Whole-body Vibration and Risk of Lumbar Injury- Field studies on Dumper Operators Using Biomechanical Models in Compliance with ISO 2631-5:2018

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Abstract: Exposure to whole-body vibration (WBV) is linked to musculoskeletal disorders, with chronic low back pain (LBP) and lumbar disc degeneration being common outcomes. This study aims to assess the likelihood of lumbar injury in dumper operators with occupational exposure to whole-body vibration (WBV). Cross-sectional study design was used to determine the prevalence of self-reported LBP among dumper operators through standard Nordic questionnaire. Field tests were conducted to assess the WBV exposure levels of dumper operators(n=61) in an open-cast coal mine. Biomechanical models were employed to predict the long-term health risks associated with WBV exposure and its cumulative effects on the operators' lumbar spine, following the guidelines outlined in ISO 2631-5:2018. Fast Fourier transform analysis revealed predominant peaks in seat-pad acceleration within the 2-8 Hz frequency range. Risk factor (R^A) and equivalent daily compressive dose ($S_d{}^A$) values were calculated for six spinal levels ranging from T12/L1 to L5/S1. $S_d{}^A$ values ranged from 0.29 to 0.73 MPa, and the RA factor values ranged from 0.27 to 0.93. Two sample t-test revealed a statistically significant difference in mean RA values between individuals with and without LBP ($p<0.001$). This finding highlights the potential association between risk of lumbar injury and the presence of self-reported low back pain. The study emphasizes the importance of epidemiological validation of the boundary limits specified in ISO 2631-5:2018 to efficiently reduce health risks linked to WBV exposure in industrial environments.

Keywords: ISO 2631-5:2018, low-back pain, musculoskeletal disorder, occupational health

1. Introduction

Whole-body vibration (WBV) significantly contributes to musculoskeletal disorders (MSDs) in high-risk industries like mining (Murtoja Shaikh et al., 2022). Mining, essential for the global economy, exposes workers to occupational hazards, including WBV from heavy machinery such as dump trucks, excavators, and drills (Duarte et al., 2020). This exposure is linked to chronic low back pain (LBP) and lumbar disc herniation (Wahlström et al., 2018). Chronic LBP and degenerative spine disorders, such as osteophytes, sciatic pain, and peripheral nervous system changes, are associated with WBV exposure (Bovenzi, 1996; Mandal & Manwar, 2017). Additionally, WBV leads to postural disorders, vestibular disturbances, muscle fatigue, and digestive issues (Bovenzi & Hulshof, 1999). Prolonged exposure to vibrations causes mechanical overloading of the spine, resulting in spinal degeneration and anatomical damage (Seidel, 2005). Chronic LBP affects physical and psychological health, highlighting the importance of exploring WBV exposure and its long-term health consequences (Smith & Osborn, 2007).

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2. Methodology

This cross-sectional study was conducted to assess the prevalence of low back pain (LBP) and the associated risk of lumbar injury among dumper operators exposed to whole-body vibration (WBV) in an open-cast coal mine. The study adhered to ethical standards, and informed consent was obtained from all participants. The study involved 61 dumper operators who were selected based on specific inclusion criteria: Minimum five years of professional driving experience. No history of major spinal surgery or severe musculoskeletal disorders unrelated to WBV. Willingness to participate in the study and provide informed consent. The prevalence of self-reported LBP was determined using the standardized Nordic questionnaire, a validated tool for assessing musculoskeletal symptoms. Participants were asked to report the occurrence and of LBP over the past 12 months and the past 7 days. Field measurements of WBV exposure were conducted using seat-pad accelerometers mounted on the operators' seats. Data were collected over a typical work shift to capture representative WBV exposure levels. Biomechanical models were employed to predict long-term health risks associated with WBV exposure. The study followed the guidelines outlined in ISO 2631-5:2018 to calculate the risk of lumbar injury factor (R^A) and the equivalent daily compressive dose (S_d^A) at six spinal levels (T12/L1 to L5/S1). These metrics were used to evaluate the cumulative effects of WBV on the lumbar spine.

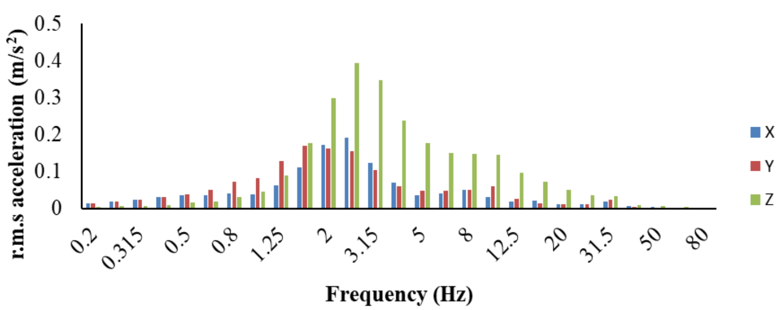


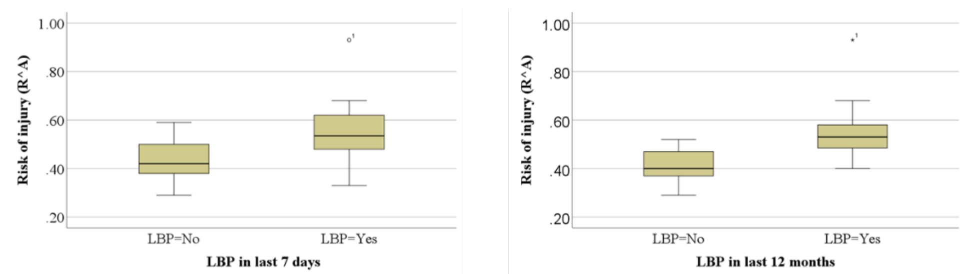
Figure 1. One-third octave band analysis of input seat-pad acceleration

3. Results and discussion

The Fast Fourier Transform (FFT) analysis of seat-pad acceleration data revealed predominant peaks within the 2-8 Hz frequency range, a critical range for assessing WBV effects on the lumbar spine (figure 1). Biomechanical modeling, in accordance with ISO 2631-5:2018 guidelines, was used to calculate R^A and S_d^A for six spinal levels from T12/L1 to L5/S1. The S_d^A values ranged from 0.29 to 0.73 MPa, indicating varying levels of compressive stress experienced across different spinal segments. The R^A factor values ranged from 0.27 to 0.93, reflecting the relative risk of lumbar injury. Our cross-sectional survey revealed that the prevalence of self-reported low back pain (LBP) over the past 12 months was significantly higher, with 45.9% of participants reporting LBP, compared to 32.7% reporting LBP in the last 7 days. A two-sample t-test comparing R^A values between dumper operators with and without self-reported low back pain (LBP) showed a statistically significant difference ($p<0.001$) (table 1). Specifically, individuals reporting the presence of LBP in last 7-days had a higher mean R^A value (0.551) compared to those without LBP (0.425). Similarly, for LBP reported in the last 12 months, individuals with LBP had a higher mean R^A value (0.551) compared to those without LBP (0.425) (Figure 2). This significant difference indicates the potential association between elevated R^A values and the prevalence of LBP among operators exposed to WBV.

Table 1. Results of the t-Test Comparing R^A Values between Participants with and without Self-Reported LBP

Test	LBP Reported	LBP No Mean	LBP Yes Mean	t-value	p-value	95% CI
Welch two sample t-test	Last 12 months	0.425	0.551	-5.042	<0.001	-0.176 to -0.075
Welch two sample t-test	Last 7 days	0.436	0.552	-3.869	<0.001	-0.177 to -0.054



(a) (b)

Figure 2. Box plot illustrating the distribution of R^A values among participants with and without self-reported Low Back Pain (LBP) in (a) last 7 days, (b) last 12 months

4. Conclusion

These findings stress on to the importance of thoroughly validating the boundary limits outlined in ISO 2631-5:2018 through epidemiological studies. The significant difference in R^A values between operators with and without LBP emphasizes the need for continuous epidemiological validation and refinement of these guidelines. Following these guidelines is crucial to effectively reduce health risks associated with WBV in industrial settings. Continuous monitoring and proactive policy interventions can significantly lower the incidence of lumbar injuries, ensuring safer and healthier working conditions. The observed differences emphasize the importance of ongoing epidemiological research to validate and refine WBV exposure guidelines. Future studies should continue to explore this relationship to develop effective strategies for mitigating WBV impacts and preventing LBP in occupational settings. By prioritizing worker health and safety through effective policy-making, we can create a more sustainable and productive industrial environment.

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