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Development and application of a noise hazard scheme for road maintainers

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Abstract

Background: Transportation road maintenance and repair workers, or 'maintainers', are exposed to hazardous and variable noise levels and often rely on hearing protection devices (HPD) to reduce noise exposure levels. We aimed to improve upon HPD use as part of the HearWell program that used a *Total Worker Health®*, participatory approach to hearing conservation.

Methods: Full-shift, personal noise sampling was performed during the routine task of brush cutting. Work activities and equipment were recorded and combined with 1-min noise measures to summarize personal noise exposure levels by equipment. Using noise monitoring results, HPD noise reduction ratings, and input from worker-based design teams, a noise hazard scheme was developed and applied to the task and equipment used during brush cutting.

Results: Average (standard deviation) and maximum L_{eq} 1-minute, personal noise exposure levels recorded during brush cutting included chainsaws at 92.1 (7.6) and max of 111 dBA, leaf blowers at 91.2 (7.5) and max 107 dBA and wood chipper at 90.3 (7.3) and max of 104 dBA. The worker-designed noise hazard scheme breaks down noise exposures into one of three color bands and exposure ranges: red (over 105 dBA), orange (90–105 dBA), or yellow (85–90 dBA). The scheme simplifies the identification of noise levels, assessment of noise hazard and choice of appropriate hearing protection for workers.

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Conclusion: Combining noise exposure assessment with intervention development using participatory methods, we characterized noise exposure and developed an intervention to educate and assist in protecting workers as they perform noisy tasks.

INTRODUCTION

Noise is a ubiquitous occupational exposure with an estimated 22 million workers in the United States (US) exposed at hazardous levels each year.[1] While occupational noise exposures are associated with hypertension[2–4] and elevated cholesterol,[2] it is noise-induced hearing loss (NIHL) that accounts for the highest burden of disease from occupational noise exposure, and is one of the most prevalent occupational conditions in the US.[5]

The US Occupational Safety and Health Administration (OSHA) mandates a hearing conservation program (HCP) when workers are exposed to noise at or above the threshold action level, an 8-hour time-weighted average (TWA) of 85 dBA and defines a permissible exposure limit (PEL) of 90 dBA.[6] While OSHA HCP content is specified (audiometry, noise monitoring, employee education, exposure control, recordkeeping), there are no program delivery guidelines. Typically, HCPs are delivered as top-down organizational interventions where workers are passive program recipients. The HearWell project aims to improve upon traditional HCPs by adopting the participatory, *Total Worker Health®* root causes approach developed by the Center for the Promotion of Health in the New England Workplace (CPH-NEW) and implemented in the Intervention Design and Analysis Scorecard.[7] HearWell, seeks to protect and promote hearing health using an integrated approach involving behavioral changes by workers as well as changes to the work organization and environment. We piloted HearWell in a unionized, state-based workforce within the Department of Transportation (DOT), specifically among transportation road maintenance and repair workers or “maintainers”. Maintainers are construction trade workers who perform seasonal tasks including snow plowing, brush cutting, road paving, and mowing. Estimates suggest that the majority (76%) of the estimated 325,900 construction trade workers within the transportation sector are exposed to hazardous noise levels.[1]

The current analysis focuses on one component of HearWell, the development of an intervention to increase hearing protection device (HPD) use. OSHA recommends engineering controls as the first line of defense against noise exposure, “if feasible”. Likewise, the National Institute of Occupational Safety and Health (NIOSH) suggests a hierarchy of noise controls from most to least effective; elimination or reduction of the noise source, engineering controls, administrative controls, and, as last resort, use of HPD. Despite these recommendations, the use of HPD is typically the go-to noise control solution.[8] This is the case for maintainers where tasks and tools change from day-to-day and hour-to-hour, resulting in variable noise exposures.

The aims of the current analysis are multifold. First, we sought to characterize personal noise exposure during brush cutting, one of the routine tasks performed by maintainers. Second, we sought to describe the development of a novel noise hazard scheme for selecting HPD use using a participatory approach as outlined in the CPH-NEW Healthy Workplace

Participatory Program (HWPP). Lastly, we provide an illustration of the application of the noise hazard scheme to noise levels generated and HPD use required during brush cutting.

METHODS

HearWell overview

Using the CPH-NEW HWPP, we implemented the core components of the HWPP, which included: a two-committee structure (steering committee and design team), a facilitator, and the methods outlined in the Intervention Design and Analysis Scorecard (IDEAS) Tool [7]. A steering committee of key management stakeholders facilitated the formation of and supported the work of the design teams of line level workers. Research staff were trained on the IDEAS process and content and served as the facilitators for both committees. Additionally, an employee survey on hearing safety and health was administered, components of which are reported elsewhere.[9]

The two DTs each consisted of 5–6 maintainers from 2 regional DOT garages who gathered for 1-hr biweekly meetings. Design team workers used the IDEAS Tool to identify contributing factors as root causes to hearing loss specific to their work experience. They developed a wide range of intervention objectives and activities in collaboration with the steering committee to be incorporated into the HearWell intervention. The first objective of the design team was to focus on HPD use. The UConn Health Institutional Review Board reviewed and approved all study protocols. Written informed consent was obtained by all study participants.

Noise monitoring and hearing protection device use

As a way to better understand noise exposure, work organization and work practice among maintainers, full-shift, personal noise monitoring and personal sound level measurements were performed during the routine task of brush cutting and removal. A total of three work crews each from different maintenance garages were monitored over three consecutive days in the Fall of 2016. As part of the larger HearWell project, the garages were randomly selected out of 12 garages within similar districts within the state. A total of 3 work crews over 3 workdays was chosen to assess the variability in noise samples by day and crew performing the same task. The entire work crew which included 4 maintainers and a crew leader were monitored.

Brush cutting occurs routinely to maintain a clearing beside the roadways and may also be performed following a storm when debris from trees litter roadway areas. Workers from garage 1 were assigned to a one lane on-ramp to an interstate with low traffic flow (approximately 1 car per minute). The wooded work area was on a steep hillside with numerous rock outcroppings along the path where small to medium trees were cut and removed. Workers from garage 2 were assigned to a 4-lane freeway with high traffic flow (approximately 30 cars per minute). The work area included a moderate embankment where small trees and brush were cut and removed. Workers from garage 3 were assigned to a 2-lane state highway on a hill with a passing lane with moderate traffic flow (approximately 10 cars per minute). The work area was close to a package distribution center and traffic included numerous large trucks. All work crews cut and removed small trees and brush. Equipment used during the brush cutting task included one to two chainsaws, one to two pole chainsaws, and a chipper. In general, the chipper was placed on the roadway and work crew members used the same equipment within and across days. Workers using the chainsaw and pole chainsaw worked up to 50 feet up the side of the roadway, felling trees. A helper, along with the chipper operator walked to the fallen trees, and proceeded to carry and feed them into the chipper.

Noise exposure levels were measured using data-logging noise dosimeters (Cirrus doseBadge, North Yorkshire, UK). The dosimeters were configured to measure A-weighted equivalent sound level in 1 minute intervals, using both an OSHA setting (80 dB threshold, 90 dB criterion level, 5 dB exchange rate, slow response time) and an EU ISO setting (no threshold, 85 dB criterion level, 3 dB exchange rate, no time weighting) At the beginning of each work shift, noise dosimeters were calibrated and placed on each worker's right shoulder. A Certified Industrial Hygienist continuously observed the employees and noted the tasks performed and tools used, indicating their primary noise exposure source along with approximate start and end times on worker logs. All workers, except for 2 used the same primary equipment across the workday. A post-sampling calibration was performed at the end of monitoring. The task and tool monitoring data was combined with the 1-min L_{eq} noise exposure data to identify the primary noise exposure source for each workers across each monitoring day. In addition to the chainsaw, pole chainsaw and chipper, workers also used leaf blowers to clear the site of debris. Researchers observed HPD use frequency, make and model.

Descriptive statistics (mean, standard deviation) were calculated for the full-shift summary measures. ANOVAs were used to investigate whether noise exposures varied by garage or equipment (based on the equipment used for the majority of their work shift). Descriptive statistics (mean, standard deviation, min and max, and percentiles) were also calculated across the equipment or task for the 1-min noise data. For all analyses an alpha level of 0.05 was used to determine statistical significance, and all analyses were conducted using SAS (version 9.4).

Noise hazard scheme development

Development of the noise hazard scheme was through an iterative process with the design teams and steering committee. In working through the IDEAS, root causes approach, the design teams identified obstacles to wearing HPD. First, they were unsure of the noise levels of the various equipment that they used. Second, they were unclear of the different levels of noise reduction that HPDs provide. Workers wanted to know which HPD was required for the task or equipment they were using, rather than the actual noise level of the equipment. The research team, design teams and steering committee worked together to identify and characterize the tasks, noise levels and hearing protection that factor into noise exposure and hearing risk. An iterative process of reviewing data elements, with worker feedback was used to create a noise hazard scheme providing a systematic approach to assess the noise hazard of tasks and to choose the correct HPD.

An inventory of HPD routinely stocked by the department was identified along with the corresponding manufacturer and OSHA noise reduction rating (NRR), the unit measurement that determines the effectiveness of a HPD to reduce noise exposures. To account for differences in extrapolating the laboratory derived manufacturer NRR (NRR_{mfg}) to the workplace, the OSHA NRR (NRR_{OSHA}) was calculated by subtracting 7 from the NRR_{mfg} or in the case of double hearing protection, adding 5 to the most protective HPD NRR_{OSHA}. A total of 4 HPD types and models were available including ear plugs (NRR_{mfg} 29; NRR_{OSHA} 22), standard ear muffs (NRR_{mfg} = 29; NRR_{OSHA} = 22), mounted ear muffs for hard hats (NRR_{mfg} = 27; NRR_{OSHA} = 20), and ear bands (NRR_{mfg} = 22; NRR_{OSHA} = 15) and double protection which includes plugs (NRR_{OSHA} = 22) and either muffs (NRR_{OSHA} = 22 or NRR_{OSHA} = 20) for an NRR_{OSHA} of 27. It should be noted that while the OSHA technical manual on Noise and Hearing Conservation advises employers to further reduce the NRR by 50 percent to account for the overstated reduction that the NRR provides due to differences in laboratory versus workplace performance and resulting noise exposures (a practice referred to as de-rating), the steering committee opted to use the NRR_{OSHA} without additional adjustment.

Noise level ranges (red, above 105 dBA; orange, 90 – 105 dBA; and yellow, 85–90 dBA) were iteratively developed by the steering committee with feedback from the design teams to categorize task noise levels and to assign hearing protection (Figure 1). The noise levels for the hazard categories were chosen based on the ability of the HPD NRR to reduce maximum noise exposures to below 85 dBA. The noise exposure time was also considered by the design team s and steering committee. Early versions of the noise hazard schemes included the time range in noise allowed before an 8-hour TWA of 85 dBA is reached when no HPD is used. For example, at 105 dBA within the red noise hazard band, in less than 5 minutes, workers' 8-hour TWA would reach 85 dBA when no HPD is worn. However, workers opted to simplify the scheme to clearly indicate the type of HPD for each task or piece of equipment without having to calculate how much time would be spent in the noisy environment. Likewise, maximum noise exposure levels for each task or equipment was used to categorize noise exposures into the appropriate hazard bands due to the potential for long exposure periods beyond 8 hours during storm work.

RESULTS

Noise exposure during selected tasks

A total of 17 workers were monitored, with the majority of workers participating across all three days (n=11) and five participating for two days and one for one day, for a total of 44 worker monitoring days. The workers were all male, with a mean (SD) age of 41 (9) years and three workers declining to give their age. The majority of workers identified as White (n=14), one as other and 2 declined to answer. The majority (n=13) of workers had a job title of maintainer, 4 were crew leaders. The workers had a mean (SD) tenure at the DOT of 7.3 (8.5) years with 2 declining to answer.

Descriptive statistics of noise levels by garage and equipment used are presented in Table 1. One sample was lost due to equipment malfunction. On average, workers were monitored for 7.2 hours, ranging from 6.5 to 7.8 hours over their 8-hour shift. Most workers were within OSHA permissible exposure limit (PEL) of 90 dBA, with mean (standard deviation) of 87.3 (2.6) dBA L_{AVG}, 86.2 (2.6) dBA TWA_{8hr} and 62.1 (25) % dose. Overall, two work shifts for two workers were above the 90 dBA OSHA PEL for an 8-hour workday. However, all workers were above the ISO criteria with mean (standard deviation) of 90.8 (3.1) dBA L_{eq}. All workers wore HPDs including either ear muffs or ear plugs. Average noise levels across the three garages ranged from approximately 86.2 to 88.1 dBA L_{AVG} over the work shift. The difference in full-shift noise levels between work crews was not statistically significant. The difference in full shift noise levels by equipment used was statistically significant ($p<0.01$) with the highest noise levels among workers primarily using a chainsaw and the lowest noise exposure among workers primarily using the chipper. This was also the case for the 1-min, task data (Table 2), where the mean (sd) exposure level while using the chainsaw was 92.1 (7.6) dBA L_{eq}. When assisting with brush cutting, not at any piece of equipment, but moving trees and brush, the mean (sd) exposure level was lowest at 87.3 (7.5) L_{eq}. The maximum exposure level exceeded 105 dBA while using the chainsaw, chipper and leaf blower, and was below 105 but exceeded 90 dBA while using the pole chain saw or providing brush cutting assistance.

Noise hazard scheme

The brush cutting noise exposure levels was used to assign a hazard band to the equipment and tasks based on the following criteria: red for over 105 dBA, orange for 90–105 dBA, and yellow for 85–90 dBA (Figure 1). Given the maximum exposures above 105 dBA for chainsaw, chipper and leaf blower, each were assigned to the red noise hazard zone. The corresponding hearing protection needed includes double protection of both ear muffs and plugs. Given that the pole saw and brush cutting assistance were between 90–105 dBA, they were assigned to the orange noise hazard zone. The corresponding hearing protection needed includes either ear muffs or plugs. None of the equipment or tasks during brush cutting were within the yellow zone.

DISCUSSION

Combining noise exposure assessment with intervention development using participatory methods, we characterized noise exposures and developed an intervention to educate and protect workers with HPDs as they perform noisy tasks. Among a population of maintainers, we found that certain tasks occurring during brush cutting were noisier than others, but all required hearing protection.

The maintainers relied on HPD as well as administrative controls to reduce their noise exposures. Typically, when choosing the correct HPD, a series of steps are required. First, the noise level and duration of exposure are needed. Second, the noise reduction rating of the available HPD is needed. Ideally, each worker would undergo fit-testing to obtain their personal attenuation rating (PAR) with the available HPDs. The PAR ensures that the individual is achieving the appropriate attenuation with that particular HPD. In lieu of fit-testing, the NRR provides an estimate of attenuation that an average worker will achieve. Based on the noise level, duration of exposure and HPD NRR, the correct HPD can be chosen. The noise hazard banding simplifies these steps and may be especially useful for workers in variable noise environments where the task and/or equipment noise levels vary as does the appropriate HPD needed. For workers in variable noise environments, tools such as a noise level indicator badge which alerts workers when in an area of high noise level requiring HPD, along with audiometry and training has been shown to increase HPD use in construction workers.[10] As another tool, noise hazard bands provide a simplified approach to noise level awareness along with HPD requirements, although it relies on understanding of the hazard bands as compared to real-time feedback offered by the noise level indicator badge.

The noise hazard scheme is only one part of a larger hearing conservation program that also emphasizes the elimination of noise to prevent workers from having to wear HPD. In addition, the hazard scheme is to be used along with enforcement of HPD use and other required program elements. In addition to design of the noise hazard scheme, the design teams were involved in implementation of the noise hazard scheme which included the creation of a 45-minute training video, noise hazard scheme posters for the tool sheds and work areas, and implementation of the noise hazard color-coding scheme on the daily work orders alongside each assigned task. Importantly, the training incorporated best practices in noisy environments, especially when working in or near traffic while wearing double hearing protection.

The participatory approach of HearWell allowed workers to both identify and prioritize workplace changes, which in this case was HPD use. However, the noise hazard scheme should be viewed in light of its limitations, and the participatory approach resulted in a mix of choices that included both less and more hearing protective elements. The steering committee chose the OSHA permissible exposure limit, rather than a more protective exposure limit, such as the National Institute of Occupational Safety and Health recommended exposure limit at 85 dBA as an 8-hour time-weighted average. Likewise, in addressing hearing protection attenuation, the steering committee did not apply a 50% de-rating to the NRR, as is best practice. On the protective side, the committees choose to use the maximum noise exposure level, rather than an average. While this choice was guided by the work pattern among maintainers which in storm work can extend beyond 8 hours, it may result in over protection. Important elements including the exposure limit, hearing protection de-rating, and the use of maximum versus average noise exposure levels should be considered when implementing the noise hazard scheme approach among other noise-exposed populations.

We believe there is utility for the noise hazard scheme for workers, especially who perform tasks in variable noise environments due to multiple equipment, for example workers in the construction industry.[11] Noise levels of tasks and equipment in other industries can be categorized into the noise hazard categories and matched with the available HPD to make it easy for workers to choose the correct HPD. Importantly, the scheme can easily be incorporated into training programs through tailgate talks, posters, and other reminders to assist workers in choosing the right HPD. The noise hazard scheme is currently being expanded to include additional equipment and tasks for transportation maintainers.

While numerous studies confirm that increased HPD use frequency correlates with reduced NIHL,[12,13] according to the hierarchy of controls, personal protective equipment, including HPD use, is the last resort to protecting workers. This is at the heart of a Total Worker Health approach, which prioritizes controlling workplace hazards through the hierarchy of controls. A preferred approach to noise, or any hazard, is to reduce noise level at the source as is the emphasis of the NIOSH Prevention through Design Approach which has been applied to noise exposures in mining,[14] and the related NIOSH Buy Quiet Program[15] which encourages to companies to seek out and demand quieter equipment. Unfortunately, historic review of hearing conservation programs indicate that the majority of companies rely primarily on HPD use rather than engineering controls.[8] Nonetheless, using a participatory Total Worker Health approach allowed us to create an intervention, the noise hazard scheme, that included worker and management input and was customized to the workers' needs. The noise hazard scheme, when incorporated as part of a larger HCP, provides an easy way to identify and choose the correct HPD for the noisy task or equipment and to ultimately preserve worker hearing as part of a larger hearing conservation program.

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Figure 1.
HearWell noise-hazard scheme for maintainers

Table 1:

Noise exposure levels during brush cutting by crew and equipment used

	n	OSHA Criteria			ISO Criteria	
		L_{AVG}, dBA Mean (SD)	8-Hour TWA, dBA Mean (SD)	Dose (%) Mean (SD)	L_{eq}, dBA Mean (SD)	Dose (%) Mean (SD)
All	43	87.3 (2.6)	86.2 (2.6)	62.1 (25)	90.8 (3.1)	436 (359)
Garage						
1	15	88.1 (2.2)	86.2 (1.7)	61.1 (14)	91.2 (1.8)	405 (137)
2	14	86.2 (3.3)	85.2 (3.4)	57.1 (35)	90.0 (4.4)	435 (548)
3	14	87.7 (2.0)	87.1 (2.0)	67.9 (19)	91.5 (2.0)	457 (239)
Equipment*						
Chainsaw	9	89.2 (2.7)	88.5 (2.8)	85.2 (35)	91.9 (5.2)	696 (620)
Chipper	22	87.5 (2.5)	86.2 (2.1)	59.1 (15)	91.0 (1.8)	391 (133)
Pole saw	12	85.8 (2.0)	84.5 (1.8)	47.2 (13)	89.4 (1.5)	261 (101)

*ANOVA results indicate a statistically significant difference in exposures by equipment used.

Table 2:

Characterization of L_{eq} 1-minute noise levels by equipment use or task in dBA.

Location	n	Mean (SD)	Min	P10	P25	P50	P75	P90	Max
Chainsaw	1762	92.1 (7.6)	61.8	81.0	88.0	93.1	97.2	101	111
Chipper	3599	90.3 (7.3)	61.7	80.2	86.6	92.1	96.0	98.0	106
Pole chainsaw	1511	87.5 (7.8)	61.7	76.2	84.9	89.5	92.8	95.4	104
Brush cutting assistance	585	87.3 (7.5)	67.7	77.0	82.0	88.0	93.0	97.0	104
Leaf blowing	392	91.2 (7.5)	70.5	79.0	88.1	93.3	96.3	98.7	107