R2562

R01-OH 03136
NIOSH-20000865

Use of Hearing Protection and Perceptions of Noise Exposure and Hearing Loss Among Construction Workers*

Sally L. Lusk, PhD, RN, FAAN

Madeleine J. Kerr, PhD, RN

Sirkka A. Kauffman, PhD, MPA

School of Nursing
University of Michigan

* This study was supported by Grant No. OH03136 from the National Institute for Occupational Safety and Health.

The authors wish to acknowledge the assistance provided by Leslie Martel Baer, MA, co-owner of Mountain Muse Publications, Englewood, Colorado, in the early conceptualization of this paper, and by David Ronis, PhD, University of Michigan, with the multivariate analysis techniques.

Reprint requests and correspondence may be addressed to Dr. Lusk, School of Nursing, 3160 SNB, University of Michigan, Ann Arbor, MI 48109-0482.

ABSTRACT

The purpose of this study was to describe construction workers' use of hearing protection devices (HPDs) and determine their perceptions of noise exposure and hearing loss.

Operating engineers, carpenters, and plumbers/pipefitters in the Midwest (n=400) completed a written questionnaire regarding their use of HPDs and their perceptions of noise exposure and hearing loss. Subjects were recruited through their trade union groups. Mean reported use of HPDs and mean perceived noise exposure were compared across trade groups. Bivariate and multivariate analysis techniques were used to assess relationships between use of HPDs and trade category, education, age, years of employment, noise exposure, and hearing loss.

Bivariate analyses identified significant differences in mean use of HPDs by age, years of employment, and trade group. Multivariate logistic regression assessing the independent effects of these variables found significant differences only by trade group.

Results indicate a need for significant improvement in all three trade groups' use of HPDs, and suggest a need to consider use and exposure levels, demographics, and trade group membership in designing hearing conservation programs.

INTRODUCTION

Although construction workers are not specifically included in the provisions of the mandated Hearing Conservation Program for industrial workers, the Occupational Safety and Health Administration (OSHA) does have a standard relating to hearing protection when workers are exposed to noise within the construction industry.[1,2] Noise standard 29CFR 1926.52 requires that the construction industry provide feasible administrative or engineering controls, hearing protection and a hearing conservation program for employees who are exposed to noise at or above an 8-hour time-weighted average (TWA) of 90dBA. This standard is less complete than the one for industrial workers because it lacks specificity regarding the nature of an effective hearing conservation program.[3,4] Despite the existence of this standard, little is known about construction workers' exposure to hazardous noise, their use of hearing protection, or the existence of hearing conservation programs provided by employers. In particular, no prior studies have reported on noise exposure and use of hearing protection in several construction trade groups at multiple job sites.

There are a number of factors unique to the construction industry to consider when monitoring workers' exposures to noise and use of hearing protection. First is the variability of noise levels to which construction workers are typically exposed. Currently the OSHA standard specifies a maximum permissible exposure limit of 90 dBA (TWA) over the course of eight hours. In 1988, the National Occupational Exposure Survey conducted by OSHA reported that over 500,000 construction workers nationally are routinely exposed to noise levels of 85 dBA TWA or greater on the job.[5]

Construction workers, however, typically encounter a different exposure pattern than the continuous noise exposures on which the OSHA standard is based. Franks has noted that the dosimetry methods commonly used to collect noise exposure data may not be adequate for the complex combinations of noise sources or the high variability of noise experienced by most construction workers at their work sites.[6] According to the Department of Health and Human Services, when continuous, intermittent and/or impulsive sounds occur simultaneously at levels between 80 and 130 dBA and are evaluated together to determine an 8-hour TWA level, errors may occur that could lead to the overexposure of workers to loud noise.[3] In a recent study of health hazards at a single construction site, it was reported that workers encountered noise above this level and that noise was a significant hazard during all phases of the project and for workers from a variety of trade groups.[7] This study indicated that although the typical sources of noise, such as construction equipment and tools, are often viewed as exposing construction workers to a steady amount of noise over the course of a day, the actual use of such equipment often provides for short but intense noise exposures. In addition, construction workers typically share a work site with other trades and are exposed to additional noise from the equipment of others as well as noise from the equipment of their own trade.[6]

The second factor to consider is the high mobility of construction workers. Because of their high rate of self-employment (approximately one-fifth of all workers in the construction industry are self-employed [8]) they frequently change job sites. Even if not self-employed, construction workers may work on several different sites in one day.

Such mobility increases the challenge of measuring an individual's noise exposure and encouraging good self-protective behaviors.

Finally, while employers and unions often provide occupational health and safety information to construction workers, no national organization exists to gather data on those workers' occupational health hazards, or to disseminate safety information to them. The fact that there is no single definition of what the "construction industry" actually is further complicates efforts to disseminate occupational health and safety information. Since construction "is not a single activity, but a group of activities loosely related to one another by the nature of their products, technologies, and institutional settings",[9] this further complicates efforts to gather statistics, construct research and design effective safety programs.

The construction trades have historically had less stringent hearing conservation regulations than workers in other fields.[6] As OSHA considers tighter regulations, it is useful to gather data on construction workers' current exposure to high noise and their use of hearing protection.[10] In this study, operating engineers, carpenters, and plumber/pipefitters were surveyed to determine their perceptions of their noise exposure, hearing loss, and use of hearing protection devices (HPDs).

As Schneider has noted, hearing conservation programs for construction workers have proven effective in other countries, but are not required in this country outside of industrial worksites.[11] Since many construction workers do not work at such sites, it is imperative to gather data from workers in a variety of work settings to understand their noise exposure and HPD use patterns, and their needs for hearing conservation

programs. Thus, the data provided by this study is an important addition to the small database on construction workers, and can be combined with results reported on the predictors of HPD use by such workers to help design the elements of future hearing conservation programs.[12,13]

METHOD

Subjects and Settings

Carpenters, operating engineers (heavy equipment operators), and plumber/pipefitters in the Midwest were recruited through trade unions and trade group associations to participate in the study. Both trainees and apprentices, as well as experienced workers in the three trades were included. Among the sample of 400 workers, approximately one third represented each of the three trades. The majority were male (94%), non-Hispanic white (86%), married (55%), and had at least a high school education (95%). Almost half (49%) had education beyond high school. Ages ranged from 18 to 63 years with a mean of 33 years. There were too few women and subjects of racial/ehtnic backgrounds other than Caucasian/White to include in the analysis of factors related to use of HPDs: Women (n=22), African American/Black (n=34), Native American (n=9), Hispanic (n=5), Asian (n=2), and Other (n=3).

Measures

The items measuring demographic variables, perceptions of noise exposure and hearing loss, and use of HPDs were part of a larger questionnaire regarding health and hearing protection that required 35-40 minutes to complete. Trade category was measured by worker self-report of their skilled trade. The remaining variables were

collapsed into categories in order to create approximately equal size groups for statistical analyses. Reported education (highest level completed) was recoded into 0 for high school or less and 1 for college or trade school. Reported year of birth was recoded 0 for under age 30 and 1 for age 30 and over. Reported number of years of employment in the trade was recoded into 3 categories (1-4, 5-11, and 12-42 years). Noise exposure was measured by workers' perceptions of the percent of time (0% to 100%) on their job sites they were exposed to high noise, defined as a noise level causing them to shout to be heard by a co-worker three feet or less away from them. Mean perceived noise exposure was computed from responses for three time periods (percentage of time during the past week, past month, and past three months), and was recoded into 3 separate categories (0-29.9%, 30-69.9%, and 70-100%). Perception of hearing loss was measured by asking "Do you think you have any hearing loss (Yes/No)". Use of HPDs was measured by workers' report of the percent of time (0% to 100%) they used hearing protection, defined as earmuffs or earplugs, when exposed to high noise on their job sites, during different time periods: (a) on their last job site, (b) on the job site before that, (c) the past week, (d) the past month, (e) the past three months. A dichotomous dependent variable was created by recoding the mean of the last 3 measures (past week, month and three month) into a value of 1 for consistent use (95% or more of the time) and 0 for inconsistent use (less than 95%).

Preliminary studies, using similar instruments and including interviews of workers exposed to high noise on the job, resulted in the development of these measures of exposure. While some may have concerns about self-reports as a reliable measure, the

high correlation (r=.89) of factory workers' self-reports of hearing protection use with observed use supported the use of self-reports for this study.[14]

ANALYSIS AND RESULTS

Table I describes use of HPDs and perceived noise exposure for different time periods and perceptions of hearing loss. Among the three trade groups, operating engineers reported the most exposure to noise (61%), use of HPDs when exposed to noise (49%) and perceived hearing loss (65%) while carpenters reported the least exposure to noise (45% of the time they are at work), use of HPDs (18%), and amount of hearing loss (44%). Strong correlations were found among noise exposure in the past week, past month, and past three months for the entire sample (Pearson r = .75 to .88) and for the three trade groups (Operating engineers: r = .75 to .91, Carpenters: r = .69 to .88, and Plumber/pipefitters: r = .77 to .88).

There was also evidence for congruence among the three indicators of use of HPDs which were combined to create the dependent variable; Pearson correlations showed strong relationships between use in the past week, past month, and past three months (r = .89 to .96) for the entire sample and the three trades (Operating engineers: r = .91 to .97, Carpenters: r = .89 to .96, and Plumber/pipefitters: r = .84 to .93). Strong relationships were also found between use in the most recent job and the job before that (Entire sample: r = .83, Operating engineers: r = .82, Carpenters: r = .77 and Plumber/pipefitters: r = .83).

Table II describes the bivariate and multivariate relationships between use of HPDs and six predictor variables representing demographic variables, noise exposure, and

hearing loss. The left side displays the bivariate statistics which show the percentage of workers in each group who used hearing protection consistently (at least 95% of the time), the odds ratio from logistic regressions predicting use from each variable separately, and the p-value from the Wald test (a statistic which tests the null hypothesis that a coefficient in a logistic regression model is zero)[15] in these logistic regressions. Each predictor was coded into one or more dummy variables. In Table II, the odds ratio of 1 represents the reference category in each analysis. The reference categories were a) plumber/pipefitters, b) high school or less, c) under age 30, d) 12-42 years employment, e) noise exposure 70-100% of the time and, f) no perceived hearing loss. In the bivariate analyses, use of HPDs significantly differed by trade group ($p = .0001$), age ($p = .002$), and years of employment in the trade ($p = .0001$), but not by education level, noise exposure or hearing loss. Operating engineers were most likely to use HPDs (odds ratio = 3.0) and carpenters least likely (odds ratio = .30). Further, workers 30 years and older, and workers with 12 or more years of employment in the trade were most likely to use hearing protection.

In order to assess the independent effect of each of the variables on use of HPDs while controlling for others, a multivariate logistic regression was conducted. The right side of Table II shows p-values from the Wald test in a multiple logistic regression predicting use from all six variables, the odds ratios, and confidence intervals for these odds ratios. Trade category had a significant relationship with use of hearing protection ($p = .005$), but education, age, years of employment, noise exposure, and hearing ability were not significant predictors of use. On average, the odds of

operating engineers consistently using HPDs was 2.72 times that of plumber/pipefitters. In contrast, carpenters were less likely than plumber/pipefitters (.39 odds ratio) to be consistent users of HPDs when exposed to noise.

DISCUSSION

No published reports of actual use of hearing protection or of perceptions of noise exposure and hearing loss by construction workers have appeared in the literature. While the results of this study regarding self-report of use of HPDs and perceptions of noise exposure and hearing loss by three trade groups of construction workers cannot be generalized to all construction workers, they do provide useful baseline information regarding these trade groups within the construction industry. In regard to reported use, as can be seen in Table I, standard deviations were very high. This is a result of the bimodal distribution, with most workers reporting either a very low or a very high percentage time of using hearing protection. This is apparently a typical pattern of use as it is consistent with the self-reported use of hearing protection by factory workers.[14] Although use of hearing protection varied by three of the demographic variables (trade group, age and years of employment in the trade), when the effects of these variables were controlled, only trade group had an independent effect.

Perceptions of noise exposure and of hearing loss also differed by trade group, with operating engineers reporting greater exposure and more loss. It was beyond the confines of this study to measure the actual noise exposure or hearing ability of these trade groups; thus, it is impossible to validate the workers' perceptions of their noise exposures and losses. The effect of recall bias cannot be eliminated; however, due to

their work involving the operation of heavy equipment, it seems plausible that operating engineers could, in fact, have greater constant exposure to noise and that, along with their older age and greater number of years of work, could lead to more hearing loss.

Even though a significant difference was found among trade groups' perceptions of the percent of time they were exposed to high noise at work, that perception was not a significant predictor of use of hearing protection. This finding was surprising because more consistent noise exposures, and therefore more continuous need for use of hearing protection, have been believed to be a factor in higher reported use of HPDs. Lusk, Ronis, Kerr, and Atwood suggested in their study of factory workers that lower use of hearing protection by skilled trade workers than by blue collar workers was likely due to their movement in and out of high noise areas, necessitating repeated actions to use and remove HPDs.[16] In contrast, blue collar workers were more likely to constantly be in high noise areas and could just apply HPDs once at the beginning of their shifts. Another possible explanation for this result with construction workers was the recoding of the noise exposure variable into only 3 levels, which may have blunted its effect on use of HPDs.

Regardless of the effect of perceived noise exposure on use of hearing protection, it is important to emphasize the findings of inadequate use of HPDs and the high proportion of the workers who perceive they have a hearing loss. In considering mean scores, Table I shows that the use of hearing protection ranged from only 18% to 49% of the time it should have been used (when in noise, defined as having to shout to be

heard by someone three feet or less away). Table II indicates that consistent use (95% or more of the time) ranged from 3% to 25% of the workers in the trade groups. Since use of hearing protection less than 100% of the time when in high noise greatly increases the likelihood of noise-induced hearing loss,[17] there is an urgent need to increase construction workers' use of HPDs. The differences in use of HPDs by the different trade groups suggests that training programs tailored to specific trade groups may be more effective in changing behavior. Tailoring would allow consideration of the particular characteristics of a trade's work and work settings. For example, differing characteristics of the work settings may result in differences in workers' perceived barriers to use.

Even though there was no way to validate these workers' perceptions of hearing loss, the high proportion of workers maintaining that perception (44 to 65%) is very alarming. Since noise-induced hearing loss is an irreversible but preventable impairment, such a high proportion of workers perceiving a hearing loss suggests a potential failure in providing a safe and healthful workplace.

In a previous study of factory workers, and as a part of this same study, a causal model (the Health Promotion Model) was tested to explain factory workers' and construction workers' use of HPDs.[16,18] As reported elsewhere, psychosocial factors which predicted use varied by trade group and gender, and should also be taken into consideration in designing future hearing conservation programs.[18,19]

Rather than focusing on a single approach, hearing conservation programs need to consider options such as purchasing or retrofitting quieter equipment;[4] educating both

employers and construction workers on alternative HPDs available;[4, 20] and incorporating surveillance data on noise sources and exposure and the variations across trade groups, sites, and times of day. In particular, disseminating information on new types of hearing protection devices, such as level dependent protectors, active hearing protectors which neutralize specific frequencies, and communication headsets may prove critical in preventing future noise-induced hearing loss in the construction industry.[11, 20, 21]

In addition to these approaches to HPD use, the workers' own perspectives should be considered. Tailoring training programs to trade groups, and on the psychosocial factors influencing use of HPDs is proposed as a means to increase the effectiveness of training programs in promoting use of HPDs, thereby reducing noise-induced hearing loss.

REFERENCES

1. U.S. Department of Labor, Occupational Health and Safety Administration. Construction Industry Digest. Washington, DC: United States Government Printing Office: 40 (1995).

2. Occupational Health and Safety Administration. Occupational noise exposure: Hearing conservation amendment. (OSHA publication no. 29 CFR 1910.95) Federal Register 48(46). Washington, DC: United States Government Printing Office (1983, March 8).

3. U.S. Department of Health and Human Services. Proposed national strategies for the prevention of leading work-related diseases and injuries: Noise-induced hearing loss. (publication no. 89-135) Washington, DC: United States Government Printing Office (1988).

4. Schneider, S., Eckhart, J., B'lard, J., & Engholm, G. Noise, vibration, and heat and cold. Occupational Medicine: State of the Art Reviews. 10:363,383 (1995)

5. U.S. Department of Health and Human Services. Proposed national strategies for the prevention of noise-induced hearing loss. (NIOSH publication no. 09 103) Washington, DC: United States Government Printing Office (1988).

6. Franks, J.R. Noise in the construction industry and its effect on hearing. Hearing Instruments. 41:18,21 (1990).

7. Schneider, S.S., & Susie, P. Final Report: An Investigation of Health Hazards on a New Construction Project. Washington, DC: The Center to Protect Workers' Rights. (1993).

8. U.S. Bureau of the Census. Statistical Abstract of the United States, 112th ed. Washington, DC: United States Government Printing Office (1992).

9. Lange, J.E., & Mills, D.Q. The Construction Industry: Balance Wheel of the Economy. Lexington, MA: Lexington Books (1979).

10. Dumas, K. House panels vote measures on worker health, safety. Congressional Quarterly Weekly Report. 49: 2081 (1991).

11. Schneider, S. Preventing Hearing Loss Among Construction Workers. Presented at the National Hearing Conservation Conference III/XX; (March 23, 1995); Cincinnati, OH.

12. Lusk, S.L., Ronis, D.L., & Kerr, M.J. Predictors of workers' use of hearing protection. Human Factors. 37: 635-640 (1995).

13. Lusk, S.L., Ronis, D.L., Kerr, M.J., & Eakin, B.L. Predictors of construction workers' use of hearing protection and implications for changes in the work environment. Manuscript in preparation (1997).

14. Lusk, S.L., Ronis, D.L., & Baer, L.M. A comparison of multiple indicators: Observations, supervisor report, and self-report as measures of workers' hearing protection use. Evaluation and the Health Profession. 8: 51-63 (1995).

15. Agresti, A. Categorical data analysis. New York, John Wiley and Sons. 1990

16. Lusk, S.L., Ronis, D.L., Kerr, M.J., & Atwood, J.R. Test of the Health Promotion Model as a causal model of workers' use of hearing protection. Nursing Research. 43(3): 151-157 (1994).

17. Else, D. A note on the protection afforded by hearing protectors -- implications of the energy principle. Annals of Occupational Hygiene. 16(1): 81-83, (1973 Apr).

18. Lusk, S.L., Ronis, D.L., & Hogan, M.M. Test of the Health Promotion Model as a causal model of construction workers' use of hearing protection. Research in Nursing and Health. 20(3): 183-194

19. Lusk, S.L., Ronis, D.L., & Baer, L.M. Gender differences in blue collar workers' use of hearing protection. Women and Health. In Press.

20. Suter, A.H. Hearing Conservation Manual (3rd ed.). Milwaukee, WI: Council for Accreditation in Occupational Hearing Conservation.

21. Casali, J.G. & Berger, E.H. Technology advancements in hearing protection circa 1995: Active noise reduction, frequency/amplitude-sensitivity, and uniform attenuation. American Industrial Hygiene Association Journal. 57: 175-185 (1996).

TABLE I. Noise Exposure, Use of Hearing Protection and Hearing Loss.

	Operating Engineers		Carpenters		Plumber/ Pipefitters			
	Mean	S.D.	Mean	S.D.	Mean	S.D.	F	p
Noise exposure								
Past week	58.6	36.4	39.4	30.2	39.6	31.0	14.95	.0001
Past month	60.2	34.9	46.0	28.2	40.6	27.3	15.11	.0001
Past 3 months	62.6	31.9	48.1	28.4	40.7	26.4	20.01	.0001
Mean noise exposure	60.5	32.5	44.7	26.7	40.3	26.6	18.42	.0001
Use of Hearing Protection								
At last job site	52.8	41.0	17.1	29.4	38.4	39.2	28.67	.0001
At job before	49.2	40.7	18.2	30.8	36.4	36.8	22.52	.0001
Past week	49.7	42.6	12.8	28.2	27.5	39.1	28.94	.0001
Past month	49.3	41.4	15.6	28.9	29.8	37.1	26.44	.0001
Past 3 months	49.7	39.8	19.6	30.9	34.0	36.5	22.09	.0001
Mean use	49.3	40.4	17.7	29.7	31.5	36.3	25.18	.0001
	%		%		%		χ^2(df)	p
Perceived Hearing loss	65.2		44.0		48.9		12.81(2)	.002

TABLE II. Relationships With Use of Hearing Protection (n=400).

		Bivariate Statistics			Multivariate Statistics		
	n	Consistent Use (% of workers)	Odds Ratio	p	Odds Ratio	p	(95% CI)
Trade Category				.000		.005	
Operating Engineers	132	25.0	3.05		2.72		(1.09-6.80)
Carpenters	126	3.2	0.30		0.39		(.12-1.29)
Plumber/Pipefitters	142	9.9	1.0		1.0		1.0
Education				.164 NS		.595 NS	
HS grad or less	202	14.9	1.0		1.0		1.0
Any college or trade grad	196	10.2	0.65		0.83		(.41-1.66)
Age				.002		.903 NS	
Under 30	190	6.8	1.0		1.0		1.0
30 and over	206	17.5	2.9		1.06		(.40-2.86)
Years of Employment				.000		.433 NS	
1-4 years	146	8.2	0.30		0.70		(.24-2.04)
5-11 years	111	7.2	0.26		0.53		(.20-1.42)
12-42 years	127	22.8	1.0		1.0		1.0
Noise Exposure				.200 NS		.868 NS	
0-29% of the time	135	11.9	0.65		1.05		(.47-2.35)
30-69.9%	141	9.9	0.53		0.84		(.38-1.86)
70-100	122	17.2	1.0		1.0		1.0
Perceived Hearing Loss				.22 NS		.832 NS	
No	188	10.6	1.0		1.0		1.0
Yes	210	14.8	1.45		1.08		(.54-2.13)