Whole body and seat to head vibration exposure during the operation of different mining vehicles: A pilot study

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Summary

Whole body vibration (WBV) and head vibration were measured during the operation of three different mining vehicles in various operating conditions. WBV exposure was assessed according to ISO standards, and the relationship between seat and head vibration was also examined. WBV exposure was highest in the skid steer, but head vibration was amplified relative to the seat in all conditions.

Introduction

WBV exposure has been extensively studied in mining vehicles; typically, exposure and risk levels are assessed against ISO standards [1]. The transmission of vibration from the seat to head is less frequently measured but would provide valuable information regarding potential health effects of vibration. While prolonged WBV vibration at the spine's resonant frequency may damage the spine and surrounding musculature, prolonged head vibration may result in deleterious cognitive effects [2], but this has yet to be explored in mining equipment. The purpose of this study was to measure WBV and seat to head vibration patterns during the operation of various mining vehicles.

Methods

Two accelerometers (NexGen Ergonomics) secured within a rubber seat pad and on the top of the hardhat of 5 miners measured WBV and head vibration exposure during the operation of 3 different mining vehicles: an 8-yard scoop tram (ST), a 6-yard ST, and a skid steer. Vibration was measured in four 20-minute blocks for each vehicle, in which driving conditions varied (ST: loaded/unloaded, gear 1/gear 2; skid steer: loaded/unloaded, maintained/mixed terrain).

WBV exposure was assessed according to ISO-2631-1 standards. The extrapolated level of exposure for 2, 6, 10, and 11 hours of daily exposure was computed and compared against the Health Guidance Caution Zone upper (threshold limit value; TLV) and lower (action limits; AL) limits. Additionally, the Z axis (vertical) acceleration data was used to determine the seat to head signal coherence and transmissibility within the frequency range of 0.5-20 Hz [3]. Outcomes were descriptively compared between conditions.

Results and Discussion

WBV exposure was below the TLV for the full day (up to 11 hrs) for both the 8 and 6-yard STs when operated in gear 1 (slow speed), but for only up to 6 hrs when operated in gear 2 (fast speed). Operation of the skid steer for greater than 2 hrs in any condition resulted in exposure values above the TLV. Increased driving speed and decreased weight of vehicle have previously been shown to increase vibration exposure [1], which is in agreement with the current results.

A strong relationship between the seat and head vibration signals was found; peak coherence was above 0.80 in all vehicles/conditions (Table 1), indicative of a transfer of vibration from the seat to head. Additionally, peak transmission values were greater than 1 in all conditions, indicating amplification of the head vibration (Table 1). The greatest amplification of head vibration occurred during operation of the skid steer (peak transmission = 5.05). In all vehicles, strong coherence (>0.80) and/or head vibration amplification (transmission >1) occurred at frequency ranges known to cause resonance of the spine (4-6 Hz), that may lead to negative health effects with prolonged exposure.

Conclusions

While certain conditions resulted in WBV exposure within acceptable ISO limits, the transfer and amplification of head vibration should be considered to provide a more comprehensive assessment of potential health effects.

References

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Table 1: Coherence and transmission metrics. In each condition (gear, terrain), the exposure when driving loaded and unloaded were combined.

Vehicle	Condition	Freq. where coherence >0.80 (Hz)	Peak Coherence	Peak Coherence Freq. (Hz)	Freq. where transmission >1 (Hz)	Peak Transmission	Peak Transmission Freq. (Hz)
8-Yard ST	Gear 1	2.1-2.9	0.91	2.48	0.5-11	2.75	0.50
	Gear 2	1.5-3.1	0.98	2.25	0.5-6.7	2.21	5.05
6-Yard ST	Gear 1	2.5-3.2	0.87	2.80	0.5-9.2	3.32	0.70
	Gear 2	1.9-3.6	0.95	2.75	0.5-8.5	2.71	0.74
Skid Steer	Maint. terrain	3.4-5.6	0.93	4.27	0.5-6, 11.5-18.2	5.05	0.75
	Mixed Terrain	2.9-4.6	0.91	3.65	0.5-5.6, 10.7-20	3.37	0.73