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Noise, Vibrations, and Hearing Loss in the Workplace

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1. **Introduction**

Long term exposures to high noise levels present a serious health hazard affecting millions of workers worldwide. In Canada alone, 42% of working individuals reported employment in occupations with hazardous noise exposure [1].

Exposure to mechanical vibrations is also prevalent in the workplace. The European Agency for Safety and Health at Work [2] has pointed out that 24% of all workers interviewed during a survey reported being exposed to mechanical vibration. The vibrations arise from a wide variety of processes and operations performed in industry, mining and construction, forestry and agriculture, and public utilities.

There are two ways to categorize vibrations depending on the way they enter the human body. Whole-body vibrations (WBV) occur when the body (seating or standing) is supported on a surface which is vibrating, e.g. in all forms of transportation and when working near heavy industrial machinery. Hand and arm transmitted vibrations (HAV) occur when the vibration enters the body through the hands, e.g. in various work processes where rotating or percussive power tools, or vibrating workpieces, are held by the hands or fingers. There are well documented musculoskeletal issues and pathologies that arise when workers are exposed to mechanical vibrations [3].

In many situations, workers exposed to mechanical vibrations (WBV and/or HAV) are also exposed to high levels of noise. The question that has been frequently asked is does the combined action of noise and vibrations have a synergetic (additive or interactive) effect regarding hearing loss. In other words, is the resulting loss larger when vibrations are also

present?

In the field of Occupational Hygiene, there will be some occasions where there are exposures to two or more agents acting simultaneously. The term “synergetic effects” is used when the resulting health effects are larger than those expected by the sum of the individual effects acting separately. In the case of noise and vibrations, the term might not apply because there is no evidence of effects of vibrations on hearing. So, it will be more appropriate to talk in terms of “enhancement” of the effects of the noise, when vibrations are present. In summary, the question is “does the presence of vibrations (WBV or HAV) increases the risk of hearing loss”?

A search of the literature was conducted using Google ScholarTM and MendeleyTM databases. Keywords for our search included noise induced hearing loss and mechanical vibration. The search yielded very few investigations. The present paper is a systematic review of those investigations from our search that we judged to be conducted with adequate rigor.

2. **Review of the literature**

In an early study, Okada [4] measured temporary threshold shift (TTS) after exposing 5 male students to a 101?dB sound?pressure level (SPL) broad band steady?state noise. The TTS was increased by simultaneous vibration of 500 cm/sec2 and 5 Hz, which is regarded as the resonance frequency of human body.

Pyykkö et al. [5] performed a longitudinal study of hearing loss and hand-arm vibrations among a group of lumberjacks in the years 1972 (n=72) and 1974— 1978 (n=203). Among the conclusions, he found that with equal noise exposure the noise induced permanent threshold shift (NIPTS) was about 10 dB greater in lumberjacks with vibration induced white fingers symptoms (VWF) than without VWF. Pyykkö and colleagues surmised that the possible reason for more advanced NIPTS in subjects with VWF is that vibration might operate in both of these disorders through a common mechanism— that is, producing a vasoconstriction in both cochlear and digital blood vessels as a result of sympathetic nervous system activity.

Manninen [6] undertook an experimental investigation of the combined effect of noise, whole body vibrations, and dynamic muscular work on TTS2 (after 2 minutes) at 4000Hz and 6000 Hz. He found that noise plus vibration, and noise plus dynamic muscular work, caused the most obvious combined effects. The combined effect of all three factors (noise, vibration, and work) on the TTS2 values after three consecutive exposure periods was significant at the ?= 0.025 level at 4000 Hz, and at the ?= 0.05 level at 6000 Hz.

In a study by Pyykkö, Pekkarinen & Starck [7], a detailed analysis of risk factors for the development of sensory-neural hearing loss (SNHL) was carried out on 122 forestry workers. The authors stated: “We did not observe any exaggerated risk of hearing loss due to combination of noise and vibration”. Another interesting observation is that in combined exposure, subjects with Vibration White Fingers (VWF), as well as subjects with enhanced diastolic blood pressure, will run a higher risk for noise induced hearing loss.

Pekkarinen [8] studied the interaction between noise exposure (broadband at 100 dB(A)) and hand-arm vibration (125 Hz at an acceleration of 2 m/s2) in people with vibration induced white finger symptoms (VWF). As per the author, this interaction is evidenced as a permanent hearing loss. However, he couldn’t explain why this interaction is seen only in people with VWF.

Zhu, Sakakibara, & Yamada [9] investigated whether hand-arm vibration and noise have a combined effect on temporary threshold shift (TTS2) of hearing among healthy subjects. Their results showed that simultaneous exposure to hand-arm vibration and noise can enhance the TTS2 of hearing compared to only exposure to noise. However, hand-arm vibration alone did not cause TTS2.

The data from Palmer et al. [10] support an association between finger blanching and hearing loss, which is not explained by confounding occupational exposure to noise. They suggest that further investigations are warranted to confirm the association and explore possible mechanisms, such as sympathetic vasoconstriction in the cochlea.

Zou, Pyykkö, Sutinen, & Toppila [11] applied transcranial vibration to seven animals at a frequency of 250 Hz for 15 min (five animals were used as normal controls) to investigate cellular and molecular mechanism linked to vibration induced hearing loss in animal models. Compound action potential (CAP) thresholds were measured by round window niche action electrodes. The average immediate hearing loss was 62 dB and 48 dB after three days. The authors concluded that transcranial vibration from temporal bone drilling produces cochlear shear stress that may be linked to both the damage and repair process of the cochlea.

Sutinen, Zou, Hunter, Toppila, & Pyykkö [12] studied the role of temporal bone vibration in the etiology of hearing loss, following the hypothesis that sensorineural hearing loss after middle ear surgery can be explained by the noise generated by drilling, without considering the vibration generated by the burr. They used an electromagnetic shaker to vibrate the bony external ear canal of guinea pigs (n = 30) at different frequencies and accelerations. The hearing threshold was measured with auditory evoked responses. A significant threshold shift developed but recovered after 7 days.

House, Sauvé, & Jiang [13] assessed construction workers for hearing loss and other factors. The authors found that vibration white fingers (VWF) had a statistically significant effect on hearing loss for all audiometric frequencies combined after controlling for years worked in construction.

Pettersson, Burström, Hagberg, Lundström, & Nilsson [14] studied 189 workers in a heavy engineering industry, with Hand-Arm Vibrations (HAV) exposure, through questionnaires, observations, and measurements. The results showed that working with vibrating machines in an environment with noise exposure increases the risk of hearing loss, supporting an association between exposure to noise and HAV, and the noise-induced hearing loss.

Turcot, Girard, Courteau, Baril, & Larocque [15] identified 96 workers with Vibration White Fingers (VWF) in a population of 15,751 vibration-exposed workers. They all had significantly worse hearing at every frequency studied (500, 1000, 2000 and 4000 Hz) compared with other mining and forestry workers without VWF. The authors conclude that their study confirms previous findings of greater hearing loss at higher frequencies in workers with VWF. The authors also found a significant difference in hearing loss at low frequencies. Therefore, these findings support the association between combined noise and hand-arm vibration (HAV) exposure and noise induced hearing loss (NIHL) in workers with VWF.

3. **Summary**

The review of the above papers appears to confirm that the risk of hearing loss increases in the presence of vibrations, both hand-arm or whole body. Although the cause is not clearly identified, the effects appear to be evident especially in workers with VWF. The blanching of the fingers (in the HAV pathology), suggests a circulation problem common to fingers and

cochlear hair fiber cilia, but this is something that needs further investigation.

Another possibility that cannot be discounted based on the available evidence is that workers with VWF were also exposed to a high level of bone-conducted noise. At the cochlea, air-conducted and bone-conducted noise exposures should not be distinguishable. Future experimental studies involving animal models might consider incorporating noise exposure with and without bone-conducted noise exposure in order to rule out this alternative explanation.

Regardless of the mechanism involved, it appears that the presence of vibrations represents an additive hearing loss risk. The action to be taken is the same as when vibrations are not present: the noise exposure should be brought to below the 85 dBA level either by engineering noise controls of by wearing of hearing protectors. There is no evidence of hearing loss caused by only exposure to vibrations. However, vibrations (both HAV and WBV) can be harmful. As a result, measures must be put in place to bring vibration amplitude (and accelerations) below safety limits.

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