WHOLE BODY VIBRATION ENERGY TRANSMISSION IN A PASSIVE SUSPENSION AND ELECTROMECHANICALLY ACTIVE SUSPENSION SEAT

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Introduction

Lower back injuries (LBI) are the most prevalent and costly non-lethal medical condition affecting the US workforce, resulting in significant financial implications in terms of lost work time and medical costs[1]. Exposure to whole-body vibration (WBV) has been deemed a risk factor for the onset and development of occupational LBI via epidemiological associations[2]. Vehicle seat design is among several factors which can greatly influence occupational WBV exposure[3]. The purpose of this study was to characterize WBV exposure and energy transmission in seats with differing suspension systems.

Methods

WBV exposures from two seats were compared as sixteen expereinced truck drivers drove a flatbed semi-truck (Model CL120064S-T; Freightliner Inc.; Portland, OR) over a 60 km standardized route. Floor and seat Power Spectral Densities (PSDs) were compared as the trucks travelled 2.09 (±0.4) km over a two lane highway for 163.5 (±16.3) seconds. One seat was a passive suspension air-ride seat (passive seat) (National Seating, Model 50093, 2000 Series; Commerical Vehical Group; New Albany, OH), which is standard equipment in most North American semi-trucks. The second seat was an electromechanically active suspension seat (EM-active seat) (BoseRide System; Bose Corporation; Framingham, MA). The passive seat relied on an air bellows and mechanical components to reduce vibration exposure while the EM-Active seat performed real-time vibration cancellation via an electromagnetic actuator.

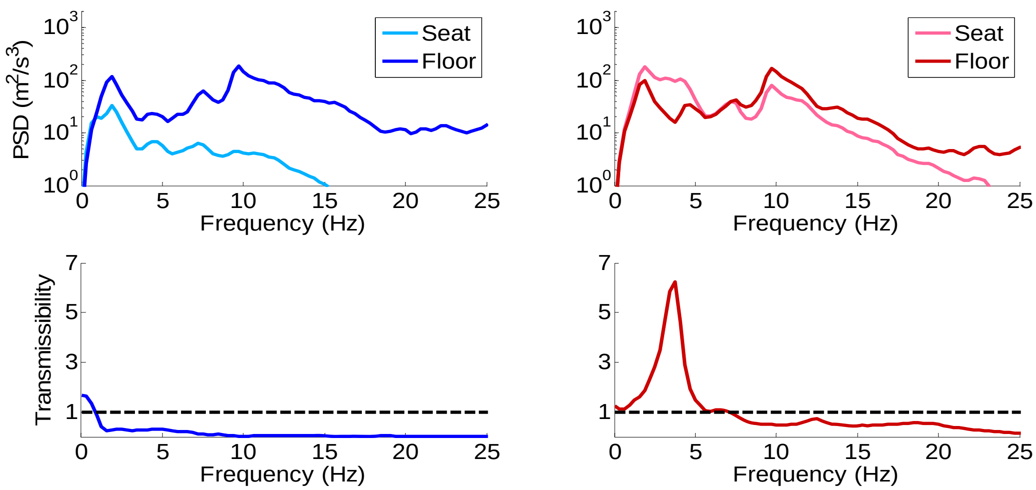
WBV exposures were collected in accordance with ISO 2631-1 standards. A tri-axial seatpad accelerometer (Model 356B40; PCB Piezotronics; Depew, NY) was mounted on the driver's seat and an identical accelerometer was magnetically mounted to the floor of the truck cab beneath the driver's seat. Acceleration data was collected at 1280 Hz using an eight channel data recorder (Model DA-40; Rion Co. LTD; Tokyo, Japan). Vehicle speed and location were simultaneously recorded at 1 Hz using a GPS logger (Model DG-100; GlobalSat; Chino, CA).

A LabVIEW program (v2009; National Instruments; Austin, TX) was used to parse the acceleration data based on GPS coordinates and then calculate the daily average weighted vibration [A(8)] for the whole route and the PSDs for the highway road segment. Acceleration data was weighted in accordance with ISO 2631-1 standards. PSDs for the weighted seat and floor accelerations were calculated using the Welch method[4] with a window size of 2048 points, an overlap of 512 points (256 points at each tail), and 2048 frequency bins. PSDs for each seat and accelerometer location were averaged for each frequency bin to derive a composite PSD from the 16 subjects. Energy transmissibility for each seat was calculated by dividing the PSD values at the seat by those at the floor.

Results

Over the whole route, the mean (±SEM) average weighted vibration normalized to reflect 8 hours of driving [A(8)] was 0.18 (±0.004) and 0.40 (±0.007) m/s^2 for the EM-active and passive seats, respectively. The top of Figure 1 shows the PSDs for the EM-active and passive seats. Energy transmissibility by seat is shown in the bottom of Figure 1, where values greater than 1 indicate amplification of the floor vibration energy and values less than 1 indicate attenuation. The EM-active seat attenuated vibration energy from the floor above 1 Hz whereas the passive seat amplified vibration energy between 1 - 7 Hz.

Figure 1 – PSDs and energy transmissibility for EM-active (left) and passive (right) seats.



Discussion

The A(8) exposures, PSDs, and energy transmissibility highlight the potential for EM-active seats to serve as engineering controls to reduce vibration exposure, particularly for the low frequency vibrations between 1-7 Hz. Attenuation at low frequencies is important because the resonant frequency of the lumbar vertebrae is near 4-5 Hz[5]. Though weighted acceleration values provide measures of exposure, PSDs should be evaluated to provide information on the frequency content of the vibration. Conclusions with respect to seat vibration amplification and attenuation cannot be drawn without spectral analyses of the vehicle seat and floor.

References

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