INRS Mixed exposures conference 2012
Poster presentation- Reference:

Title: The effects of exposure to multiple occupational health stressors on distortion product otoacoustic emissions

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Introduction

Mineworkers are exposed to combinations of stressors, since they spend most of the working shift performing physical work under noisy, hot, humid and dusty conditions, in some cases with exposure to chemicals. Such combined exposure confounds the evaluation of impacts from individual stressors. Studies have demonstrated that exposure to noise combined with physical work can have synergistic impacts[1,2]. Similarly, exposure to noise and chemicals accelerates and exacerbates the development of noise-induced hearing loss (NIHL)[3,4]. Furthermore, exposure to heat is believed to influence the biochemical properties of cochlear outer hair cells (OHCs) and heat stress structurally modifies the OHCs, making them stiffer through an increase in F-actin[5].

This experiment aimed to simulate some conditions in a mining environment (noise, heat/humidity, physical work) and to measure the effects of individual, and combinations of occupational health (OH) stressors on the functioning of the inner ear, using Distortion Product Otoacoustic Emissions (DPOAEs).

Otoacoustic emissions (OAEs)

The clinical application of OAEs has become an integral part of the audiological evaluation, and is a sensitive measure of cochlear OHC function[6]. DPOAE testing uses two tones as an input into the ear and measures the "echo" that returns from the interacting waves elicited from the cochlear OHCs and the fluids in the inner ear[7,8].

Hypothesis

The research hypothesised that the OH stressors of noise, heat/humidity, and physical work would have measurable additive and cumulative effects on DPOAE responses.

Research design

An experimental study under controlled and specified laboratory conditions was conducted, with the focus on each participant's responses to individual and combined stressors, as compared with his/her responses to baseline conditions.

Methodology

Objectives

The objectives of the study were to compare:

- DPOAE levels in responses to noise exposure alone with the DPOAE levels in responses to combinations of noise+exercise, noise+heat and noise+exercise+heat.

Participants

Eleven volunteers participated in the study. The climatic chamber used was only large enough to accommodate six participants at once, so the experiment was conducted in two sessions over four days.

The sample size was not ideal for statistically valid deductions, but since each participant's baseline recordings were used as a control, some of the limitations of the small sample size were counteracted.

Participants were between 18 and 30 years old, the age of most new recruits to the mining industry. Researchers aimed to evaluate the effects of the selected stressors on young, healthy, non-occupationally exposed persons for later comparison with miners' responses and to provide information about a normal response to multiple health stressors.

Inclusion criteria

The criteria for inclusion in the study were that:

- The participant complied with the minimum acceptable standards of health used to determine fitness for work at an underground mine;
- There was no evidence of middle ear pathology (determined with otoscopy and tympanometry) and hearing was within normal limits (determined with screening audiometry);
- There had been no recent occupational exposure to heat/humidity or noise.

Data collection

Data was collected using the equipment described below.

Otoacoustic emissions

DPOAEs were measured using standard audiological equipment calibrated on a daily basis, with the precautions of controlling noise levels in the test area and ensuring satisfactory probe fit. Default settings for stimulus frequencies and intensities were used as prescribed by the instrument manufacturer.

Climatic chamber

The study was conducted in the CSIR Centre for Mining Innovation's climatic chamber to ensure precise control of temperature, humidity, and air velocity. Test conditions requiring physical work made use of graded stepping blocks chosen on the basis of each participant's body mass. White noise was presented through the climatic chamber loudspeakers. Noise levels were measured with a calibrated Class 1 sound level meter. During rest periods, participants sat in a temperature-controlled room adjacent to the climatic chamber.

Data analysis

Descriptive statistics were calculated to evaluate the significance of differences between each individual's baseline results and results for the various test conditions. A paired t-test was applied to the DPOAE measurements at each of the seven test frequencies pre- and post-experimental condition. The non-parametric Wilcoxon signed ranks test and a three-way analysis of variance (ANOVA) were performed to evaluate the significance of the differences between test conditions.

Experimental procedures

The researchers followed the experimental protocol summarised in Table 1.

Table 1 Summary of experimental procedures

Test day, stressor and duration of exposure	Procedure
Day 1	Sit at room temperature (18.0°C wet-bulb/25.0°C dry-bulb) for 30 minutes
	OAE testing
Baseline recordings: two hours	Sit quietly at room temperature (18.0°C wet-bulb/25.0°C dry-bulb)
	OAE testing
Noise: two hours	Sit at room temperature (18.0°C wet-bulb/25.0°C dry-bulb), with 87 dBA white noise
	OAE testing
Day 2	Sit at room temperature for 30 minutes (18.0°C wet-bulb/25.0°C dry-bulb)
	OAE testing
Heat/humidity: two hours	Sit at 30.0°C wet-bulb/31.5°C dry-bulb
	OAE testing
	Rest at room temperature (18.0°C wet-bulb/25.0°C dry-bulb)
Exercise: two hours	Block-stepping at 12 steps per minute (35 watts) at room temperature (18.0°C wet-bulb/25.0°C dry-bulb) for ten-minute intervals, each followed by a 15-minute rest interval
	OAE testing
Day 3	Sit at room temperature (18.0°C wet-bulb/25.0°C dry-bulb) for 30 minutes
	OAE testing
Heat and exercise: two hours	Block-stepping at 12 steps per minute (35 watts) at 30.0°C wet-bulb/31.5°C dry-bulb for ten-minute intervals, each followed by a 15-minute rest interval
	OAE testing
	Rest at room temperature (18.0° wet-bulb/25.0°C dry-bulb) for two hours
Heat and noise: two hours	Sit at 30°C wet-bulb/31.5°C dry-bulb, with 87 dBA of continuous white noise
	OAE testing
Day 4	Sit at room temperature for 30 minutes (18.0°C wet-bulb/25.0°C dry-bulb)
	OAE testing
Exercise and noise: two hours	Block-stepping at 12 steps per minute (35 watts) at 18.0°C wet-bulb/25.0°C dry-bulb for ten-minute intervals, each followed by a 15-minute rest interval, with 87 dBA of continuous white noise
	OAE testing
	Rest at room temperature (18.0° wet-bulb/25.0°C dry-bulb) for two hours
Heat, exercise and noise: two hours	Block-stepping at 12 steps per minute (35 watts) at 30.0°C wet-bulb/31.5°C dry-bulb for ten-minute intervals, each followed by a 15-minute rest interval, with 87 dBA of continuous white noise
	OAE testing

Results

Distortion product otoacoustic emissions

The results of the experiment are shown in Figures 1 to 4, which indicate averaged F2 levels for all 11 participants. Figure 1 shows that only at 2 375 Hz was there a deterioration in cochlear function after two hours of noise exposure at 87 dBA. When physical work was combined with noise, there appeared to be a

synergistic impact, since seven of the eight frequencies tested had lower DPOAE levels after two hours of physical work (Figure 2). Noise combined with heat resulted in a deterioration of emission level at only three of the test frequencies, less of an effect on cochlear function than for physical work alone. When participants were exposed to all three stressors, DPOAE levels were affected at seven of the frequencies tested (Figure 4). The results show that the DPOAE levels deteriorate by between 1 and 4 dBSPL. The largest degree of deterioration in cochlear function, approximately 4 dBSPL, occurred when physical work was combined with noise.

Figure 1 DPOAE comparisons of pre- and post-noise exposure measurements

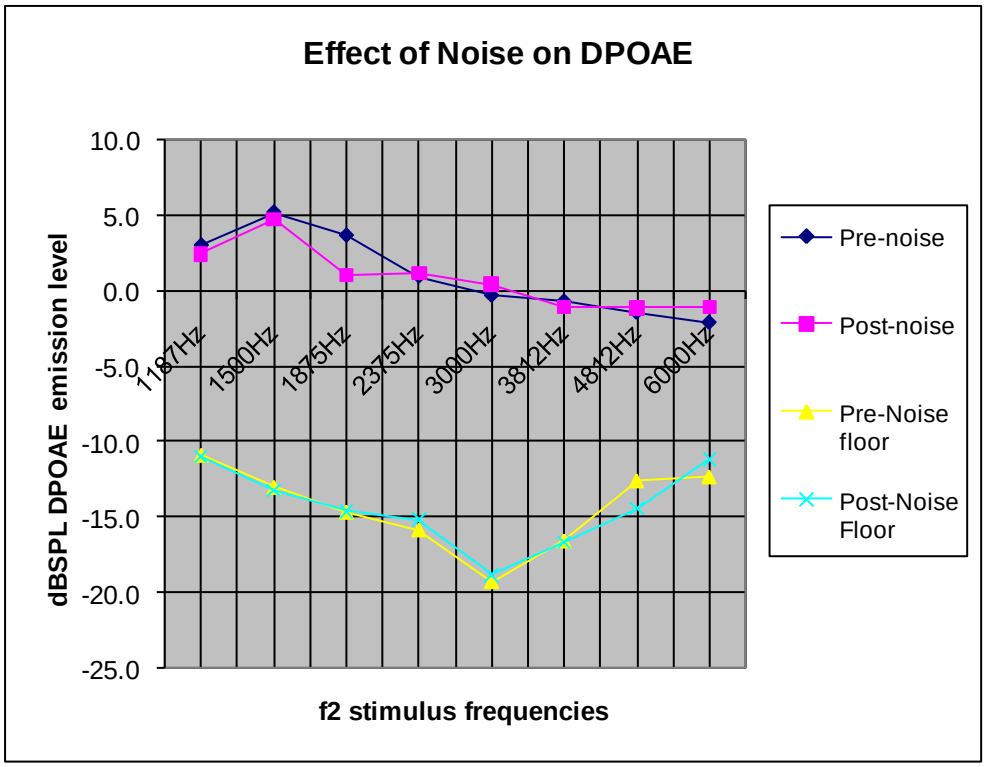

Figure 2 DPOAE comparisons of pre- and post-noise plus exercise exposure measurements

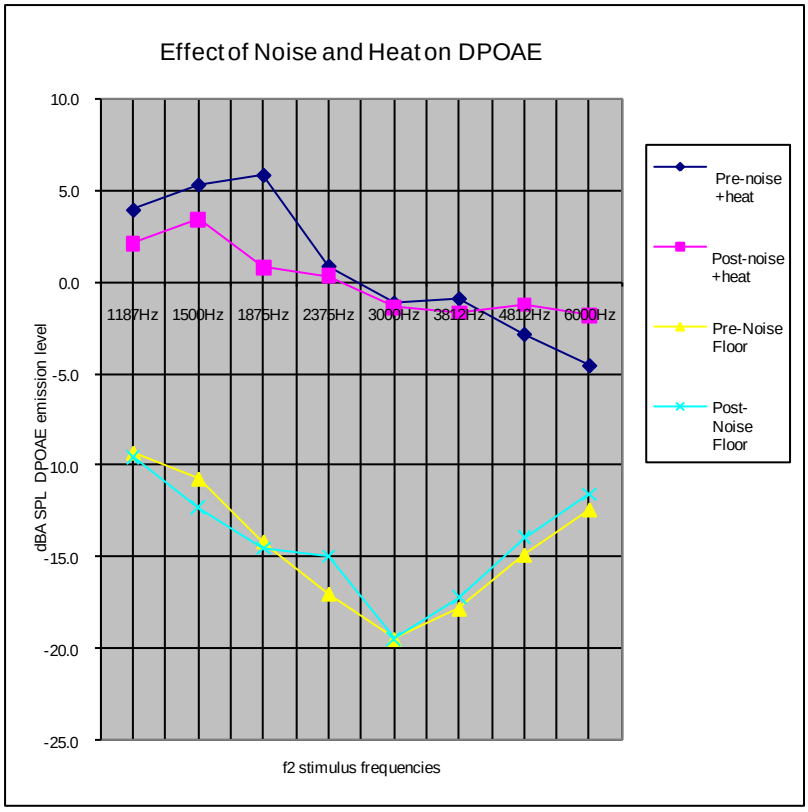

Figure 3 DPOAE comparisons of pre- and post-noise plus heat exposure measurements

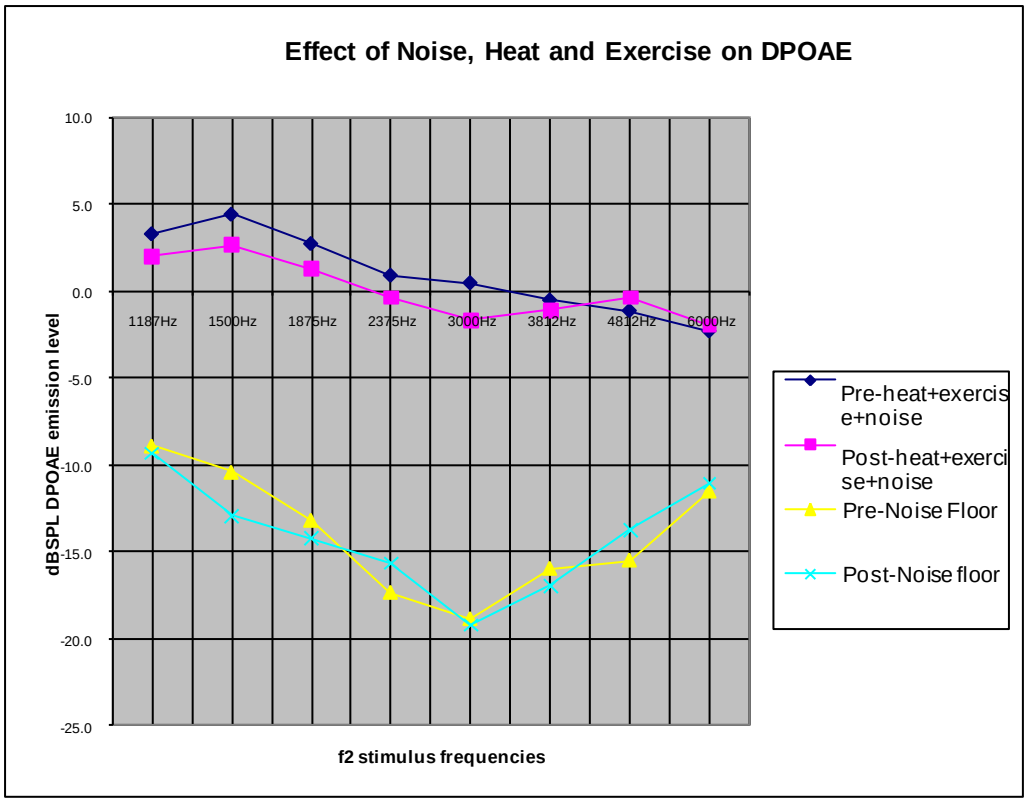

Figure 4 DPOAE comparisons of pre- and post-exposure to heat, noise and exercise measurements

The Wilcoxon signed ranks test indicated that the difference between the measurements pre- and post-exposure was only marginally significant for heat+noise ($p<0.06$) and for heat+exercise+noise ($p<0.005$). The three-way analysis of variance (ANOVA) found no significant differences between the experimental conditions.

Table 2 Statistical analysis of DPOAE averages for OH stressors

Experimental condition	**Z**	**Post–exposure minus pre-exposure**
		Asymp. Significance (2-tailed)
Exercise	-0,621	0,534
Heat/humidity	-1,158	0,247
Heat+exercise	-1,802	0,072
Heat+exercise+noise	-3,489	0,000
Heat+noise	-1,933	0,053
Noise	-0,617	0,537
Noise+exercise	-0,656	0,512

Cochlear functioning as measured by DPOAEs appears to be affected by noise and heat exposure combined and by the impact of all three health stressors, noise, heat/humidity and exercise. The low frequencies were the most affected by the exposure to the health stressors.

CONCLUSION

The results were not conclusive owing to the small sample size and the ethical restraint of exposing participants to safe levels of health stressors. However, despite the lack of statistically significant results, DPOAE testing can be used to compare cochlear function on a pre- and post-exposure basis, since the use of pre-exposure results as a comparative index has been shown to be feasible in demonstrating changes in cochlear function.

The results appear to indicate that exposure to multiple OH stressors increases the risk of cochlear damage and therefore, in the long term, of the development of hearing loss.

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Risk for hearing loss increased with exposure to environmental and workplace stressors