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Title: Evaluating the Effects of Multi-axial Whole Body Vibration Exposure on Postural Stability in Mining Heavy Equipment Vehicle Operators

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Focus Area: Musculoskeletal Disorders and Fall-related Injuries

Project Summary: Mining heavy equipment vehicle operators suffer from the highest occupational injury rates. Among all the injuries, the fall-related injuries are the second largest components in mining industry. The rate of the fall-related injuries has been much higher (up to 8 times) during egress as compared to ingress of vehicles. A likely cause for the disproportionally high fall-related injury rates during egress is thought to be loss of postural stability. Prolonged exposure to whole body vibration (WBV) negatively affects postural stability, by increasing neuromuscular reaction times and adversely affecting the visual, vestibular and somatosensory systems, therefore increasing the risk of falling.

In off-road mining vehicles, WBV exposures are multi-axial, meaning that the predominant WBV exposure is not necessarily limited to the vertical (z-axis) but can often include significant fore-aft (x-axis) and/or lateral (y-axis) WBV exposures. Because such multi-axial components of WBV exposures often have more detrimental effects on human responses, mining vehicle operators are at even greater injury risks compared to on-road drivers whose WBV exposures are predominantly on the vertical axis. However, the nature of the additional impact of multi-axial WBV on fall-related risk (e.g., postural stability) is poorly understood. Moreover, we do not have effective mechanisms to mitigate multi- axial WBV exposures because current engineering approaches to reduce these exposures rely on passive vertical (z-axis) suspension systems. Therefore, to serve this critical need for applied research, our objectives in this application are to quantify the impact of multi-axial WBV exposure on postural stability, and to understand how this impact may be mitigated. This work supports our longer-term goal of reducing the prevalence of falling and related injuries among mining vehicle operators.

Our central hypothesis is that exposure to multi-axial WBV increases the risk of falling more so than single-axial vertical WBV by altering sensory orientation derived from effective integration of visual, vestibular and somatosensory information, hence impairing postural stability. We also hypothesize that this risk can be more effectively mitigated by a multi-axial active suspension seat than the current industry standard of single-axial (vertical) passive suspension seats. These hypotheses are supported by our preliminary work showing that exposure to lateral-dominant WBV significantly increases head acceleration, which is known to affect postural stability. In addition, the increased head acceleration during multi-axial WBV exposure was more effectively reduced by using a new multi-axial active suspension compared to industry-standard seat suspensions. Our rationale for this study is that if we can use an effective engineering control to reduce multi-axial WBV to levels previously unobtainable, we can alleviate the associated loss in postural stability and therefore lower risks for fall- related injuries among mining vehicle operators. To achieve our research objectives, we propose a repeated-measures laboratory study using 20 subjects in which we will replicate actual field-measured multi-axial vibration profiles and measure important aspects of postural stability in the following specific aims:

Specific Aim 1: Determine the relative impact of single- and multi-axial WBV exposure on postural stability. Our working hypothesis is that exposure to WBV with significant multi-axial components will, as compared to vertical-dominant WBV: (i) reduce functional limits of stability, (ii) increase sway during quiet standing (reduced standing balance) and (iii) prolong the duration of the preparatory imbalance phase and increase center-of-pressure displacement during the preparatory imbalance phase preceding functional tasks such as gait initiation and stair descent (impaired anticipatory postural adjustments).

Specific Aim 2: Determine the efficacy of single-axial passive and multi-axial active suspension seats in alleviating the adverse effects of multi-axial WBV on postural stability. Our working hypothesis here is that the use of a multi-axial suspension seat would alleviate the effects of multiaxial WBV on postural stability measures better than a single-axial passive suspension seat. Outcome measures will be the same as used in Specific Aim1.

The primary expected outcome of this proposed study is a clear delineation of the relative impact of single- and multi-axial WBV exposures on postural stability among off-road vehicle operators. This outcome will provide the neurophysiological underpinnings relating the type and extent of WBV with the risk of fall-related injuries. If, as expected, a new innovative engineering control evaluated in this study reduces exposure to multi-axial WBV and its adverse effects on postural balance more effectively than industry standard approaches, our results have the great potential to change industry practice and reduce fall-related injury risks. Equally important, the results are expected to have substantial translational impact because understanding the extents to which the different aspects of postural stability (i.e., the three measures listed above) are affected by multi-axial WBV will help understand the relative contribution of the different underlying postural control systems. This, in turn, will provide a basis for developing new engineering controls to reduce multi-axial WBV and help in better targeting such future interventions to improve occupational health outcomes among mining vehicle operators.