

VIBRATION-WHITE FOOT IN A WORKER WITH DIRECT VIBRATION EXPOSURE TO THE FEET

Aaron Thompson¹, Tammy Eger², Kristine Krajnak³, and Ron House¹

¹University of Toronto and St. Michael's Hospital, Toronto, Ontario, Canada,

²Laurentian University, Sudbury, Ontario, Canada,

³Health Effects Laboratory Div., National Institute for Occupational Safety and Health, Morgantown, WV, USA

1. INTRODUCTION

The acute and chronic effects of segmental vibration exposure to the hands are well documented (Noel, 2000). Chronic exposure to hand-transmitted vibration results in hand-arm vibration syndrome (HAVS), a disorder consisting of vascular, neurological and musculoskeletal pathology in the upper extremities. That a condition analogous to HAVS might occur in the feet after segmental lower-extremity vibration exposure is biologically plausible though not well studied; the presented case (Thompson et al., 2010) represents the first published report on this topic in the English language literature, with only one other case report in a non English journal (Tingsgard et al., 1994).

2. CASE REPORT

A 54-year-old retired miner presented with a 2-3 year history of cold intolerance in his feet and cold-induced blanching in his toes. The worker denied any significant symptoms suggestive of HAVS such as finger blanching, cold intolerance in the hands or numbness and tingling in the fingers. He had worked in the mining industry for 35 years and was exposed to foot-transmitted vibration primarily via the use of underground bolters at least 4 hours per day, 3 days a week in the 4 years immediately preceding assessment. The main control console of underground bolters is located on a platform mounted on the machine. When the machine is in operation the platform vibrates, which exposes the worker standing on the platform to continuous foot-transmitted vibration.

The worker had a past history of hypertension and hypercholesterolemia, and was an ex-smoker with a 35-pack year history of smoking. He stopped smoking 6 years prior to the assessment. Doppler imaging at the time of assessment showed no peripheral artery insufficiency in the arms or legs. The worker had no history of connective tissue disease, diabetes mellitus, gout, arthritis, neurological problems, or thyroid disease. There was no reported history of frostbite to the fingers or toes. The only medication at the time of assessment was rosuvastatin. Physical examination showed blood pressure of 160/90. Heart rhythm was regular. There was no evidence of vessel occlusion on Adson's or Allen's testing. Vascular, neurological and musculoskeletal examination of the lower limbs was unremarkable.

Blood tests for systemic causes of secondary Raynaud's phenomenon, including complete blood count, erythrocyte sedimentation rate, thyroid-stimulating hormone, cryoglobulins, rheumatoid factor, antinuclear antibody and serum immunoelectrophoresis were all normal. Standard testing for HAVS was performed. All results were normal, with the exception of cold provocation plethysmography, which showed normal plethysmographic toe waveforms at room temperature, with significant dampening of the waveforms post cold stress. The results in the fingers were normal. These results were consistent with a vasomotor disturbance in the toes associated with cold sensitivity, but not in the fingers. The worker was diagnosed with vibration white foot. He was advised to avoid cold exposure as much as possible, to dress warmly whenever exposed to cold ambient conditions, and to minimize future vibration exposure to the feet. A trial with a calcium blocking agent was suggested for treatment of his cold-induced vasospastic symptoms. At four months follow-up, the worker reported no change in his symptoms, though he had not yet attempted pharmacological therapy as a treatment option.

3. EXPOSURE ASSESSMENT

Vibration measurements from the platforms of bolting machines and similar platforms upon which miners work indicate vibration exposure at the feet; however, a full description of the conditions under which the measurements have been taken are often not reported. Hedlund (1989) reported that vertical vibration exposure measurements at the feet during the operation of two drills on a metal raise platform exceeded the International Organization for Standardization (ISO) 2631-1 health guidelines after 2.5 hrs of exposure (Hedlund, 1989). Hedlund did not report the frequency weighted vibration acceleration values, though did report the dominant frequency as being 40 Hz. Foot transmitted vibration from bolting off a scissor lift and a bolting platform were reported to be below the International Organization for Standardization (ISO) 2631-1 health guidelines for whole body vibration (WBV) for 8-hrs of exposure (Eger et al., 2006). The dominant frequency was not reported in this study but was confirmed with the author to be 40 Hz [Personal communication; Eger, T.].

4. DISCUSSION

This case demonstrates vasospastic disease in the feet of a worker with a history of foot-transmitted vibration exposure. The diagnosis was based on history of segmental vibration exposure to the feet, compatible symptoms, a negative work-up for other secondary causes of Raynaud's phenomenon, and documentation of cold-induced vasospasm in the toes by plethysmography. Unremarkable Doppler investigation argued against significant peripheral arterial insufficiency, while Buerger's disease was deemed unlikely given the worker's current non-smoking status, lack of findings in the hands, normal laboratory investigations, and normal baseline plethysmography.

Postulated vascular pathophysiological mechanisms of vibration syndrome (local and systemic) include: 1) vasospasm resulting from centrally mediated increased sympathetic tone; 2) increased circulating systemic vasoactive mediators such as endothelin-1; 3) vasospasm due to local selective loss of calcitonin-gene-related peptide (CGRP) fibers in the digits, resulting in an imbalance between endothelin-1 (vasodilator) and CGRP nerve fibers (vasoconstrictor); 4) hypertrophy of smooth muscle cells due to repetitive episodes of vasoconstriction; 5) microangiopathy as a result of direct trauma from segmental vibration exposure, and 6) arterial thrombosis due to traumatic shear stress to the vascular endothelium, triggering a coagulation cascade. These postulated mechanisms help to explain why symptoms are usually most severe in the extremities directly exposed to vibration (in this case the feet), while non-exposed extremities tend to have less severe symptoms best attributed to central mechanisms and circulating systemic vasospastic mediators.

The literature provides some insight into the characteristics of vibration levels from mining machines applicable to foot-transmitted vibration. While reported acceleration values vary, the dominant frequency appears to be in the 40 Hz range (Hedlund, 1989; Eger et al., 2006). The current guideline used for assessing health risks from vibrating platforms in mining is the ISO 2631-1 health guideline for whole body vibration (WBV). However, the frequency weighted acceleration values in ISO 2631-1 are focused on frequencies between 1 and 20 Hz (resonant frequencies for the pelvis and spine), while the relevant anatomic factors of the feet and toes might be expected to be more analogous to the finger-hand-arm system which is more susceptible to vibration at higher frequencies (40-100 Hz for the hand-arm system, and > 100 Hz for the fingers) (Dong et al., 2004). If this is the case, workers exposed to foot-transmitted vibration through platforms, drills and bolters, where the dominant frequency is 40-50 Hz, may not be protected by the ISO health risk guidelines, and may be at risk of developing vascular dysfunction in the feet. Additional research is needed to characterize foot

exposures and to determine which workers are at greatest risk for developing vibration-white foot.

A population-based prevalence estimate for the number of workers exposed to foot-transmitted vibration is not available. The United States Bureau of Labor Statistics 2009 estimates 4,950 workers roof bolters in mining (BLS 2009). While not all of these workers would use vehicle-mounted underground bolters (as in this case), the prevalence of foot exposure to vibration in the mining sector may increase as greater use is made of mechanized equipment for drilling, bolting and moving materials (McPhee B, 2004). Foot-transmitted vibration may also occur in the use of other equipment and locations, such as forklifts operated from a standing position, jacklegs in construction, and crusher plant operations (the platform the operator stands on may not be isolated from the crusher).

No exposure limits exist for prevention of foot vascular effects from direct vibration exposure to the feet. The ISO provides guidelines for whole body and hand-arm vibration exposure assessment and risk evaluation, but as noted in this report, vibration white foot may not be adequately prevented by use of the whole body guideline. Legislation in the European Union controls occupational exposure to hand-arm vibration. The U.S. American Conference of Governmental Industrial Hygienists has exposure limits for whole body and hand-transmitted vibration. In Ontario, where this case was seen, there are no regulations for hand-arm or whole body vibration, though the general duty of employers to protect workers might be interpreted as requiring them to observe the exposure limits of other jurisdictions. In the future, foot transmitted vibration may be considered as an additional hazard requiring attention.

REFERENCES

- Dong, R. G., Schopper, A. W., McDowell, T. W., Welcome, D. E. Wu, J. Z., Smutz, W. P., Warren, C., and Rakheja, S. (2004). "Vibration energy absorption (VEA) in human fingers-hand-arm system," *Med. Eng. Phys.* **26**(6), 483-492.
- Eger, T., Salmoni, A., Cann, A., and Jack, R. (2006). "Whole-body vibration exposure experienced by mining equipment operators," *Occup. Ergo.*, **6**, 121-127.
- Hedlund, U. (1989). "Raynaud's Phenomenon of fingers and toes of miners exposed to local and whole-body vibration and cold," *Int. Arch. Occup. Environ. Health*, **61**, 457-461
- Noel, B. (2010). "Pathophysiology and classification of the vibration white finger," *Int. Arch. Occup. Environ. Health*, **73**, 150-155.
- Thompson, A., House, R., Krajnak, K., and Eger, T. (2010). "Vibration white foot: a case report," *Occup. Med. (Lond.)* **60**, 572-574.
- Tingsgard, I., and Rasmussen, K. (1994). "Vibration-induced white toes," *Ugeskr Laeger*, **156**, 4836-4838.
- U.S. Bureau of Labor. Occupational Employment Statistics, 47-5061 Roof Bolters, Mining. 2009.
- McPhee, B. (2004). "Ergonomics in mining," *Occup. Med.*, **54**, 297-303.