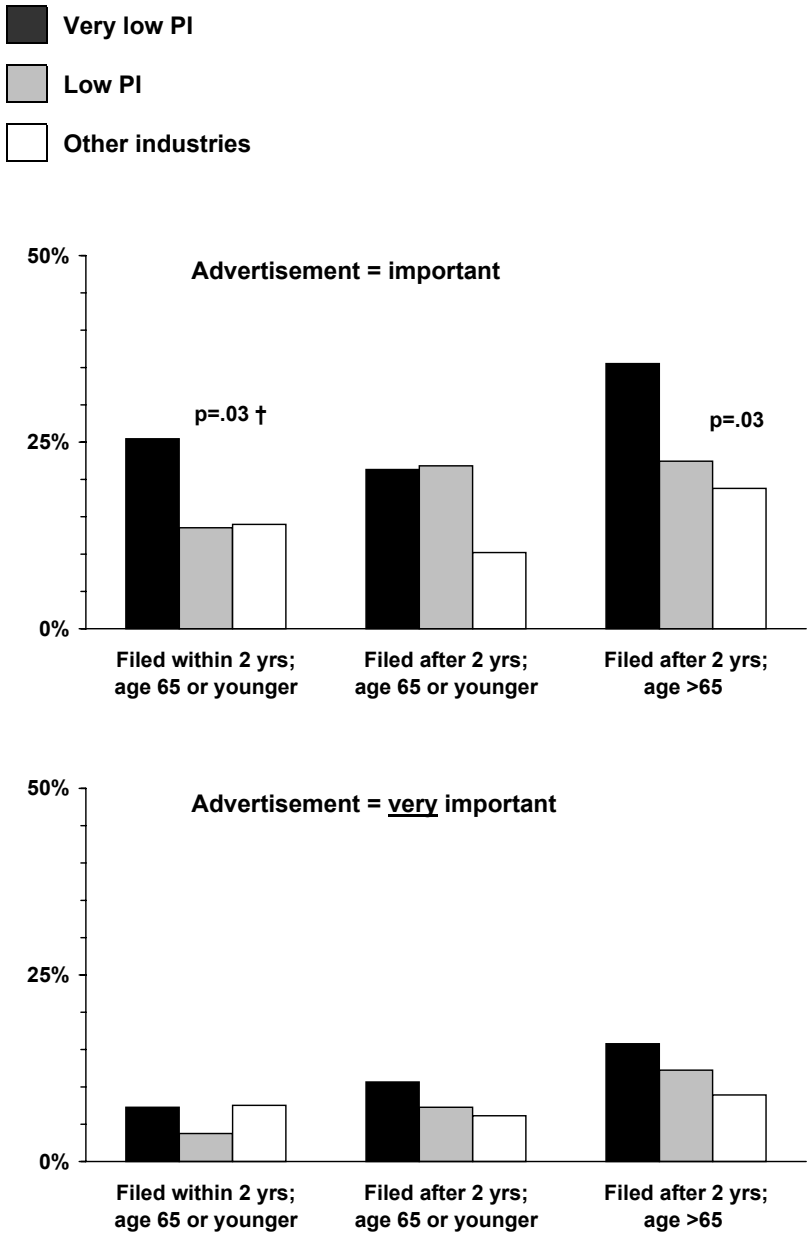


* Timing = claim filed within (or later than) two years after "date of injury."
Figures do not include 30 subjects who filed within two years but were older than 65 years of age.

** Prevention index = average of $rank_{number}$ and $rank_{incidence}$.
Very low PI = 13 industries with lowest PI values. Low PI = next lowest 13.

Figure G7 **Percent of subjects who said an advertisement was important influence in their decision to file an OHL claim, relative to industry category, timing of claim, and subject age (n=741) ***

Industry category, defined by prevention index for 1997-1998 OHL claims **



* Timing = claim filed within (or later than) two years after "date of injury." Figures do not include 30 subjects who filed within two years but were older than 65.

** Prevention index = average of $rank_{number}$ and $rank_{incidence}$. Very low PI = 13 industries with lowest PI values. Low PI = next lowest 13.

† Figures show p-value for difference between industry categories, within the timing-age groups, using Pearson chi-square test (p>.10 not shown).

Figure H1 **Duration of personal noise monitoring, by industry**

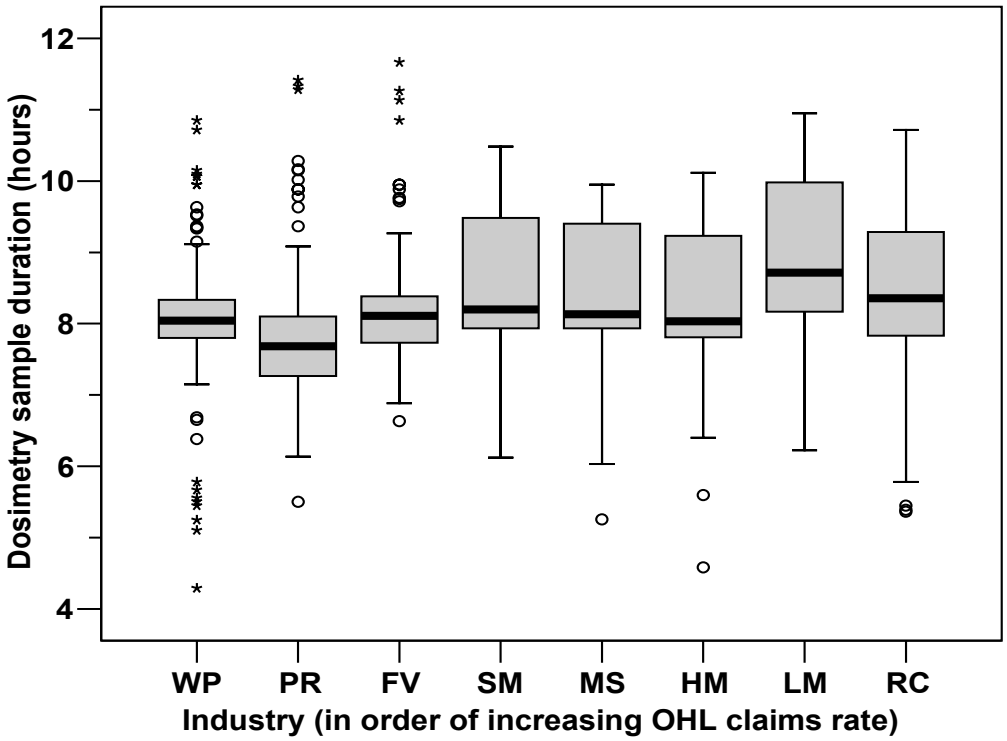


Figure H2A **Full-shift personal noise exposure (L_{ave}), by industry**

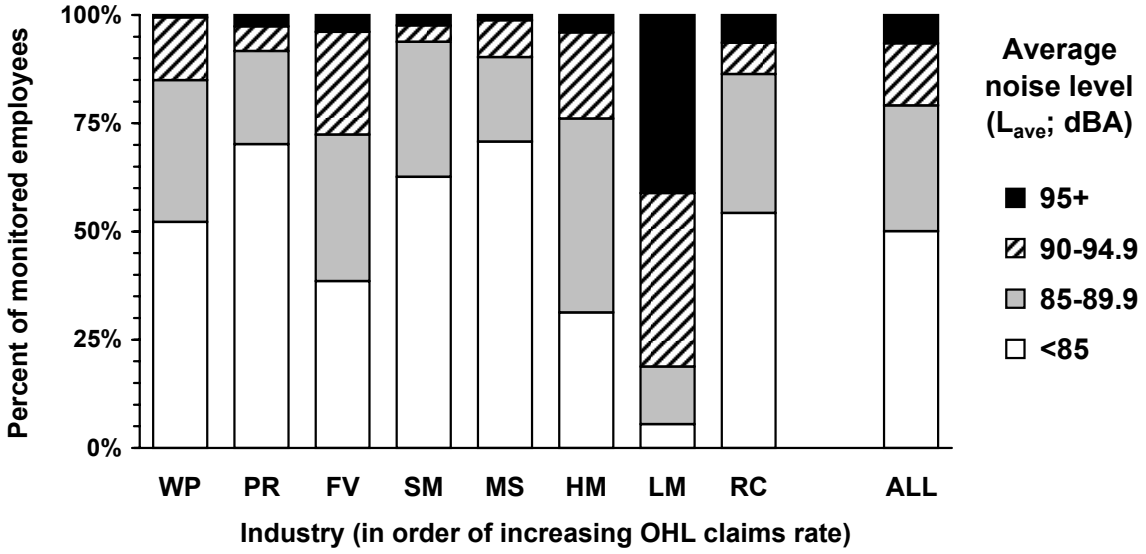


Figure H2B **Full-shift personal noise exposure (L_{eq}), by industry**

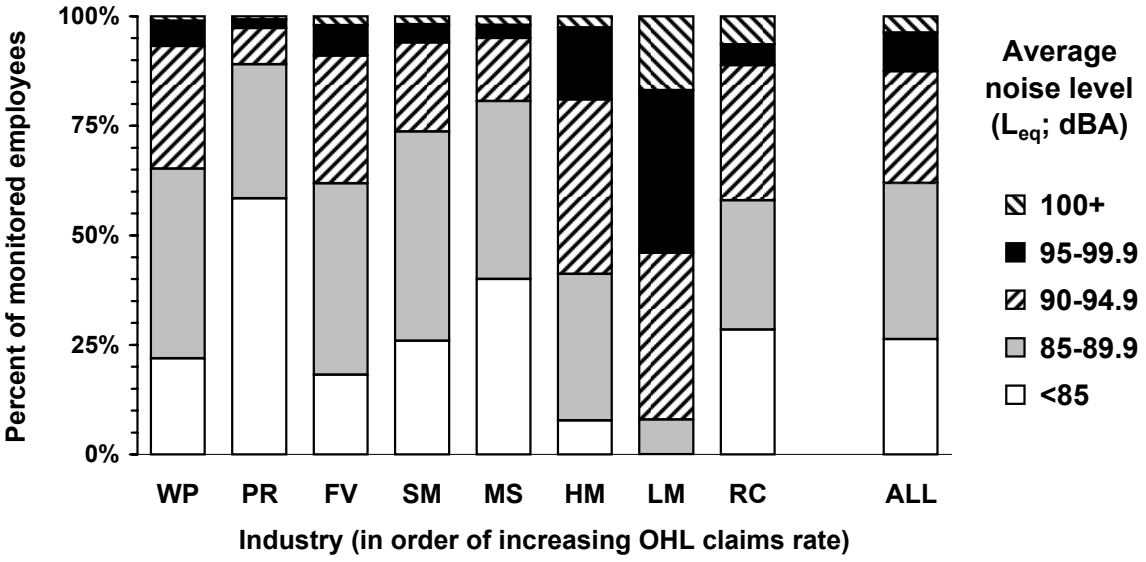
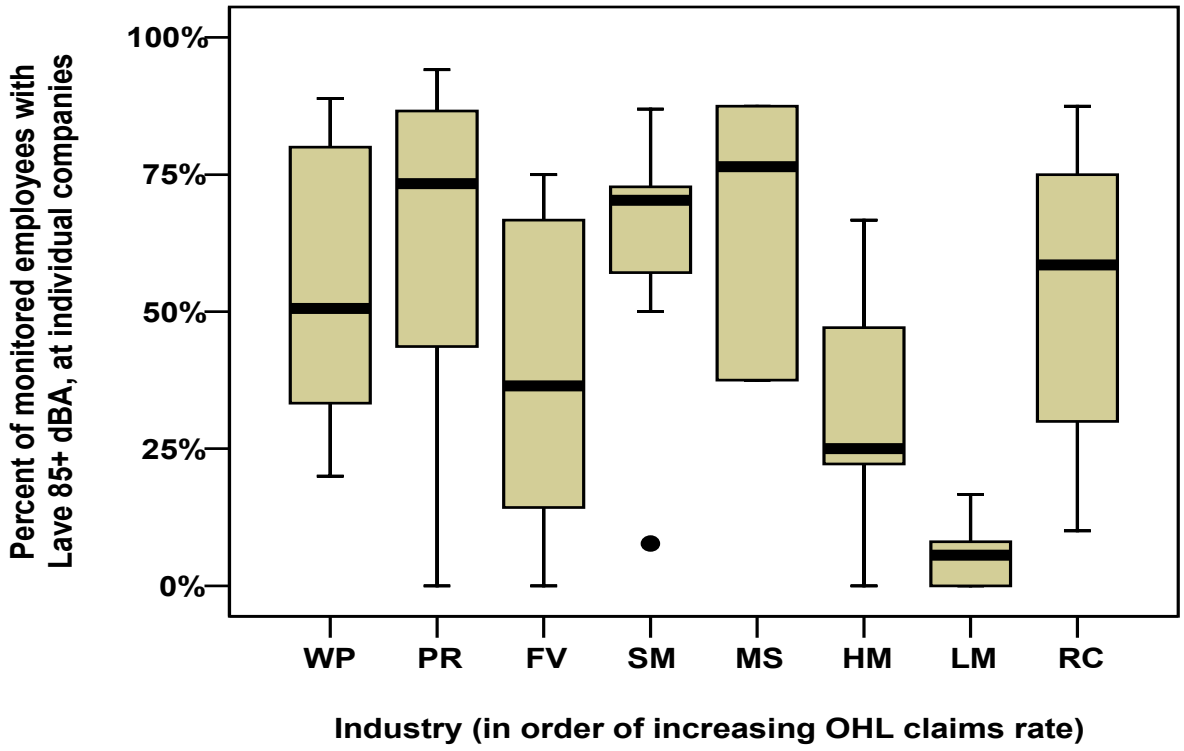
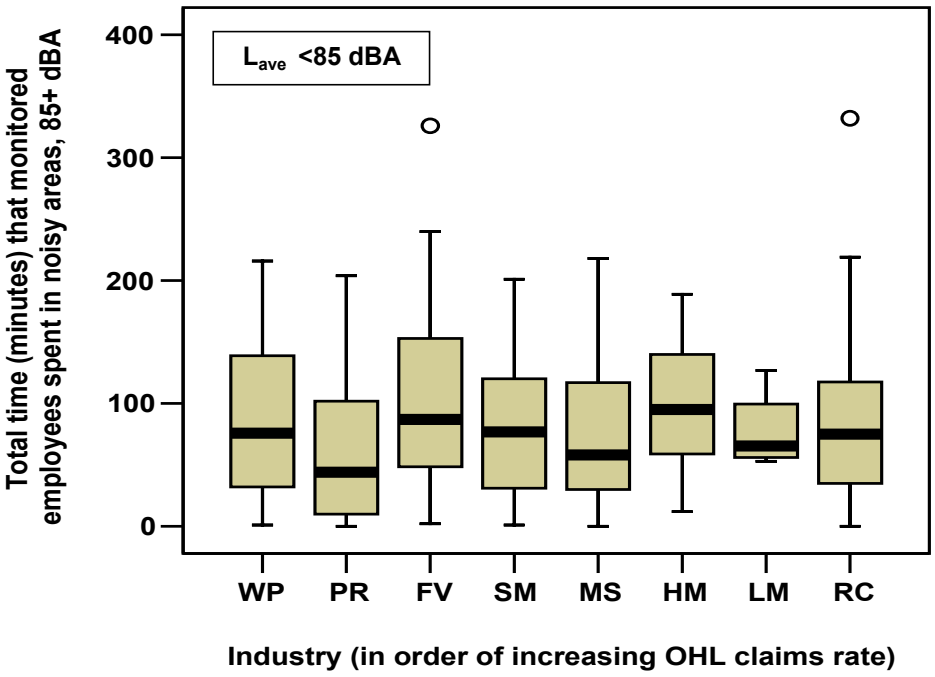
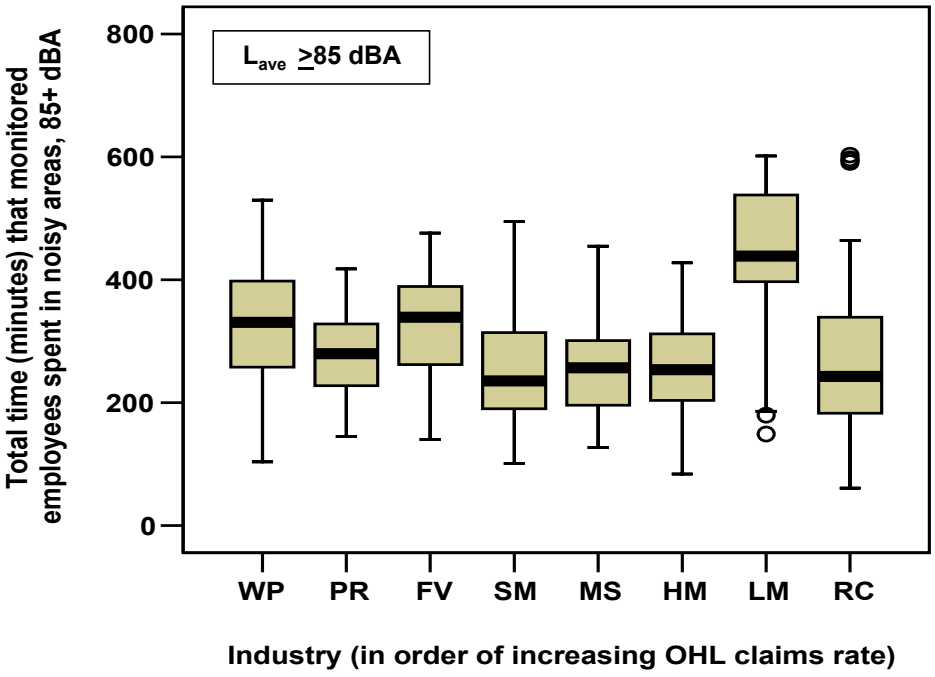


Figure H3 **Prevalence of excessive employee noise exposure ($L_{ave} \geq 85$ dBA) at each company, by industry**



Figures H4A and H4B **Amount of time spent in noisy areas (≥85 dBA), by industry and full-shift noise exposure**





Note: Employee data were not aggregated by company for these two figures.

Figure H5A Management interview scores, by industry

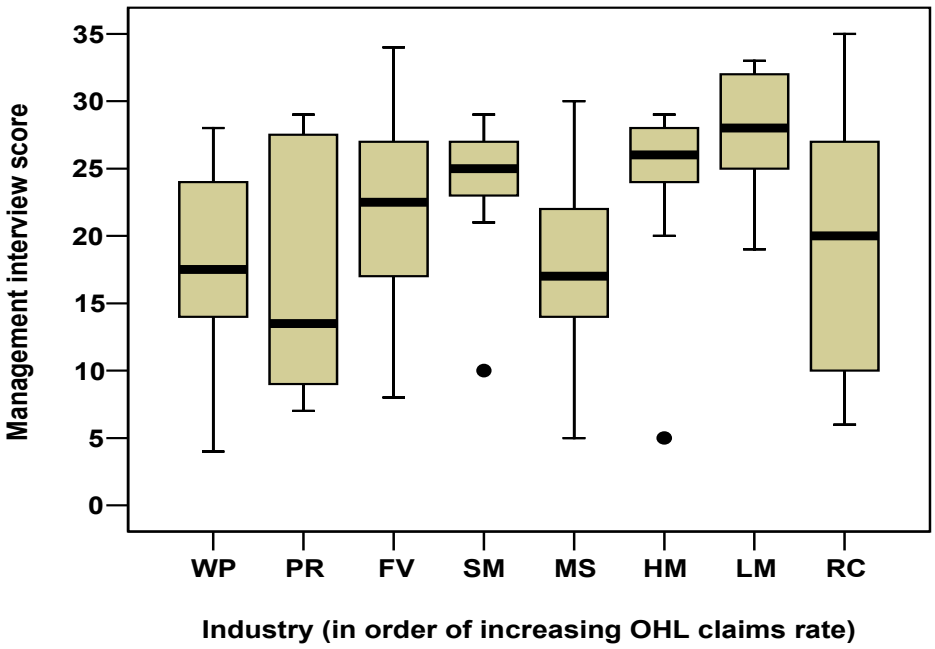
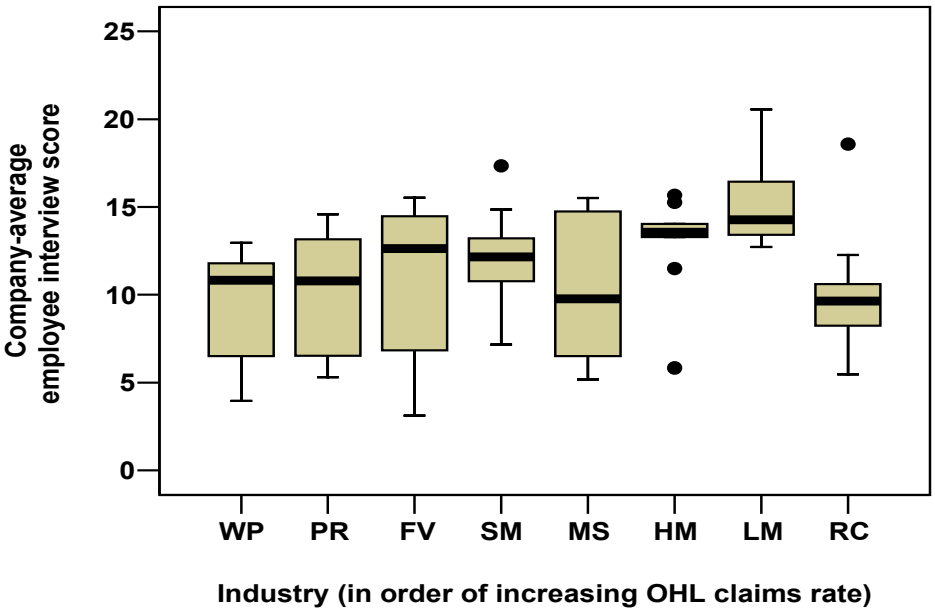


Figure H5B Company-average employee interview scores, by industry



Figures H6 **Management interview score quartiles, by industry**

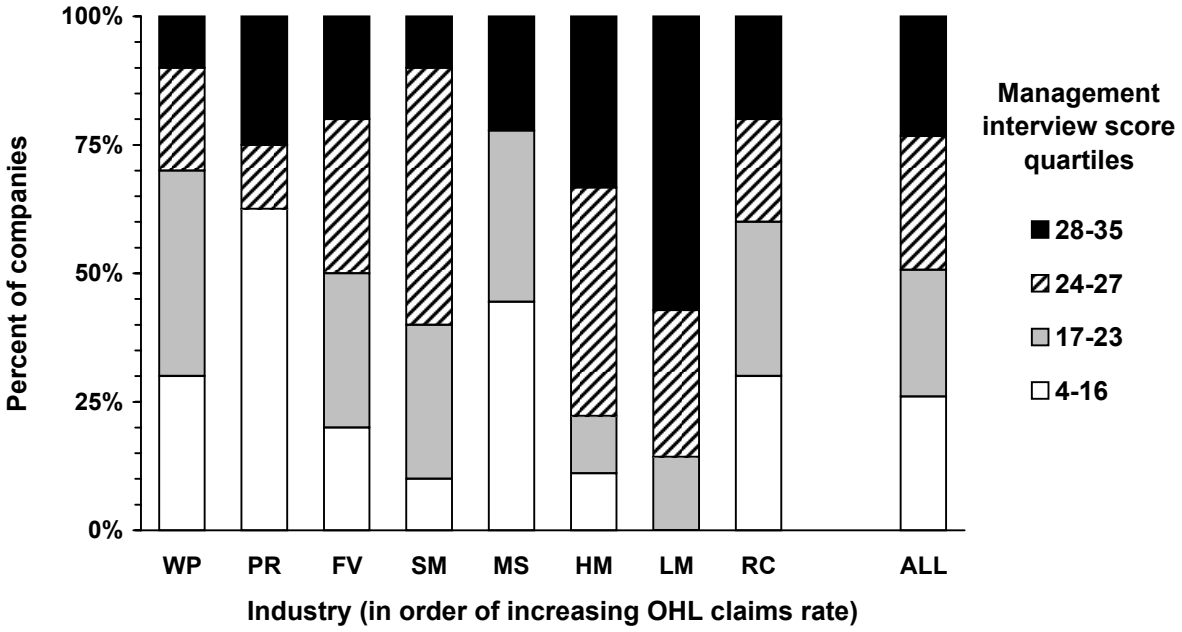


Figure H7A **Company-average employee interview scores relative to management interview scores**

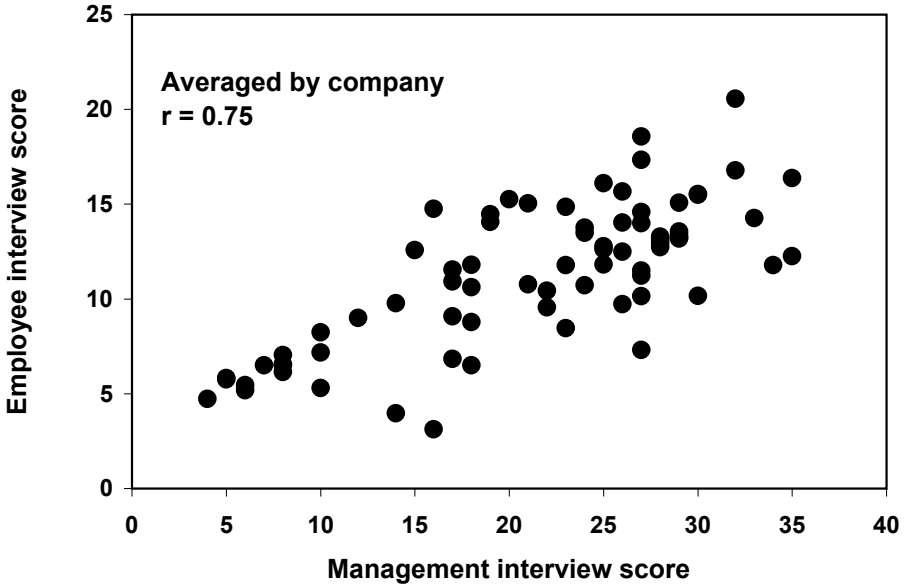
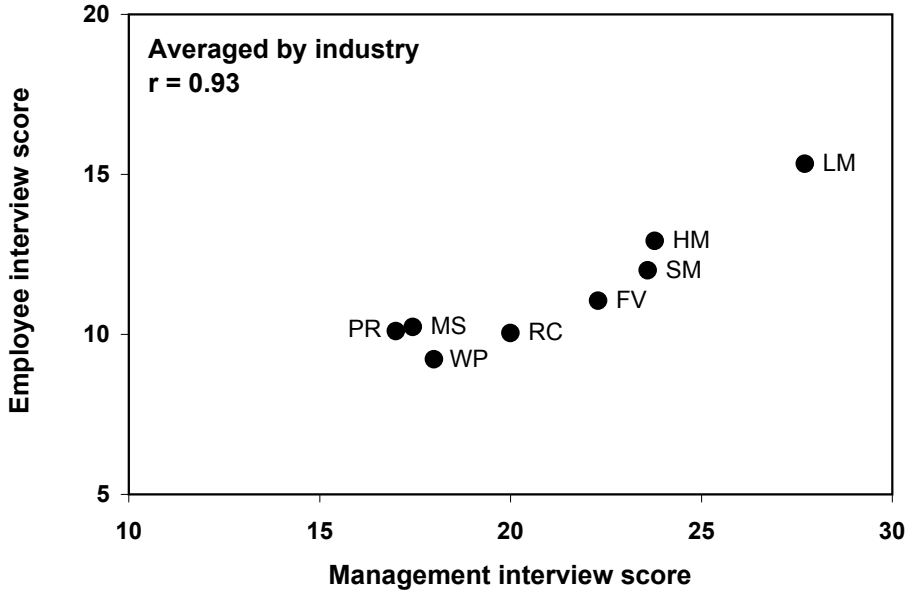
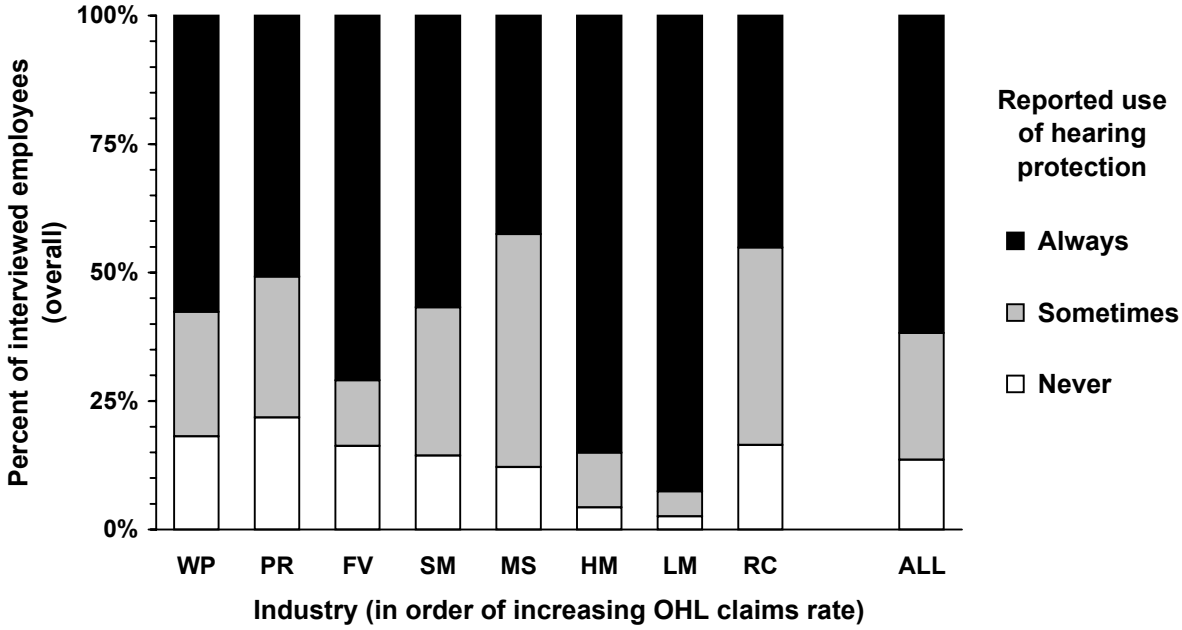


Figure H7B **Company-average employee interview scores relative to management interview scores, by industry**



Figures H8A and H8B **Reported use of hearing protection, when exposed to loud noise**



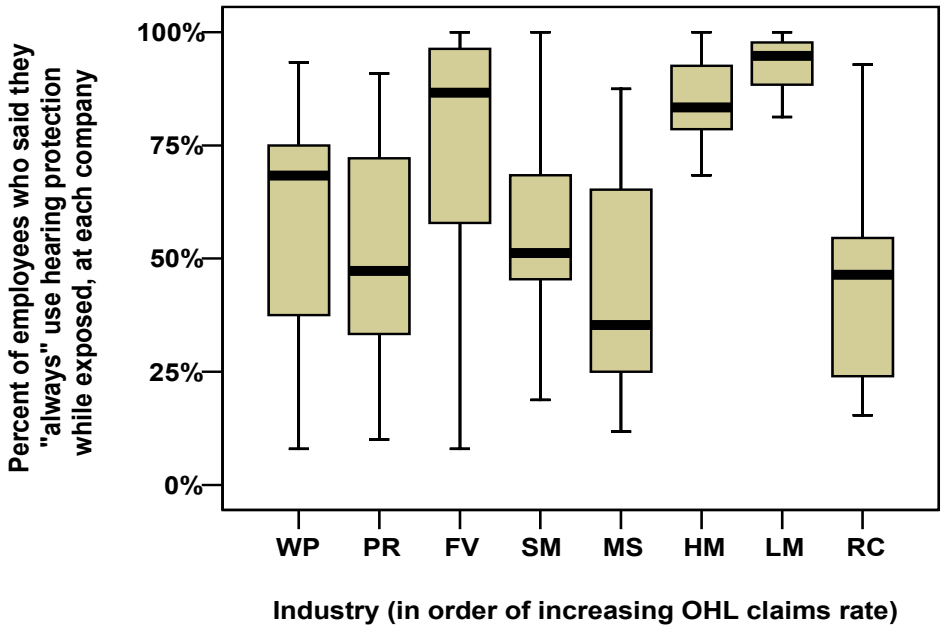


Figure H9A **Agreement between reported and measured exposure**

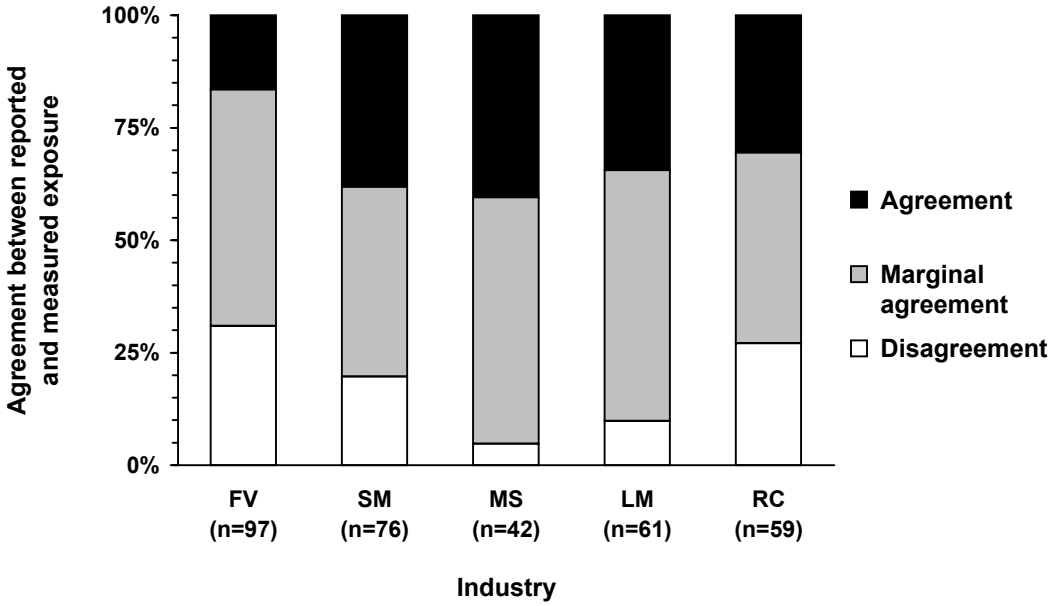
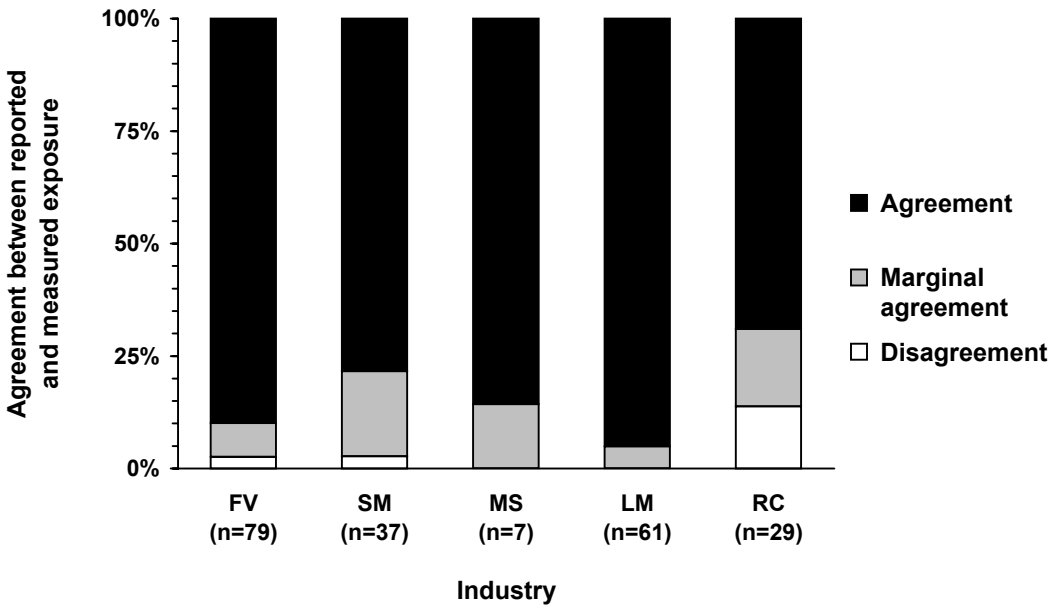


Figure H9B **Agreement between reported and observed use of hearing protection**



Note: Figures do not include one industry (WP), which had data for only 3 subjects.
Figure H8B is limited to subjects with ≥3 observations, including ≥1 observation while exposed.

Figure H10 **Relationship between reported and measured time exposed to loud noise, using different noise level thresholds**

Figure H10a: >70 dBA

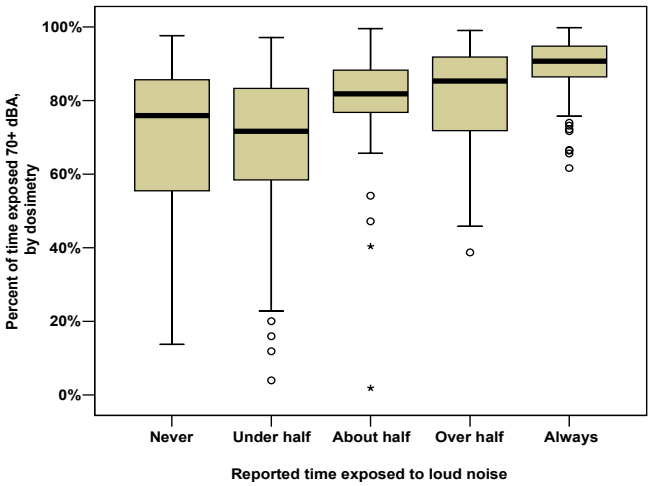


Figure H10b: >75 dBA

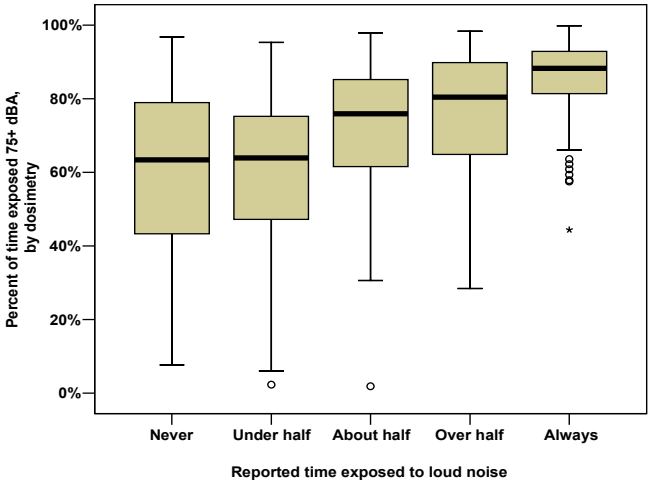


Figure H10c: >80 dBA

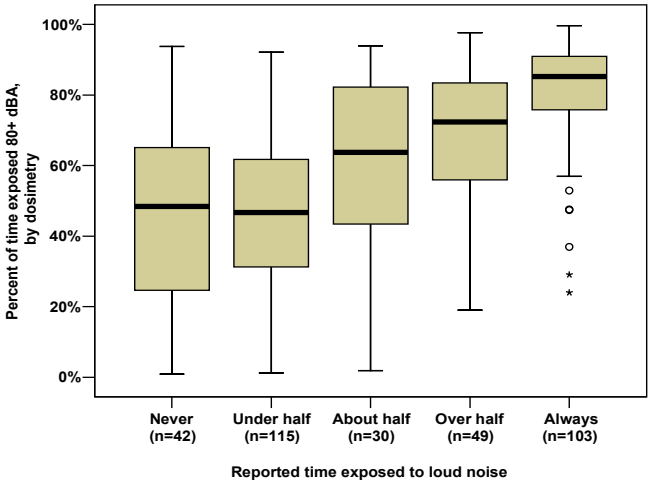


Figure H10d: >85 dBA

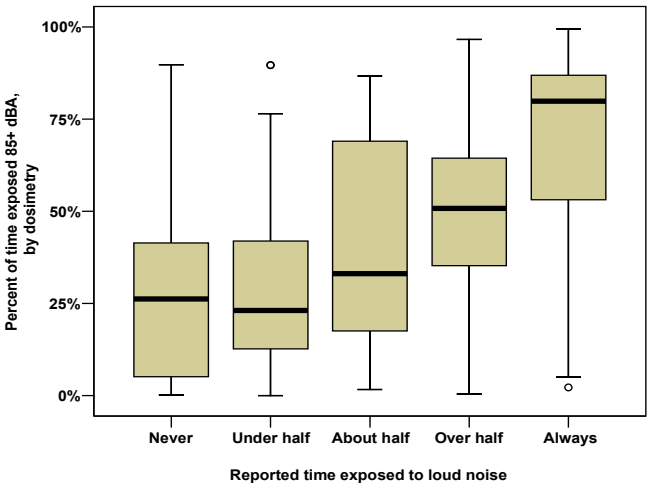


Figure H10e: >90 dBA

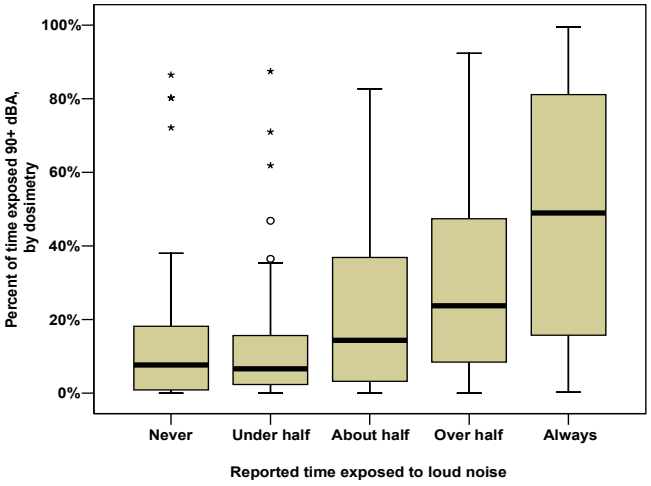


Figure H10f: >95 dBA

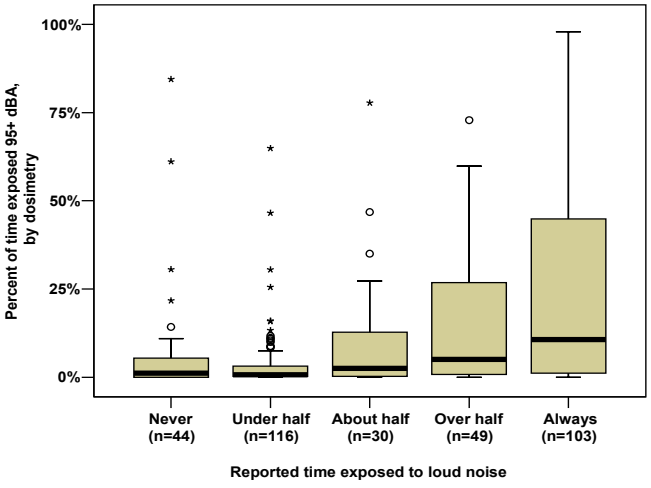
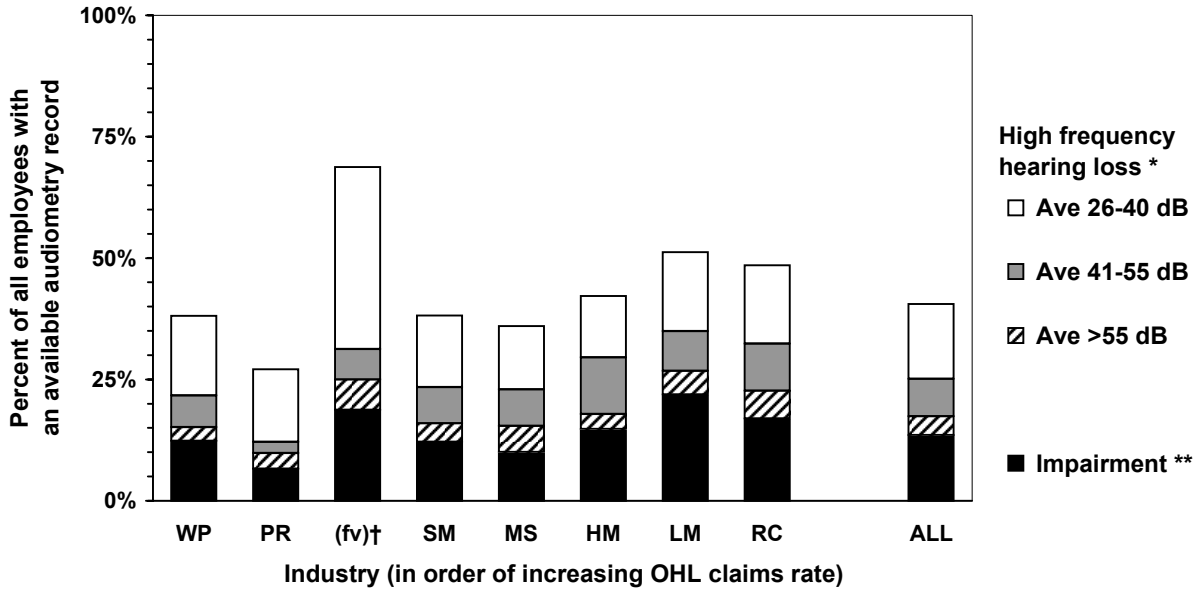
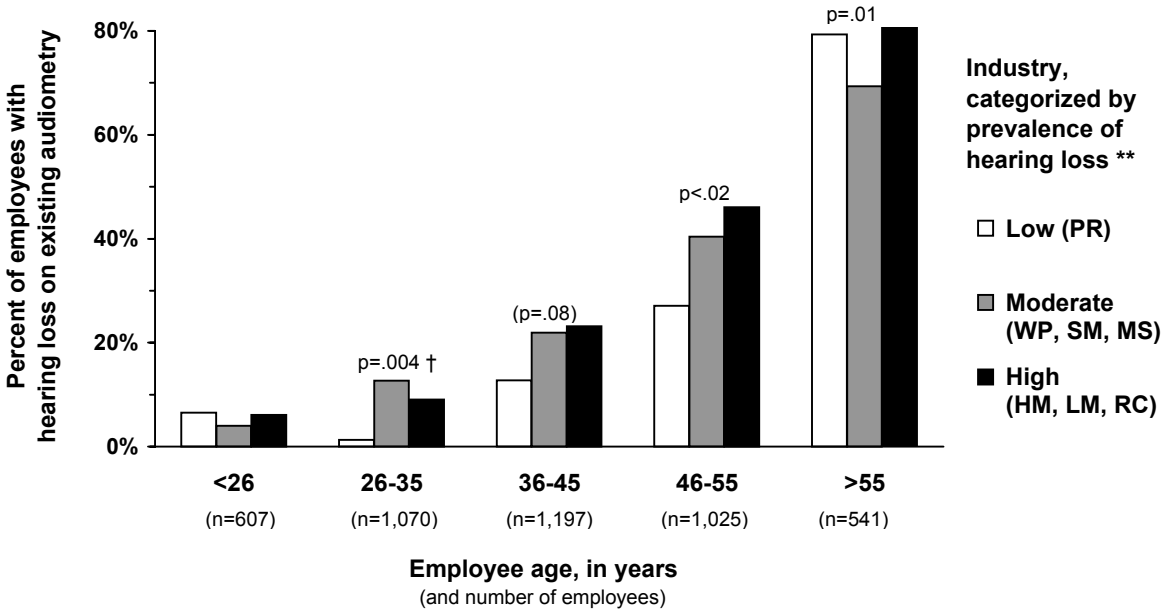


Figure H11 Hearing loss on existing audiograms, by industry



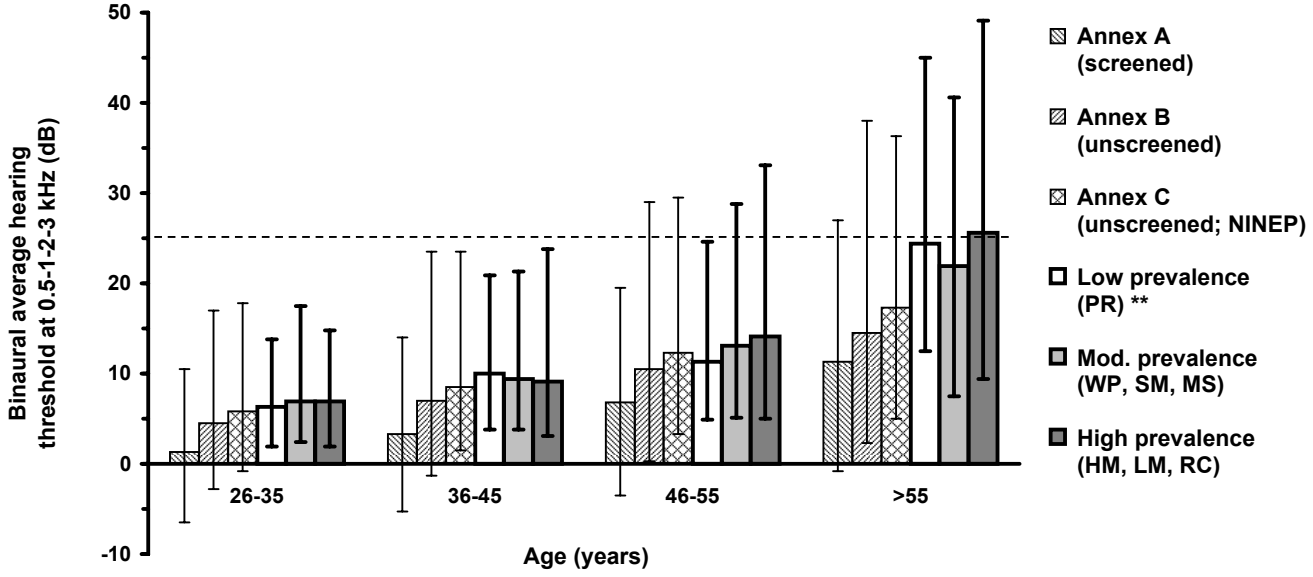
* Average hearing threshold at 3, 4, and 6 kHz in worst ear (and no quantifiable impairment).
** Impairment as defined by AMA criteria.
† Audiometry records available for only 16 interviewed employees at one company.

Figure H12 **Hearing loss on existing audiograms, by industry category and age ***



* Results are shown for individual employees (males only); data were not aggregated by company.
** Hearing loss = impairment (AMA criteria) or average threshold >40 dB at 3-4-6 kHz in worst ear.
† Contingency table; chi-square test

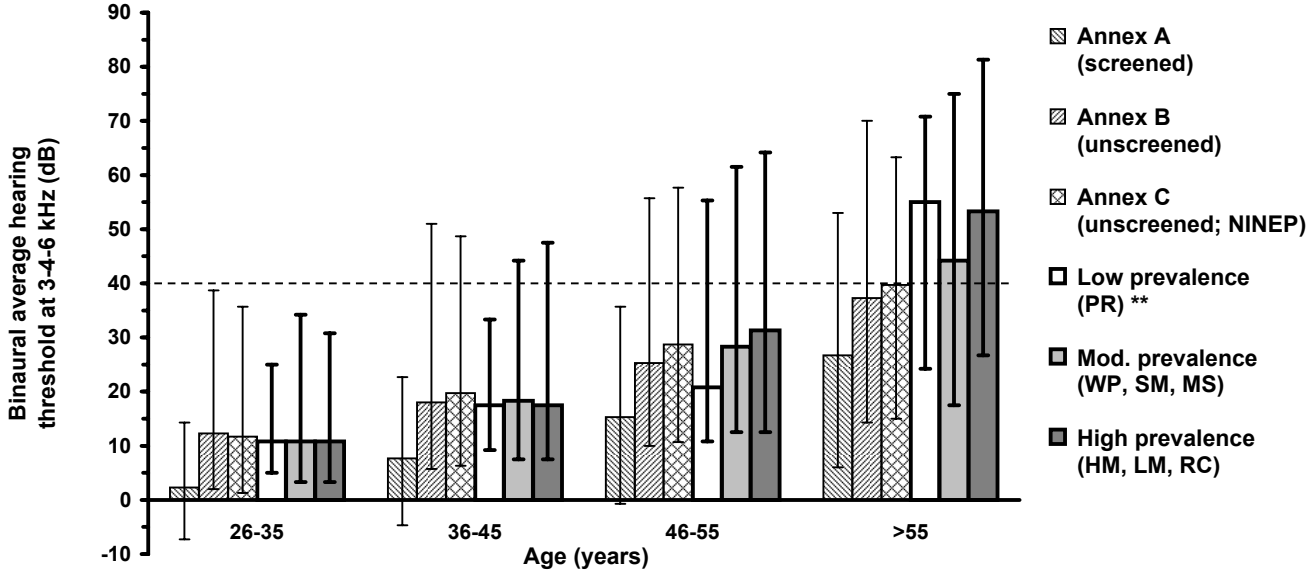
Figure H13A **Hearing threshold levels at 0.5-1-2-3 kHz by industry category and age, relative to three reference databases (ANSI S3.44-1996) ***



* Vertical bars represent the median, and whiskers represent the 10th and 90th percentiles. Dashed line indicates value approximately consistent with "impairment" by AMA criteria.

** Study industries categorized by relative overall prevalence of hearing loss (low, moderate, high).

Figure H13B **Hearing threshold levels at 3-4-6 kHz by industry category and age, relative to three reference databases (ANSI S3.44-1996) ***



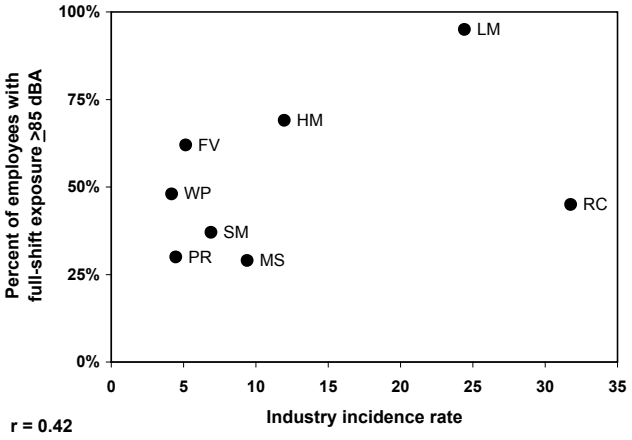
* Vertical bars represent the median, and whiskers represent the 10th and 90th percentiles. Dashed line indicates value used in this study to define "moderate" or worse high frequency hearing loss.

** Study industries categorized by relative overall prevalence of hearing loss (low, moderate, high).

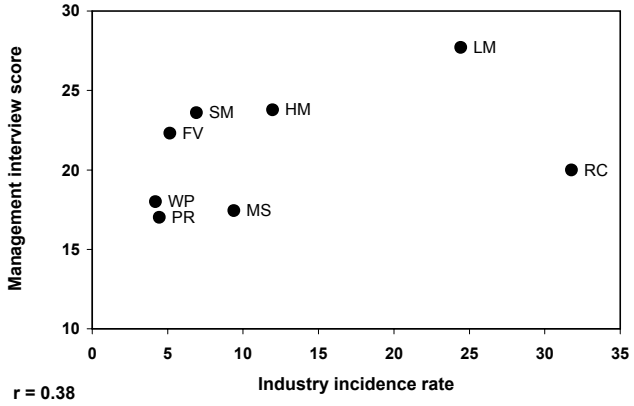
Figure H14 Relationship of claims incidence to noise exposure, hearing loss prevention practices, and hearing loss in eight industries

Values in graphs represent the company value (e.g., average employee interview score, or percent of employees with full-shift exposure ≥85 dBA), averaged across the industry.

Hearing loss = impairment or moderate (or worse) high frequency hearing loss, on audiometry performed previously by company, using available records 1999-2002.



r = 0.42



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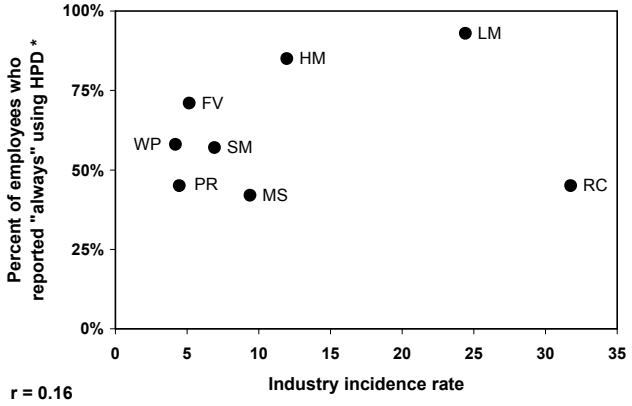
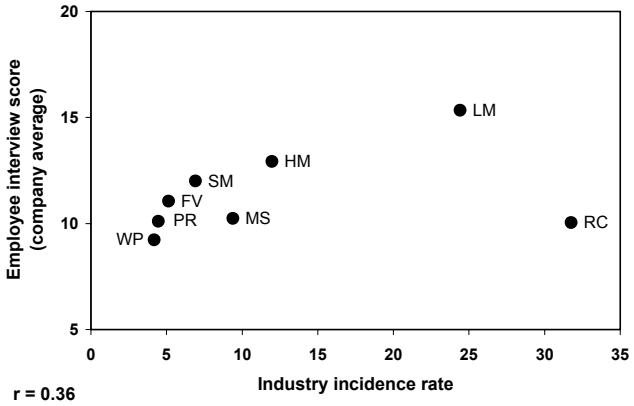


r = 0.16



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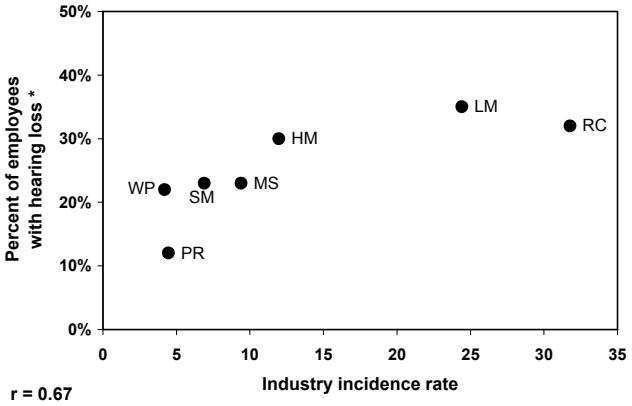
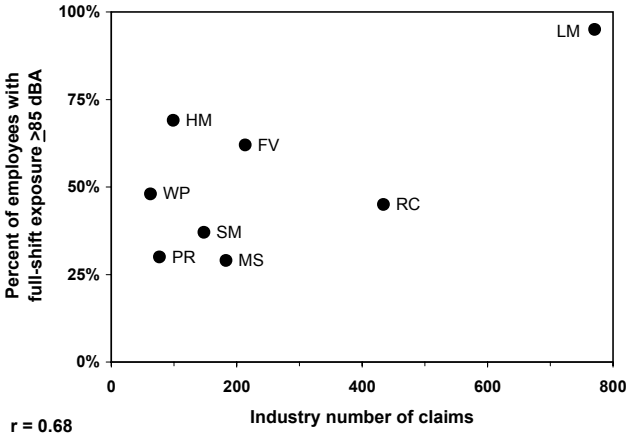


r = 0.67

Figure H15 Relationship of claims number (count) to noise exposure, hearing loss prevention practices, and hearing loss in eight industries

Values in graphs represent the company value (e.g., average employee interview score, or percent of employees with full-shift exposure ≥85 dBA), averaged across the industry.

Hearing loss = impairment or moderate (or worse) high frequency hearing loss, on audiometry performed previously by company, using available records 1999-2002.



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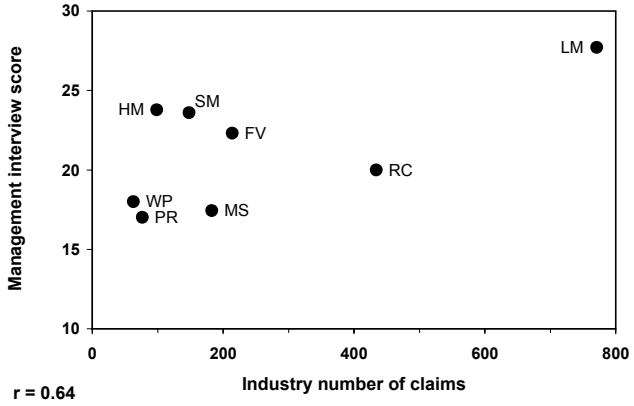

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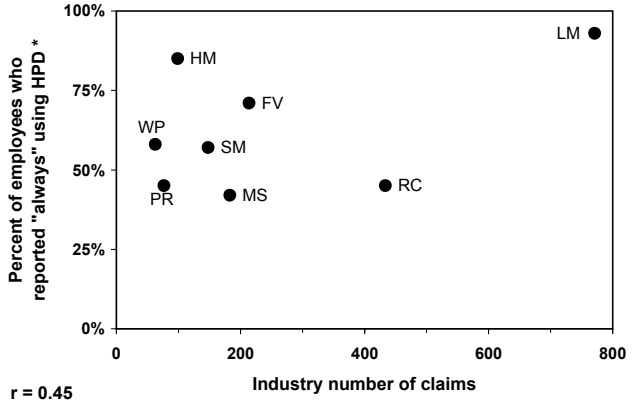
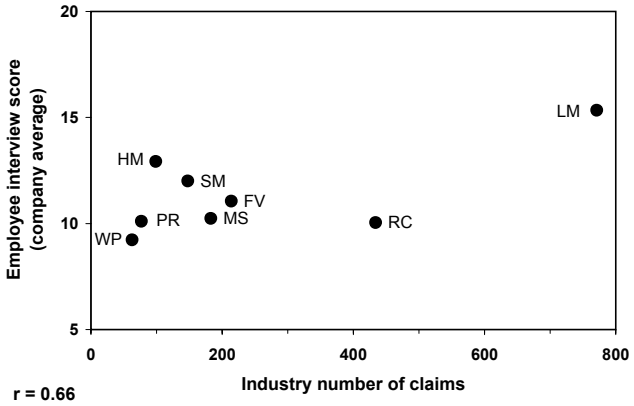
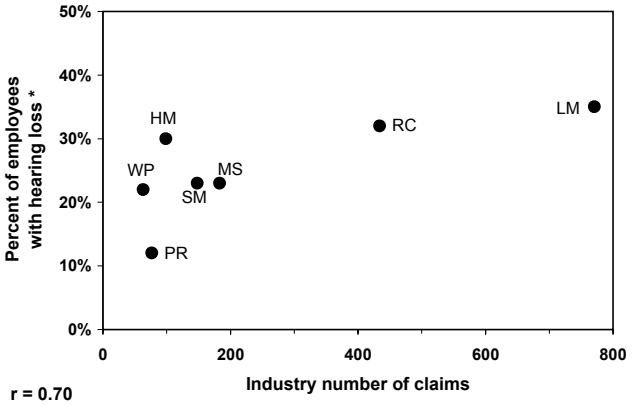


r = 0.45



r = 0.66

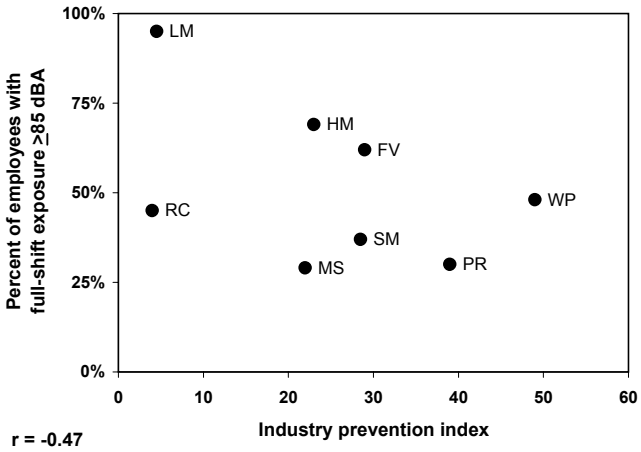


r = 0.70

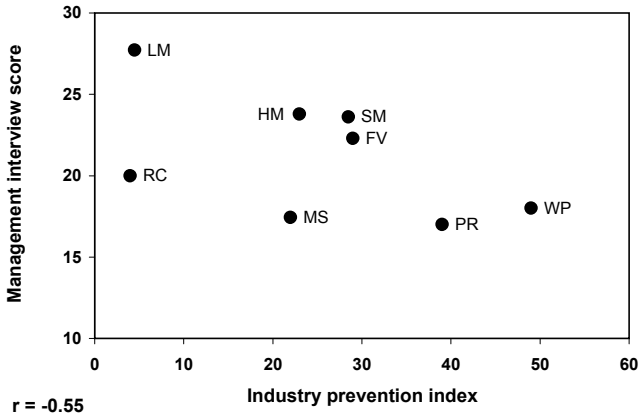
Figure H16 Relationship of claims prevention index to noise exposure, hearing loss prevention practices, and hearing loss in eight industries

Values in graphs represent the company value (e.g., average employee interview score, or percent of employees with full-shift exposure ≥85 dBA), averaged across the industry.

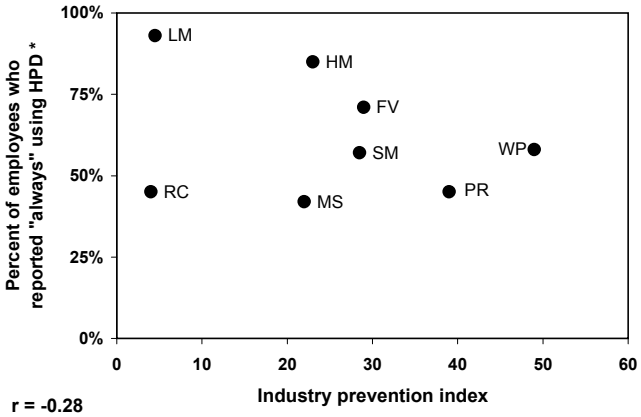
Hearing loss = impairment or moderate (or worse) high frequency hearing loss, on audiometry performed previously by company, using available records 1999-2002.



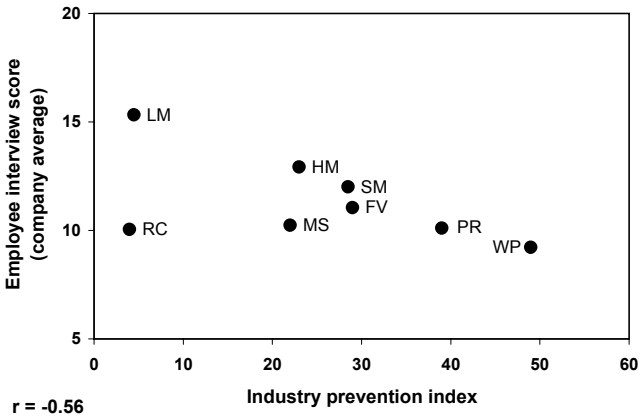
r = -0.47



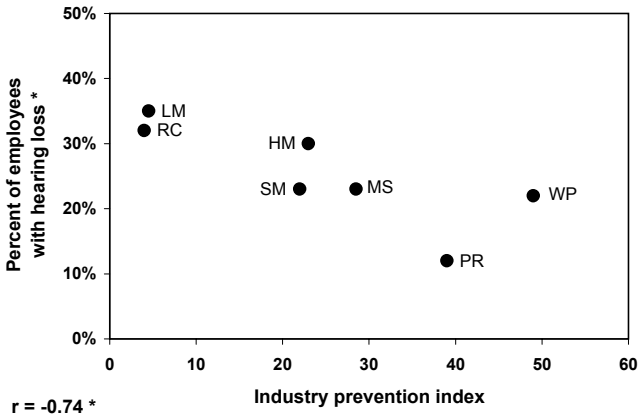
r = -0.55



r = -0.28



r = -0.56



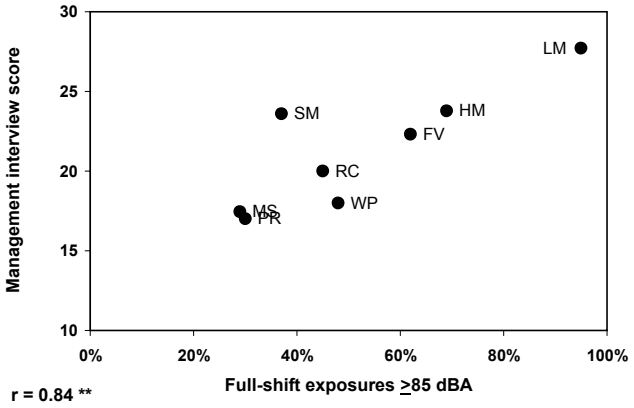
r = -0.74 *

* p< 0.05

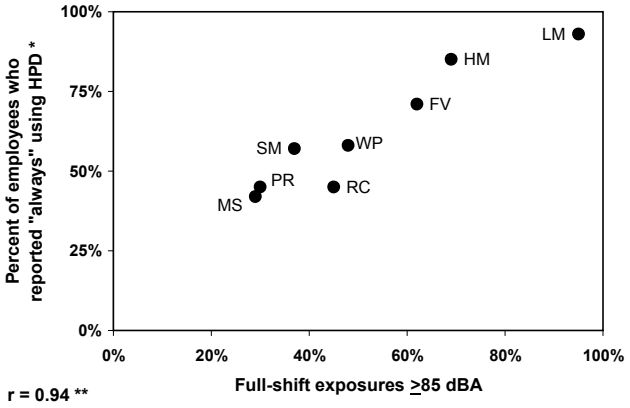
Figure H17 Relationship of noise exposure to hearing loss prevention practices, and hearing loss in eight industries

Values in graphs represent the company value (e.g., average employee interview score, or percent of employees with full-shift exposure ≥85 dBA), averaged across the industry.

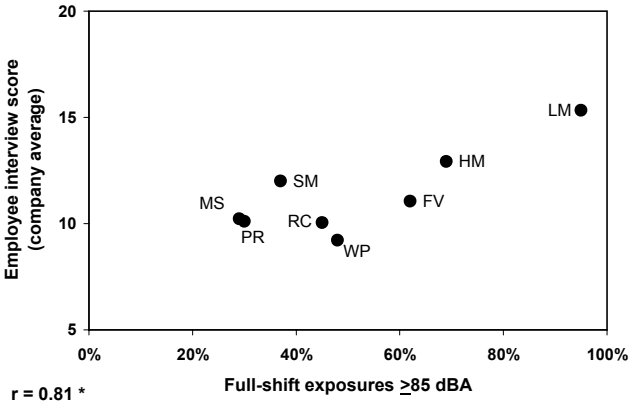
Hearing loss = impairment or moderate (or worse) high frequency hearing loss, on audiometry performed previously by company, using available records 1999-2002.



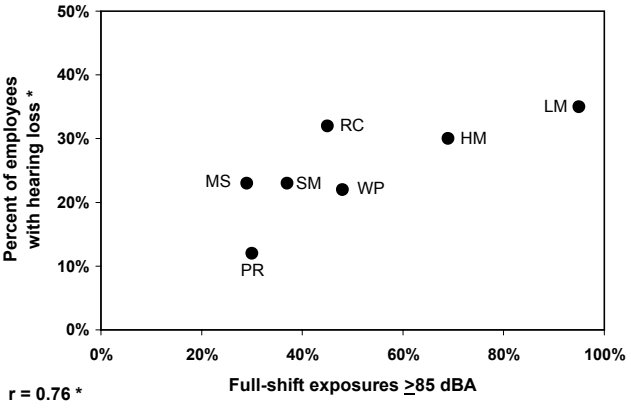
r = 0.84 **



r = 0.94 **



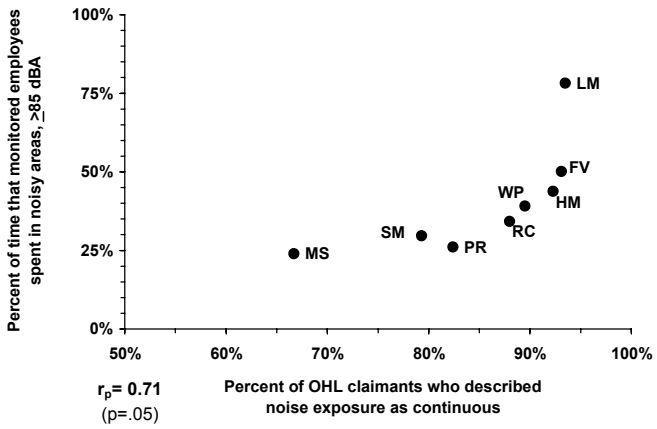
r = 0.81 *



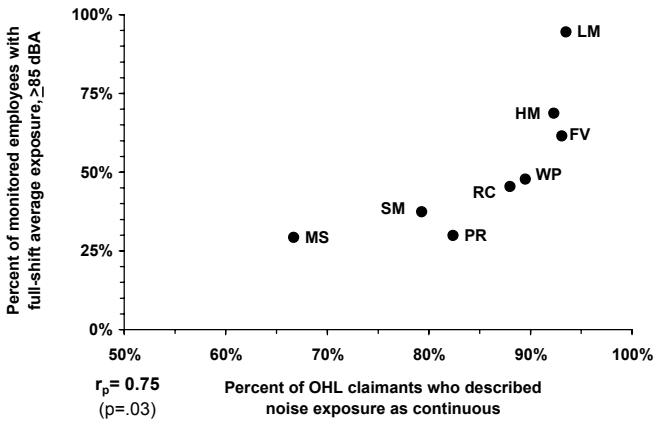
r = 0.76 *

* p< 0.05
** p< 0.01

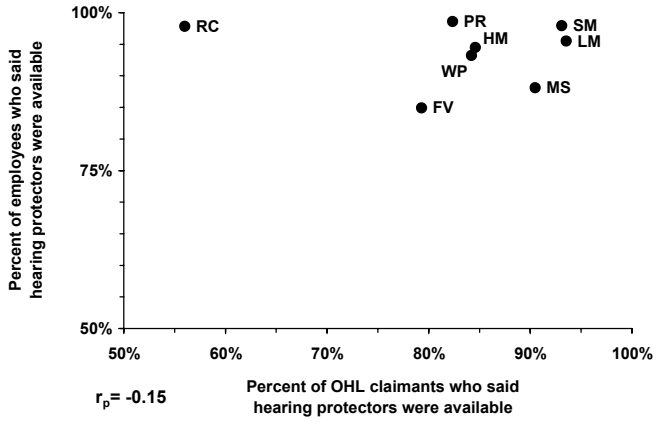
Figure H18 **Findings of work site evaluations compared to findings of Project 2 telephone survey of OHL claimants**



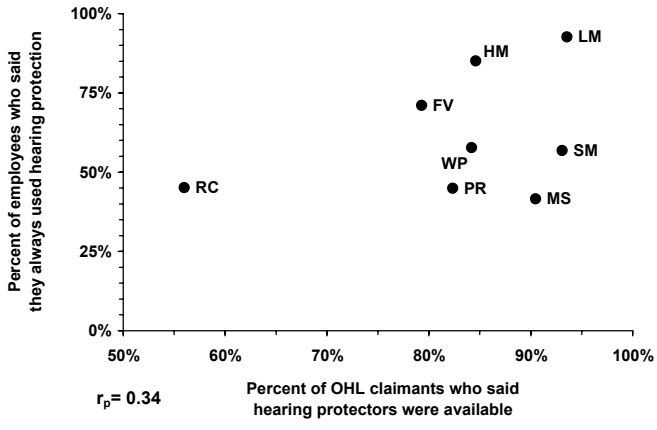
r_p= 0.71
(p=.05)



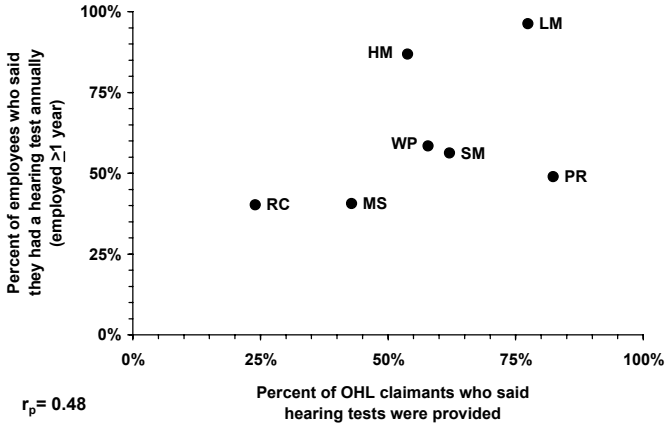
r_p= 0.75
(p=.03)



r_p= -0.15



r_p= 0.34



r_p= 0.48

r_p = Pearson correlation coefficient

Figure H19A **Findings of work site evaluation, relative to whether or not the company was liable for an OHL claim during 1992-1998 ***

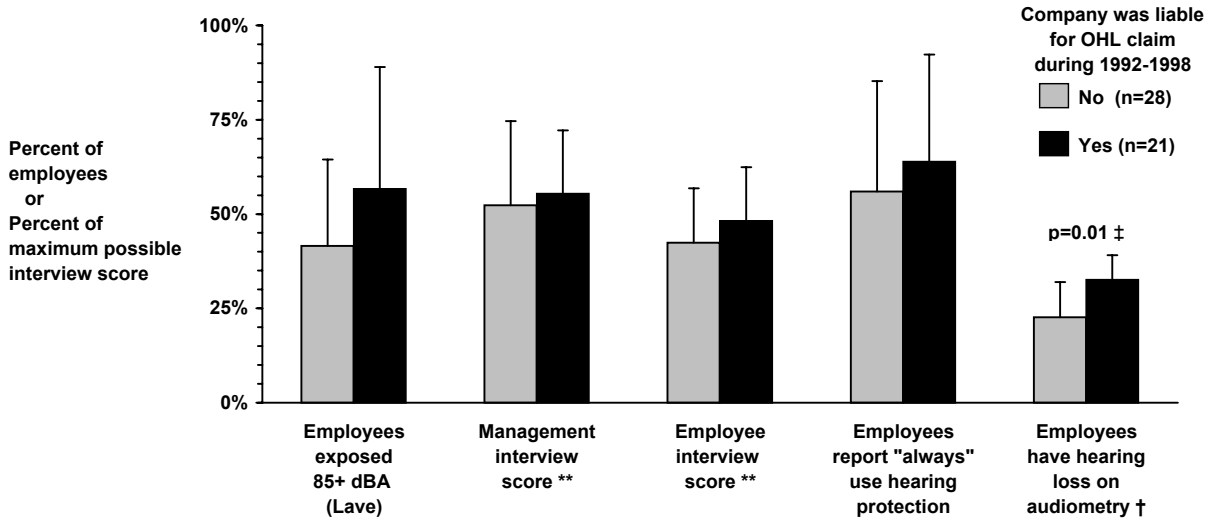
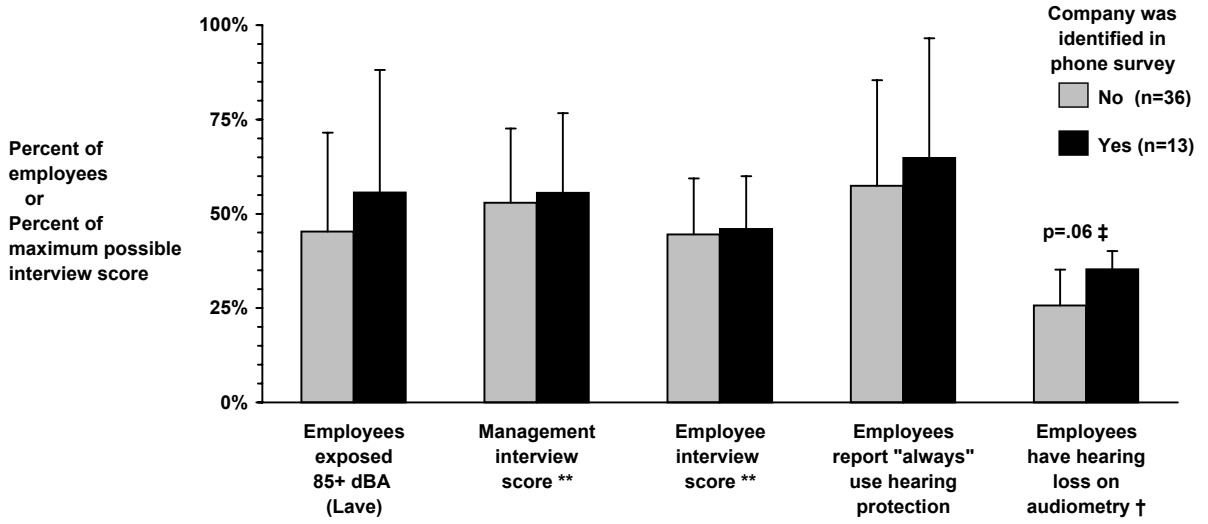


Figure H19B **Findings of work site evaluation, relative to whether or not the company was identified by a surveyed OHL claimant as their most recent noisy employment ***



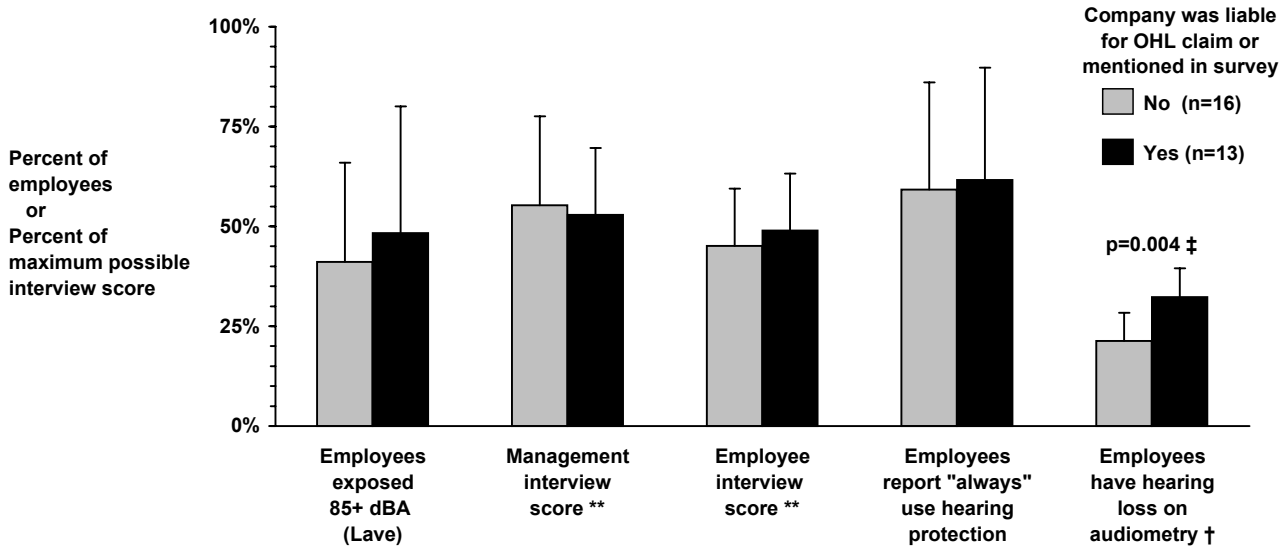
* Figures include 49 companies from five industries (FV, SM, MS, HM, and RC).

** Excluding three companies where no monitored employees had L_{ave} (or 8-hour equivalent TWA) $\geq$85 dBA.

† Audiometry was available only for 23 companies in four industries (SM, MS, HM, and RC).
Hearing loss = impairment (AMA criteria) and/or average threshold >40 dB at 3-4-6 kHz in worst ear

‡ Oneway analysis of variance.

Figure H20 **Findings of work site evaluations in three industries, relative to whether or not the company was liable for an OHL claim during 1992-1998 or mentioned in the phone survey ***



* Figures include 29 companies from three industries (SM, MS, and HM).

** Excluding one company where no monitored employees had L_{ave} (or 8-hour equivalent TWA) $\geq$85 dBA.

† Audiometry was available only for 19 companies.
Hearing loss = impairment (AMA criteria) and/or average threshold >40 dB at 3-4-6 kHz in worst ear

‡ Oneway analysis of variance.

Appendices

Appendix 1: Daniell WE, Swan SS, McDaniel MM, Stebbins JG, Seixas NS, Morgan MS. Noise exposure and hearing conservation practices in an industry with high incidence of workers' compensation claims for hearing loss. *Am J Indust Med* 2002; 42:309-17.

Appendix 2: Daniell WE, Fulton-Kehoe D, Cohen M, Swan SS, Franklin GM. Increased reporting of occupational hearing loss: Workers' compensation in Washington State, 1984-1998. *Am J Indust Med* 2002; 42:502-10