Occupational Health Clinics for Ontario Workers Inc.

WHOLE BODY VIBRATION

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Our bodies are exposed to vibration at work from many machines, such as construction machinery *(bulldozers, towmotors, forklifts and cranes),* heavy equipment *(grinders, jack hammers),* and power hand tools. Vibration has been proven to result in musculoskeletal disorders of both the hand and arm, the neck, and the back.

There are two types of occupational vibration: segmental and whole body. Segmental vibration is transmitted through the hands and arms, and is known to cause specific health effects such as Raynaud's syndrome. Whole body vibration is transmitted through the body's supporting surfaces such as the legs when standing and the back and buttocks when sitting. Along with musculoskeletal problems, exposure to occupational whole body vibration also presents a health risk to the psychomotor, physiological, and psychological systems of the body.

Whole Body Vibration Exposure

Industry	**Vehicles**
Manufacturing	Forklifts
Construction	Power shovels, towmotors, cranes, wheel loaders, bulldozers, caterpillars, earth moving machinery
Transportation	Buses, helicopters, subway trains, locomotives, trucks *(tractor/trailer)*
Agriculture	Tractors

Whole body vibration is transmitted to the body through the supporting surfaces such as the feet, buttocks or back. There are various sources of whole body vibration such as standing on a vibrating platform, floor surface, driving, and construction, manufacturing, and transportation vehicles.

The health effects of whole body vibration on drivers of heavy vehicle versus workers in a similar environment who were not exposed to whole body vibration have been compared. Research indicates back disorders are more prevalent and more severe in exposed to vibration versus non-exposed workers. With short term exposure to vibration in the 2-20 Hz range at 1 m/sec2, one can feel several different symptoms:

- Abdominal pain
- General feeling of discomfort, including headaches
- Chest pain
- Nausea
- Loss of equilibrium *(balance)*
- Muscle contractions with decreased performance in precise manipulation tasks
- Shortness of breath
- Influence on speech

Long-term exposure can cause serious health problems, particularly with the spine:

- disc displacement
- degenerative spinal changes
- lumbar scoliosis
- intervertebral disc disease
- degenerative disorders of the spine
- herniated discs
- disorders of the gastrointestinal system
- uro-genital systems

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MEASURING THE RISK FROM WHOLE BODY VIBRATION

Human response to whole body vibration depends on the frequency of vibration, acceleration (or magnitude) of the vibration, and how long a person is exposed to the vibration. Because of the difficulty of evaluating the response to vibration and inconsistencies in quantitative data obtained from research, the International Standards Organization (ISO) 2631/1, Evaluation of human exposure to whole body vibration, has been established. When using these criteria and limits, it is important to bear in mind the restrictions placed upon their application. Some research indicates that the standards are not low enough and that musculoskeletal disorders are caused from exposure to vibration levels below the standard.

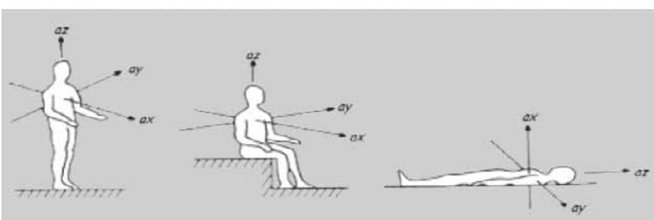
This standard is applicable only to situations involving people of normal health: that is persons who are considered fit to carry out normal living routines, including travel, and to undergo the stress of a typical working day or shift. The standard provides numerical limits for exposure to vibrations transmitted from solid surfaces to the human body in the frequency range of 1 to 80 Hz.

The standard addresses three different levels of concern: Reduced Comfort, Fatigue Decreased Proficiency, and Exposure Limits.

1. Reduced Comfort Boundary is applicable where passenger comfort is of concern, for instance on trains, subways, and buses. This limit will not be addressed here.

2. Fatigue Decreased Proficiency Boundary is applied to the situations where maintaining operator efficiency of a vehicle is of concern, such as situations where operators are required to work with safe manipulation of controls or to read the gauges accurately.

3. Exposure Limit applies to situations where the health and safety of the worker, such as back injuries and injuries to internal organs, is of concern.



Coordinate system to evaluate whole-body vibration (From ISO 2631)

MEASURING THE RISK FROM WHOLE BODY VIBRATION

Vibration is measured in three directions; longitudinal (buttocks to head –az), and two transverse directions (chest to back –ax, and right to left side –ay). When vibrations occur in more than one direction simultaneously, the effect on comfort and performance of the combined motion can be greater than that of any single component. In order to simplify measurements and comparisons of a vibration environment for the frequency range of 1 to 80 Hz, with respect to its effect on the worker, weighted accelerations can be determined. When the weighted acceleration (ax, ay, az) are combined, the resultant acceleration is the vector sum, a. This amount of the vector sum can be used primarily for comparison with the vector sum of other motions.

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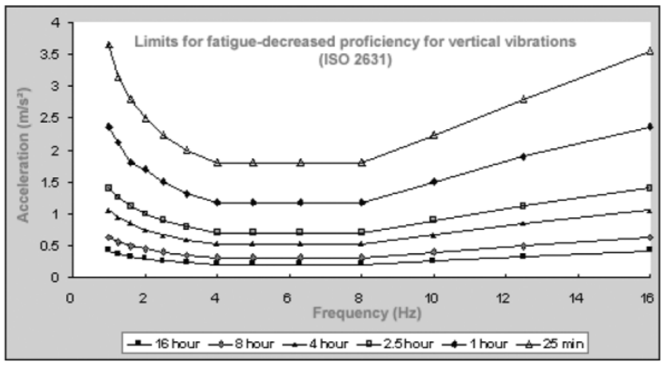
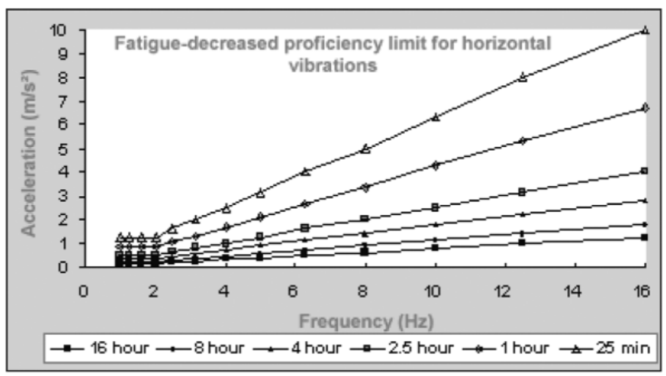
The following graph shows the fatigue decreased proficiency boundary for vibration based on the frequency of the vibration, and its acceleration. To obtain "Exposure Limit": multiply acceleration value by 2.



HOW TO DETERMINE EXPOSURE LIMIT



If the measured acceleration is in the vertical direction use graph 1, otherwise use graph 2. Studies have found that the resonance frequency-range of the lower back is 4–8 Hz. Given this information and the measured acceleration value at work, an exposure work time and acceleration limit can be determine. For example, the limit to whole-body vibration acceleration (vertical direction–graph 1) allowed for an 8 hours working day is 0.315 m/s2 if fatigue-decreased proficiency is the criterion and 0.63 m/s2 if health is the criterion *(exposure limit).*

Several studies have published vibration levels for various vehicles used in the construction, manufacturing and farming industries. These values are summarized below in order to compare them to the ISO Fatigue-Decreased Proficiency Boundary and Exposure Limits. Some of the vibration values were measured on various terrain types. Most values, however, did not take into account the maintenance level, age of vehicle, and other contributing factors. Thus, caution should be taken when using the value.

COMPARISON OF VIBRATION VALUES FOR VEHICLES RESEARCHED IN LITERATURE

Vehicle	Acceleration in the x,y,& z direction
Forklift truck	0.8
Bulldozer with standard seat	0.52–0.64
Tractor on brick paved road	1.76–2.03
Bulldozer with vibration absorption seat	0.43–0.80
Tractor on asphalt	1.17
Forklifts	0.4–2.3
Tractor on road	1.1
Caterpillar	0.6
Tractor in field	0.6
Bulldozers	0.4–1.3
Freight container	1.0
Power Shovels	0.5–2.3

CONTRIBUTING FACTORS TO THE VIBRATION MAGNITUDE

Although a new piece of machinery may expose workers to vibration levels within the ISO standards, several other factors influence the actual whole body vibration exposure magnitudes. The actual whole body vibration magnitude to which a worker is exposed is affected by vehicle maintenance, the terrain travelled, seat design, and other vibrating equipment on the vehicle. Whole body vibration is a contributing factor but not the sole cause of back disorders occurring to drivers of heavy machinery. The prolonged awkward sitting postures often required by drivers also affects back health. Drivers are often required to drive backwards or view to the side of the vehicle thus adopting twisted postures.

Drivers work in these awkward sitting postures for prolonged periods of time often between 6 and 14 hours depending on shift schedules. Awkward postures combined with repetition/duration and/or forceful exertions are considered risk factors for the development of musculoskeletal disorders. Furthermore, poor ergonomic designs of cabs, seats and inaccessible control gear *(pedals, steering wheel)* will affect the musculoskeletal health of a worker.

RECOMMENDATIONS TO REDUCE THE EFFECTS OF WHOLE BODY VIBRATION

1. Reduce the transmission of vibration to the worker by engineering the equipment or workplace more effectively. For example:
   - improving vehicle suspension
   - altering the position of the seat within the vehicle
   - mount equipment on springs or compression pads
   - maintain equipment properly *(i.e., balance and replace worn parts)*
   - proper engineering of seating
   - use materials that generate less vibration
2. Decrease the amount of vibration to which the driver is exposed by:
   - reducing the speed of travel
   - minimizing the exposure period by alternating working tasks where vibration is present and
   - those where it is negligible
   - increasing rest/recovery time between exposures.
3. Modify the seat and control positions to reduce the incidence of forward or sideways leaning of the trunk, and provide back rest support.
4. Eliminate awkward postures due to difficulty of seeing displays or reaching control.
5. Where feasible, reduce or isolate workers from the vibration source. For example:
   - in seated tasks, provide a spring or cushion as a vibration isolator
   - in standing operations, provide a rubber or vinyl floor mat
   - minimize the undulations of the surface over which the vehicle must travel.

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Created 2005