Development and Pilot Test of Hearing Conservation Training for Construction Workers

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Background *Hearing conservation efforts in construction frequently rely on use of hearing protection devices (HPDs): however, training on HPDs is often not provided, and usage rates remain low. In this study, a hearing conservation training program was developed and pilot tested.*
Methods *A theoretical model was selected as the basis for the program, and program contents and delivery methods were selected to optimize the effectiveness and flexibility of the training. Two evaluation measures were selected to assess training-related changes in self-reported HPD use. The first was a validated method using concurrent work-shift noise dosimetry, and the second was a survey concerning workers beliefs and attitudes towards HPDs and HPD use.*
Results *The training program was pilot tested on a single construction site. Complete assessment data were available for 23 workers. The percent of time when hearing protection was used during noise levels above 85 dBA nearly doubled post-training, and the change was statistically significant.*
Conclusions *Pre- and post-training data from participating workers demonstrated that HPD use can be increased significantly with basic model-based training, even in industries with complex noise exposures such as construction.* Am. J. Ind. Med. 51:120–129, 2008.

KEY WORDS: occupational noise exposure; noise-induced hearing loss prevention; health promotion; hearing protection

INTRODUCTION

Despite the widespread existence of regulations mandating hearing conservation programs (HCPs) for noise-exposed workers and indications that such programs can be effective in preventing noise-induced hearing loss (NIHL) [Lee-Feldstein, 1993], noise remains a major source of hearing loss and disability [Nelson et al., 2005]. Nearly 25 years after the passage of the US Occupational Safety and Health Administration's (OSHA) Hearing Conservation Amendment high noise levels continue to be common in many US industries, including manufacturing [Daniell et al., 2002], mining [Murray-Johnson et al., 2004], and construction [Neitzel et al., 1999].

Although noise controls are considered the best strategy for NIHL prevention, many HCPs rely on use of hearing protection devices (HPDs) to reduce noise exposures. There are numerous problems associated with dependence on HPDs for exposure reduction, including attenuation rating inadequacies and variability in attenuation achieved by individuals [Berger, 2000]. However, the most important limitation of HPDs is that usage rates remain low, especially

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in industries like farming and construction, where noise levels are high but variable [Carpenter et al., 2002; Neitzel and Seixas, 2005]. Increasing HPD usage depends on effective hearing conservation training, which is often not provided in US industry [Daniell et al., 2002, 2006], particularly in industries like construction which are characterized by a transient workforce.

Strategies for increasing HPD use have been evaluated among workers in various industries, including manufacturing [Lusk et al., 2003], firefighting [Ewigman et al., 1990], and construction [Lusk et al., 1999]. These strategies have ranged from efforts as basic as increased enforcement of a mandatory HPD use policy [Hager et al., 1982] to creation of computer programs designed to simultaneously deliver hearing conservation training and audiometric testing [Hong and Csaszar, 2005]. In industries like construction, where worker turnover is high, most employers are small, and training facilities may be rudimentary or non-existent, technologically or logistically complex interventions may be ineffective or difficult to implement, and simpler approaches are more likely to be successful.

The goal of the current study was to develop a model-based hearing conservation training program for construction workers and pilot test effects on trainee behavior and its adherence to the constructs of the model. This paper describes the four-part process used to meet this goal: (1) identification of an appropriate theoretical model; (2) design of the training contents and delivery method; (3) design of training evaluation measures; and (4) pilot testing the effectiveness of the training at a single construction site. Training effectiveness was assessed by measurements made before and after the delivery of training using two methods: an on-site characterization of HPD use in conjunction with real-time noise measurement, and indirectly through use of a questionnaire. Adherence of the training to the model was evaluated through questionnaire items based on model constructs. This project represents the first part of a larger, multi-component construction HPD use intervention study.

MATERIALS AND METHODS

Part 1—Identification of a Theoretical Model

Selection of an appropriate theoretical framework is a critical step in the development of intervention programs [Glanz et al., 2002]. Lusk et al. [1994, 1997] found that Pender's health promotion model (HPM) [Pender et al., 1990; Pender, 1996] could account for up to 50% of measured variance in HPD use, and have applied original and revised versions of the HPM to the study of HPD use in construction and other industries [Lusk et al., 1994, 1999; Kerr et al., 2002; McCullagh et al., 2002; Ronis et al., 2006]. Based on this body of work, the revised HPM was selected as the basis for the current study. The revised HPM used by Lusk and colleagues does not always include perceptions of NIHL severity or susceptibility; however, these concepts are related to HPD use [Melamed et al., 1996; Arezes and Miguel, 2005], and were added to the revised model used here.

Figure 1 shows the eight model components adopted. The components include five belief factors (perceived susceptibility to NIHL, severity of NIHL, benefits of HPD use, barriers to HPD use and self-efficacy regarding HPD use), two HPD use cofactors (interpersonal norms concerning HPD use and situational influences on HPD use), and one knowledge factor. These model components were used to identify constructs to be addressed in the training materials and to guide the development of the survey instrument used to evaluate the training.

Part 2—Development of Training Content and Delivery Method

Content

Training concepts were specifically matched to the constructs of the modified HPM, while also designed

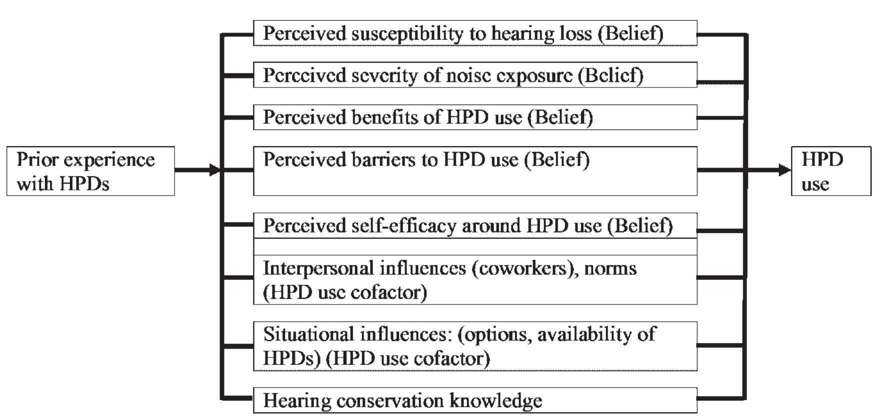

FIGURE 1. Modified HPM used in the current study [based on Pender, 1996; Lusk et al., 1997].

to meet (or exceed) the requirements of the OSHA Hearing Conservation Amendment training requirements (1910.95(k)) [OSHA, 1983]. Thus, the topical areas covered in the first half of the training included occupational and non-occupational noise exposure, construction noise sources and levels, health effects resulting from noise exposure (including temporary and permanent threshold shift and tinnitus), actions for reducing noise exposure, audiometric testing, and strategies for identifying hazardous noise levels. The second half focused on HPD use, and covered strengths and weaknesses of four different types of HPDs (foam and pre-molded earplugs, banded ear caps, and earmuffs), benefits of wearing HPDs, approaches to overcome commonly-cited barriers to HPD use, and tips for wearing HPDs effectively.

All eight model constructs are addressed repeatedly throughout the training session through industry-specific examples and statements (Table I). Concepts are conveyed through written and spoken language (e.g., a description of tinnitus designed to increase perceived severity of NIHL), through graphics (e.g., the use of pictures depicting correct HPD use designed to address interpersonal influences), and through hands-on demonstrations (e.g., a trainer-led HPD demonstration designed to increase self-efficacy).

Two hands-on demonstrations are built into the training to increase understanding and self-efficacy in preventing noise exposure. The first is used to demonstrate non-HPD methods of preventing noise exposure, and involves measurement of noise produced by a common construction tool (a handheld rotary grinder). A trainee reads the display of a sound level meter (SLM) with the tool running. The trainee then steps back 6 feet and re-measures the sound to illustrate reduction in exposure due to increased source-receiver distance. The trainee then returns to their first position and the instructor inserts a 2 foot $\times$ 2 foot piece of plywood between the SLM and noise source to illustrate the reduction in exposure from a simple barrier. To reinforce the need for

TABLE I. Model Constructs and Examples of Associated Training Concepts

Construct	Example training concepts (flip-chart page or demonstration)
Self-efficacy	Trainer demonstrates proper use of three types of HPDs; trainees try all three on under trainer supervision; trainer confirms, lauds proper fit (HPD demonstration)
	Common thought "I can't tell when it's too loud" used to highlight ways workers can tell when noise $>$85 dBA: have to raise voice to be heard at arm's length, "hearburn" (temporary threshold shift); noise measurements; signs (page 16)
Perceived susceptibility	Graphical noise thermometer used to point out that most construction tools produce noise $>$85 dBA, which is loud enough to cause NIHL over time (page 8)
	Common occurrence of "hearburn" (temporary threshold shift), analogy drawn to familiar temporary effects of sunburn, which is common in construction (page 3)
Perceived severity	Six aspects of everyday life that can suffer following NIHL: social events, music, warning signals, women's and children's, sounds of nature (page 5)
	Undesirable and incurable tinnitus which may accompany NIHL (page 6)
Benefits of HPD use	Three benefits associated with wearing HPDs provided, including: NIHL is prevented, since noise exposure is reduced to safe level; proper attenuation can make it *easier* to hear machinery or communicate; noise "glare" reduced (with analogy to sunglasses improving vision on sunny day) (page 21)
	Proper use of HPDs will preserve hearing (page 34)
Barriers	Four things that can help trainees select the right HPD: comfort; convenience and ease of use; NRR label means HPD is legitimate, and denotes relative amount of attenuation; avoid HPDs that seem to block too much noise (page 22)
	Six common thoughts on barriers to HPD use provided, including: "They take too long to put on" (trainer notes HPDs that can be inserted quickly); "Things sound funny when I wear them" (trainer notes that this means HPDs are working); and "I can't hear important sounds or talking" (trainer discusses over-attenuation and notes appropriate HPDs can make it easier to focus on certain sounds) (page 24)
Interpersonal influences	Repeated use of pictures showing real construction workers using HPDs during noisy tasks. HPD use is emphasized by green callouts, and many pictures have "thought bubble" illustrations coming from the workers emphasizing the point that they are using HPDs to protect their hearing (pages 1, 2, 10, 11, 19, 32)
	Trainees raise hands if they've had a "hearburn" (temporary threshold shift) after loud noise; most have, and trainees see this is common experience (page 3)
Situational influences	Need for HPDs tied to specific tools and equipment which are common on construction sites through use of graphical noise thermometer (pages 8 and 23)
	Need to keep HPDs handy, convenient; if not, unlikely they will be worn (page 32)
Hearing conservation knowledge	Methods to reduce noise exposure covered repeatedly in training; elements of hearing conservation program are discussed; need to use HPDs 100% of time in noise is emphasized; effects of noise on hearing covered (all pages)

HPDs during high noise, all participants in the noisy tool demonstration wear earmuffs. The second demonstration/exercise is specifically designed to increase self-efficacy in relation to HPD use. The instructor demonstrates the proper insertion of three types of hearing protection, followed by trainee insertion of each plug, with encouragement and correction of the trainee, as needed. Previous successful hearing conservation training efforts have included provision of several types of HPDs [Ewigman et al., 1990; Lusk et al., 1999].

One major departure from typical hearing conservation training is treatment of 85 dBA as a threshold above which HPDs must be used, regardless of exposure duration. This is in contrast to regulatory requirements which require use of HPDs when 8-hr average levels exceed 85 (or 90 dBA in some jurisdictions), or any time levels exceed 115 dBA. The 85 dBA threshold was adopted to simplify the rules regarding use of HPDs, to prevent workers from having to estimate their full-shift exposure, and to insure that HPDs are always worn in potentially damaging noise levels. The training repeatedly highlights techniques for recognizing levels greater than 85 dBA, and reinforces the need for HPD use in noise at or above this level regardless of exposure duration. Another departure from standard practice is an emphasis on comfort and usability of HPDs, rather than the traditional focus on attenuation. HPDs with greater acceptability to workers are more likely to be worn, and may achieve greater effective protection than HPDs which are uncomfortable but have higher rated attenuation [Arezes and Miguel, 2002]. Most construction workers will be adequately protected with just 5–10 dB of protection [Neitzel and Seixas, 2005]; this level of attenuation can be achieved by most properly-worn HPDs.

Delivery

Live instructor presentation combined with visual materials was selected to ensure that the training could be delivered with maximum flexibility in the widest variety of training settings by experts or peer trainers who have been given a ‘‘train-the-trainer’’ orientation to the content and materials. Peer trainers have been shown to be effective in delivering health and safety materials [Kurtz et al., 1997], likely due to increased peer trust and influence. A comparison of the effects of the current training when delivered by experts versus peer trainers can be found elsewhere [Trabeau et al., 2006, 2007]. The training was designed to last approximately 1 hr, and to be given to relatively small groups (10–20 participants) either as a 1-hr session, or in two 30 min segments.

A flip-chart format was selected for the visual materials in order to simplify presentation in on-site locations and to avoid problems with electronic displays. Each chart incorporated simple text with graphical elements. The graphics selected provided appropriate industry-specific images and were used heavily throughout the materials (see Fig. 2a,b for example displays). The language used was set

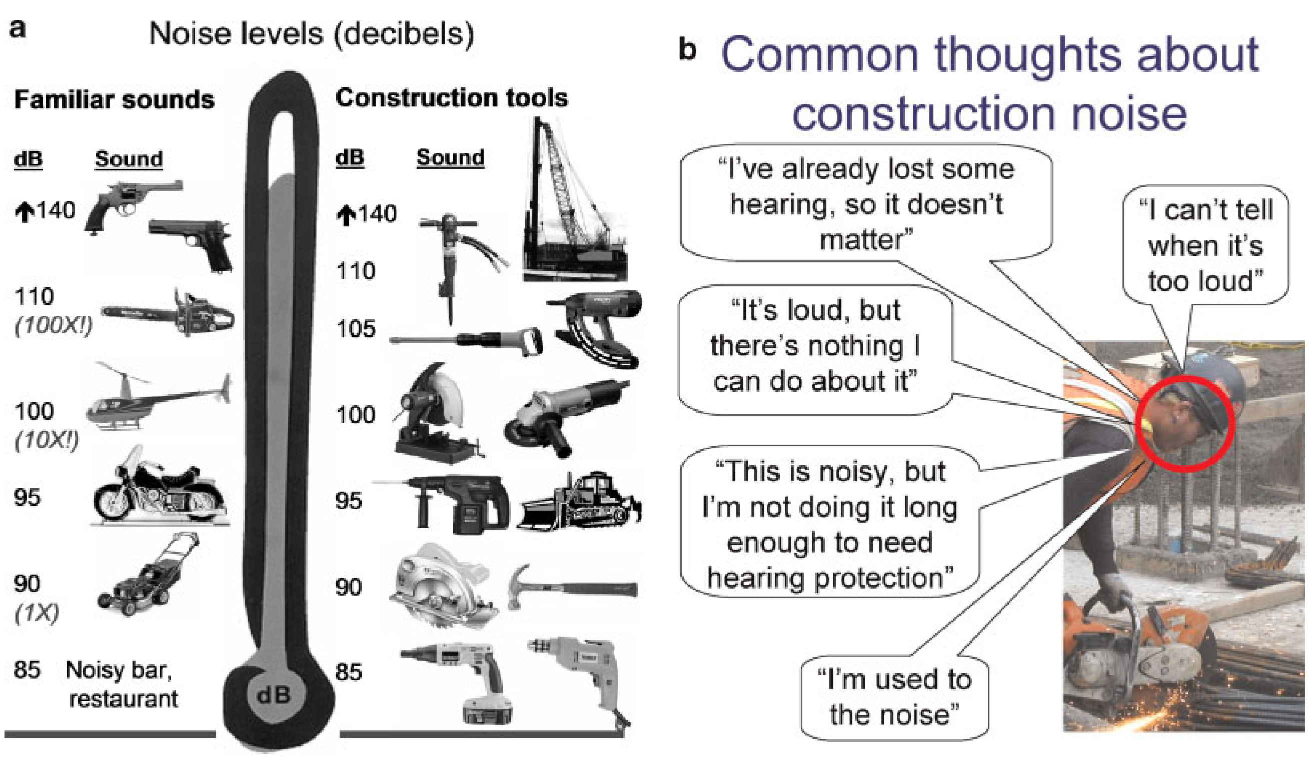

FIGURE 2. Sample elements from training program; (**a**) example noise sources and levels and (**b**) common thoughts used to address barriers.

at a 4th-grade level (Flesch–Kincaid grade level score, MS Word) to insure high comprehension. Materials were developed only in English; translation will be required to reach non-English speaking workers in the future.

Teach-back elements, in which trainees are asked to respond to questions about basic concepts that have been taught, were included at the end of the two training modules. The lecture format of the training restricts the valuable opportunity for the trainer or trainees to share relevant real-life experience [Helmkamp et al., 2004]. Specific ‘‘common thoughts’’ from construction workers were incorporated to increase trainees identification with the material presented. Many of the ‘‘common thoughts’’ identified represent barriers to HPD use, allowing the trainer to refute misconceptions and overcome these barriers (see Fig. 2b), while others highlight techniques by which trainees can recognize overexposure (e.g., greater than 85 dBA) situations.

Developmental Training Sessions

After a draft-training program was developed, a series of four test sessions were conducted with construction workers. The sessions were designed to provide feedback from the target audience on their comprehension of the material and the suitability of the formats adopted. The sessions, which lasted about 2½ hr each, consisted of delivery of the complete draft materials by a single researcher followed by a page-by-page review of the individual training elements with the trainees. Trainee comments were documented and later classified into four categories: wording, graphical, stylistic, and content. The four groups consisted of: (1) 13 ironworker apprentices (age range about 20–30 years), (2) 18 electrician apprentices (age range about 20–30 years), (3) nine construction foremen and superintendents (ages 50+), and (4) six construction safety personnel (age range about 40–50). A total of 29 changes (2 wording, 10 graphical, 3 stylistic, and 14 content) were implemented following the four sessions. Changes ranged in complexity from removal of a teach-back question deemed ‘‘too easy’’ to addition of an illustration showing the logarithmic nature of decibels. After the training materials were finalized, they were printed on 18 × 24 inch flip chart pages for all future presentations.

Part 3—Measures to Evaluate Changes in HPD Use

Two measures were selected to evaluate the effects of the training on HPD use: an activity card-based system which has been previously validated for accuracy of short-term self-reported HPD use against direct observations [Neitzel et al., 1999; Reeb-Whitaker et al., 2004], and long-term self-reported HPD use collected via questionnaire. For the activity card method, the subject wears a noise dosimeter which datalogs the average and maximum noise levels for each minute of the monitored work shift. The subject simultaneously reports the timing of all of their activities and tasks, tool use, HPD use, and other environmental factors on a trade-specific activity card for the entire monitored shift. The activity cards allow for reporting with an approximately 15-min time resolution, and are typically filled in during breaks, at lunch, and at the end of the monitored shift. After merging the activity card data with the logged dosimetry files, the percent of time when workers are overexposed (i.e., the percent of all 1-min average dosimetry noise levels within the shift which exceed 85 dBA) and concurrently report using HPDs can be computed for each monitored work shift.

The second evaluation method was a model-based survey instrument, designed to assess long-term self-reported HPD use, as well as to evaluate changes in motivation, beliefs, and knowledge engendered by the training. The 52-item survey was designed to take 10–15 min to complete, and assessed HPD use directly with two questions: ‘‘How often do you *currently* wear hearing protection in high noise?’’ and ‘‘How often do you plan to wear hearing protection in high noise *in the future*?’’ Possible responses for both questions were: ‘‘less than 10%,’’ ‘‘10–50%,’’ ‘‘51–90%,’’ and ‘‘more than 90%.’’

Twenty-nine of the survey items were mapped directly to individual components of the theoretical model. Nineteen of these had five-point Likert scale responses and addressed the five belief and two HPD use cofactor components of the model. These questions were loosely based on items developed by the National Institute for Occupational Safety and Health (NIOSH) [Stephenson, 2004] and evaluated on a group of Swedish workers [Svensson et al., 2004]. The hearing conservation knowledge component of the model was assessed through 10 items (five multiple-choice and five true-false) derived directly from the training content. Questions on demographics (age, gender, trade, seniority, previous hearing conservation training, education, and primary language spoken at home) and perceived health status (self-assessed hearing level and tinnitus) were included as possible co-factors that could be associated with changes in beliefs and HPD use. Full-text versions of specific questions are presented by Trabeau et al. [2007].

Part 4—Pilot Test

A large commercial construction project in Seattle agreed to participate in the pilot test of the training. Study methods were approved by the University of Washington Institutional Review Board. Approximately 40 workers at the site attended a recruitment meeting in which a researcher described the purpose and methods of the study. Interested individuals signed a consent form and were enrolled into the study. Participants completed a baseline survey at enrollment, wore a noise dosimeter (Quest Q-300, Quest

Technologies, Oconomowoc, WI) and completed an activity card over a single shift during the next 4 weeks. The dosimeter measured L_{avg} noise levels according to the requirements of the OSHA Permissible Exposure Limit [OSHA, 1983], and L_{eq} levels according to the more protective NIOSH Recommended Exposure Limit [NIOSH, 1998]. The first survey and dosimetry-activity card measurement represented baseline HPD use. All participants were trained onsite in a quiet conference room by a single expert research industrial hygienist 4–6 weeks after enrollment. Participants completed a post-training survey immediately after the training, and another dosimetry-activity card measurement on a second shift within 2 weeks of the training. The second survey and dosimetry-activity card measurement represented post-training HPD use. For the first survey and dosimetry measurement, two different styles of HPD provided by the participating site were available to all subjects. For the second survey and measurement, the original two HPDs were available, as well as three other styles that all subjects received during their training.

Activity card and dosimetry data were cleaned to remove or adjust spurious dosimeter measurements, and merged into a database using a previously-described method [Seixas et al., 2005]. Survey results were entered into a separate database. Likert scale responses were assigned values of 1–5, with 1 corresponding to "Strongly disagree" and 5 to "Strongly agree." For items where "Strongly disagree" was associated with a desirable response, the numerical scale was reversed during coding. For all items, "Don't know" and missing answers were recoded as missing.

Descriptive statistics were computed for both the pre- and post-training dosimetry-activity card and survey results using SAS (Cary, NC). For the dosimetry-activity card data, the percent of time above 85 dBA and percent of time above 85 dBA when HPDs were used were computed for individual work shifts. Mean values for these variables were then computed across all measured shifts. Dosimetry-activity card pre- and post-training HPD use data were non-normally distributed, so a non-parametric test (the Wilcoxson signed rank test), was used to assess whether changes were statistically significant. Pre- and post-training differences were assumed to be statistically significant when $P < 0.05$ for all inferential tests.

Cronbach's alpha was used to evaluate the consistency of the 19 items selected a priori to address the five belief and two HPD use cofactor components of the theoretical model. Items with Cronbach's alpha >0.6 were left in their initial groups, and mean and standard deviation scores and pre- and post-training differences were computed from individuals' scores across the groups. Items with Cronbach's alpha <0.6 were analyzed separately. The percentage of knowledge items answered correctly by each subject was computed for both the pre- and post-training surveys, and the difference in percent of items answered correctly was then computed. A paired Student's *t*-test assuming equal variance was used to determine if the percentage of knowledge items answered correctly was significantly different post-training. This test was also used to assess the statistical significance of changes in the scores of the belief and HPD use cofactors. Changes in the four response categories of the current and intended HPD use survey items were evaluated with Wilcoxson signed rank tests.

RESULTS

Final Training Materials

The training materials consist of 35 flip chart pages, each covering a different concept. The materials take about 52 min to deliver on average [Trabeau et al., 2007]. The final training materials are available for review online (http://depts.washington.edu/occnoise/hc_training.pdf).

Survey Development

After assessing the correlations of each question within the initial groups of items representing the eight components of the theoretical model, most of the initial groupings were modified. Only one of the final groupings, barriers to HPD use had a Cronbach's alpha >0.6 and was retained as a group. All other groupings had Cronbach's alpha ranging from 0.1 to 0.5, and items in these groupings were therefore analyzed individually. The final items analyzed are presented in Table II.

Pilot Test

Thirty-three workers from eight trades participated in the pilot test, and were trained in four groups (mean group size about eight workers). Almost all workers were male (94%), spoke English at home (97%), and considered their hearing good or fair (91%). Participants had over 15 years of construction experience and more than a high school education on average. One-third had received hearing conservation training before, on average 1.8 (±1.7) years prior to the pilot test. All participants completed pre- and post-training dosimetry-activity cards and post-training surveys, but five did not complete pre-training surveys and were excluded from analysis. Fourteen dosimetry measurements were excluded: three were removed during data cleaning for short duration or excessive variability, and 11 were excluded due to missing activity card data. This left 46 dosimetry-activity card measurements. Training effects were analyzed using data from the 23 participants with complete pre- and post-training surveys and dosimetry.

The percentage of time workers were exposed >85 dBA was higher during pre-training dosimetry-activity card

TABLE II. Dosimetry-Activity Card and Survey Results

	Baseline		Post-training		Change
Dosimetry-activity card	**N**	**Mean (SD) %**	**N**	**Mean (SD) %**	***P*-value***
Use of HPDs in noise >85 dBA	23	29.2 (45.2)	23	57.1 (46.2)	0.03
Survey	*N*	*% Subjects*	*N*	*% Subjects*	*P-value**
Self-reported use of HPDs					
Current use					0.34
Less than 10%	4	17.4	4	17.4	
10–50%	12	52.2	11	47.8	
51–90%	5	21.7	6	26.1	
More than 90%	2	8.7	2	8.7	
Intended future use					0.10
Less than 10%	1	4.4	0	0	
10–50%	3	13.0	2	8.7	
51–90%	8	34.8	8	34.8	
More than 90%	11	47.8	13	56.5	
Hearing conservation knowledge	*N*	*% (SD)*	*N*	*% (SD)*	*P-value***
Percent answers correct	23	76.2 (12.7)	23	87.8 (10.9)	<0.0001
Beliefs and HPD use cofactors	*N*	*Mean (SD)*	*N*	*Mean (SD)*	*P-value***
Self-efficacy					
Hazard recognition ability	23	4.4 (0.7)	23	4.5 (0.9)	0.54
Hazard control ability	23	4.7 (0.6)	23	4.6 (0.9)	0.84
Availability of assistance	23	4.3 (1.0)	21	4.8 (0.9)	0.07
Severity of NIHL					
Communication impairment	22	4.2 (1.6)	22	4.5 (1.2)	0.35
General impairment[a]	23	4.0 (1.6)	23	3.6 (1.9)	0.43
Importance of prevention	23	4.7 (0.6)	23	4.9 (0.3)	0.16
Susceptibility to NIHL					
Without HPD use[a]	22	4.5 (1.1)	22	4.7 (0.9)	0.14
In general	23	4.8 (0.9)	21	4.8 (0.9)	0.58
Interpersonal influences					
Coworker HPD use	23	3.5 (1.2)	23	4.0 (1.1)	0.18
Coworker support	23	2.6 (1.4)	22	2.9 (1.4)	0.44
Coworker obstruction[a]	21	4.4 (0.8)	22	4.6 (1.0)	0.48
Situational influences					
Access to HPDs	22	4.6 (0.9)	23	4.7 (0.9)	1.0
Variety of HPDs	22	3.0 (1.3)	22	2.8 (1.5)	0.64
Benefits of HPDs (one item)	22	4.5 (1.0)	23	4.9 (0.3)	0.16
Barriers to HPD use (five items)	22	2.4 (0.7)	22	2.3 (0.6)	0.90

* ilcoxon signed rank test.
**Paired two-way Student's *t*-test with equal variance.
[a]Likert scale reversed for analysis.

measurements (33.3% vs. 26.7% post-training) due to changes in onsite operations. Across all trades, the percent of time >85 dBA when HPDs were used nearly doubled post-training (increasing from 29.2 ± 45.2% to 57.1 ± 46.2% of time, Table II), and the increase was statistically significant ($P = 0.03$). The large standard deviations associated with HPD use are indicative of the wide range of reported use times.

The results of the pre- and post-training surveys are shown in Table II. The percentage of workers reporting current or intended future use of HPDs 51% or more of the time increased after the training, however, neither change was statistically significant. The percentage of knowledge items answered correctly increased significantly post-training ($P < 0.05$). The mean scores for the other item groupings and individual items associated with the model constructs did not change significantly after training; only a single self-efficacy-related item, availability of assistance, approached significance. However, more than two-thirds of the pre-training group and item mean scores were greater than four on the five-point Likert scale, leaving little room for post-training improvement on these items and groups. In particular, items related to self-efficacy, benefits of HPDs, importance of prevention of NIHL, and general susceptibility to NIHL had very high mean pre-training scores. The high pre-training scores for these and other items suggest that many workers already had strong beliefs about noise and hearing loss prior to the training. Reported current HPD use was consistent pre- and post-training, but intended future HPD use reported pre-training was much lower than current HPD use reported post-training. In other words, intended future HPD use reported at baseline did not match current use reported 4–6 weeks after the baseline survey.

DISCUSSION

The results of the pilot test of the model-based hearing conservation training program developed and evaluated in the current study, as well as the results of previous studies of other interventions, suggest that HPD use can be increased significantly following delivery of a basic training program, even among workers with complex exposures and HPD needs, such as construction workers. Two measures were used to evaluate changes in HPD use: a validated dosimetry-based measure of short-term HPD use and a new survey instrument mapped to the constructs of the theoretical model used to develop the training and intended to evaluate long-term HPD use. The training produced a statistically significant increase in use of HPDs during exposures above 85 dBA among the workers trained (as measured using the validated approach of dosimetry and activity cards). The amount of time HPDs were used during noise greater than 85 dBA nearly doubled post-training, with an increase of $27.9 \pm 49.0\%$.

Workers' current and intended future use of HPDs reported via survey was not significantly changed post-training, and there was a significant change in only one of the nine construct areas covered by the HPM-based survey instrument. Workers' hearing conservation knowledge increased significantly post-training. The absence of measured change in HPD behavior-related items on the survey, despite the presence of measured behavioral change, suggests a lack of sensitivity and reliability and poor mapping of the survey items to the theoretical model constructs, and highlights the importance of proper measurement of model constructs in evaluating the performance of the model. The poor performance of the survey may have been a result of the small sample size. The high pre-training scores for many of the survey items and construct groups also reduced the opportunity for significant post-training changes. Finally, the introduction of new styles of HPDs during the training may have contributed to the measured increase in HPD use behavior without producing changes in any behavior-related survey items. Nevertheless, even in the absence of significant changes in the model constructs, the validated dosimetry-activity card method showed an increase in use of HPDs. The presence of a behavior change in the absence of measured changes in the model constructs indicates that the revised HPM (upon which the training program was based) is a reasonable model with which to study HPD use and design behavioral interventions, but also highlights the need for sensitive measures of post-intervention changes in the constructs.

Previous studies of construction hearing conservation training program effectiveness have shown increases in HPD use smaller than those seen in the small pilot test of the current study. Lusk et al. [1999] found that an approximately 1 hr training significantly increased self-reported use of HPDs (from 44% to 53% of self-reported time in high noise) among 837 construction workers assessed 10–12 months post-training compared to a baseline measurement taken immediately before training. Dineen et al. [1998] administered a training program to 50 male construction workers, preceded immediately by a baseline survey. Surveys administered 4 months post-training found that HPD use time had increased significantly (from 23.2% pre-training to 35.3% post-training). The HPD use question in the Dineen et al. study inquired about overall use time, rather than time spent in high noise. While the increase in HPD use seen in the current study is larger than previous studies, the small sample size must again be considered when evaluating the results presented here.

One major strength of the current study when compared to previous studies of hearing conservation interventions is use of a previously-validated outcome measure related to actual noise levels (i.e., short-term self-reported HPD use with simultaneous noise measurements). Most previous studies have relied on self-reported long-term measures of HPD use, and have not related HPD use to noise levels. Rather, changes in HPD use are often assessed through questions regarding current or intended future use of HPDs over long periods of time (weeks to months or more) collected via self-report questionnaire. Questionnaire-reported HPD use has been shown to agree well with actual observed HPD use in a stable noise environment [Lusk et al., 1995], and was used as the foundation for subsequent analysis of the revised HPM for study of HPD use. However, for workers with highly variable noise exposures, such as those in construction and agriculture, long-term reporting of HPD use does not appear to agree with either observed or self-reported use by the same worker during high noise over a single workshift on a construction site [Neitzel and Seixas, 2005]. Long-term self-reported HPD use questions may therefore not be appropriate for use with workers in variable noise environments, despite the fact that this approach has been used as an outcome in many previous studies. Use of observational data, a combination of observational and self-reported data, or self report data from questions validated for use in variable noise environments are preferable outcome measurements for training studies intended to produce behavior change (e.g., HPD use) in workers with variable exposures.

This study demonstrated that a one-time model-based hearing conservation-training program has the potential to increase use of HPDs among construction workers during periods of hazardous noise. The results of the study indicate that existing behavior change models can be useful in developing occupational health training programs. Proper measurement of theoretical constructs within the chosen model is critical in evaluation of the performance of the model; however, even without significant changes in most of the theoretical constructs of the model used in the current study, the training program resulted in significant behavior change as measured using a previously validated strategy of noise monitoring with concurrent HPD use reporting.

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