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# Indicators of Hearing Protection Use: Self-Report and Researcher Observation

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## Abstract

Hearing protection devices (HPD) are commonly used to prevent occupational noise-induced hearing loss. There is a large body of research on hearing protection use in industry, and much of it relies on workers' self-reported use of hearing protection. Based on previous studies in fixed industry, worker self-report has been accepted as an adequate and reliable tool to measure this behavior among workers in many industrial sectors. However, recent research indicates self-reported hearing protection use may not accurately reflect subject behavior in industries with variable noise exposure. This study compares workers' self-reported use of hearing protection with their observed use in three workplaces with two types of noise environments: one construction site and one fixed industry facility with a variable noise environment, and one fixed industry facility with a steady noise environment. Subjects reported their use of hearing protection on self-administered surveys and activity cards, which were validated using researcher observations. The primary outcome of interest in the study was the difference between the self-reported use of hearing protection in high noise on the activity card and survey: (1) over one workday, and (2) over a 2-week period. The primary hypotheses for the study were that subjects in workplaces with variable noise environments would report their use of HPDs less accurately than subjects in the stable noise environment, and that reporting would be less accurate over 2 weeks than over 1 day. In addition to noise variability, other personal and workplace factors thought to affect the accuracy of self-reported hearing protection use were also analyzed. This study found good agreement between subjects' self-reported HPD use and researcher observations. Workers in the steady noise environment self-reported hearing protection use more accurately on the surveys than workers in variable noise environments. The findings demonstrate the potential importance of noise exposure variability as a factor influencing reporting accuracy.

### Keywords

exposure variability; noise exposure assessment; personal protective equipment

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# INTRODUCTION

## Self-Reported Hearing Protection Use

Noise is one of the most pervasive hazards in the workplace,[1] and noise-induced hearing loss (NIHL) is one of the most common occupational diseases.[2] Chronic noise-induced hearing loss is most commonly caused by prolonged exposure to high levels of noise. The effects of NIHL are permanent and irreversible yet entirely preventable.[1–3]

Construction and manufacturing industries are among those with the highest number of workers exposed to hazardous noise.[2] Whereas the most effective way to reduce NIHL is through the use of engineering controls, these methods are not always feasible or adequate to alleviate the noise hazards in all workplace environments. Hearing protection devices (HPDs) are commonly used in manufacturing and construction to prevent NIHL.

Much of the recent research on noise-induced hearing loss and hearing protection device use has relied on subject self-report.[4–22] In a 1995 study of multiple indicators of hearing protection use among blue-collar factory workers, Lusk et al.[23] found that researcher observations and worker self-report were highly correlated (Pearson correlation = 0.89). The study concluded that "self-report is clearly an adequate, comparatively inexpensive means of obtaining large amounts of reliable data regarding workers' use of hearing protection." [*p*.62]

Other research on HPD use among workers in fixed industry also found good agreement between self-report and researcher observation (Cohen's kappa = 0.70) in a validation sample.[18] However, recent research indicates survey self-reported hearing protection use does not correlate well with observed subject behavior in the construction industry (kappa = 0.13), where noise exposure has been characterized as variable and unpredictable.[24] Noise variability has been thought to influence workers' self-reported use of hearing protection. In studies conducted by Lusk et al.,[13,25] blue-collar factory workers who were constantly exposed to high noise levels reported greater frequency of HPD use than skilled trade workers who moved in and out of high noise areas.

These research findings bring into question the influence of noise variability and other potential factors on the accuracy of self-reported HPD use, which has not been explicitly studied. Self-reported data are less expensive and easier to obtain than researcher observation data, but accuracy can be limited by a number of factors, including the subjects' recall of events and when these events occurred, and the effects of social desirability bias.[23]

In contrast, researcher observations are more objective than self-reported data, assess target behaviors in real time, and are not susceptible to subjects' recall or social desirability biases.[26] However, researcher observations are logistically challenging, and have the potential to influence worker behavior.[23] In addition, observations are typically neither comprehensive nor cumulative, and generally represent only snapshots of subjects' behavior during the study period.

### Current Study

The goal of the current study was to better understand the factors influencing the accuracy of self-reported data and to determine the suitability of self-reported HPD use data for use in future research. Factors potentially influencing the accuracy of self-reported hearing protection use were measured over a single workday and a 2-week period. The principal predictors of interest were type of work site and noise exposure variability. Work sites were selected for participation in the study based on researchers' subjective determination of noise exposure variability.

The primary hypotheses for the current study were that subjects in the workplaces with variable noise environments would report their use of HPDs less accurately than subjects in the steady noise environment, and that reporting would be less accurate over 2 weeks than over 1 day. Other potential confounders were also measured and analyzed in this study.

## METHODS

### Site Selection and Recruitment

Three work sites in Seattle, Washington, were selected based on type of noise environment. The three participating work sites included a commercial construction site and a sheet metal shop, both with variable noise environments, and a state-operated warehouse with a steady, predictable noise environment. A convenience sample of 20 workers was recruited from the participating sites; the total number of workers at these facilities constituted the sampling frame of the study. There were no exclusion criteria for being included in the study, with the exception of an age of 18 years or more, English literacy, and availability during the entire 2-week study period.

All potential subjects at each participating work site were given a brief overview of the purposes and procedures of this study by a researcher prior to participation, and interested individuals signed a consent form and were recruited into the study. Participants were offered a $20 incentive for each day they participated in the study. All study procedures were approved by the University of Washington Institutional Review Board.

### Data Collection and Data Management

This study utilized four data collection instruments to measure noise, HPD use, and other factors: dosimetry provided an objective measure of noise exposure; an activity card was used to assess self-reported hearing protection use; a survey provided a second measure of self-reported hearing protection use and data on potential modifying factors; and researcher observations provided an objective measure of hearing protection use.

Subjects were evaluated over a 2-week period during which they wore a noise dosimeter for a total of four randomly selected work shifts. Ten to 20 subjects were monitored at each site per monitoring day, over a total of 16 total monitoring days. The dosimeters measured three noise metrics: the U.S. Occupational Safety and Health Administration $L_{avg}$, with a 5 dB exchange rate, 90 dB criterion level, slow response time and 80 dB threshold; the National Institute for Occupational Safety and Health $L_{eq}$, with a 3 dB exchange rate, 85 dB criterion level, slow response time, and no threshold; and the maximum level ($L_{max}$), using a fast response time. All three metrics used A-weighting. The dosimeters measured $L_{eq}$, $L_{avg}$ and $L_{max}$ at the shift level as well as for each of the minutes in the measured shift.

Exposure variability was assessed using dosimetry data including: the standard deviation of the 1-min $L_{eq}$ measurement; and the 1-min and full-shift average ratios of $L_{eq}$ to $L_{avg}$ and $L_{max}$ to $L_{eq}$.[27] The standard deviation of the 1-min $L_{eq}$ provides a general measure of exposure variability over the measured work shifts. The $L_{eq}/L_{avg}$ ratio measures temporal exposure variability; a high $L_{eq}/L_{avg}$ ratio indicates intermittent exposures to high noise over the shift. The $L_{max}/L_{eq}$ ratio is an indicator of exposure to impact noises, with frequent high peaks above the average exposure level.

Over the course of each of the four monitored work shifts, study subjects completed an activity card describing their use of hearing protection. Subjects were instructed to indicate the time of day they wore hearing protection, with 15-min resolution. Researchers did not train subjects or provide any information on when to use HPDs; instead, they were instructed to wear HPDs as they normally would at work.

At the end of each worker's first and last monitored work shifts, participants completed a 37-item self-administered paper survey. The surveys collected measures on HPD use and factors potentially related to the accuracy of self-reporting data, including: subject demographics; perception of high noise; noise variability; noise exposure predictability; perceived hearing loss, tinnitus, and temporary threshold shift; feelings about noise exposure; supervisor expectation of and support for HPD use; overreporting due to social desirability bias; and, ability to recall previous noise exposure and HPD use. The survey administered on the first shift asked questions specific to that work shift; the second survey asked questions about the subject's average exposure over the 2-week study period.

The activity card served as the reference for this study, against which self-reported HPD use on the survey was compared. The activity card was validated using researcher observations. The goal was to collect at least one observation of each subjects' use of hearing protection per monitoring day. At the start of each monitoring day, subjects were informed that researchers would observe them periodically during their work but were not told that the focus of these observations was their use of hearing protection. Researchers recorded the time of the observation and noted the subjects' use of hearing protection at that moment. Each observation was treated as a 1-min snapshot.

Methods used to check dosimetry data for errors and potentially flawed measurements have been described previously.[27]

## Data Analysis

Survey, activity card, and dosimetry data were imported into Intercooled Stata 9.1 statistical software for Windows for analysis. All dosimetry data were first described using means and associated standard deviations. A mixed-effects linear regression model, clustered on subject to account for repeated measures, was used to test if these full-shift measures differed by site over the 2-week study period. Each subject's full shift exposure levels ($L_{eq}$ and $L_{avg}$) were exponentially averaged to estimate noise exposure over the 2-week monitoring period.[28]

Measures of variability were arithmetically averaged to estimate variability over the 2-week study period. One-way analysis of variance (ANOVA) was used to test differences by site for these average noise exposure measures. A binary variable was created for each of the noise measures using the median of the distribution for each measure as the cutoff.

Researcher observations were compared with the appropriate 15-min time block on the activity card to measure the accuracy of this self-reported data. A binary variable was created where success was defined as concordance between the activity card and observation, and failure was defined as nonconcordance. A mixed-effects logistic regression model was used to calculate the probability of agreement between the observation and activity card by site, clustered on subject to account for repeated measures, and adjusted for noise level and variability.

The activity card data were compared with the noise dosimetry data to determine if the subject was exposed to high noise (>85 dBA 1-min $L_{eq}$) when they reported using hearing protection. Together, the activity card and dosimetry provided a measure of the percentage of time workers reported wearing hearing protection in high noise for each monitored workday. For Day 1, this continuous measure was categorized into the following data ranges: (1) 0–10%, (2) 11–40%, (3) 41–60%, (4) 61–90%, and (5) 91–100%. An average of the continuous measures for the four monitored shifts was computed for the 2-week study period and then categorized into the same ranges. Two five-level categorical measures were then used to describe the activity card self-reported time wearing HPDs in high noise for Day 1 and over the 2-week study period.

Hearing protection use was evaluated on the survey using the questions, "How often did you wear hearing protection in high noise today?" and "How often did you wear hearing protection in high noise in the past two weeks?" Both questions were answered on a five-point scale ranging from "Never to almost never" to "Always to almost always." Two five-level categorical measures were then used to describe the survey self-reported time wearing HPDs in high noise for Day 1 and over the 2-week study period.

The primary dependent variables of interest in the study were the difference between the self-reported use of hearing protection in high noise on the activity card and survey over: (1) 1 workday, and (2) over a 2-week period. The activity card and survey data were categorical measures; concordant responses were defined as "success" and discordant responses were defined as "failure." Results of the activity card were described using mean and standard deviation and analyzed using one-way ANOVA for Day 1 and mixed-effects linear regression for the 2-week study period. Concordance between the activity card and survey was described using frequencies and percentages and analyzed using Pearson's chi square. Concordance was also examined using a five-by-five table comparing the activity card and survey results.

Logistic regression was used to analyze the probability of concordant response. The primary predictors in the models were work site, noise exposure, and variability. In general, questions with categorical responses were recoded to provide a binary response (always/other, success/fail). Any "Don't know" responses were recoded as missing data.

In a secondary analysis, the pattern of reporting on the activity card was used as the primary predictor of concordant response: subjects who reported wearing hearing protection less than 10% of the time in high noise ("never") or greater than 90% of the time in high noise ("always") were compared with subjects who reported some HPD use in high noise. Always and never reporting was analyzed using Pearson's chi square. Logistic regression was then used to analyze the probability of concordant response with never/always reporting as the primary predictor.

# RESULTS

## Subject Demographics

The study population was majority white (68%), male (90%), and English speaking (97%) with an average age of 37.6 years (data not shown). The three groups shared similar demographic characteristics with the exception of race (Fisher's exact test, $p < 0.001$); there were more nonwhite participants at the state-operated warehouse than at the construction site or sheet metal shop.

## Noise Exposure

A total of 206 full-shift noise measurements were collected at the three work sites. The mean number of shifts measured per worker was 3.4 (±0.8, standard deviation). Minutes of dosimetry ranged from 70–516 with a mean of 474 (±48) min of dosimetry over all measured shifts. Over all 206 full-shift noise measurements, workers were exposed to noise levels > 85 dBA ($L_{eq}$) for an average of 35% (±19) of the shift; high noise exposure time did not differ significantly by site (mixed-effects linear regression, $p = 0.76$; Table I).

Full-shift average and ratio metric noise levels showed statistically significant differences, by site (Table I). In general, workers at the construction site had the highest average full-shift noise exposures; the fixed facility with steady noise exposure had the lowest exposures. Measures of both variability and "peakiness" (1-min $L_{eq}$ (sd), $L_{eq}/L_{avg}$ and $L_{max}/L_{eq}$ ratio) were higher at the construction site and the fixed facility with variable noise exposure than at the facility with a steady noise environment. Two-week average noise exposures showed the same patterns of noise exposure and variability found in the full-shift measures.

## Activity Card Validation

A total of 419 observations were collected on 58 of 60 study subjects. The number of observations per subject ranged from 1–19 with an average of 7.0 (±4.0) over 4 days. Only a small percentage (14%) of workers had fewer than four observations; limited observation data were the result of work in areas not accessible to researchers (e.g, work at height or in confined spaces). In a mixed-effects logistic regression model, the probability of concordance between the activity card and observation was highest at the fixed-steady site (99.5%) and lowest at the fixed-variable facility (92.6%). The probability of concordance did not change appreciably when adjusted for noise level and variability (data not shown).

## Accuracy of Self-Reported HPD Use

**Activity Card—**Self-reported use of hearing protection on the Day 1 and Week 2 activity card is described in Table II. On the Day 1 activity card, subjects reported wearing hearing protection an average of 38% (±46) of the time in high noise (>85 dBA $L_{eq}$). Reporting varied by site: subjects at the fixed-variable site reported wearing hearing protection 82% (±34) of the time in high noise, compared with workers at the fixed-steady site who reported wearing HPDs only 5% (±22) of the time in high noise (one-way ANOVA, $p < 0.0001$). The patterns of reported HPD use time on the activity cards did not change significantly over the 2-week study period.

**Survey—**The survey results reveal significant differences in reported HPD use time between the three sites (Table III). Fifteen of 20 workers at the fixed-variable site reported always wearing hearing protection in high noise on the Day 1 survey; the same number of workers at the fixed-steady site reported never wearing hearing protection in high noise. Results of the Week 2 survey were similar to the results of the survey administered on Day 1.

**Activity Card and Survey Concordance—**Overall, 40 workers (69%) reported concordantly on the Day 1 activity card and survey (Table IV). Concordance was highest at the fixed-steady site and lowest at the construction site, although the differences between sites were not statistically significant (Pearson's chi square, $p = 0.19$; data not shown). Generally, nonconcordant responses were due to overreporting HPD use time in high noise on the survey compared with the use time reported on the activity card. Concordance between the activity cards and Week 2 survey was highest at the fixed-steady site (80%) and lowest at the fixed-variable site (63%). Thirty-nine of 57 workers (68%) reported concordantly on the Week 2 survey.

Logistic regression models were used to analyze the probability of concordant response on the activity card and survey on Day 1 and at the end of Week 2. Compared with subjects at the construction site, workers at both the fixed-steady site and the fixed-variable site were more likely to report concordantly on the Day 1 activity card and survey, although the differences were not statistically significant (fixed steady site, OR = 3.9, $p = 0.08$); fixed-variable site, OR = 1.4, $p = 0.6$). Results were similar over 2 weeks (fixed steady site, OR = 2.3, $p = 0.2$; fixed variable site, OR = 0.9, $p = 0.9$).

Select multivariate logistic regression models were analyzed on the primary predictors of interest. After adjusting for noise exposure (full shift $L_{eq}$ >85 dBA) and noise variability (standard deviation of the 1-min $L_{eq}$ >7.0), workers at the fixed-steady site were nearly 20 times as likely to report concordantly on the Day 1 activity card and survey (OR 19.42, $p = 0.02$) as workers at the construction site. Models adjusted for noise level and other measures of noise variability ($L_{eq}/L_{avg}$ratio and $L_{max}/L_{eq}$ratio) performed in a similar manner. Models adjusted for $L_{avg}$, rather than $L_{eq}$, noise levels yielded similar results to the $L_{eq}$ models (data not shown). The odds of concordant reporting were lower over the 2-week period than over a single day.

**Always/Never Reporting—**The pattern of activity card reporting is described in Table V. The majority of subjects at the construction and fixed-steady sites reported never wearing HPDs in high noise on the Day 1 activity card, while most subjects at the fixed-variable site reported always wearing HPDs in high noise (Pearson's chi square, $p < 0.0001$). Only seven subjects reported wearing HPDs between 10 and 90% of the time in high noise on Day 1. Over the 2-week study period, the majority of workers at the fixed-variable site reported always wearing hearing protection in high noise; most subjects at the construction and fixed-steady sites reported never wearing HPDs in high noise on the activity cards. Only 25% of all subjects reported wearing HPDs between 10 and 90% of the time in high noise over the 2-week period.

Results of the secondary logistic regression analysis in which the pattern of reporting on the activity card was used as the primary predictor of concordant response show that subjects who reported wearing hearing protection less than 10% of the time in high noise ("never") or greater than 90% of the time in high noise ("always") were more likely to report concordantly than subjects who reported some HPD use in high noise. For Day 1, never/always reporting was a strong predictor of concordant reporting on the activity card and survey in a univariate analysis (OR = 7.31, $p = 0.03$). In a model adjusted for work site, noise level (full shift $L_{eq}$ >85 dBA) and noise variability (standard deviation of the 1-min $L_{eq}$ >7.0), never/always reporting was a strong predictor of concordant reporting (OR = 7.13, $p = 0.05$). Over the 2-week study period, never/always reporting was the strongest predictor of concordant reporting in the multivariate models.

## DISCUSSION

The results of the study conform to the *a priori* hypotheses: self-reported HPD use is more accurate among workers in a steady noise environment, and accuracy of self-report is better over a single day than over a 2-week period. The results suggest that the accuracy of self-reported data can vary significantly depending on the type of noise exposure. Additionally, reporting accuracy declined over a 2-week period, and nearly all nonconcordance between the activity card and survey was due to overreporting HPD use time in high noise on the survey.

These results are significant for three reasons: First, researchers in this field have relied on survey data to assess HPD use in both fixed industries and construction under the assumption that self-reported HPD use is as accurate among workers in variable noise environments as it is among workers in steady noise environments. Second, in previous studies researchers have asked subjects in construction and manufacturing settings to self-report HPD use in the past week, month, and 3 months and have generally found little within-worker variability in reported HPD use over these periods.[7,15,16,23]

The results of the current study are consistent with these earlier findings, indicating that workers report similar HPD use in a single work shift compared with a 2-week period. The current results suggest that workers would be unlikely to accurately report HPD use over a period as long as 3 months, given the poor concordance between observed and reported HPD use over a period as short as a single work shift. Finally, the tendency to overreport

HPD use on the survey could introduce bias into studies that collect HPD use data using only surveys.

Researcher observations were used to validate self-reported HPD use on the activity card, which served as the reference for the study. In previous research, self-reported behavior on the activity cards has correlated well with observed behavior.[24,27,29,30] Overall, our findings confirm the reliability of the activity card for collecting self-report data.

As part of her research on training and hearing protection use in construction, Trabeau[24] used researcher observations to complete a validation analysis of both survey and activity card self-reported hearing protection use among a subset of her study population. The results of her validation analysis showed that workers' survey self-reported HPD use did not agree with researcher observations (kappa = 0.13) and that workers typically overreported HPD use on the survey. Subjects' activity card self-report, however, correlated well with researcher observations (kappa = 0.60) in this validation analysis.[22]

Results of the current activity card validation analysis confirm Trabeau's findings that these data collection instruments have a high level of agreement with researcher observations among workers in the construction industry. The current study did not include a direct comparison of survey self-report to researcher observations; however, our findings also reveal a pattern of survey over-reporting, as described by Trabeau.[22]

There are important assumptions about the activity card, survey, and concordant reporting in the current study that warrant discussion. Two five-level categorical variables were used to describe activity card and survey self-reported HPD use time. Researchers equated five ranges of percent of time subjects reported wearing hearing protection in high noise on the activity card to the five categorical responses ("always" to "never") on the survey (Table V). Subjects were not informed that the categorical responses represented numerical ranges; for example, they were not told that a "less than half the time" response on the survey would equate to wearing hearing protection between 11–40% of the time in high noise.

Concordant reporting on the two instruments was defined as perfect agreement between the activity card and survey. Any number of changes could have modified the measure of concordance between these two instruments. If subjects were more explicitly informed of the numerical ranges represented by the categorical survey responses, they may have reported differently. If researchers redefined the numerical ranges associated with the survey categorical responses, concordance with the activity card may have changed. Concordance could have also been defined more broadly by allowing subjects to over- or underreport by one category on the survey.

Finally, both activity card and survey data could have been collapsed into three categories: (1) those who report wearing HPD less than 10% of the time in high noise; (2) greater than 90% of the time in high noise; and (3) other. Such a broad definition of concordance would have eliminated much of the nonconcordance in our study population. The concordance outcome, therefore, is largely dependent on how the survey and activity card responses are defined, and how narrowly concordance between the survey and activity card is defined.

Results of the secondary analysis of never/always task card reporting show that subjects who consistently report wearing HPDs less than 10% or greater than 90% of the time in high noise are more likely to report concordantly on the survey and activity card. These results are logical given that concordant reporting is easier to achieve by summarizing one's behavior as "never" or "always" than it is to report HPD use time in high noise more specifically throughout the shift. These results evince a potential limitation of the activity card: some workers have a tendency to complete the activity card as a summary of their behavior over the whole day, rather than reporting behavior accurately in the 15-min time periods. This may be a reflection of the complexity of the instrument or it may be that workers are not able to recall and report HPD use in such detail regardless of the instrument.

In a study of hearing protection use among construction workers, Neitzel and Seixas[19] found that workers who reported "Always" using HPDs in high noise on a survey actually wore them 32.9% (±43.1) of the time when assessed via activity card and dosimetry. Workers who reported "Sometimes" using HPDs in high noise used them 12.6% (±32.7) of the time, and "Rarely or never" reporters wore HPDs 0% (±0) of the time. These findings help confirm that "Never" reporters are more likely to report their behavior accurately than those who report some HPD use while in high noise.

The study design included only one work site to represent each of the three noise environments of interest, which complicates the interpretation of the findings. Many factors, including noise exposure, variability, and potential modifying factors were correlated with work site. Because of the inherent colinearity of the data, it was not possible to determine if the workers at a given site reported HPD use as they did because of the characteristics of their noise exposure or because of other workplace characteristics.

Data were collected on a number of workplace and personal factors to determine their influence on the accuracy of self-reported data. These predictors were analyzed first in univariate logistic regression models then in multivariate logistic regression models using the primary predictors of interest: work site, noise exposure and noise variability. Results of the univariate logistic regression models show that the odds ratios for concordant reporting were not statistically significant for any of the potential modifying factors. Future research in this area should include multiple sites with each type of noise environment of interest to avoid confounding by work site and to allow the effects of potential modifying factors to be explored.

Results from the state-operated warehouse are especially challenging to interpret. First, it is possible that workers at the state-operated warehouse may have self-reported HPD use more accurately than workers at the other sites because of their experience completing work-related paperwork, not because of their exposure to steady noise levels. This potentially modifying factor was not analyzed in the current study.

Second, overall noise exposures were the lowest at this facility, as was reported HPD use time. HPD use can be explained largely by the type of noise exposure and other workplace factors. Most of the noise-exposed workers at the warehouse were in an area adjacent to a series of mechanical lifts, conveyer belts, and rollers, which were believed to be the major noise sources. Workers in this area also had radios, however, which were located at eye level only a few feet from their work area and were generally in use for the entire shift. After completing data collection at this facility, researchers returned to measure the noise levels in this area with the radios powered off and found that the radios were causing exposures to exceed 85 dBA $L_{eq}$. This is believed to influence HPD use because from the workers' perspective the radios are not a source of noise but a source of enjoyable sound. Hearing protection is therefore not considered as desirable by these workers as it would be for workers exposed to other types of high noise.

During the initial visit to the warehouse to determine suitability for the study, approximately half of the noise-exposed workers were observed wearing hearing protection. During the study period, however, many fewer workers were observed using hearing protection. Researchers were not able to explain this behavior change, except for the possibility that workers may have been advised by management to wear their hearing protection during the first visit.

Workplace safety climate, policies regarding use, and supervisor enforcement have the potential to influence workers' HPD use.[31] Supervisors at both the construction site and sheet metal shop reported having a hearing conservation program in place, including audiograms and worker training. The questionnaire asked participants if they were informed of noise levels at work, if their supervisor expected and encouraged their HPD use, and if they received training on noise and hearing protection. The majority of workers at all three sites (79%) reported not being informed of noise levels, which may indicate poor communication of workplace hazards. In addition, very few workers reported receiving supervisor encouragement to wear HPDs (79%). Eighty percent of construction workers and 100% of sheet metal workers reported that their supervisors expected them to wear HPDs, compared with 37% of warehouse workers (Pearson's chi square, $p < 0.0001$). Similarly, only 25% of warehouse workers reported receiving training on noise and hearing protection use, compared with 70% of construction workers and 85% of sheet metal workers. These results indicate significant differences in safety climate between sites. Unfortunately, because these potentially modifying factors are confounded by work site in the current study, the role of safety climate and related factors could not be explicitly analyzed and remains an area for exploration in future research.

In conclusion, self-reported hearing protection use data from workers in variable noise environments is not as accurate as data from workers with steady noise exposure. The accuracy of self-reported data declines over time and workers tend to overreport HPD use. Future research in this area that relies on self-reported HPD use data should consider noise variability as a factor influencing reporting accuracy. This study confirms the reliability of the activity card for collecting self-reported HPD use data. In addition to using the activity card, researchers should consider validating any survey self-reported data with researcher observations, as subjects have shown a tendency to overreport HPD use on surveys.

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## TABLE I

Noise Exposures, All Shifts and 2-Week Average, by Site

| All Shifts Mean (SD) | All Shifts (n = 206) | Construction (n = 67) | Fixed–Variable (n = 65) | Fixed–Steady (n = 74) | p-Value[A] |
|---|---|---|---|---|---|
| $L_{avg}$ (dBA) | 83.4 (±4) | 84.6 (±4) | 83.7 (±4) | 82.0 (±5) | 0.0122 |
| $L_{eq}$ (dBA) | 87.7 (±5) | 90.1 (±5) | 88.1 (±4) | 85.1 (±4) | <0.0001 |
| SD of 1-min $L_{eq}$ | 6.9 (±1.5) | 8.1 (±1.4) | 6.7 (±1.5) | 6.1 (±0.9) | <0.0001 |
| $L_{eq}/L_{avg}$ ratio | 2.0 (±0.5) | 2.0 (±0.3) | 2.2 (±0.6) | 1.7 (±0.6) | 0.0001 |
| $L_{max}/L_{eq}$ ratio | 46.0 (±15) | 58.3 (±10) | 46.4 (±9) | 34.6 (±13) | <0.0001 |
| % of shift>85dBA $L_{eq}$ | 35 (±19) | 36 (±16) | 36 (±16) | 34 (±24) | 0.76 |

| 2-Week Average Mean (SD) | All Subjects (n = 60) | Construction (n = 20) | Fixed–Variable (n = 20) | Fixed–Steady (n = 20) | p-Value[B] |
|---|---|---|---|---|---|
| $L_{avg}$ (dBA) | 83.9 (±3.4) | 85.4 (±2.9) | 84.0 (±2.7) | 82.2 (±4.0) | 0.0111 |
| $L_{eq}$ (dBA) | 88.6 (±4.0) | 91.5 (±3.8) | 88.8 (±2.9) | 85.5 (±2.8) | <0.0001 |
| SD of mean 1-min $L_{eq}$ | 7.0 (±1.3) | 8.2 (±0.9) | 6.7 (±1.2) | 6.0 (±0.7) | <0.0001 |
| Mean $L_{eq}/L_{avg}$ ratio | 2.0 (±0.39) | 2.0 (±0.18) | 2.2 (±0.37) | 1.7 (±0.44) | 0.0006 |
| Mean $L_{max}/L_{eq}$ ratio | 46.5 (±12) | 58.4 (±6.6) | 46.2 (±6.2) | 34.8 (±10.4) | <0.0001 |
| % of shift > 85dBA $L_{eq}$ | 35.0 (±15) | 36.5 (±13) | 35.8 (±12) | 32.7 (±19) | 0.49 |

[A] Mixed-effects linear regression.

[B] One-way ANOVA.

**TABLE II**

Activity Card: Day 1 and Week 2 Outcomes

| **Activity Card** | **All Subjects** | | **Construction** | | **Fixed–Variable** | | **Fixed–Steady** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Mean (SD) percent of minutes report wearing HPD** | **n** | **%** | **n** | **%** | **n** | **%** | **n** | **%** | **p-Value**[A] |
| Day 1 | | | | | | | | | |
| All shifts | 58 | 36 (±44) | 19 | 23 (±39) | 20 | 78 (±32) | 19 | 5 (±22) | <0.0001 |
| Minutes with 1 min $L_{eq}$ >85 dBA | 58 | 38 (±46) | 19 | 24 (±40) | 20 | 82 (±34) | 19 | 5 (±22) | <0.0001 |
| Week 2 | | | | | | | | | |
| All shifts | 206 | 37 (±44) | 67 | 30 (±39) | 65 | 78 (±33) | 74 | 8 (±25) | <0.0001 |
| Minutes with 1 min $L_{eq}$ >85 dBA | 206 | 38 (±46) | 67 | 30 (±40) | 65 | 82 (±33) | 74 | 8 (±25) | <0.0001 |

*Note:* n = number of shifts subjects reported wearing HPDs, all shifts and in high noise.

[A] One-way ANOVA.

## TABLE III

Survey: Day 1 and Week 2 Outcomes

| Survey<br>How often did you wear HPD in high noise today? | All Subjects (n = 60) | | Construction (n = 20) | | Fixed–Variable (n = 20) | | Fixed–Steady (n = 20) | | |
|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | p-Value[A] |
| Never | 23 | 38 | 7 | 35 | 1 | 5 | 15 | 75 | <0.0001 |
| Less than half time | 7 | 12 | 4 | 20 | 1 | 5 | 2 | 10 | |
| About half time | 4 | 7 | 3 | 15 | 0 | 0 | 1 | 5 | |
| More than half time | 6 | 10 | 3 | 15 | 3 | 15 | 0 | 0 | |
| Always | 20 | 33 | 3 | 15 | 15 | 75 | 2 | 10 | |

| In the last two weeks? | All Subjects (n = 57) | | Construction (n = 19) | | Fixed–Variable (n = 18) | | Fixed–Steady (n = 20) | | |
|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | p-Value[A] |
| Never | 21 | 37 | 7 | 35 | 0 | 0 | 14 | 70 | <0.0001 |
| Less than half time | 6 | 11 | 2 | 11 | 2 | 11 | 2 | 10 | |
| About half time | 8 | 14 | 4 | 21 | 2 | 11 | 2 | 10 | |
| More than half time | 3 | 5 | 3 | 16 | 0 | 0 | 0 | 0 | |
| Always | 19 | 33 | 3 | 16 | 14 | 78 | 2 | 10 | |

n = number of positive responses.

[A] Pearson's chi-square test.

## TABLE IV

Survey and Activity Card Concordance, All Subjects

| Survey<br>How often did you wear HPD in high noise today? | | Never or Almost Never | Less Than Half Time | About Half Time | More Than Half Time | Always or Almost Always | Total |
|---|---|---|---|---|---|---|---|
| | | | | Day 1 Survey | | | |
| Day 1 activity card | 0–10% | 23 | 7 | 1 | 2 | 0 | 33 |
| Percent of minutes >85dBA report wearing HPD | 11–40% | 0 | 0 | 1 | 0 | 1 | 2 |
| | 41–60% | 0 | 0 | 1 | 0 | 0 | 1 |
| | 61–90% | 0 | 0 | 0 | 1 | 3 | 4 |
| | 91–100% | 0 | 0 | 0 | 3 | 15 | 18 |
| Total = 40/58 | Total | 23 | 7 | 3 | 6 | 19 | 58 |
| | | | | Week 2 Survey | | | |
| Total activity card | 0–10% | 21 | 4 | 0 | 1 | 1 | 27 |
| Mean percent of Minutes>85dBA report Wearing HPD over all monitored days | 11–40% | 0 | 1 | 4 | 1 | 0 | 6 |
| | 41–60% | 0 | 0 | 3 | 0 | 2 | 5 |
| | 61–90% | 0 | 0 | 0 | 1 | 3 | 4 |
| | 91–100% | 0 | 1 | 1 | 0 | 13 | 15 |
| Total = 39/57 | Total | 21 | 6 | 8 | 3 | 19 | 57 |

## TABLE V

Activity Card Never/Always Reporting, by Site

| | All Subjects (n = 58) | | Construction (n = 19) | | Fixed–Variable (n = 20) | | Fixed–Steady (n = 19) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Day 1 Activity Card** | **n** | **%** | **n** | **%** | **n** | **%** | **n** | **%** | **p-Value**[A] |
| Never (<10%) | 33 | 57 | 13 | 68 | 2 | 10 | 18 | 95 | <0.0001 |
| Always (>90%) | 18 | 31 | 4 | 21 | 13 | 65 | 1 | 5 | |
| Other (10–0%) | 7 | 12 | 2 | 11 | 5 | 25 | 0 | 0 | |

| | All Subjects (n = 60) | | Construction (n = 20) | | Fixed–Variable (n = 20) | | Fixed–Steady (n = 20) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Week 2: Mean Activity Cards** | **n** | **%** | **n** | **%** | **n** | **%** | **n** | **%** | **p-Value** |
| Never (<10%) | 28 | 47 | 11 | 55 | 1 | 5 | 16 | 80 | <0.0001 |
| Always (>90%) | 17 | 28 | 3 | 15 | 13 | 65 | 1 | 5 | |
| Other (10–90%) | 15 | 25 | 6 | 30 | 6 | 30 | 3 | 15 | |

[A] Pearson's chi square test.