# ADJUSTING HISTORICAL NOISE ESTIMATES BY ACCOUNTING FOR HEARING PROTECTION USE: A PROBABILISTIC APPROACH AND VALIDATION

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## 1. INTRODUCTION

Earlier retrospective noise exposure assessments were not adequately characterized for several methodological limitations, including not properly accounting for use of hearing protection devices (HPD), which would result in the over-estimation of noise exposure and, consequently, in potential misclassification.

Exposure misclassification has been shown to attenuate exposure-outcome relations. In the case of already subtle relationships such as noise and cardiovascular diseases, this would potentially obscure any association. Our study was motivated by an earlier investigation of noise and ischaemic heart disease in a cohort of sawmill workers where the exposure-response relation was strengthened when the authors limited their analyses to workers who terminated their work before 1970, a date where HPD were presumably not used [1]. This finding supports the fact that HPD use contributes to a misclassification of exposure.

In this study, we re-examined this cohort of workers and examined an approach to account for HPD and to validate the new exposure measures by testing the predictive ability of the HPD-adjusted noise estimates to predict noise-induced hearing loss.

## 2. DATA

### 2.1 Population data

A cohort of 27,500 sawmill workers was enumerated in 14 BC lumber sawmills selected because of the high quality of their work history data [2]. We utilized a subset of this cohort (referred to as the study cohort) linked to an audiometric database, described below, who were employed for at least one year between 1950 and 1998, and who had at least one audiogram test.

### 2.2 Noise exposure data

Noise exposure data was gathered from research, industry and regulatory sources. 1,900 full-shift dosimetry measurements, from cohort mills, were used in modeling the determinants of noise exposure. Defining an exposure data matrix, and using the determinants of noise exposure model, we obtained for 3700 unique combinations of job/mill/time, the predicted A-weighted dB(A) noise exposure estimates [2]. These retrospective noise exposure estimates did not account for use of HPD.

### 2.3 Audiometric data

Audiometric data was obtained from WorkSafe BC, the local regulatory agency that coordinates hearing conservation programs in workplaces where noise is deemed to be higher than the regulatory limit, 85 dB(A). As part of the program, WorksafeBC archives routine audiometry surveillance data. Approximately 90,000 hearing tests were linked to the cohort sawmills.

Since each hearing test was also accompanied by a questionnaire administered by an audiometric technician, this data offers three distinct types of information:

(1) Information on HPD use: self-reported by worker at time of hearing test;
(2)Audiograms which comprise binaural hearing threshold levels for frequencies of 500Hz to 8 Khz;
(3) Personal information on subjects' otological health history, occupational and leisure noise exposures.

## 3. METHODS

We linked the three data sources to obtain the study cohort. We re-estimated the historical noise estimates in three steps: (1) the 'real-world' attenuation of HPD used were derived; (2) determinants of use of hearing protection devices were modeled; (3) we used the results from the two previous steps to predict use of HPD for workers in the study cohort, and to adjust the exposure according to the HPD field performance estimates.

### 3.1 'Real-World' attenuation

Performance data literature on earplugs and earmuffs was used [3] and calibrated to Canadian Standards for class A and class B ear protectors [4], resulting in a nominal attenuation factor, denoted A. Given that workers seldom use their ear protectors throughout the work shift, we accounted for partial compliance of usage of HPD, and obtained the effective attenuation [5].

### 3.2 Hearing protection use modeling

A subset of the study cohort was used to model the determinants of use of HPD. Mixed effects models were used to handle the binary response (yes/no) for use of HPD as well as the nested structure of the data (workers within mills). We applied this model to the study cohort and obtained predicted probability of use of HPD, noted $\pi$ thereafter, for each combination of calendar year/job/exposure level.

### 3.3 Retrospective noise exposure re-estimation

A correction factor was computed for each job-exposure observation using a time-varying HPD-specific effective attenuation weighted by the predicted probability of use of HPD, $\pi$.

We calculated the cumulative exposure for the noise metric, (for both HPD-adjusted and unadjusted). Cumulative exposure is the sum of products of noise intensity and duration of employment, in units of dB(A)×year, in a given job j, for jobs 1 to k, as follow:

$$\text{Cumulative exposure} = 10\log\left[\sum_{j=1}^{k} Tj * 10^{\frac{Leq_j}{10}}\right] \quad (1)$$

### 3.4 Validation

Ideally the validity of any exposure measures should be tested. In the absence of a 'gold standard', we proposed to examine in a further study the predictive validity of the re-estimated noise estimates against a well-established noise health effects, namely noise-induced hearing loss.

Using the archived audiometric data, we will define the hearing loss for all cohort workers.

Additional information gathered by audiometric technicians, including potential confounders for the noise-induced hearing loss association can also be used and accounted for in the noise-hearing loss relation.

Using a linear mixed-effects modeling to account for within-subject correlation in repeated hearing loss measurements, we would have the following general formulation of the validation model, where the indices i and j are for hearing tests and workers, respectively, and where only the intercept is allowed to have random effects u0ijj among workers:

$$y_{ij}^{*} = \beta_{0j} + \sum_{p=1}^{P} \beta_{pij} x_{ij} + e_{0ij} \quad (2)$$

$$\beta_{0j} = \beta_0 + u_{0ij}, u_{0ij} \sim N(0, \sigma_u^2), e_{0ij} \sim N(0, \sigma_e^2) \quad (3)$$

The βs here are fixed effects for P predictors (age, sex, ethnicity, noise exposure, significant risk factors), and var($u_{0j}$) and var( $e_{0ij}$ ) are two variance parameters to be estimated. The slopes (β) of the relationship between hearing loss and the adjusted or unadjusted metric can then be compared to determine whether adjustment for HPD use improved the exposure-response relation.

## 4. RESULTS

### 4.1 Descriptive

The study cohort comprised 13147 workers representing a total of 183,115 records defined by job, exposure, and self reported use of HPD. It was predominantly male (99%) and composed of three major ethnic groups with 8.8% East Indian (mostly Sikhs), 1.5% Chinese, and the remaining majority being Caucasian, (mostly of European descent 89.7%). Workers were highly exposed to noise; without accounting for HPD the average measured exposure was 90.6 dB(A) and the mean unadjusted cumulative exposure was 101.4dBA)×years.

The validation sub-cohort had a slightly lower exposure than in the study cohort with a mean adjusted cumulative exposure of 99.7 dB(A) )× year. This difference was driven by the job length as workers in the validation subgroup had shorter job tenure (716 days on average) than in the study cohort (894 days on average). In this subgroup, workers had between 2 and 16 hearing tests (on average 4.3 hearing tests).

### 4.2 HPD-adjusted noise estimates

The mean predicted probability of using hearing protection was 0.82 (standard deviation 0.27).

The mean correction factor for all types of self-reported hearing protection devices (earplugs, or earmuffs, class A or class B) after accounting for partial use was 9.7dB. This value was based on yearly prevalence of use of hearing protection devices, the probability of use of HPD, and the HPD filed attenuation values.

The mean adjusted cumulative exposure since first entry in the study cohort was 98.26 dB(A) )× year and the mean corrected exposure was reduced to 84.6dB(A).

### 4.3 Validation

The results of the validation study will show whether an increase in the dose-response relationship does support the hypothesis that accounting of HPD lessens misclassification of exposure.

## 5. CONCLUSION

We showed in this study, that adjusting for HPD use led to a stronger and more significant noise-hearing loss relationship than exposure estimates with no adjustment, thereby demonstrating that HPD use contributes to non-differential misclassification.

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