Surveillance of Hearing Loss Among Older Construction and Trade Workers at Department of Energy Nuclear Sites

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Background *Medical screening programs at three Departments of Energy (DOE) nuclear weapons facilities (Hanford Nuclear Reservation, Oak Ridge, and the Savannah River Site) have included audiometric testing since approximately 1996. This report summarizes hearing evaluations through March 31, 2003.*
Methods *Occupational examinations included a medical history, limited physical examination, and tests for medical effects from specific hazards, including audiometric testing. Hearing thresholds by frequency for DOE workers were compared to age-standardized thresholds among an external comparison population of industrial workers with noise exposures <80 dBA. Multivariate analyses were used to explore the risk of hearing impairment by duration of construction trade work and self-reported noise exposure, while controlling for potential confounders such as age, race, sex, smoking, elevated serum cholesterol, hypertension, solvent exposures, and recreational noise exposures.*
Results *Hearing thresholds among DOE workers were much higher than observed in a comparison population of industrial workers with low noise exposures. Overall, 59.7% of workers examined were found to have material hearing impairment by NIOSH criteria. Age, duration of construction work, smoking, and self-reported noise exposure increased the risk of hearing loss. The risk of material hearing impairment was significantly elevated for construction trade workers compared to the external comparison population (odds-ratio = 1.6, 95% CI = 1.3–2.1) and increased with the duration of trade work.*
Conclusions *These medical screening programs confirm worker concerns about risks for hearing loss and the need for hearing conservation programs for construction workers, with emphasis on the prevention of noise exposures.* Am. J. Ind. Med. 48:348–358, 2005.
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KEY WORDS: DOE; Hanford; Oak Ridge; Savannah River; noise; construction; trades; hearing loss; audiometry; surveillance

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BACKGROUND

In 1993, Congress added Section 3162 to the Defense Authorization Act, calling for the Department of Energy (DOE) to determine whether workers within the nuclear weapons facilities were at a significant risk for work-related illnesses and if so, to provide them with medical surveillance. In 1996, DOE established six pilot programs, including two programs directed at construction workers at the Hanford Nuclear Reservation in Richland, Washington, and at the Oak Ridge Reservation in Oak Ridge, Tennessee. These construction worker programs are conducted by a consortium from the Center to Protect Workers' Rights, University of Cincinnati; Duke University; Medstar Research Foundation/ Washington Hospital Center, and Zenith Administrators. In 1997, another program was added at the Savannah River Site (SRS) in Aiken, South Carolina.

Excess noise exposures among construction workers and high rates of noise induced hearing loss among these workers is well documented, and has been known for more than 40 years [Worker's Compensation Board of BC, 2000; Kerr et al., 2002; Suter, 2002]. Nevertheless, in the United States, the Occupational Safety and Health Administration (OSHA) has not established a regulation to require hearing conservation in the construction industry, and under-use of hearing protection is widespread [Lusk et al., 1998]. Although Washington State has a specific regulation that applies to the construction industry, recent studies in Washington State found that excessive noise exposures are still common in the construction trades [Neitzel et al., 1999; Seixas et al., 2001]. The rate of hearing loss claims in the construction industry in Washington State is approximately five times higher than the average rate for all industries combined [Daniell et al., 2002].

The lack of hearing conservation programs in the construction industry stems not from the lack of evidence to support the effectiveness of such programs. In general industry, it is well established that rates of hearing loss are reduced with hearing conservation programs. [Pell, 1973; Hager et al., 1982; Cohen and Colligan, 1998]. In Sweden and British Columbia, Canada, which have implemented hearing conservation programs in the construction industry, epidemiological studies have found large declines in the rate of hearing loss as a result [Bruhl and Ivarsson, 1994; Schneider et al., 1995; CPWR, 2002; Worksafe, 2003].

Construction trade workers employed in nuclear weapons facilities have potential exposure to high-noise levels during facility construction, maintenance, renovation, and demolition. As construction workers at Hanford, Savannah River, and Oak Ridge were mostly employed by sub-tier contractors and typically not considered to be ''permanent employees,'' work history and exposure information on them are either non-existent or very sporadic and unreliable and most were not included in site medical surveillance programs.

MATERIALS AND METHODS

Surveillance Program Overview

In 1996–1997, medical surveillance programs for construction trade workers at Hanford, Oak Ridge, and Savannah River were developed and implemented. This report covers finding for hearing loss based on examinations using standard audiometric tests for participants from program inception (1996–1997) through March 31, 2003. The surveillance programs at each of these sites were designed with a common approach, as previously described [Dement et al., 2003; Welch et al., 2004]. The initial step in the medical screening consisted of a work history interview to determine whether a worker had sufficient evidence of exposures or health concerns to merit referral to step two of the screening. The work history interview was conducted in person or by telephone by trained project outreach staff interviewers using computer-driven screens to ask questions and enter data. Prior to the interview, workers were given a list of questions and other tools to help recall their work at the sites. During the interview, extensive use was made of site-specific information such as site maps and process descriptions by building to help with recall [Bingham et al., 1998]. Step two of the program was a limited medical screening examination, which is described below.

Study Population

Table I shows the number of construction workers at risk, and the number of participants who have completed the screening program through March 31, 2003. Participation in the program is voluntary, and workers may also choose to accept only parts of the protocol. These factors have resulted in the following participation rates to date:

- We estimate that approximately 226,000 construction workers have been employed at these three facilities from the start of their construction to the present time. Over half of these workers were involved only in the initial construction of the first reactors, which in the case of Hanford and Oak Ridge was during World War II, while for Savannah River this construction took place during 1949–1951. Most of these and many of the subsequent workers are deceased or very old at this point. Many worked in the trades or on any DOE facility for only very short periods performing specialized work. Therefore, out of this total population, we have estimated that the total number of workers who might still be alive and able to participate in these programs to be approximately 75,000.
- The medical screening programs as of March 31, 2003 examined a combined total of 5,352 workers: Hanford, 1990; Savannah River, 1,875; and Oak Ridge, 1,475. This represents 7.6% of the estimated available population.

TABLE I. Older Construction and Trades Workers at DOE Sites by Sites

Parameter	Hanford	Savannah River	Oak Ridge	All Sites
Date site opened	1943	1949	1943	
Approximate number of workers ever employed	109,000	67,000	50,000	226,000
Number of workers potentially available for screening	30,000	37,000	15,000	75,000
Number of workers screened (March 2003)	1,990	1,887	1,475	5,352
Number with audiometric tests	903	1,628	979	3,510
Participation in audiometric testing	45%	88%	66%	65.6%

- Of those who have participated, 3,510 workers agreed to complete audiometric testing and had acceptable test results. These participants are a subset of 65.5% of all workers who have been examined by these programs, or approximately 5% of the total number of workers who could participate. These participation patterns create the potential for selection biases, both with regard to selection into the screening program, and in terms of the tests that participants have agreed to accept once they are in the program.

Exposure Assessment

The work history focuses on the type of trade in which the worker was employed and whether the worker was exposed to hazards identified and reported in needs assessment [Dement et al., 2003; Welch et al., 2004]. Workers are asked a detailed list of questions about: working in or around high-hazard work tasks, working with or around high-hazard materials, and working in buildings or areas associated with potential exposures to hazardous materials or where known exposure incidents or emergencies occurred. For each component of the occupational exposure history, workers were asked to qualitatively estimate his/her extent of exposure to the task, material, or building. Each task or material exposure is assigned a qualitative frequency value by the interviewer based on responses provided by the worker ranging from 1 to 5 as follows: 1, rarely; 2, few times per month; 3, couple of times per week; 4, daily or most days per week; 5, continuous.

Since prior studies have suggested that occupational exposures to solvents may enhance or contribute to the detrimental effects of noise exposures, worker exposures to solvents were included in the current analyses. For these analyses, elevated solvent exposure was defined to be workers who reported daily or continuous exposures to one or more solvents.

The occupational and exposure history also asked about the percentage of time that a worker experienced quiet, loud, and very loud noise. The following definitions were used as anchors to define relative noise exposures: quiet, ‘‘You could speak in a normal voice;’’ loud, ‘‘You had to raise your voice;’’ very loud, ‘‘You had to shout to be heard.’’

Medical Screening Examinations

The medical screening examinations were performed under contract with approximately 200 local clinical providers who meet credentialing requirements and adhere to a detailed protocol. The medical examination included a detailed medical history, smoking history, limited physical examination, and tests for medical effects from specific hazards. The findings from each examination were reviewed by the project nurse coordinator and medical director (when necessary) before the examining physician reported them to the participant. Quality assurance was done through on-site visits, chart reviews, and periodic data evaluations to identify and explain unusual patterns.

Audiometric Testing

Audiometric tests were conducted according to procedures recommended by the National Institute for Occupational Safety and Health [NIOSH] at frequencies of 500-8,000 Hz [NIOSH, 1998]. In addition to audiometric test data, information concerning levels of serum cholesterol and blood pressure was available for program participants. The definition of hearing handicap used by NIOSH in their risk assessment for noise induced hearing loss [Prince et al., 1997] was used for analyses presented in this report. In accordance with NIOSH criteria, ‘‘Material Hearing Impairment’’ was used as the primary outcome for this study and defined as a biaural average threshold of greater than 25 dB calculated as the articulation index weighted average across frequencies of 1, 2, 3, and 4 kHz [Prince et al., 1997; NIOSH, 1998]. We also investigated the potential impact of selection bias due to a prior diagnosis of hearing loss using an alternative case definition. Hearing loss for these alternative analyses was defined as a finding of NIOSH material hearing impairment, current hearing aid use, or a prior diagnosis of hearing loss.

Data Analyses

All data collected by these programs are stored in Microsoft Access Data Management Systems (DMS). In addition to providing data storage and management capability, the DMS is used extensively for program management, quality control, and reporting. For these analyses, custom queries were developed to extract appropriate demographic, work history, exposure history, and medical information. These data were converted to SAS data sets for statistical analyses. All analyses presented in this report were conducted using PC SAS Version 8 [SAS Institute Inc., 2000].

Several surrogate measures of lifetime noise exposures were considered. These measures included the duration of work at a DOE site, years of trade work, and percentage of time that each worker reported being exposed to quiet, loud, and very loud noise as previously described. For statistical analyses, each worker was classified by the percent of work time exposed to high- or very-high noise levels. Categories for the percentage of time exposed to loud or very loud noise were established based on quartiles of the overall distribution. (<50%, 50%–69%, 70%–89%, and ≥90%). In a similar manner, categories for age (<45, 45–54, 55–64, and ≥65), and duration of trade work (<15, 15–23, 24–32, and ≥33 years) were created based on quartiles of the overall distribution.

Both descriptive and multivariate analysis methods were used. Demographic data were summarized by calculation of means and standard deviations of study parameters such as age, DOE work time, trade work duration, etc. Stratified analyses were used to explore trends in hearing loss prevalence by age, employment duration, and cigarette smoking history. Unconditional logistic regression was used to further explore the risk of hearing loss by duration of trade work, extent of reported noise exposure, and solvent exposures, while controlling for potential confounders such as age, race, sex, hypertension, and elevated cholesterol. Other studies have suggested that elevated serum cholesterol and hypertension may be risk factors for hearing loss [Toppila et al., 2000]; therefore, these parameters were considered in the models as categorical variables. Elevated serum cholesterol was defined as total cholesterol in excess of 250 mg/dl and hypertension was defined as either systolic blood pressure in excess of 150 mmHg or diastolic blood pressure in excess of 100 mmHg. For these models, an indicator variable was created to account for worker participation in non-work related activities possibly associated with elevated noise exposures. These activities included recreational hunting, use of power equipment (including farm equipment and chain saws), auto racing, hunting, use of indoor firing ranges, listening to loud music or playing in a band, and operation of powerboats or motorcycles. The logistic regression analyses were restricted to workers at Hanford and Savannah River as these sites used nearly identical occupational history questionnaires, which facilitated combining data to investigate duration of trade work as a risk factor for noise induced hearing loss.

The strategy for logistic regression model-building followed guidance offered by Hosomer and Lemeshow [1989] with the objective of selecting variables which produce the best parsimonious model in the context of known risk factors for material hearing impairment and biological plausibility. This strategy involved first performing univariate logistic regression for each of the parameters identified as candidates for inclusion in the preceding univariate and stratified analyses. Main effects multivariate logistic regression models were next constructed using parameters found to be statistically significant in the univariate analyses. We chose a moderate level of statistical significance ($P < 0.25$) for initial inclusion of parameters into the multivariate logistic model. With all variables in the model, we refined the model to arrive at the set of biologically plausible covariates which best predict the risk of material hearing impairment. Our primary tool for assessing the contribution of any given covariate was the change in the model −2log likelihood function with and without the variable and changes in the β coefficients for the remaining covariates. SAS Proc logistic regression procedures and associated regression diagnostics were used [SAS Institute Inc., 2000].

External Comparison Population

In addition to the multivariate analyses of risk factors for occupational hearing loss within the cohort of DOE trade workers; we compared the prevalence of material hearing impairment among these workers with an external comparison population. NIOSH provided hearing loss data from the American National Standard Institute (ANSI) S12.13 Working Group; which consisted of 22 diverse companies within the US and Canada [Adera and Gaydos, 1997; Adera et al., 2000]. A comparison population of industrial workers from companies identified by Adera et al., as having been exposed to <80 dBA was selected. The most recent audiometric test data for each worker were selected, along with demographics (age at the time of hearing test, race, and sex) and noise exposure level. Unconditional logistic regression was used to estimate the risk of noise induced hearing loss among DOE trade workers compared to the comparison population; adjusting for age, race, and sex. No adjustment for cigarette smoking could be made in these analyses, as smoking data were not available for the comparison group. In addition to logistic regression analyses, age-standardized hearing thresholds by audiometric test frequency for DOE trade workers were compared to those of the low-noise exposed referent population. The distribution by age category among the DOE worker population served as weights for age-standardized hearing thresholds.

RESULTS

Descriptive and Stratified Analyses

Table II includes key demographic characteristics on the participants in the audiometric testing. They had an overall mean age of 56.6 years and had been employed at one of the DOE sites for an average of 12.2 years. The population studied was predominately male (93.8%) and Caucasian (82.8%). More workers at Savannah River were female (10.4%) and African-American (26.7%). Also, the Savannah River population was on average 5.5 and 6.7 years younger than the Hanford and Oak Ridge populations, and had worked on average about 3 years less in the trades. The overall prevalence of current cigarette smokers was 20.2% while 42.5% were former smokers. Workers included in these analyses reported frequent exposures to loud or very loud conditions at work. On average, these workers reported loud noise conditions 38.7% of time and very loud conditions 30.1% of the time.

Age-standardized hearing thresholds by audiometric test frequency for DOE workers and the low-noise exposed comparison population are presented in Figure 1. The audiometric data for the comparison population did not

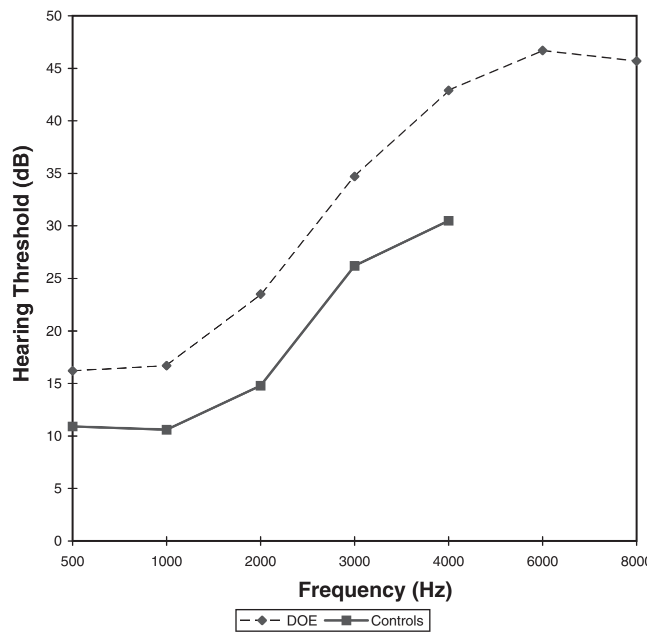

FIGURE 1. Age-standardized mean hearing thresholds.

TABLE II. Demographic Characteristics of Participants in Audiometric Testing*

Parameter	Hanford	Savannah River	Oak Ridge	All sites
Number with audiometric tests	903	1628	979	3510
Age[a]				
Mean (SD)	58.9 (12.8)	53.2 (12.0)	60.3 (12.9)	56.6 (12.9)
Sex				
Male (%)	879 (97.3%)	1441 (89.6%)	950 (97.6%)	3270 (93.8%)
Female (%)	24 (2.7%)	168 (10.4%)	23 (2.4%)	215 (6.2%)
Race				
Caucasian (%)	802 (91.0%)	1144 (70.5%)	929 (95.8%)	2876 (82.8%)
African-American (%)	24 (2.7%)	434 (26.7%)	33 (3.4%)	491 (14.1%)
Hispanic (%)	25 (2.8%)	6 (0.4%)	1 (0.1%)	32 (0.9%)
Asian (%)	2 (0.2%)	3 (0.2%)	0 (0.0%)	5 (0.1%)
Alaskan/Indian (%)	10 (1.1%)	6 (0.4%)	2 (0.2%)	18 (0.5%0
Other (%)	18 (2.1%)	30 (1.9%)	5 (0.5%)	53 (1.5%)
Years at DOE site				
Mean (SD)	10.6 (10.0)	11.7 (8.2)	14.6 (11.5)	12.2 (9.8)
Years in trades[c]				
Mean (SD)	26.1 (12.9)	23.3 (11.5)	—[b]	24.3 (12.2)

Workers completing medical exams though March 31, 2003.
[a]Demographics and other data in this report are for workers completing audiometric tests. Sex was missing for 25 workers and race for 35 workers.
[b]Total trade years not available for workers at Oak Ridge.
[c]Years in trades includes both DOE and non-DOE work.

consistently have hearing thresholds for 6,000 and 8,000 Hz., thus only values for 500–4,000 Hz are shown. Figure 1 shows that DOE workers had higher hearing thresholds than the comparison population for all frequencies, with a greater degree of hearing loss being observed at higher frequencies.

Using NIOSH criteria, the crude prevalence of material hearing impairment ranged was 49.1% at Savannah River, 69.7% at Oak Ridge, 68% at Hanford, with an overall prevalence across all sites of 59.7%. The crude prevalence of material hearing impairment by trade for trades having 25 or more audiometric tests is given in Table III. These data demonstrate that most construction trades had a high prevalence of hearing loss, with the highest prevalence being observed for plumbers/steam fitters (78.7%) and the lowest for asbestos workers (47.1%). These prevalence rates are not adjusted for age, race, or sex; therefore, some degree of caution is needed in comparing trades and attribution to construction noise exposures.

As expected, hearing loss prevalence increased quickly with age over 45 years, reaching 92.7% for construction workers older than 65. The prevalence of hearing loss also increased with years of DOE site work and years of work in the trade. Simple chi-square tests for trends found significant increasing trends ($P < 0.01$) for age, DOE work years, and trade work years. Age and years of trade work were reasonably correlated ($r^2 = 0.3$); therefore, these univariate stratified data reflect the combined effects of both parameters.

Table IV displays the prevalence of material hearing impairment by years of trade work and worker reported percentage of time exposed to loud or very loud noise. These analyses were restricted to the subset of workers from SRS and Hanford with less than 5 years of non-trade work after the age of 20 years (N = 979). These data show that the prevalence of hearing loss increased with years of trade work and with more frequent exposures to loud noise levels. Among workers employed in construction trades for less than 15 years, the overall prevalence of material hearing impairment was 13.3% and increased to 73.6% for 33+ years of trade work.

TABLE III. Crude Prevalence of Hearing Impairment by Trade Trades with 25 or More Tests-All Sites Combined

Longest trade worked	Prevalence of material hearing impairment (%)
Asbestos workers	32 (47.1%)
Boilermakers	69 (67.0%)
Carpenters	200 (67.8%)
Cement masons	16 (59.3%)
Electricians	390 (56.3%)
Insulators	21 (50.0%)
Ironworkers	120 (71.9%)
Laborers	264 (50.8%)
Millwrights	64 (70.3%)
Operating engineers	121 (64.4%)
Painters	62 (51.2%)
Pipefitters	399 (58.7%)
Plumbers/Steam fitters	70 (78.7)
Sheetmetal workers	116 (66.3%)
Teamsters	66 (60.6%)

Logistic Regression Analyses

We constructed several logistic regression models in order to explore contributions of construction trade work and work at DOE sites as risk factors for noise-induced hearing loss while controlling for potential confounders. Our primary measures of potential noise exposures were years of work in construction trades, years of work at a DOE site, and the percent of time exposed to loud or very loud noise. Based on our worker interviews and focus group discussions, workers reported that their construction work tasks at DOE sites were similar to those performed at non-DOE sites; therefore, we assumed that the percentage of time exposed to loud or very loud noise was the same for DOE and non-DOE construction trade work. In addition, many workers had significant periods of work in non-construction trades and we had no information concerning their noise exposures while performing this work. In order to address this issue, we performed several additional analyses. For the main model, we constructed a dichotomous variable to indicate potential periods of non-trade work in excess of 5 years. This variable was constructed based on the assumption that most workers entered the workforce by age 20; therefore, differences between the workers age at interview and years of trade work (i.e., age–trade work years) in excess of 25 years represented unaccounted for work with unknown potential for noise exposure. We also constructed a separate logistic model restricted to workers with less than 5 years of work outside the construction trades.

The final logistic regression models for all Savannah River and Hanford workers and those with less than 5 years of non-trade work are shown in Table V. All models are adjusted for age, race, and gender. Neither daily solvents exposure separately nor solvent-noise interactions were found to be statistically significant predictors of material hearing impairment in these analyses. Likewise, hypertension, elevated serum cholesterol, and recreational noise exposures were not found to be significantly associated with material hearing impairment. However, these main effect parameters were included in the final models based biologic plausibility, suggestions from other published studies, and the general paucity of published data with this level of personal risk factor detail.

TABLE IV. Prevalence of Material Impairment by Percentage of Time Exposed to Loud to Very Loud Noise and Duration of Trade Work for Savannah River and Hanford Workers Employed Less 5 Years of Other Work After Age 20 (N = 979)

	Prevalence by duration of trade work—Number with hearing loss and percent				
Percent of time exposed to loud or very loud noise	**<15 years**	**15–24 years**	**25–33 years**	**33+ years**	**Overall prevalence by noise exposure**
<50%	2 (12.5%)	5 (10.9%)	23 (34.9%)	28 (53.9%)	58 (32.2%)
50%–69%	2 (9.5%)	4 (7.0%)	29 (36.7%)	52 (66.7%)	87 (37.0%)
70%–89%	2 (7.4%)	16 (23.2%)	48 (49.5%)	49 (81.7%)	115 (45.5%)
90+%	6 (23.1%)	16 (24.6%)	61 (55.0%)	91 (83.5%)	174 (56.0%)
Overall prevalence by duration of trade work	12 (13.3%)	41 (17.3%)	161 (45.6%)	220 (73.6%)	434 (44.3%)

TABLE V. Logistic Regression Results for Material Hearing Impairment; Hanford and Savannah River Site (SRS) Workers*

Model parameter	**Odds-ratio (95% CI) all Hanford & SRS workers (N = 2,469)**	**Odds-ratio (95% CI) Hanford & SRS Workers with less 5 years of other work after age 20 (N = 942)**
Duration of trade work (quartiles)		
<15 years	1.0	1.0
15–23 years	1.2 (0.9–1.7)	1.9 (0.8–4.9)
24–33 years	1.4 (1.0–1.9)	2.7 (1.0–7.7)
33+ years	1.8 (1.1–2.7)	4.6 (1.5–14.4)
Loud or very loud noise exposure (quartiles)		
<50%	1.0	1.0
50–69 %	2.0 (1.4–2.7)	1.3 (0.8–2.2)
70–90%	2.7 (2.0–3.7)	2.8 (1.7–4.5)
90+ %	2.7 (2.0–3.6)	3.2 (2.0–5.2)
Other possible non-trade work		
<5 Years	1.0	—
5+ Years	1.5 (1.2–2.0)	—
Cigarette smoking history		
Never smoked	1.0	1.0
Ever smoked	1.4 (1.2–1.7)	1.2 (0.9–1.7)
Daily or continuous solvent exposure		
No	1.0	1.0
Yes	0.9 (0.7–1.1)	1.0 (0.7–1.4)
Hypertension		
No	1.0	1.0
Yes	1.2 (0.9–1.6)	1.4 (0.9–2.5)
Elevated serum cholesterol		
No	1.0	1.0
Yes	1.1 (0.8–1.4)	1.1 (0.7–1.7)
Recreational noise exposure		
No	1.0	1.0
Yes	0.9 (0.7–1.2)	0.7 (0.5–1.1)

*Unconditional logistic regression model odds-ratios and 95% confidence intervals controlling for age (quartiles), race, sex, and other model covariates as shown. N varies due to missing data.

Duration of trade work was associated with increased risk and demonstrated an increasing trend in both the full model and the model restricted to workers with less than 5 years on non-trade work. In the full model, the dichotomous parameter for more than 5 years of non-trade work also was statistically significant (OR = 1.5, 95% CI 1.2–2.0), indicating that other work related noise exposures likely occurred for some workers. However, the effect of trade work duration was stronger in the model restricted to workers with less than 5 years of other work, suggesting that construction related noise exposures is the primary work related risk factor for noise-induced hearing loss among these workers.

Our surrogate estimates of noise exposure levels were found to be reasonably strong predictors of material hearing loss after controlling for other covariates in both models. Among all SRS and Hanford workers, the risk was 2.0 (95% CI = 1.4–2.7) for exposure too loud or very loud noise 50%–69% of work time and 2.7 (95% CI = 2.0–3.6) for high noise exposures more than 90% of trade work time. The risk of noise-induced hearing loss tended to level off after the percent of time exposed to loud or very loud noise was greater than 70%. Analyses restricted to the subset of workers (N = 942 with all model parameters) with less than 5 years of non-trade work found patterns of risk similar to those observed for all workers, although the parameter estimates were less stable due to smaller numbers. Cigarette smoking was found to be a significant predictor of material hearing loss in the main analysis.

Our ability to investigate the contribution of DOE work independent of other trade work was limited due to the small number of workers (N = 232) who had only performed trade work at a DOE site and had less than 5 years of non-trade work. We constructed an additional logistic regression model using data for these workers and dichotomizing the period of DOE work into 15 or fewer years and 15 or more years. This model was adjusted for age, race, sex, and smoking; parameters found to be significant predictors of hearing loss in the main model. While parameter estimates in this model were less stable than the models shown in Table V, the general trends were substantially the same. The odds-ratio for DOE work more than 15 years compared to work less than 15 years was 2.0 (95% CI = 0.6–7.2) and the risk of noise-induced hearing loss for exposure to loud or very loud noise during more than 70% of work time was 2.0 (95% CI = 0.7–5.5). The risk associated with smoking was 1.9 (95% CI = 0.8–4.1).

Logistic regression analyses of material hearing impairment among DOE trade workers compared to the external comparison population are presented in Table VI and provide additional support for elevated risk among DOE trade workers. In these logistic models, the overall age, race, and sex adjusted odds-ratio for material hearing impairment among DOE trade workers was 1.6 (95% CI = 1.3–2.1) compared to the comparison population of workers with noise exposures less than 80 dBA. The risk increased with duration of trade work and was highest for trade workers employed 33+ years (odds-ratio = 2.2, 95% CI = 1.5–3.2).

TABLE VI. Logistic Regression Odds Ratios for Material Hearing Impairment Hanford & SRS Workers with Less Than 5 Years of Non-Trade Work Comparison Population TWA Noise Exposures <80 dBA

Duration of trade work	Odds-ratio for material hearing impairment (95% CI)
Low noise exposed comparison (N = 1914)	1.0
<15 years	1.0 (0.4–2.3)
15–23 years	1.5 (1.0–2.2)
24–33 years	1.6 (1.2–2.1)
33+ years	2.2 (1.5–3.2)
Overall DOE compared to controls	1.6 (1.3–2.1)

Note: The NIOSH reference population consisted workers with TWA noise exposures <80 dBA for all companies combined [Adera et al., 2000]. Odds ratios are adjusted for age, race, and sex.

Because these screening programs were voluntary, we evaluated whether selection could be a major factor influencing the findings. There were significant differences in the rate of participation in the audiometric testing between the sites. However, an examination of whether there were significant differences in key characteristics between those who participated in audiometric testing and the overall population of screened workers found none that were significant.

Workers who had been previously diagnosed with hearing loss and were using a hearing aid were not referred for audiometric testing. We investigated the potential impact of selection bias due to a prior diagnosis of hearing loss using an alternative case definition in the logistic regression models. For these analyses the study population was expanded to include workers with information concerning current hearing aid use or reported a prior diagnosis of hearing loss, regardless of audiometric testing by the surveillance programs. Hearing loss for these analyses was defined as a finding of material hearing impairment, current hearing aid use, or a prior diagnosis of hearing loss. The same unconditional logistic regression model shown in Table V for workers with less than 5 years of non-trade work was then fit to these data. Using this expanded case definition, the odds-ratio for construction trades work for 15–23 years was increased to 2.0 (95% CI = 1.2–3.4), with odds ratios for longer periods of trade work being essentially the same as in the Table V model. Risks associated with other model parameters (e.g., age, race, sex, smoking, and exposure to loud to very loud noise) were comparable. The hypertension point estimate was comparable but did reach borderline statistical significance (OR = 1.7, 95% CI = 1.0–2.8).

DISCUSSION

We report results of a medical screening examination of construction workers with a mean age of 56.6 years, and find a high prevalence of typical noise induced hearing loss (see Fig. 1). Hearing loss is correlated with all construction work, and with construction work specifically at DOE facilities. The noise exposures reported by workers were strong predictors of subsequent hearing loss. Having ever smoked cigarettes was found to significantly increase the risk of hearing loss. There was no indication that solvent exposure, elevated serum cholesterol, hypertension, or recreational noise exposure was significantly associated with material hearing impairment. Hypertension was found to be of borderline statistical significance in one model.

There were two apparent inconsistencies in the data that are easily explained. The first is the low participation rate (45%) in audiometric testing in the Hanford population. This was due to the fact that Washington State is one of the few states that provide workers compensation benefits for noise-induced hearing loss, and hearing aid providers, through seeking workers compensation coverage, had already evaluated many Hanford construction workers. More Hanford workers (16%) were already wearing hearing aids when they came for the examination than was the case at Oak Ridge (11%) or Savannah River (6%).

The second apparent inconsistency is the lower rate of hearing impairment (49.1%) in the Savannah River population. We performed two additional analyses to explore this observation. The first was an analysis of reported noise exposures. The Savannah River population had considerably fewer workers reporting exposure to loud or very loud noise during more than 75% of work time (39.8% at SRS compared to 66.2% at Hanford and 56.5% at Oak Ridge). Second, because the SRS population was younger, had somewhat fewer years in the trades, had more black and female participation and smoked less, we performed a multivariate logistic regression analysis that compared the risk by site while controlling for age, race, sex, duration of trade work, noise exposure level, and smoking. After control of these covariates, the risk of material hearing impairment among Savannah River workers was not statistically different from Oak Ridge or Hanford.

Several factors may have influenced our results, likely resulting in underestimates of risk. First, the DOE worker population participating in the medical screening programs was older and most had considerable trade work and noise exposures. Our internal analyses used workers employed for less than 15 years as the reference for calculation of odds-ratios. Recent studies of construction apprentices in their first 3 years of work, with average noise exposures under 90 dBA found measurable losses in hearing function [Seixas et al., 2005]. Given these observations, our reference population of workers in construction trades less than 15 years likely dampens the effect of trade work duration in the logistic models. Furthermore, our estimates of noise induced hearing loss among this population are likely underestimates as workers with a prior diagnosis of hearing loss were less likely to participate in the hearing evaluation offered by the DOE programs. For example, only 36% of workers who reported a prior diagnosis of hearing loss at Hanford participated in the hearing screening, compared to a participation rate of 51% for workers without a prior diagnosis. These differences were less pronounced for workers at SRS and Oak Ridge, likely reflecting the effect of the Washington State hearing loss compensation program.

We have evaluated, to the extent that data allow, the potential effects of selection/participation on study results. We found no significant differences in the demographic characteristics of those who participated in audiometric testing and the overall population of screened workers. However, many former DOE workers are deceased or cannot be located; therefore, we can not state with certainty the degree to which our results reflect the general status of all former DOE workers. Generalizability of study findings is strengthened by similarity of findings across multiple sites and increasing risk with duration of both trade and DOE work. Furthermore, many of the older and now deceased workers were employed at these DOE sites during early time periods and likely experienced greater noise exposures, suggesting that our data may represent underestimates of risk.

There is no reason to expect that noise exposure among our DOE cohort is substantially greater than in the general construction industry. If anything, we would expect conditions in the DOE facilities to be better, since larger construction contractors control the DOE facilities. We know from the Bureau of Labor Statistics Annual Survey of Employer reported injury and illness rates that the largest contractors report injury rates that are 80% below the average for all employers in the construction industry [BLS, 2003].

The finding that construction workers have noise-induced hearing loss, a fact that is supported by a great deal of additional knowledge developed over the past 40 or more years, begs the question: given that we know so much about noise and hearing loss in the construction industry, why is so little being done to prevent it? A three-part lack of incentives seems to stand out in response to this question: first, there are no real costs to the industry associated with hearing loss. Few states provide compensation for hearing impairment, and those that do provide such small amounts of compensation that when spread over the industry it has no economic consequence; second, since OSHA has not promulgated a hearing conservation standard for the construction industry, and since it is not industry practice to report hearing impairment under existing OSHA rules, noise induced hearing loss does not affect an employer's safety record; third, in an industry where employment is intermittent and workers move from employer-to-employer, it makes little financial sense for one employer to implement hearing conservation when other employers are not doing so. This would not only be relatively inefficacious, but also, it could place that employer at a competitive disadvantage.

What then, should be done to enhance the implementation of hearing conservation programs in the construction industry? We can look to the advances made in Sweden and British Columbia for solutions. British Columbia implemented a specific hearing conservation program in construction in 1987. Since that time, reported use of hearing protection has increased from 55% to 85% of workers surveyed, and the proportion of construction workers 50–59 with a hearing handicap has dropped from 36% to 25% [Worksafe, 2003]. This program clearly demonstrates feasibility and efficacy of a hearing conservation program. In contrast, in a recent US study the construction workers assessed were found to use hearing protection less than one-quarter of the time that they were exposed above 85 dBA [Neitzel and Seixas, 2005]. The first step to take in the US would be the establishment and enforcement of an OSHA hearing conservation rule for the industry, because without a strong rule, there is no backbone for preventive action. The second would be the establishment of industry-wide hearing conservation programs, with all employers paying equally for it and with workers having portable coverage that moves with them as they go from employer-to-employer.

CONCLUSIONS

These medical screening programs confirm the concerns about risks for hearing loss reported by workers. Clearly, since the majority of construction workers are experiencing material hearing impairment, much needs to be done to implement hearing conservation programs for them, with emphasis on the prevention of noise exposures. This applies not only to DOE facilities but to all construction sites, and all construction workers.

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