Whole-Body Vibration: Overview of Standards Used to Determine Health Risks

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Key Messages

- Routine measurements of WBV exposures are necessary to establish a prevention program
- Increased exposure duration and increased vibration intensity are associated with increased health risks; however, there is insufficient epidemiological evidence to establish a quantitative relationship between vibration exposure and health risks[4]
- ISO 2631-1 and ISO 2631-5 can be used to determine the probability of adverse health effects associated with WBV exposure
- ISO 2631-1 uses the Health Guidance Caution Zone to assess general health risks based on a worker's daily exposure to WBV using A(8) or VDV_{total}
- ISO 2631-5 uses stress values (MPa) and risk factor (R factor) values to suggest the risk of adverse health effects for the lumbar spine

Workers exposed to whole-body vibration (WBV) can be at increased risk for musculoskeletal disorders including low back problems, neck problems, and muscle fatigue[1,3]. Although there are no occupational health and safety regulations specifically related to daily vibration exposure limits in Ontario, the general duty clause, 25. (2)(h), which states "take every precaution reasonable in the circumstances for the protection of a worker", can be used to require risk determination and implementation of control strategies. Two standards that are commonly used to determine the probability of adverse health effects for workers in a seated position when exposed to WBV include ISO 2631-14 and ISO 2631-5[5].

ISO 2631-1

The ISO 2631-1 (1997) is a widely accepted standard for WBV assessment and provides guidelines on how to properly measure and interpret WBV exposure in relation to human health and comfort. A rubber seat-pad which contains a tri-axial accelerometer is secured to the seat (often using duct tape) below the buttock of the worker and orientated so the x-axis, y-axis and z-axis measure vibration in the fore and aft, side-to-side, and vertical directions respectively. The standard also indicates the weighting-curve that must be applied to each axis (z-axis W_d; x and y-axis W_k) to calculate a frequency-weighted acceleration[4]. The axes are weighted differently because the human body responds differently depending on the direction of transmission and the frequency content of the vibration exposure. Next, the standard defines several methods to evaluate health risks associated with WBV exposure. The basic evaluation method uses the frequency-weighted root mean square (r.m.s). The r.m.s. is a second-power equation that represents the average acceleration over the measurement period, and is relatively insensitive to shocks or jolts (acceleration peaks). The fourth power vibration dose method (VDV) is more sensitive to acceleration peaks than the basic method4. The criteria for using either the r.m.s or VDV is based on the crest factor (CF), which is the ratio of the peak acceleration to the r.m.s. A CF greater than 9 suggests that the VDV would be a more appropriate method for health risk assessment.

When determining the probability of adverse health effects, the frequency-weighted r.m.s. acceleration is determined for the x, y, and z-axes. The axis with the highest r.m.s magnitude is used in the health risk assessment. Although there is ambiguity in this application, the standard also states, "When vibration in two or more axes is comparable, the vector sum is sometimes used to estimate health risk."[4] The standard also indicates that a multiplying factor, k=1.4, should be applied to the x and y-axis; however, the application of this factor is not supported by all researchers[2]. The next step is to compare the r.m.s. acceleration or VDV to the Health Guidance Caution Zone (HGCZ). The standard suggests that health risks should be based on exposure durations between 4-8 hours, as assessments based on "shorter durations should be treated with extreme caution."[4] Both the r.m.s and VDV can be expressed in the form of a daily vibration exposure values, A(8) and VDV_{total} , respectively.

The HGCZ consists of lower-and upper-boundary values, which define the probability of health risks based on the magnitude of vibration exposure. The upper and lower boundaries of the eight-hour HGCZ for frequency-weighted r.m.s. accelerations, A(8), are 0.9 m/s^2 and 0.45 m/s^2 , respectively and 17 $m/s^{1.75}$ and 8.5 $m/s^{1.75}$ for the 8-hour equivalent vibration-dose value (VDVtotal). The standard states that, "For exposures below the zone, health effects have not been clearly documented and/or objectively observed; in the zone, caution with respect to potential health risks is indicated and above the zone health risks are likely."[4]

Implications for the Prevention of MSD

Long-term exposure to WBV puts workers at an increased risk for low back and spine disorders. ISO 2631-1 or ISO 2631-5 can be used to determine the probability of adverse health effects. A vibration management program should include regular monitoring of worker exposure to WBV to ensure daily exposure to WBV is below the upper boundary of the ISO 2631-1 HGCZ and the upper limit of the Sed and R factor values published in ISO 2631-5.

ISO 2631-5

The ISO 2631-5 (2004) was developed to determine the risk of adverse health effects on the lumbar spine when exposed to WBV contacting multiple shocks5. Much of the setup for measuring the acceleration at the seat pan follow the guidelines in the ISO 2631-1, except that the acceleration values are used to calculate a daily equivalent static compression dose (Sed), and a risk factor (R factor) value. The S_{ed} represents the average daily dose of peak acceleration values experienced by the lumbar spine, and its units are megapascal (MPa; force per unit area). The R factor is calculated from the Sed, and also takes into account the age at which a person is first exposed to vibration, the number of days a year the person is exposed to vibration, and the number of years the person has been exposed to vibration. A S_{ed} value below 0.5 MPa is associated with a low lumbar spine injury risk while a value greater than 0.8 MPa is associated with a high probability of injury risk to the lumbar spine5. Similarly, an R factor value below 0.8 suggests a low injury risk, while a value greater than 1.2 suggests an elevated risk5. ISO 2631-5 also differs from ISO 2631-1 in that the calculated R factor value is unique to the worker since the calculation of the R factor is based on the worker's personal history of vibration exposure. A limitation of the ISO 2631-5 is that it has not been validated at the population level. Due to its limited use, the boundary levels of the ISO 2631-5 are likely to change when the standard is updated. Therefore, users should periodically check for standard updates for revised risk assessment values.

Conclusion

Due to ambiguities and lack of epidemiological support between standards, it is highly recommended that the methods of measurement and evaluation are clearly stated when reporting the level of health risk. Routine monitoring of WBV exposure in the workplace is key to managing risk and evaluating the effectiveness of control strategies. Full details on the equations and frequency-weighting curves required to conduct a risk assessment can be found in ISO 2631-1 and ISO 2613-5 documentation. Although both standards can be used to comment on health risks associated with exposure to WBV, decisions to implement control strategies should be based on multiple measurements of adequate duration. It is important that the users of the standards know the limitations of each method, and that the interpretations of adverse health risks are within the scope of the standards.

References

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