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SHORT PAPER

Noise Exposures and Hearing Protector Use at Small Logging Operations

Shawn C. McLain[1] · Daniel A. Autenrieth[1] · Xufei Yang[2] · William J. Brazile[3]

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Abstract

The study objective was to characterize noise exposures and hearing protector usage at small-scale logging operations. Noise dosimeters were used to measure exposures of 31 loggers at two cable operations and five mechanized operations in the United States. Activity cards were employed to evaluate hearing protector usage. Ninety-two percent of cable operation loggers were overexposed to noise according to National Institute for Occupational Safety and Health recommended criteria, but only 46% of cable loggers wore hearing protection. Six percent of mechanized operation loggers were overexposed to noise over the 8-h shifts observed, but this number increased to 33% when working 12-h shifts, which was a common practice among the participant companies. Only 6% of mechanized loggers wore hearing protection. Mean noise exposures and the proportion of hearing protection usage were both significantly greater at cable operations than at mechanized operations. None of the logging operations had hearing conservation programs in place. Despite the use of mechanized logging equipment and methods, the potential for noise-induced hearing loss remains a concern for workers employed at small-scale operations in the logging industry.

Keywords Hearing loss · Occupational noise · Tree harvesting · Forest safety

✉ Daniel A. Autenrieth
dautenrieth@mtech.edu

[1] Safety, Health, and Industrial Hygiene Department, Montana Technological University, 1300 West Park Street, Butte, MT 59701, USA

[2] Environmental Engineering Department, Montana Technological University, 1300 West Park Street, Butte, MT 59701, USA

[3] Department of Environmental and Radiological Health Sciences, Colorado State University, 150 Environmental Health, Fort Collins, CO 80523, USA

Introduction

Logging is very dangerous work and has consistently been ranked as one of the most deadly jobs in the United States and around the world. Logging is practiced worldwide, with a reported 13.2 million timber workers employed globally, according to the World Bank (Preneuf 2016). Because logging is so dangerous, acute exposures have been the focus of much of the occupational safety and health research. The mechanization of logging using heavy machinery has helped the industry experience a decrease in these acute exposures. According to a Swedish study on forestry workers, mechanization has lowered the accident frequency rate by 73% when compared to chainsaw-based methods of logging (Axelsson 1998). The accident rate for manual loggers was approximately four times higher than that for machine operators, both in Sweden and in Louisiana (Lefort Jr et al. 2003; Axelsson 1998). In the United States, there was a significantly lower percentage of injuries by crushing or being struck by trees and branches observed at harvesting operations using heavy equipment (Shaffer and Milburn 1999). However, the effect of these mechanized logging methods on chronic health hazard exposures, such as noise exposures, is less clear.

Loggers have historically had high noise exposures from working with chainsaws (Tunay and Melemez 2008; Neitzel and Yost 2002; Miyakita et al. 1987). Noise-induced hearing loss (NIHL) can commonly occur in the logging industry. The authors of a study conducted on Washington State workers' compensation claims found that the incidence of compensable hearing loss was 15-fold higher in the logging industry (4.6 per 1000 full-time equivalent worker years as compared to 0.3 for all industries combined) during the period between 1986 and 1991 (Daniell et al. 1998). As these were accepted worker's compensation claims, they included a medical diagnosis including consideration of factors other than occupational noise in the compensability determination. In addition, researchers of two epidemiological studies showed that U.S. workers had a high but declining prevalence of hearing loss in the past decade for the agriculture, forestry, fishing, and hunting sector, which includes logging (Masterson et al. 2013, 2015). Despite the risk of developing NIHL, it has been reported that hearing protection devices (HPDs) are frequently either not used or are misused by forestry workers (Abizu-Urionabarrenetxea et al. 2013). In contrast, however, in a study of loggers employed by large logging companies in the U.S., researchers found that HPDs were worn by loggers 83.7% of the time monitored as measured using self-reporting on activity cards, and they also found that higher proportions of use were associated with higher noise levels (Neitzel and Yost 2002). No studies are known to have examined small-scale logging operations for occupational noise exposures or HPD usage.

The research objective for this study was to characterize noise exposures and hearing protector usage at small-scale logging operations that use heavy machinery, which have been under explored in the literature. For purposes of this study, small-scale operations were considered those that employ 15 or fewer workers. A local logging representative estimated that more than 80% of their over 500

member companies have fewer than 15 workers and that many have five or fewer (personal communication 2020). It was hypothesized that noise exposures and HPD usage would be higher at cable sites, where chainsaw work is common, than at mechanized sites, where chainsaw use is less common. Mechanized logging operations use heavy machinery to process trees into logs. Most of the machines have enclosed cabins, with little to no chainsaw work being performed, thereby potentially reducing the amount of noise to which workers would be exposed. Cable-based operations, in contrast, are commonly used on very steep terrain where most mechanized equipment is unable to operate. Cable operations use chainsaws to fell the trees and a crane or cable yarder is then used to move the trees up the steep terrain to the landing area for further processing, either with chainsaws or a piece of mechanized logging equipment at the landing.

Materials and Methods

Thirty-one U.S. loggers in the State of Montana were recruited using an Institutional Review Board approved protocol. These subjects worked for seven different small logging companies (range 3–7 people working on each site) and each company was visited once during the sampling period. At the start each field sampling day we would gather the workers around a tailgate to explain the study and provide coffee and doughnuts for everyone. When the explanation was complete, subjects were asked if they were interested in participating, and if they were, they were given two copies of the informed consent document, one to keep and one to sign and return to the research team. All subjects were over the age of eighteen, and all loggers who were solicited agreed to participate in the study.

Each company operated only one site during the sampling period, and the sites were mutually exclusive (there were no multi-company sites in this study). Sites were selected based on convenience and accessibility with the assistance of a local logging association representative. The logging representative was a logger himself and had established relationships with the companies and knowledge of their programs and work practices. During the visits, he would verify their typical work shifts and whether they had established a hearing conservation program since his last visit with the company.

Personal noise monitoring was focused on four positions at cable operation sites, including sawyer, hooker, crane operator, and landing. The sawyer would fell the trees with a chainsaw. The hooker would attach the fallen trees to the crane to be transported uphill to the landing. The crane operator operated the crane to transport the logs. The landing position worker would unhook the trees from the crane. Mechanized operations consisted of five tasks: feller-buncher operator, skidder operator, processor operator, truck driver, and bulldozer driver. The feller-buncher operator would fell the trees and stack them to be transported by the skidder. The skidder operator would transport the trees to the processor, who would de-limb the trees and cut them to length. The truck driver would load logs onto the haul truck with a loader and transport the processed logs to the mill in a haul truck. The bulldozer was primarily used for road building but was

sometimes used as a skidder as well. Personal noise exposure monitoring was conducted at the seven logging operations from August 2016 through September 2017. Noise exposure monitoring results were provided to the participating loggers and logging companies.

3M Quest Edge 4 and Edge 5 model dosimeters (3M, St. Paul, MN) were used to measure personal noise exposures at each logging site. The dosimeters were pre- and post-calibrated onsite using a 3M Quest QC-10 calibrator (3M, St. Paul, MN). The dosimeters were set to measure noise levels using voluntary National Institute for Occupational Safety and Health (NIOSH) criteria, which specify slow meter response, an 85 A-weighted decibel (dBA) criterion level, an 80 dBA threshold level, and a 3 dBA exchange rate (Sriwattanatamma and Breysse 2000). The dosimeters were attached to the subjects' collars within the subjects' hearing zones. The dosimeters were then collected at the end of shift and the data recorded in a logbook. The average equivalent, A-weighted sound pressure level (L_{Aeq}), was measured for each worker over the measurement period. This level was used to determine the maximum allowable exposure time, projected 8-h time-weighted average (TWA), and a projected percent dose based on the reported shift duration, which ranged from 8 to 12 h. One-way roads limited travel to the logging operations and an escort using a two-way radio was needed to travel to each logging site. Due to these constraints, actual dosimetry measurement times were less than the full-shift length in most cases. All noise dosimetry measurements were as close to full shifts as possible.

At the end of each sampling day, subjects were instructed to complete an activity card detailing their duties for the day. The activity card was divided up into 15 min increments of time, in which the worker would check a box indicating whether that activity was done during that increment of time. The activities on the card were the use of specific logging tools and equipment and the use of HPDs. The type of HPD was also indicated. The approximate exposure time (as a surrogate for the shift length) for the sampling day could also be derived from the activity card, because the completed cards indicated start and end times workers were using any logging tools and equipment. The activity card was based on one used in a previous study of noise exposures, vibration exposures, and hearing protector use among forestry workers at large logging companies (Neitzel and Yost 2002). HPD use self-reports on activity cards at the end of the day have been demonstrated to have good agreement with actual HPD usage as determined via researcher observation (Griffin et al. 2009).

Noise exposures and HPD usage between the two different types of logging operations, cable sites and mechanized sites, were compared statistically. A one-sided, two-sample *T* test was used to compare the mean L_{Aeq} between the two types of logging sites (H_o: $\mu_{mechanized} \geq \mu_{cable}$, H_A: $\mu_{mechanized} < \mu_{cable}$), after the assumptions of normality and homogeneity of variance were assessed. A one-sided, two proportion comparison of HPD usage between the two types of logging sites was conducted (H_o: $\rho_{mechanized} \geq \rho_{cable}$, H_A: $\rho_{mechanized} < \rho_{cable}$), and the Fisher's exact test was used due to the small sample sizes. All analyses were conducted using Minitab 17 Statistical Software, version 17.1.0 (Minitab, State College, PA).

Results

All of the 31 loggers at the seven sites (n = 13 cable and 18 mechanized) worked 8-h shifts while monitored during the study. However, working 12-h shifts was a common practice among these companies and others in the region according to the logging industry representative. The mean run times for the dosimeters were 4 h and 17 min at cable operation sites and 6 h and 39 min at mechanized operation sites.

Twelve of the 13 loggers at cable operations (92%) had projected exposures over the NIOSH recommended exposure limit (REL). As seen in Table 1, 80% of the crane operators were overexposed to noise. This was the only task for the cable operations where any of the loggers had noise doses below the REL. In contrast, only 1 bulldozer operator out of 18 loggers at mechanized operations (6%) had an estimated exposure above the NIOSH REL for the observed 8-h shifts. However, 6 of 18 loggers at mechanized sites (33%) were estimated to be over the REL assuming they worked the reported 12-h shifts, as detailed in Table 2. A comparison of noise exposure levels at both types of logging operations is provided in Fig. 1. The outlier depicted in Fig. 1 was a truck driving task at a mechanized operation.

Self-reported hearing protector usage at cable sites was higher than at mechanized sites at 46% compared to 6%, respectively. All participant workers wore earplugs and none wore over-the-ear HPDs during the sampling period. None of the seven logging operations that participated in this study had a hearing conservation program in place at the time of study.

A two-sample T-test was used to compare the mean L_{Aeq} between the two types of logging sites. The assumptions of the T-test were normality of the data, assessed using the Anderson–Darling test (cable operations: $p = 0.779$, mechanized operations: $p = 0.117$), and equality of variance, assessed using Levene's test ($p = 0.730$).

Table 1 Noise exposures and hearing protector usage among loggers at cable operations as determined using NIOSH criteria[a]

Task evaluated	Workers assessed per task	Mean noise dose[b]	Mean 8-h TWA[b]	Workers overexposed 8-h shift	Workers overexposed 12-h shift	HPD usage
	Number	Percent (SD)	dBA (SD)	Number (%)	Number (%)	Number (%)
Hooker	4	1165 (1385)	95.7 (5.6)	4 (100)	4 (100)	1 (25)
Crane	5	1035 (1179)	95.1 (6.6)	4 (80)	4 (80)	2 (40)
Landing	3	484 (402)	91.8 (3.6)	3 (100)	3 (100)	2 (67)
Sawyer	1	11,174	105.5	1 (100)	1 (100)	1 (100)
All tasks	13	1728 (3016)	93.2 (6.2)	12 (92)	12 (92)	6 (46)

[a]National Institute for Occupational Safety and Health criteria: slow response, A-weighted, 85 dBA criterion level over an 8 h work shift, 80 dBA threshold, and a 3 dB exchange rate

[b]Assumes exposures during the measurement period reflect those throughout the entire 8 h work shift

Table 2 Noise exposures and hearing protector usage among loggers at mechanized operations as determined using NIOSH criteria[a]

Task evaluated	Workers assessed per task	Mean noise dose[b]	Mean 8-h TWA[b]	Workers overexposed 8-h shift	Workers overexposed 12-h shift	HPD usage
	Number	Percent (SD)	dBA (SD)	Number (%)	Number (%)	Number (%)
Feller-buncher	5	39 (36)	78.6 (5.7)	0 (0)	2 (40)	0 (0)
Skidder	4	49 (31)	80.7 (4.5)	0 (0)	2 (50)	0 (0)
Processor	7	31 (29)	76.5 (7.5)	0 (0)	1 (14)	0 (0)
Truck driver	1	33	80.2	0 (0)	0 (0)	0 (0)
Bulldozer	1	714	93.5	1 (100)	1 (100)	1 (100)
All tasks	18	75 (162)	79.2 (6.8)	1 (6)	6 (33)	1 (6)

[a]National Institute for Occupational Safety and Health criteria: slow response, A-weighted, 85 dBA criterion level over an 8 h work shift, 80 dBA threshold, and a 3 dB exchange rate

[b]Assumes exposures during the measurement period reflect those throughout the entire 8 h work shift

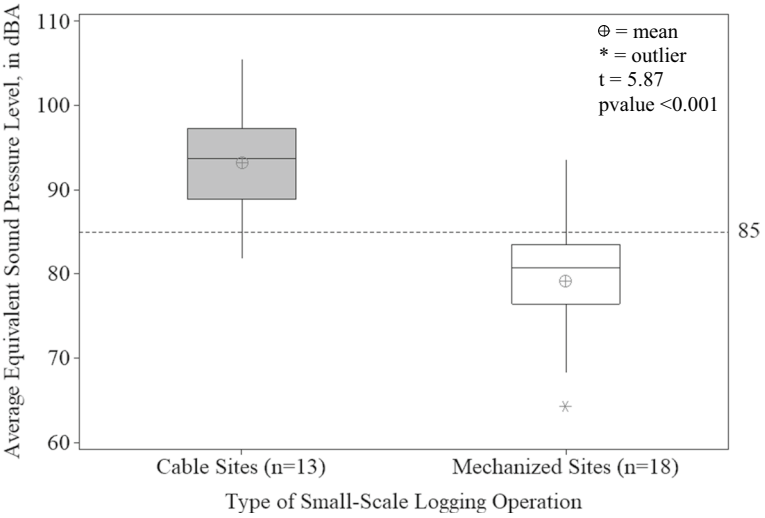

Fig. 1 A comparison of loggers' noise exposures at cable and mechanized logging operations, as measured using National Institute for Occupational Safety and Health recommended exposure limit criteria. The reference line represents the 85 dBA criterion level

The one-sided, two-sample T-test result ($p < 0.001$) indicated that the mean noise exposure was significantly higher at cable operations (93.2 dBA) than mechanized operations (79.2 dBA). The one-sided, two-proportion Fisher's exact test result

showed significantly greater proportion of self-reported HPD usage at cable operations ($p = 0.012$).

Discussion

Fully mechanized logging operations have reduced the need for handheld chainsaw use, which had been a source of considerable noise exposure to loggers, but little research has been done to monitor noise exposures during mechanized logging operations. Seixas et al. (1999), measured the noise produced by several mechanized logging machines to include: skidder, feller-buncher, and processor, and found that the average operational noise levels of the machines to be below 85 dBA except for one front-end loader at 89.6 dBA at the operator's position (Seixas et al. 1999). The study authors concluded that new mechanized equipment was not harmful to the operator's hearing (Seixas et al. 1999). These results are comparable to the results of the current study in terms of noise levels, as all of the mechanization tasks had personal noise exposures below 85 dBA as a TWA, except the bulldozer task (93 dBA). However, 31% of the loggers at the mechanized sites were still potentially overexposed to noise, and therefore potentially at an increased risk of developing NIHL, given the reported 12-h work shifts. Thus, the conclusions for this study differ from the Seixas et al. study (1999) regarding the potential for overexposures and NIHL risk.

The loudest tasks at cable operations were the sawyer and hooker tasks. This finding was consistent with Neitzel and Yost (2002) who measured noise and vibration exposures among loggers. Importantly, a much smaller proportion of the loggers in the current study wore hearing protection as compared to a previous study of workers at large logging companies in the same region (Neitzel and Yost 2002). This discrepancy is likely attributable to the fact that none of the logging operations that participated in this study had a hearing conservation program. Because hearing conservation programs require routine audiometry and training on the effects of hazardous noise loss and proper HPD use, these programs should lead to increased HPD usage.

The results from this study should be viewed in light of a few important limitations. First, the small sample sizes prevented a statistical comparison of noise exposures between tasks/positions and limit the power of the comparisons between operation types. Second, the logging sites were not chosen at random. A representative from the local logging association chose the logging sites used in this study, which were based on convenience rather than representativeness of the operations to others in the region. Logging companies that work closely with their local logging association may operate differently from other logging companies and noise exposures may be lower and/or hearing protection use higher than at other sites who do not work as closely with the association. Additionally, logging sites and practices in the Pacific Northwest region may differ from other areas of the U.S. Lastly, no full shift measurements were collected because members of the research team had to be escorted to and from the logging sites, so TWA exposures were projected out to a full shift using the measured L_{Aeq}. The researchers arrived onsite before the loggers

started working and had to collect the equipment before the loggers left the site during a single visit to each site, and exposures during the measurement period were extrapolated out to a full shift. Because the activity cards indicated similar logging equipment and tools were in use by participants during and after noise monitoring, there is reason to believe that the noise exposures during the unmonitored remainder of the shift were similar to the monitored periods.

Conclusion

The results of this study demonstrate that loggers at small-scale logging operations that use heavy machinery may potentially be exposed to hazardous levels of noise during normal harvesting operations and that these loggers may therefore be at risk of developing NIHL. All of the tasks associated with the cable operations in this study resulted in workers with estimated exposures above occupational exposure limits. Workers at mechanized logging operations had significantly lower average exposures but there was still the potential for over exposure to noise, especially when working 12-h shifts. Despite this potential risk, the majority of loggers at both sites did not wear hearing protection, and none of the operations had hearing conservation programs in place. Hearing conservation programs should be adopted at all logging sites where overexposures to noise may occur. These programs should include noise monitoring, noise controls, training, medical surveillance, and periodic program review. HPD's should also continue to be provided and their use encouraged whenever exposures are above occupational exposure limits. Potential barriers to their HPD use and program adoption may include a lack of knowledge about noise exposures; a lack of understanding about legal requirements and occupational health recommendations; a lack of awareness about free and low cost safety and health technical assistance; limited regulatory oversight at remote/transient operations; social, economic, and/or cultural barriers; and perceived comfort or communication issues (in the case of HPD use). Further research is needed to find ways to improve HPD usage among loggers and to increase adoption of hearing conservation programs at logging sites.

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