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Impact of Daily Noise Exposure Monitoring on Occupational Noise Exposures in Manufacturing Workers

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Abstract

Objective—Despite the use of hearing protective devices (HPDs), noise induced hearing loss (NIHL) remains one of the most prevalent occupational conditions. A new technology allows for daily monitoring of noise exposures under HPDs. We report on an intervention employing the voluntary use of this technology in a worksite setting.

Design—Volunteers were fitted with a device allowing them to monitor noise exposure under their hearing protection on a daily basis. The trends in noise exposures for individuals who completed at least six months of the intervention were analyzed.

Study Sample—Recruitment occurred at three manufacturing facilities, with 127 workers enrolling and 66 workers actively using the device during their work shifts.

Results—Among volunteers downloading regularly, the percentage of daily exposures in excess of the OSHA action level (85dBA) decreased from 14% to 8%, while the percentage of daily exposures in excess of 90dBA decreased from 4% to less than 2%.

Conclusion—Initial results from this longitudinal study indicate that volunteers find daily noise exposure monitoring to be feasible, and that workers who monitor daily are able to reduce exposures. The results of subject adherence shed light on the challenges and possibilities of worksite interventions for health and safety.

Keywords

Exposure monitoring; Noise; Intervention study

BACKGROUND

Noise-induced hearing loss (NIHL) is one of the most common occupational conditions (Stanbury et al., 2008; Tak et al., 2008) and globally accounts for a significant fraction of

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acquired hearing loss in adults (Nelson et al., 2005). OSHA has mandated hearing conservation programs for workers exposed at noise levels of 85dBA or greater (OSHA, 1983), but NIHL continues to occur in noise-exposed workforces (Verbeek et al., 2009). These noise-exposed workers are required to enroll in hearing conservation programs (OSHA, 1983), which includes the use of hearing protection devices (HPDs). Current conventional methods of assessing occupational noise exposures involve placing a personal dosimeter on a worker's shoulder and measuring the time-weighted ambient noise levels outside of the hearing protection (ANSI, 2007).

To predict the exposure of an individual worker wearing hearing protection, a de-rating factor is sometimes applied to the noise reduction rating (NRR) allowing for an estimate of the attenuation provided by their HPD (Neitzel et al., 2006). At the same time, studies have found that the field effectiveness of hearing protection is highly variable, and that laboratory measurements of “noise reduction rating” (NRR) may not correlate well with measures of attenuation in the field (Berger et al., 1998). Studies have also shown that HPDs are underused (Tak et al., 2009), that the effectiveness may vary widely between individuals, and that use may vary with ambient noise exposure levels, as suggested by the finding of higher hearing loss rates among workers with moderate ambient noise exposures compared to those with higher estimated ambient noise exposures (Rabinowitz et al., 2007). Because of these critical barriers to understanding true noise exposures, a principal way that worker overexposure to noise is detected is when periodic audiometric testing finds that the worker has had a substantial shift in their hearing threshold levels, by which time a significant amount of hearing has been irretrievably lost.

There have been a number of published intervention studies to promote use of hearing protective devices among noise exposed workers. Some of these, including multicomponent, longitudinal educational efforts, have shown success at increasing the rate of self-reported use of HPDs (El Dib et al., 2011; Seixas et al., 2011). To date, however, it has not been possible to assess the impact of such interventions on actual noise exposures experienced by the participating workers.

New advances in hearing protector technology include a device that allows for the collection of occupational noise exposure data under the hearing protector on a continuous basis (Michael et al., 2011). A study of noise-exposed workers using such devices on a mandatory basis reported that such use may reduce their risk of occupational hearing loss compared to matched controls (Rabinowitz et al., 2011). In that study it was noted that some of the beneficial effect could have resulted from the ongoing involvement of company personnel in overseeing the noise exposures of the individuals using the monitoring devices, or other contemporaneous changes. It was also pointed out that further studies were needed to determine whether the monitoring devices could have a beneficial impact on noise exposure and hearing loss risk when used in a voluntary program, as such trials might be necessary to validate the efficacy of these devices.

We report on the initial experience of a cohort of industrial workers enrolled in a voluntary study of the use of a device allowing them to perform daily monitoring of occupational noise exposure under their hearing protective devices.

METHODS

The study took place at three company locations of Alcoa Inc., a worldwide producer of aluminum and other industrial products. Ongoing research collaboration agreements between Alcoa, the Yale University School of Medicine, and Stanford University School of Medicine have resulted in the analysis of audiometric data collected for hearing conservation purposes.[5] As part of this research collaboration, an intervention study of voluntary use of daily noise exposure monitoring was initiated in 2007 at two aluminum smelters with funding from the National Institute for Occupational Safety and Health. The two smelters are located in geographical proximity to each other, but differ somewhat in production process, with one employing a prebake process and the other a Soderbergh smelting process. In 2010, additional volunteers were recruited at a smaller company location with a different production process (a turbine component factory).

Subject recruitment

At each site, volunteers were recruited among noise-exposed workers with the only eligibility criterion being current enrollment in the company hearing conservation program. Recruitment took place through distribution of educational materials about the study and in person meetings between groups of workers and the investigators. Company management did not take part in subject recruitment sessions, and volunteers provided written informed consent under study protocols approved by the Yale Human Investigation Committee. There was no exclusion of individuals with preexisting hearing loss or other medical conditions. After providing consent, workers were fitted with noise monitoring devices consisting of a dosimeter that is carried in a pocket or worn on a belt or hard hat (Figure 1) and connected by wires to small microphones (one for the left ear and one for the right ear) that record noise exposure under hearing protective devices. Dosimeter settings are similar to those used for OSHA hearing conservation compliance (5dB exchange rate, slow response, 80-dBA noise floor). Study volunteers were asked to use these dosimeters on a daily basis as part of their regular hearing protection and to download the noise exposure data from the dosimeter at the end of each work shift. The data are downloaded to a computer database using an infrared reader connected to a computer workstation located near the shop floor. At the time of download, the computer displays the worker's cumulative noise exposure (“dose”) for the work shift, expressed as a percentage of the OSHA permissible exposure level (90dBA for 8 hr TWA). This exposure information is confidentially transferred to the research team, and monthly summaries of exposures are sent to the study volunteers. Volunteers were advised to attempt to keep daily noise doses below the 50% dose level (85dBA for 8hr TWA), which is the OSHA action level and the Alcoa corporate occupational exposure limit level. The dosimeter comes equipped with visual warning signals to alert workers to their exposures while wearing the device. LEDs on the device turn yellow when the daily cumulative dose exceeds 45% dose (84dBA), flashes red when short-term exposures are over 85dBA, and remains a constant red when daily cumulative dose exceeds 100% (90dBA, 8 hr TWA). In addition to performing daily noise exposure monitoring, volunteers were asked to complete a baseline questionnaire of demographic information and risk factors for hearing loss, including non-occupational noise exposures. An annual questionnaire was sent to volunteers to obtain updated information about their health and hearing status, as well as information about the usability of the device. Focus groups were also conducted to address the usability of the device.

Company personnel were not involved with the maintenance of the devices, and were not aware of the exposures being recorded by the volunteers. Study personnel prepared monthly summaries of exposure data for each individual and sent a printed copy of this summary to each volunteer by mail. Volunteers were advised to consult with the company industrial hygienist if they were experiencing repeated noise exposures in excess of the OSHA action level (85 dBA). In addition, a member of the study team visited the study sites several times a week to assist the volunteers with technical device problems.

As an incentive, volunteers received a $25 gift card for completing the questionnaire, received points for each download of data, with accumulated points redeemable for $25 gift cards, and an annual $100 cash stipend. Study volunteers remained enrolled in the company hearing conservation program and received annual audiometric testing and training through that program.

Initially, 171 persons agreed to participate in the study and completed the baseline questionnaire. However, due to device production delays, 48 persons withdrew from the study without having ever used the device. Data are presented on the experience of the 127 persons who enrolled in the study and performed at least one download of noise exposure data. Sixty persons downloaded over at least a six month period.

Data analysis

Data from the baseline questionnaire were entered into an Excel database. These data as well as subject daily noise exposure data were imported into SAS v 9.2 for further analysis.

Univariate statistics were performed on demographic and other variables for the study population. Noise exposure levels and the change in noise exposure over time were calculated for individual study volunteers. We performed bivariate and multivariate analyses of the relationship between demographic variables and noise exposure levels. The multivariate linear regression used a stepwise method to select variables remaining in the model, with significance levels set at p=0.05.

RESULTS

Enrollment status

Figure 2 diagrams the enrollment history and subsequent retention status of volunteers. To date, 127 volunteers have enrolled in the study and received a dosimeter device. Of these 127 volunteers, 16 left employment, and 23 exited the study. At the time of this writing, 66 of the remaining 88 volunteers were actively downloading during their work shifts, while 22 were not downloading currently for a number of reasons including temporary layoff and illness.

Demographics

Table 1 shows the demographics of the volunteers who had enrolled into the study to date and who had downloaded at least once, compared to all 1074 workers enrolled in hearing conservation programs at the three study facilities. As the table shows, compared to the larger population, volunteers as a group are slightly older and with worse baseline hearing thresholds, and also more likely to be of Hispanic ethnicity and report a history of hunting and shooting. The average tenure was similar between the two groups, in excess of 16 years on the job, indicating that shows that many of the volunteers likely had significant noise exposure prior to enrolling in the study. The proportion of Hispanic workers was higher at the turbine factory site (data not shown). The 39 total volunteers who either left employment or left the study were similar demographically to those that remained in the study.

Downloading Status over Time Figure 3 shows the change in active enrollment over time for subjects who had enrolled prior to May 2011 and downloaded at least once (n=96). During the first six months of participation in the study, the percentage of individuals continuing to download decreased, especially in the first two months of use, but then plateaued at around 60% after six months.

Change in Noise Exposure Over Time

Table 2 displays the noise exposure experience for the 60 volunteers who had completed at least six months of downloading of exposure data. The median number of download events per month for these workers was 15 (range 1–30). These individuals, over the six month observation period, demonstrated a mean slope of decline in their daily noise exposure (for "at ear" noise exposures) of 1.3 dBA/yr (median 2.5dBA/yr).

Figure 4 shows the number of daily "at ear" noise monitor reports for these 60 individuals that exceeded either the 85dBA for an 8 hr TWA or the 90 dBA for an 8 hr TWA. As the graph shows, the percentage of daily dose readings for this group exceeding the 85dBA noise level decreased from 15% of readings in month one to 11% during month six of follow-up. There was a spike at month 4 of follow-up, which upon further sub-analysis of individual noise exposure histories corresponded to different chronological time periods for different individuals, but the overall trend was toward decreasing exposures. Over the same time period, the percentage of daily "at ear" noise exposures in excess of the 90dBA noise level decreased from 4% during the first month of use of the monitoring device to less than 2% in month 6. When this analysis was done for each of the locations individually, the location with the most volunteers enrolled in the study (the prebake smelter) appeared to be where the greatest reductions were seen. The smelter that had experienced work slowdowns due to the economic downturn had a lower rate of daily noise dose readings in excess of the 85dBA or the 90dBA levels. The third location (turbine component factory) had a smaller number of enrolled individuals, and there was no clear downward trend of daily noise doses exceeding 85dBA or 90dBA at that location. At that facility, the noise overexposures appeared to be driven by a small number of individuals working near a loud noise source.

Multivariate Modeling of Factors Associated with Changes in Individuals' Noise Exposure over Time

We performed a further analysis to determine whether individual factors could explain an individual's noise reduction experience over the first six months of use of the monitoring device. In a multivariate model, neither age, gender, HPD type, baseline hearing, nor baseline noise exposure level (average exposure level in first month of downloading) were significantly associated with the rate of decrease in noise over-exposures that individuals achieved.

DISCUSSION

The results of this study to date indicate that workers will voluntarily monitor their noise exposures on a daily basis, and that the impact of such daily exposure monitoring can lead to a reduction in personal noise exposures as well as a group decrease in the percentage of daily noise exposures in excess of 85dBA (8 hour time weighted average).

There are a number of possible explanations for the observed decrease in excessive noise levels. By receiving daily feedback about their daily noise “dose”, workers can respond by taking steps to use their hearing protection more effectively. This may involve wearing the hearing protective device more consistently (for example, not removing the device to communicate in noise), and also ensuring that the hearing protector is correctly seated in the ear canal. Workers can also reduce noise exposure through avoidance of noise sources or reducing the amount of time they spend doing noisy job tasks. Another way they might reduce exposures is to bring an excessive noise source to the attention of supervisors or other responsible plant personnel so that noise-engineering controls can be implemented and the noise source controlled.

While we found that the number of noise readings in excess of occupational exposure levels decreased over the first six months of use, and average noise exposure levels also decreased, we were unable to identify individual level factors associated with the change in noise exposure over time. The decrease in noise exposure was not monotonic- and the group of workers downloading over six months saw a collective spike in exposure levels during the fourth month of the intervention followed by a subsequent decline. Since the study is ongoing it will be possible to examine the long term trends in noise exposure in subsequent analyses. Further exploration of the factors that would lead an individual to take steps to reduce exposure appears warranted.

In addition, it appears that the major reductions in noise exposures occurred in the study smelter location where the greatest number of volunteers was located. The reasons why more reduction was found in one location compared to the two others are not clear. However, in the other smelter location, there were a significant number of layoffs and production slowdown due to the economic downturn, and this could have affected both volunteer retention as well as the efficacy of the intervention. Noise levels were generally low in that facility during the work slowdown period, making it more difficult to demonstrate a reduction in exposures. Differences in noise exposure types between the smelter and the turbine component environment may partially explain why certain individuals in the turbine component factory were having persistently high noise exposure readings. These individuals have been counseled to take steps to reduce their exposures. Further examination of such location area effects is planned.

Results from the annual questionnaire and the focus groups have been previously reported (Williams & Rabinowitz, 2011). Of individuals who consistently used the device, 89% believed it helped them control their noise exposure and 96% say it helped preserve their hearing. In focus groups, volunteers reported they were often surprised at their level of noise exposures and that the daily monitoring led them to use their HPDs more conscientiously or change the way they performed a task, and that this has improved their hearing protection. One group of workers reported being able to identify a noisy area in the factory and worked with management to make hearing protection mandatory in that area.

This longitudinal study also demonstrates some of the challenges of intervention trials to prevent noise induced hearing loss in workplaces. Since the monitoring device requires daily action by the worker to start and stop the device, wear the monitoring device consistently during the work shift, and download into the infrared reader at the end of the shift, it is highly likely that the workers who both enlist and persist in using the device are more motivated and perhaps more interested in preserving their hearing than their counterparts who either did not sign up for the study or who dropped out. The magnitude of this selection bias or "volunteerism" is difficult to assess given the non blinded and non-randomized nature of the intervention. It is also difficult to assess the impact of the financial incentives including the point earning system for daily downloads, although anecdotal reports from subjects indicated both that some felt the financial incentives were important, and others did not.

At the same time, the fact that more than 60% of the enrollees continued to use the device over a period of more than six months indicates that voluntary use of the monitoring devices may be possible in industrial worksites. There were key aspects of the study that differ from usual use of hearing protection in hearing conservation programs (aside from the daily exposure monitoring feature). These differences include the use of cash incentives to encourage use of the device, and allowing the noise exposure information to be kept confidential and not shared with management.

Since noise induced hearing loss is a cumulative disorder resulting from noise exposure over time, any preventive intervention to be effective should lead to a lasting change in exposure level, and may take several years for the preventive effect to be seen. Over the observation period reported on in this study, some persons have withdrawn from the intervention citing difficulties with the equipment and protocols, including interference of the wires with job function, ear discomfort, and the inconvenience of daily downloading. The study is now ongoing, and future studies of this cohort will examine the impact of noise monitoring on rates of hearing loss in the volunteers, as well as the long-term acceptance and perception of usability of the daily noise exposure-monitoring device.

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Figure 1.
Daily noise exposure monitoring device (courtesy Sperian Inc.)

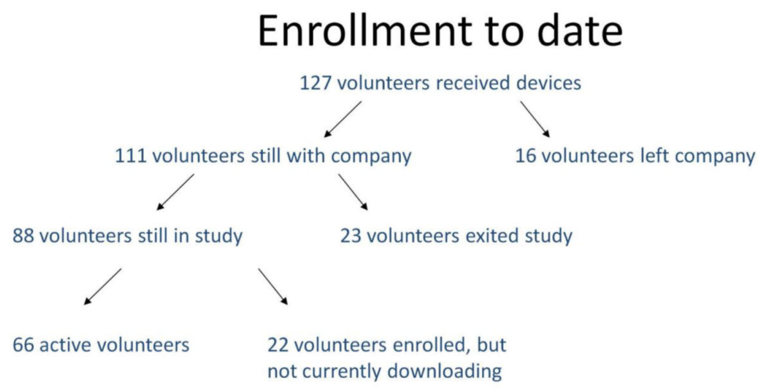

Figure 2.
Diagram of study enrollment and subsequent downloading status.

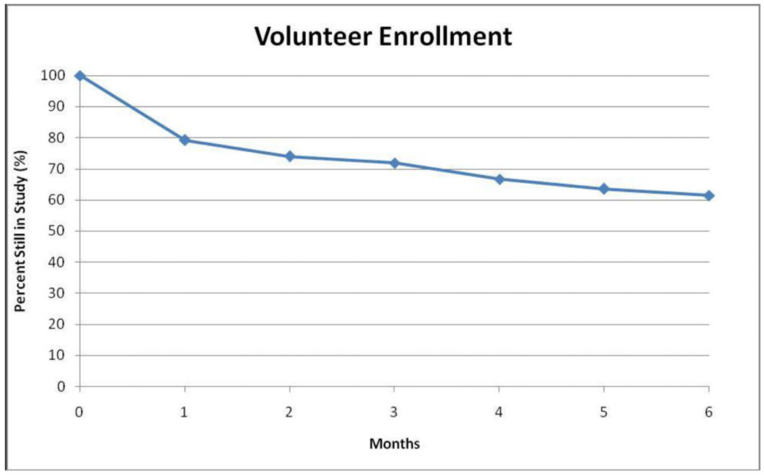

Figure 3.
Volunteer enrollment status over time

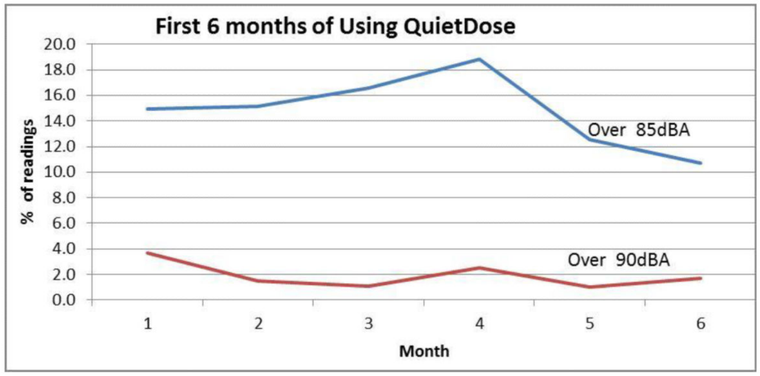

Figure 4.
Percentage of daily "at ear" noise exposure readings exceeding either 85dBA or 90dBA during first six month of monitoring

Table 1

Demographics of the volunteer cohort vs. all workers enrolled in hearing conservation programs at the study facilities (N=1074)

Characteristic	All Workers (N=1074)	Volunteers (N=127)	Dropped out of Study (N=39)
Age (mean,sd)	46.2 (10.1)	46.8 (10.3)	46.1 (10.1)
Male (n,%)	942 (88)	112 (90)	34 (90)
Race			
White (n,%)	1023 (95)	106 (85)	32 (84)
Hispanic (n,%)	23 (2)	15 (12)	5 (13)
American Indian / Alaska Native (n,%)	35 (3)	1 (2)	3 (2)
Asian (n,%)	2 (0)	0 (0)	0 (0)
African American (n,%)	3 (0)	1 (1)	1 (1)
Tenure (mean,sd) (n,%)	16.5 (11)	16.5 (12)	15.6 (12)
History of Shooting (n,%)	637 (59)	81 (65)	25 (66)
Hearing at start of Intervention - Average 2,3,4KHz (mean,sd)	16.0 (13.6)	17.4 (15.1)	20.2 (16.9)

Table 2

Number of daily "at ear" noise exposure readings and the number of downloads per person for volunteers who had completed at least six months of downloading of exposure data (n=60).

			Month			
	1	**2**	**3**	**4**	**5**	**6**
Total number of downloads	576	950	917	908	950	927
Number of downloads per person	9.6	15.8	15.3	15.1	15.8	15.5