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Comparisons of Single-axial and Multi-axial Suspension Seats in Reducing Whole Body Vibration and Related Biomechanical Stress: Mining Vehicle Application

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Abstract: Mining vehicle operators have high prevalence of work-related musculoskeletal disorders (WMSDs) with lower back being most affected areas. Among risk factors, Whole Body Vibration (WBV) is known to be a major risk factor associated with WMSDs (especially, low back pain). Due to rough terrain in mining environment, mining vehicle operators' exposure to WBV is expected to be high with frequent impulsive shocks and substantial non-vertical components (e.g., lateral vibration). However, the current industry standard seats have shown limited performance in reducing such impulsive and non-vertical WBV exposures. Recently, a multi-axial active suspension has been developed to controls both vertical and lateral vibration in real time using electromagnetic actuators, which could be an effective, viable engineering control to reduce mining vehicle operators' WBV exposures. Therefore, this study determine whether a multi-axial (lateral + vertical) active suspension would be more effective in reducing mining specific WBV exposures and related biomechanical stress as compared to an industry standard seat (single-axial passive suspension) equipped with passive air suspension that is designed to address only vertical vibration. Thirteen healthy subjects were recruited to participate in a repeated-measures laboratory study. For realistic vibration exposures, a 6-degree-of-freedom large-scale motion platform was used to recreate actual field-measured miming equipment vibration profiles. While subjects were sitting in each seat, we continuously collected WBV exposures at 1,280 Hz per the ISO 2635-1 WBV standard; net joint torques at 120 Hz in the low back (L5/S1) and neck (C7) using a 3-D motion capture system; and muscle activity at 1,000 Hz in low back (erector spinae) and neck (splenius capitis) muscles using electromyography. The multi-axial active suspension seat had significantly lower vertical (Z-axis) weighted average vibration [A(8) m/s^2] as compared to the single-axial passive suspension seat ($p < 0.001$). However, there were no differences in lateral (Y-axis) WBV exposures between the seats. Relative to the single-axial passive suspension seat, the multi-axial active suspension seat reduced the lower low back joint torques in the sagittal plane ($p=0.01$), while no significant differences in the low back and neck joint torques were found in the coronal plane between the two seats. Muscle activity in the low back and neck showed similar trend with the joint torque measures; however, due to high variability, no statistical significant differences were observed. The lower joint torque and muscle activity suggest that the multi-axial suspension may have potential to reduce risks for musculoskeletal stress and disorders.

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