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EXECUTIVE SUMMARY
NOISE AND HEARING DAMAGE IN CONSTRUCTION APPRENTICES

Final Report of a Study:
Prospective Hearing of Hearing Damage Among Newly Hired Construction Workers

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Noise-induced hearing loss, also called noise-induced permanent threshold shift (NIPTS) is among the most common occupational diseases. NIPTS usually progresses unnoticed until it begins to interfere with communication, posing a serious safety hazard and decrease in quality of life. A precise understanding of the relationship between noise exposure and NIPTS – especially for highly variable noise exposures like those found in construction – has not been established. In recent years, the potential for distortion product otoacoustic emissions (DPOAEs, measurable sounds produced by the inner ear) as a screening tool for early hearing damage, and possibly as a marker of susceptibility for hearing loss has been recognized. DPOAEs have been suggested as a far more sensitive measure of early hearing loss than the gold standard hearing test, pure-tone audiometric thresholds. However, prior to this study, no prospective research on DPOAEs in relation to well-characterized noise exposure and standard audiometry has been conducted.

From 1999-2004 the University of Washington Department of Environmental and Occupational Health Sciences conducted a prospective study of noise exposure and hearing loss on a cohort of 456 subjects. Three-hundred ninety-three of these subjects were apprentices beginning their training programs in a number of construction trades: carpenters, cement masons, electricians, ironworkers, insulation workers, masonry workers, operating engineers, and sheet metal workers. The remaining 63 were a control group of non-noise exposed University of Washington graduate students. All subjects completed a baseline evaluation, which consisted of an audiometric evaluation in a mobile test van, DPOAE tests in a quiet room, and a questionnaire concerning demographics, NIPTS risk factors, previous noisy work, military experience, non-occupational noise exposure, and other factors. Follow-up evaluations, which consisted of a similar questionnaire covering the follow-up period and the same set of hearing examinations, occurred roughly annually. Three hundred thirty-six valid first follow-up, 284 second follow-up, and 221 third follow-up evaluations were completed, for an average of 3.4 ±0.8 tests per subject among those subjects with more than one exam.

Full-shift noise dosimetry and hearing protection use data on construction workers were also collected before and during this study. These levels were measured according to both the Occupational Safety and Health Administration (OSHA) standard for noise, and the more protective standard of the National Institute for Occupational Safety and Health (NIOSH), which better reflects construction worker's risk of hearing loss. In the more than 700 total measurements made across all the trades, the mean NIOSH levels were always higher than OSHA levels (Fig. 1), and exceeded 85 dBA (the level at which risk of hearing loss becomes significant) for all but one trade. Two-thirds of all NIOSH, and one-third of all OSHA, measurements exceeded 85 dBA. As part of this study, new metrics were developed for noise exposure evaluation. Noise is usually measured only in terms of an average level, but the new metrics allow for better assessment of the variability of noise levels and the degree of impact or high-level noise – two very important issues in construction noise exposure assessment.

In addition to occupational noise, exposures to non-occupational noise were assessed, including everyday activities like commuting and less common events like concerts and riding snowmobiles. Our study found that, for most construction workers, non-occupational activities make little contribution to overall (occupational and non-occupational) annual noise dose. Only for a small fraction of workers who spend significant amounts of time in noisy activities, and in the quieter trades, would non-occupational noise significantly contribute to overall noise dose. The impact of firearms use on annual noise dose could not be assessed, but the study showed that people who shoot firearms are more likely to participate in other noisy activities. Hearing protection use was found to be even lower during noisy non-occupational activities than it was during occupational activities.

As part of the study, the amount of noise blocked by earplugs worn by construction workers was measured while the protectors were being worn. The protectors provided 20 decibels (dB) of protection on average, slightly less than 70% of the average labeled Noise Reduction Rating of 29 dB for the earplugs. Occupational exposure levels for each of the trades measured without accounting for use of hearing protection were compared with levels that were adjusted to account for both the amount of time that hearing protection was used and an assumed 20 dB of protection when they were used. The average full-shift exposure reduction provided by hearing protectors was estimated to be less than 3 dB. This very small reduction in exposure resulted from the low usage of hearing protectors among construction workers, who on average were found to wear hearing protectors less than 20% of the time they were needed (Fig. 2). Only two trades achieved more than 6 dB exposure reduction on average, and overall less than one in five shifts was brought down to safe levels (below 85 dBA) through the use of hearing protection.

Baseline audiometric thresholds and DPOAEs were analyzed at 2, 4, 6, and 8 kHz, the frequencies most commonly affected by noise-induced hearing loss, in relation to previous noise exposures reported by our subjects. Apprentices reported more noise than students prior to the beginning of the study in both their occupational and non-occupational exposure histories, and had worse audiometric thresholds and DPOAE levels at baseline (Figs. 3 and 4). Both age and previous years of work in the construction industry were found to have strong effects on audiometric thresholds and DPOAEs at 4, 6, and 8 kHz. Each year of construction work prior to baseline was associated with a 0.7 dB increase in audiometric thresholds or a 0.2 dB decrease in DPOAE levels. Overall, the pattern of effects seen in the audiometric and DPOAE data was very similar.

Follow-up test audiometric thresholds and DPOAEs were analyzed to measure changes in the hearing levels of the cohort across the duration of the study. Three noise exposure groups were used: the control group and 'low' and 'high' exposed groups (the four trades with the lowest and highest mean occupational exposure levels after accounting for HPD use). Factors expected to affect hearing and noise exposure levels, like age, gender, previous noise exposure, and baseline hearing ability, were accounted for. The audiometric thresholds displayed only slight trends toward increased (worse) threshold levels (Fig. 5) with increasing noise exposure. Small but significant noise exposure-related changes in DPOAEs were evident over time, especially at 4 kHz (Fig. 6) at about 0.5 dB decrease each year for the high exposed group, with less clear but similar patterns observed at 3 kHz.

In summary, the results of this study demonstrate that:

- Depending on the trade, construction workers are exposed over 85 dBA in about 70% of work shifts using the NIOSH exposure standard, and in about 30% of shifts using the les-protective OSHA exposure standard.
- Although non-occupational activities occasionally have high noise levels, these exposures make a meaningful contribution to total noise exposure for only a small fraction of construction workers.
- Although construction workers can attain good noise exposure attenuation using hearing protection devices, hearing protection is worn less than 20% of the time when exposure levels are over 85 dBA. As a result of this low use time, workers achieve an average of less than 3 dB of noise reduction in a full-shift exposure.
- Task-based assessment of noise exposure provides a comprehensive approach to estimation of noise levels associated with construction work. Construction workers were able to recall their work tasks with a high degree of accuracy. However, the large degree of variability in noise exposure between individuals doing the same task makes the estimated exposure level for any individual highly imprecise.
- Noise exposure can be summarized in a variety of exposure metrics. Those expressing an average level (including the NIOSH L_{EQ} and OSHA L_{AVG}) are very highly correlated with each other, and use of any of these average metrics probably makes little difference to the exposure-response analysis. Metrics which express the variability and impulse component of noise – exposure parameters which are very important in construction work – are poorly correlated with the average metrics.
- Distortion Product Otoacoustic Emissions (DPOAEs) directly monitor noise induced damage to the cochlea. Although a number of challenges were identified in the use of DPOAEs for monitoring changes in hearing, their test-retest variability is lower than that of pure tone behavioral audiometry, and therefore provides better sensitivity to subtle changes. However, with the particular protocol used for our study, the variability from year to year was slightly higher than previously reported in the literature.
- Construction work experience was associated with worse hearing (higher hearing thresholds and lower DPOAEs) in our baseline cohort of 434 subjects, with the effect seen most clearly at 6 kHz.
- Over an average of about 2.4 years of work in construction (3.4 annual tests) at estimated exposures of 85-90 dBA, there was a measurable decrease in DPOAEs of about 0.5 dB per year at 4 kHz. No measurable change was seen in audiometry.

Further follow-up of this group of construction workers will help determine if the observed changes in DPOAEs are predictive of later changes in audiometric thresholds. If so, DPOAEs may form an important tool for monitoring and preventing hearing damage. In the mean time, increased efforts to reduce noise exposure among construction workers and prevent the development of significant hearing impairment are needed.

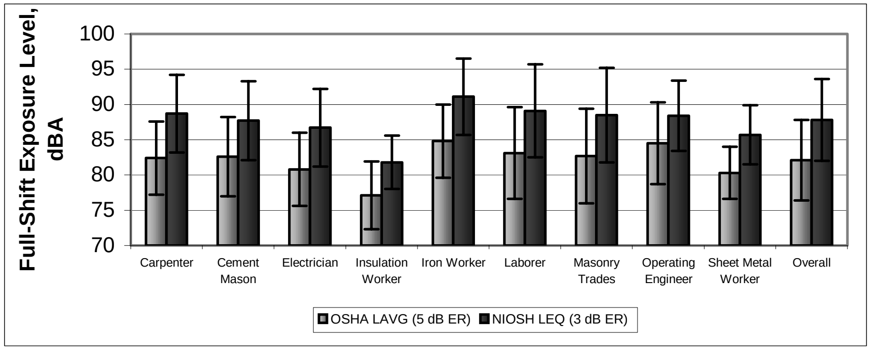

Fig 1. Full-shift average exposure levels by trade

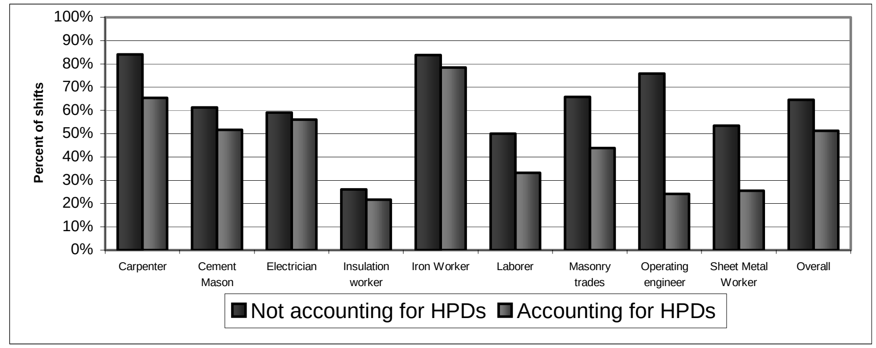

Fig 2. Percentage of workshifts above 85 dBA with and without consideration of hearing protection use

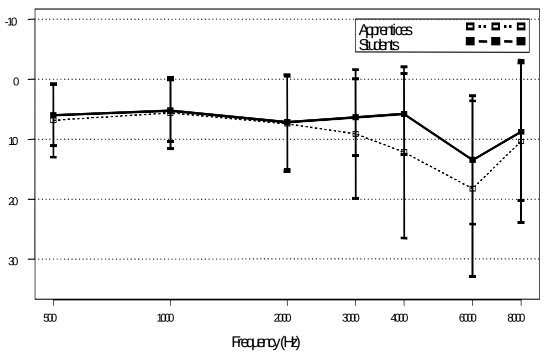

Fig 3. Baseline audiometric hearing by exposure group

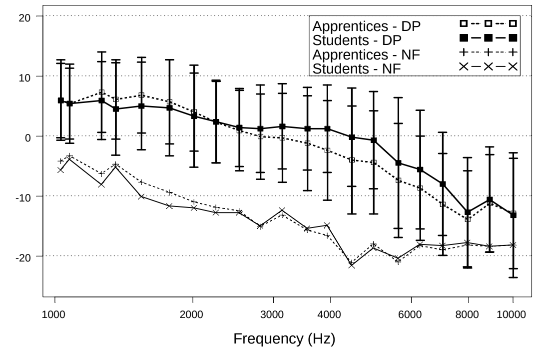

Fig 4. Baseline DPOAE DP-Gram amplitudes (L2=65 dB)

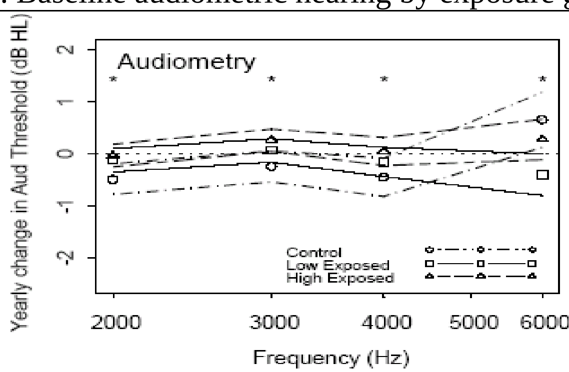

Fig 5. Longitudinal audiometric coefficients for interaction of exposure group and time

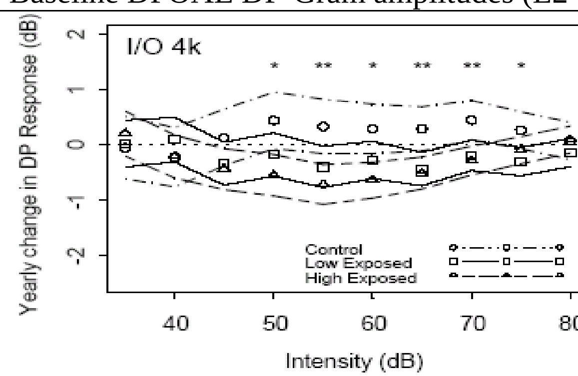

Fig 6. Longitudinal 4 kHz DPOAE I/O coefficients for interaction of exposure group/time.

Error bars are ± 1 standard deviation; lines are 95% CI; asterisks are number of exposure groups differing significantly from control