Noise Exposure and Hearing Conservation Practices in an Industry With High Incidence of Workers' Compensation Claims for Hearing Loss

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Background *Washington State has experienced a striking increase in workers' compensation claims for hearing loss.*
Methods *This cross-sectional study examined noise exposures and hearing conservation practices in one industry with a high rate of hearing loss claims. We evaluated 10 representative foundries with personal noise dosimetry, management interviews, employee interviews, and existing audiometry.*
Results *Noise levels routinely exceeded 85 dBA. All companies were out of compliance with hearing conservation regulations. Most employees with important findings on audiograms were not aware of their findings. There was a significant positive correlation between management-interview scores and worksite-average employee-interview scores ($r = 0.70$, $P = 0.02$).*
Conclusions *Companies where more effort is put into hearing conservation program activities can achieve a greater positive impact on employee awareness. However, there were broad deficiencies even in the better programs in this sample, suggesting that workers in this industry probably face a continuing substantial risk of occupational hearing loss.*
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KEY WORDS: hearing loss; noise induced; noise; ear protective devices; hearing tests; epidemiology

INTRODUCTION

Occupational noise-induced hearing loss provides an excellent model for studying the preventability of occupational illness. There are fewer gaps in knowledge about occupational hearing loss than for virtually all other occupational illnesses, and the primary barriers to prevention lie in implementation of that knowledge. The causative relationship between noise exposure and hearing loss is well characterized, and there is consensus about exposure limits that are safe for nearly all exposed individuals [Ward, 1986; NIH, 1990; NIOSH, 1998]. The tools needed to quantify the hazard and the health outcome of concern are readily available, easily operated, well standardized, and relatively inexpensive. With annual audiometric testing, it is possible to detect changes in hearing ability before the development of clinically significant hearing loss. There are recognized options for protecting workers against noise, including engineered controls to reduce noise levels, administrative strategies to reduce time spent in noisy areas, and personal hearing protection devices. Finally, all of these points have been incorporated into Occupational Safety and Health Administration (OSHA) regulations since 1983—the Hearing

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Conservation Amendment to the Noise Standard—requiring a workplace hearing conservation program when average noise levels equal or exceed 85 dBA, and noise controls for average levels over 90 dBA [OSHA, 1971, 1983].

Occupational hearing loss should be diminishing, but that is clearly not the case. In Washington State, the number of workers' compensation claims accepted for hearing loss grew from less than 500 each year throughout most of the 1980s, to more than 5,000 in 1998 [Daniell et al., 2002]. Accountable costs for 1998 alone exceeded $57 million. The rise in claims is probably attributable, at least in part, to factors not related to current workplace circumstances. The claims increase predominantly involved individuals who were older than the usual retirement age, and whose highest and most prolonged exposures to workplace noise may have occurred years or decades before retirement. However, the claims increase has been evident across most age groups, including workers in their 30s, raising questions about the adequacy of contemporary protections against noise.

The current regulatory approach to workplace noise raises further concerns about the risk of occupational hearing loss in contemporary workplaces. Noise controls are required only if technically and economically feasible [OSHA, 1971], and OSHA policy allows employers to defer controls until average noise levels reach 100 dBA, if there is an effective hearing conservation program [OSHA, 1994]. The State of Washington has no such formal enforcement policy, but most inspectors have limited training to evaluate noise controls, and citations for lack of controls are uncommon [Washington State, 1983; Lofgren, 1989; DLI, 1999].

It is conceivable that noise levels may have changed little over time in the industries associated with the observed rise in hearing loss claims. If hearing conservation programs are not optimally effective in those industries, then workers employed in those industries may still face substantial risk for occupational hearing loss. The State OSHA division of the Washington State Department of Labor and Industries (DLI), in collaboration with the University of Washington (UW), therefore conducted a "noise targeting" pilot project to evaluate noise levels and compliance with noise and hearing conservation regulations at representative worksites in one industry with a relatively high incidence rate of hearing loss claims.

MATERIALS AND METHODS

The DLI noise-targeting pilot project used a cross-sectional study design to evaluate noise levels, employer practices, and employee awareness of hearing conservation practices at 10 worksites in one industry, foundries. The worksite visits were conducted as State OSHA inspections, using standard DLI inspection procedures, with an enhanced component to assess noise exposures and compliance with hearing conservation regulations [Washington State, 1983]. The participating DLI inspectors were all trained enough to be familiar with the project procedures; however, all data collection for the pilot project was conducted by a single person, an industrial hygiene graduate student serving as a DLI intern. The pilot project only collected information that was necessary and appropriate for assessing regulatory compliance. The only difference from a routine compliance inspection was that a protocol was used to ensure uniformity across worksites. After removal of identifying information, pilot project data were transferred to UW for analysis, using procedures approved by a DLI data utilization supervisor [UW/DLI, 1996], and by the UW Human Subjects Research Committee.

Target Industry Selection

The DLI chose the foundry industry as the target industry for inspection based on: (1) the industry had a relatively high number and incidence rate of OHL claims during 1992–1996 ($n = 94$; incidence 9.6 claims per 1,000 workers per year, or 6.9 times the statewide average); (2) there were at least 10 employers in this industry category with a business address in the project area, DLI Region 2 (Seattle/King County); (3) worksites in this industry typically have fixed locations; (4) the foundry industry had not recently been targeted for a DLI inspection program; and (5) the foundry industry has numerous hazards in addition to noise. The latter two criteria were not necessary for the pilot project, but reflected the general policy of DLI in selecting industries for targeted inspections, to increase the probable yield of correctable hazards. During the inspections, noise exposures and hearing conservation practices were evaluated with a systematic protocol, for the pilot project, but no systematic protocols were used to evaluate other hazards.

Target Worksite Selection

The target industry included 29 candidate companies, some of which had business addresses in Region 2 but production facilities in adjacent counties. Ten were excluded because they had already been inspected by DLI within the preceding 2 years. Of the remaining 19, ten were selected on the basis of: (1) the company was already on another DLI targeted-inspection list; (2) the company had been cited by DLI in the past (to evaluate abatement of the cited hazards); and/or (3) the company had a relatively large number of employees, compared to other candidate companies. The presence or absence of an OHL claim was *not* a factor in selecting individual companies for inclusion. One of the selected companies operated at two locations, which were evaluated together as one company.

On the initial visit to one selected company—a foundry that exclusively manufactured lead ingots—almost all sound level measurements for the noisiest areas and job tasks were less than 85 dBA. Because the measured noise levels did not trigger the requirement for a hearing conservation program, this was not evaluated further in the inspection. The foundry still underwent routine inspection for other hazards. This foundry was replaced with another, for the pilot project.

Data Collection

Data collection was completed in a 7-month period. At the initial visit, the inspectors identified noisy areas and job tasks, and agreed on a date for a follow-up visit. Most companies had two or three workshifts. There were 339 production area workers, identified during the data collection visit and/or via workplace records from the most recent audiometric test session. About 60% of these workers were at work during the data collection visits, which were only conducted on day shifts (approximately 200 workers).

Noise monitoring

Time-weighted average (TWA) measurement of personal noise exposure was performed for 86 workers. The goal of noise monitoring was not to characterize the average or typical exposures for all production jobs, but to determine whether there were enough workers whose average noise exposures exceeded 85 dBA to warrant having a hearing conservation program at each company. The workers were selected to be representative of those working in areas or job tasks where noise exposures were most likely to exceed 85 dBA. Workers in quieter production areas or jobs received a lower sampling priority, but were included in sampling when there were enough dosimeters.

Exposures were measured with Metrosonics 3080 or 3100 dosimeters, continuously logged minute by minute, using a slow response on an A-weighted scale, 5 dB exchange rate and 90 dB criterion sound level. Dosimeters were calibrated before and after each visit. Samples less than 4 hr in duration were excluded from analysis (n = 4). Of the 82 other samples, 88% were at least 7 hr in duration. For samples shorter than 8 hr, the measured TWA was used rather than a projected TWA to avoid potentially erroneous assumptions about worker exposures when measurements were not available.

Management interview

A structured interview of the most appropriate management representative at each company obtained information about compliance with specific elements of noise and hearing conservation regulations. The interview had five sections (Table I). Interviewees had the option to access company records as needed. The only records reviewed systematically by inspectors were audiometric test records.

Employee interview

A structured interview of selected employees at each worksite covered specific points that hearing conservation regulations require the employer to address. The employee interview was also divided into five sections (Table I). Interviews were attempted for 125 employees, including 85 of 86 who wore a noise dosimeter, plus a convenience sample of 40 others who performed similar job tasks in the vicinity of a sampled worker and who spoke English well enough to answer questions unequivocally.

Data Analysis

Data analysis was conducted by the UW collaborators after all inspections were completed, using data identified only by anonymous codes. The analysis focused on summary measures of management and employee interviews, their inter-relationships, and their possible associations with company or employee descriptors, using Pearson correlation coefficients or analysis of covariance (ANCOVA) [SPSS, 1999].

Interview summary scores and subscores

Non-duplicative questions were selected from the management and employee interviews, to represent reported compliance with major points in noise and hearing conservation regulations. The management summary score was calculated as the sum of positive responses, to create section subscores and an overall score. The employee summary score and subscores were derived similarly, but not including the audiometric testing section. No summary score was calculated for 33 interviewed employees (26%) who did not complete all four sections. Failure to complete an interview generally happened because of limited English-speaking ability (n = 24), but also because of inapplicability of one or more interview sections (e.g., recent hire with no formal training or audiometry yet at this company).

Audiometry records

Audiometry data were obtained from existing employer records for all individuals who had at least one valid audiogram and were tested at the company's most recent test session (n = 305). Records were reviewed manually to identify flat, ascending or unusual audiometric patterns that would be relatively inconsistent with noise-induced hearing loss

TABLE I. Primary Questions in Employer and Employee Interviews, Foundry Workers, Washington State

Interview section	Employer interview	Employee interview
Noise monitoring and controls	Noise levels ever measured	Ever at this company:
	Noise measured by company or contractor, or during an inspection	Observed noise measurements
	Maintain records of measurements	Notified of any monitoring results
	Aware of noise levels: $\geq$ 85–90 TWA, >115 max, $\geq$ 140 peak (dBA)	Informed or consulted by employer about plans for controls
	Can identify noisy areas: >85–90, >100, or >115 (dBA)	
	Signs posted: >85–90; >115 (dBA)	
	Noise map: available; posted	
	Repeat measurements after changes	
	Plan new controls: engineered, or administrative	
Hearing protection devices (HPDs)	Available to all exposed workers	HPDs at this company:
	Ensure that HPDs are worn	Available at no personal cost
	$\geq$2 types to select from	Fitting provided at least initially
	Evaluate attenuation	Replacements as needed
	Initial fitting; periodic re-fitting	$\geq$2 types to select from
Training	Written training program	Ever told about at this company:
	Provided to all over-exposed	Effects of noise on hearing
	Repeated annually	Purpose of HPDs
		Advantages, disadvantages of various types of HPDs
		Selection, fitting, use, care of HPDs
		Purpose of audiometric testing
Informational materials	Copy of standard available	Seen at this company:
	Copy of standard posted	Copy of standard
	Other materials available: State OSHA guidelines; OSHA brochures; other	Other materials: State OSHA Guidelines; OSHA brochures; other
Audiometry[a]	Mandatory testing for over-exposed	Ever told at this company:
	No noise 14 hr before baseline	Had standard threshold shift
	Records of noise level in test room	Had any audiogram finding, other than STS and other than "normal"
	Tester/fitter informed about workplace noise levels	Should have clinical evaluation because of an audiogram finding
	Test records maintained for current employees; former employees	

[a]Audiometry subsection was not used for calculating employee interview summary score.

[Sataloff and Sataloff, 1993]. Each individual's current hearing ability was characterized with their most recent, valid audiogram. The guidelines of the American Medical Association were used to identify possible hearing "impairment," involving the 0.5–1–2–3 kHz audiometric frequencies [Cocchiarella and Andersson, 2000]. Higher frequency hearing ability was quantified by the average hearing threshold at 3–4–6 kHz, using categories of "mild" (26–40 dB) or at least "moderate" (> 40 dB). The referral guidelines of the American Academy of Otolaryngology—Head and Neck Surgery were used to identify potentially important left-right asymmetry [Dobie, 1997]. Records with more than one annual audiogram (n = 150, spanning $\geq$ 3 years) were reviewed for documentation of a standard threshold shift (STS), as defined in the OSHA and DLI Standards (i.e., > 10 dB worsening in average of hearing thresholds at 2, 3, and 4 kHz).

RESULTS

Four of the 10 companies cast with aluminum, and six cast with steel or iron (Table II). The mean number of production workers at each company was 34 (standard deviation [SD] 18). Only one company (#9) was unionized. All companies had been the subject of a previous inspection or consultation visit by the State OSHA program, and three had received noise-related citations. Four companies had one recent hearing loss claim, and another had two recent claims.

Noise Monitoring

A full-shift personal noise sample was collected for about 40% of the production workers who were present during a data collection visit (n = 82). The mean full-shift TWA for noise was 90.6 dBA (SD 5.7), with 89% of samples exceeding 85 dBA. About half (56%) were over 90 dBA, and 22% exceeded 95 dBA. The Lmax exceeded 115 dBA in 72% of samples, and peak levels were 140 dBA or higher in 66% of samples. Each company had at least three employees with a TWA over 85 dBA and at least two with a TWA over 90 dBA. Employees' noise levels were highest in parts cleaning jobs (i.e., grinding, welding, scarfing, shotblasting, and using a cutoff saw; mean 94.4 dBA, SD 4.3; n = 35) and molding jobs (91.0 dBA, SD 3.1; n = 21) (Figure 1).

Employee Sample

Limited background information was available for the 339 production workers. All were males whose mean age was 37 years (SD 11), ranging from 33 to 41 years across the 10 companies (Table II). Of the 125 workers who initiated an interview, 34% reported that English was their second language, ranging from none to 77% at the individual companies. Two-thirds (67%) of all workers had participated in at least two annual audiometric testing–training sessions at their present company. The subgroups of workers defined by interview status (complete, incomplete, or not interviewed) were similar in age; however, they differed in English-speaking ability, the major reason for incomplete interviews, and in their usual job. Documentation of job categories was lacking for 83 workers, primarily non-interviewed workers. Parts cleaning jobs, with highest average noise exposures, were disproportionately represented among the workers with incomplete interviews.

Interview Summary Scores and Subscores

The management-interview summary scores ranged from 13 to 22 (possible 35), with overall mean 16.4 (SD 3.2; Table II). The summary scores showed no clear association with any identifiable employee or company descriptors.

With the exception of one company (#8), each company's summary score was strongly paralleled by its subscores on the noise section (r = 0.85) and on the other combined "hearing protection" sections of the interview (i.e., hearing protection, training, and informational material sections; r = 0.79). Company #8, however, obtained a moderately high summary score of 18, with the lowest hearing-protection section subscore (7 compared to 8–14 at the other companies) and the highest noise section subscore (11 compared to 3–7). Company #8 had never conducted any noise monitoring, hearing conservation training or audiometric testing prior to the initial visit, but completed all three components before the data-collection visit. This demonstrated the susceptibility of the interview and summary score to the influence of recent interventions.

The 92 employee-interview summary scores showed a trimodal distribution, reflecting the tendency for individuals to give positive responses to all or nearly all questions in a section, or else to none or only one question in a section. The employee scores ranged from 3 to 16 (possible 16), with

TABLE II. Company Characteristics, Foundries, Washington State

Company	Type of metal cast	Production area size (1,000 sf)[a]	Years at present location	Previous noise citation	Previous hearing loss claim	Number of employees	Age of employees (years)[b]	Full-shift TWA noise levels (dBA; n = 82)[b]	Management interview score
1	Aluminum	18	25–50	Yes	Yes	15	39.1 (10.2)	86.0 (6.3)	21
2	Steel	34	<25	No	Yes	41	40.4 (12.9)	93.9 (5.2)	16
3	Aluminum	25	>50	No	Yes	45	40.2 (12.7)	91.0 (4.3)	14
4	Aluminum	16	>50	No	No	6	42.2 (15.6)	92.3 (0.6)	12
5	Iron	34	25–50	Yes	No	51	32.6 (7.9)	92.9 (7.7)	20
6	Steel	56	<25	Yes	Yes	49	38.8 (10.6)	92.2 (4.6)	17
7	Aluminum	20	>50	No	No	18	35.0 (11.6)	84.9 (6.1)	15
8	Iron	65	<25	No	No	37	32.7 (10.3)	93.6 (5.0)	18
9	Iron	20	>50	No	No	32	36.4 (11.0)	90.8 (3.6)	12
10	Steel	100	>50	No	Yes	36	40.6 (10.1)	90.4 (4.7)	19

[a]sf, square feet.
[b]Mean and standard deviation.

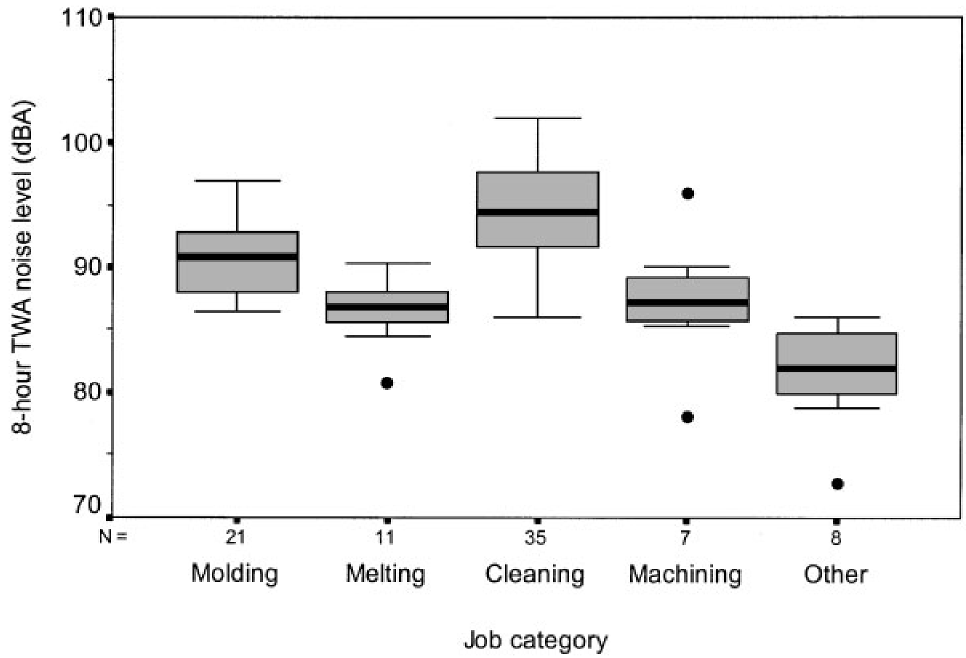

FIGURE 1. Noise levels by job category (8-hr (full-shift) time weighted average; n = 82). Boxes denote 25th to 75th percentiles; crossbars, the median; whiskers and dots, outlying values. The "cleaning" category includes grinding, welding, scarfing, shotblasting, and using a cutoff saw.

overall mean 9.7 (SD 3.1). The average employee score at individual companies ranged from 7.6 to 11.7, and showed a significant positive correlation with the management-interview summary scores ($r = 0.70$; $P = 0.02$; Fig. 2). Employee scores tended to be higher with older age (≥ 40 years, +1.1; 95%CI −0.2 to 2.5; $P = 0.09$; ANCOVA), but showed no significant association with identifiable employee or company descriptors.

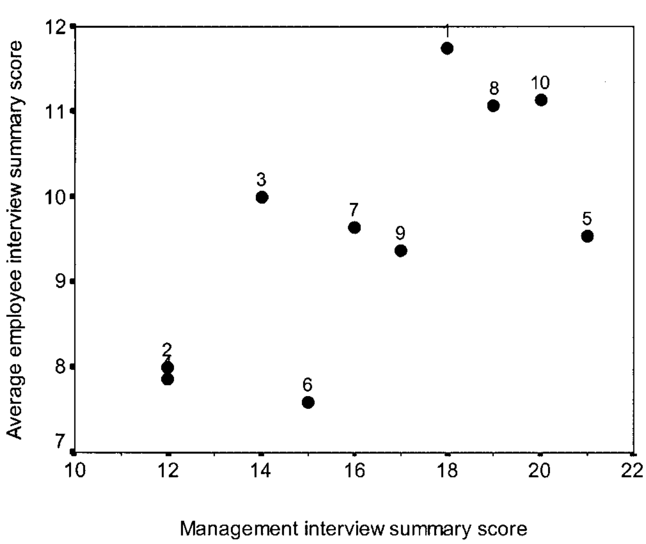

FIGURE 2. Management-interview and average employee-interview summary scores. Value labels denote the company identification number.

Noise Monitoring and Controls

Higher subscores on the noise section of the management interview (range 3–11) were dictated mostly by whether or not: monitoring records were available (n = 3); the company performed or arranged its own noise measurements (n = 3), beyond those done in a previous inspection; the interviewee was aware that noise levels exceeded regulatory thresholds (n = 3–5); warning signs were posted in noisy areas (n = 7); and a noise map was posted or available (n = 2). Only one company planned any new engineered noise controls, and no company planned any new administrative controls.

Almost half of the interviewed workers (42%) reported having seen noise levels measured at their company, but only 12% recalled ever being informed about specific noise levels. Seven workers reported being aware of company plans for new controls; however, four worked at companies where the management representative reported no such plans.

Hearing Protectors

All management representatives and employees reported hearing protectors were routinely available, although 12% of employees reported access to only one type, self-molded earplugs. Initial fitting was routinely available, by management and employee report. However, only four management representatives reported that periodic refitting was provided. Five companies reported evaluating hearing protector attenuation, but only used manufacturer specifications, without knowledge of workplace noise levels and without any derating adjustments.

Training, Informational Materials, and Audiometric Testing

Two companies did not provide hearing conservation training or audiometric testing on an annual basis, including company #8, which initiated training and testing only after the first inspection visit. Company #4 had conducted only one training-testing session for which it had records, although by report it had conducted other sessions in the distant past. A third company (#3) conducted annual training-testing through most of the 1990s, but much less frequently in the 1980s. The eight companies that conducted annual training-testing sessions, arranged to do so through an independent contractor. Of those, two had no written training program, as required by the standard. Training consistently relied on non-interactive, English-language video presentations. Translation was not provided routinely for workers who were not fluent in English, other than by bilingual coworkers in some instances.

No companies had a copy of the Hearing Conservation Standard or related informational materials, and no interviewed representative had ever read the Standard. In contrast, 35% of interviewed workers reported that information materials, including a copy of the Standard, were available at the workplace.

Audiometry Findings

There were 305 individuals with at least one valid audiogram, including 150 with two or more tests spanning at least 3 years, and 74 with at least one STS documented in their record. Of the 92 interviewed employees, 23 reported having been informed of an STS while at the present company (Table III). Two of those 23 (9%), however, had no documented audiometric testing, and 9 (39%) had not truly experienced an STS. The frequency of false positive reporting was comparable whether the interviewee recalled being informed by letter (as required in the standard) or verbally. Conversely, of the 29 interviewees who had at least one documented STS at the present company, only 12 (41%) recalled being so informed.

Abnormalities other than an STS were somewhat more likely to be found in the audiometric records of interviewed employees who reported being informed of such an abnormality at the present company, or those who were unsure, than for interviewees who reported not being so informed (Table IV). Nonetheless, the majority of audiometric abnormalities occurred in the records of individuals who reported no awareness of those abnormalities. For example, 12 interviewees had enough hearing loss to be considered ''impaired;'' however, nine did not recall ever being informed of a hearing abnormality, and three were unsure. The employee interview included no questions about hearing loss claims; however, none of the interviewed employees incidentally mentioned having a hearing loss claim.

TABLE III. Audiometry Findings and Employee Recollection of Audiometric Abnormality, Reported at Present Company

	Employee recalled being informed of audiometric abnormality		
Audiometry findings (company records)	**No (n = 79)**	**Unsure (n = 7)**	**Yes (n = 6)**
No audiometry record	4 (5%)	1 (14%)	1 (17%)
Possible hearing "impairment" [a]			
Flat or ascending pattern	1 (1%)	1 (14%)	0
Descending pattern	8 (10%)	2 (29%)	0
Hearing loss at 3–4–6 kHz, without "impairment"			
Hearing threshold average 26–40 dB	10 (13%)	0	2 (33%)
Hearing threshold average >40 dB	7 (9%)	0	1 (17%)
Right-left asymmetry [b]	2 (3%)	2 (29%)	0
Standard threshold shift	25 (32%)	3 (43%)	1 (17%)

[a] Impairment was defined with the most recent valid audiogram, using American Medical Association guidelines (average threshold >25 dB at 0.5–1–2–3 kHz, in either ear) [Cocchiarella and Andersson, 2000]. Audiometric pattern was determined by visual review of audiogram.

[b] Asymmetry was defined with the most recent valid audiogram, using otological referral criteria of the American Academy of Otolaryngology—Head and Neck Surgery (difference in average thresholds >15 dB at 0.5–1–2 kHz; >30 dB at 3–4–6 kHz) [Dobie, 1997].

TABLE IV. Audiometry Findings and Employee Recollection of Standard Threshold Shift, Reported at Present Company

	Employee recalled being informed of a standard threshold shift (STS)			
Audiometry findings (company records)	**No ($n = 68$)**	**Unsure ($n = 1$)**	**Yes, verbally ($n = 13$)**	**Yes, in letter ($n = 10$)**
No audiometry record	4 (6%)	0	2 (15%)	0
No STS	47 (69%)	1 (100%)	5 (38%)	4 (40%)
One or more STS's	17 (25%)	0	6 (46%)	6 (60%)

DISCUSSION

In this industry with a high rate of workers' compensation claims for hearing loss, workers probably continue to face a substantial risk of occupational injury to their hearing. With the exception of one foundry that specialized in the production of lead ingots, noise levels were found to routinely exceed 85 dBA and commonly exceed 90–95 dBA. None of the evaluated companies had made any substantial past effort or future plans to reduce noise levels, and all of the companies were out of compliance with major elements of hearing conservation regulations. No interviewed management representative possessed a copy of the regulations or had read them. Hearing protector devices were provided regularly. However, any fitting generally was limited to the time of initial employment, and refitting was rarely provided, even where required for individuals with an STS; and the selection of hearing protector types was generic and not based on knowledge of workplace exposures or protector appropriateness. Three of ten companies never or irregularly provided annual training and audiometric testing, and training at the other seven companies typically consisted only of a non-interactive video presentation. The training, provided in English, probably had little or no value for the large number of workers who were not fluent in English.

The evaluated companies generally were not successful at communicating critical audiometric information to individual workers in an effective manner, and probably also underutilized audiometric findings to guide efforts or evaluate the performance of their hearing conservation programs. The majority of workers whose audiometric tests revealed either clinically significant hearing impairment or high frequency hearing loss were under the impression that their audiograms showed no abnormalities. Furthermore, more than half of the workers who had experienced an STS while employed at he present workplace did not recall being informed of that finding; and of the workers who reported being informed of such a shift, only about half had truly experienced one.

These misunderstandings about STSs are significant in light of recent recommendations by the National Institute for Occupational Safety and Health that the current STS criterion be replaced with a different criterion (i.e., 15-dB worsening at any frequency from 0.5 through 6 kHz, persistent in the same ear and frequency on the next annual audiogram) [NIOSH, 1998]. The incremental gains from such a change may be dwarfed by the problems related to their implementation. In the present sample, workers' recollections about whether their audiograms had or had not shown an STS were essentially no better than if they had guessed randomly. It is likely that truly affected workers were informed at the time a shift was detected, as documented in company records, but either they did not appreciate the meaning or importance of a criterion change in hearing, or they simply forgot about it. Regardless, it is doubtful that this sentinel indicator was being used as a meaningful component in these hearing conservation programs.

The present study found a significant positive correlation between scores on management interviews and the worksite-average scores on employee interviews, suggesting that companies where more effort is put into hearing conservation program activities generally can achieve a greater positive impact on employee awareness of hearing conservation. This observation also suggests that using a structured approach to assess the policies and day to day practices of a workplace hearing conservation program can distinguish between programs with relatively better or worse levels of performance.

The interview-based approach used in this project provided useful, although limited, information about the status of hearing conservation programs in these workplaces. A true determination that a program is "effective" would require confirmation that hearing protector usage and noise control implementation were maximized, and ultimately that no workers experienced substantial loss of hearing over time. The present approach, however, was relatively expedient to conduct, and could at least identify programs or program components that were probably *not* optimally effective. This particular approach was disproportionately influenced by recent efforts to enhance a hearing conservation program, as evidenced by one worksite that had a relatively high management interview score but had no organized program until after the first inspection visit. Furthermore, any interview-based approach is potentially susceptible to reporting bias. In the context of a regulatory compliance inspection, as in the present sample, interview responses could bias an evaluation toward under-estimating the extent of program deficiencies, particularly responses from management interviews.

There is a need to determine whether hearing conservation program deficiencies are similarly prevalent in other industries with high rates of workers' compensation claims for hearing loss. It is likely that the findings in this one regional industry are not isolated, given that other investigators have made similar observations. A survey in Michigan of individuals with occupational noise-induced hearing loss found that, of 776 individuals who were exposed to noise most recently in the 1990s, 48% had no hearing tests and 15% were provided no hearing protection at their most recent noisy job [Reilly et al., 1998]. In compliance inspections at 43 of the identified companies, representing a variety of industries, 23 had average noise levels over 85 dBA; of these, 11 had no hearing conservation program, and six had deficient programs.

The present project, which targeted worksites on the basis of industry-specific rates of hearing loss claims, rather than by the occurrence of single cases, was effective at directing resources to worksites with deficiencies in hearing conservation programs. It is noteworthy that, within the targeted industry, companies with a recent hearing loss claim were no more likely to have excessive noise or program deficiencies than were companies with no recent claim. Particularly for an occupational illness related to an exposure that usually occurs over many years or even decades, workers' compensation data may be more useful for targeting high-risk industries than specific worksites. An ongoing sequel study is evaluating companies in nine other Washington State industries, selected on the basis of hearing loss claims incidence rates, to characterize current noise exposures and hearing conservation practices, and also to evaluate the utility of using workers' compensation data for targeting subsequent interventions.

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