Guide to good practice on

Whole-Body Vibration

Non-binding guide to good practice with a view to implementation of Directive 2002/44/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibrations).

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FOREWORD

Directive 2002/44/EC of the European Parliament and of the Council on the exposure of workers to the risks arising from physical agents (vibration) seeks to introduce, at Community level, minimum protection requirements for workers when they are exposed, in the course of their work, to risks arising from vibration.

Directive 2002/44/EC gives ‘exposure limit values’ and ‘exposure action values’. It also specifies employers' obligations with regard to determining and assessing risks, sets out the measures to be taken to reduce or avoid exposure and details how to provide information and training for workers. Any employer who intends to carry out work involving risks arising from exposure to vibration must implement a series of protection measures before and during the work. The Directive also requires the Member States of the EU to put in place a suitable system for monitoring the health of workers exposed to risks arising from vibration.

The evaluation and assessment of risks arising from exposure to vibration and the implementation of protection measures can be complicated. This non-binding "guide to good practice" will facilitate the assessment of risks from exposure to whole-body vibration, the identification of controls to eliminate or reduce exposure, and the introduction of systems to prevent the development and progression of injury.

This guide on whole-body vibration, together with its companion guide on hand-arm vibration (Hand-arm vibration non-binding guide to good practice with a view to implementation of Directive 2002/44/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibrations)), has been prepared under contract VC/2004/0341 for the European Commission Directorate General Employment, Social Affairs and Equal Opportunities.

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CHAPTER 1 INTRODUCTION

EU Directive 2002/44/EC (the 'Vibration Directive') places responsibilities on employers to ensure that risks from whole-body vibration are eliminated or reduced to a minimum (these responsibilities are summarised in Annex A)

This guide is intended to help employers identify hazards relating to whole-body vibration, assess exposures and risks and identify measures for safeguarding the health and safety of workers exposed to whole-body vibration risks.

The guide should be read in conjunction with the Vibration Directive or national legislation that implements the requirements of that Directive.

Whole body vibration is caused by vibration transmitted through the seat or the feet by workplace machines and vehicles (see Annex B). Exposure to high levels of whole-body vibration can present risks to health and safety and are reported to cause or aggravate back injuries (see Annex C). The risks are greatest when the vibration magnitudes are high, the exposure durations long, frequent, and regular, and the vibration includes severe shocks or jolts.

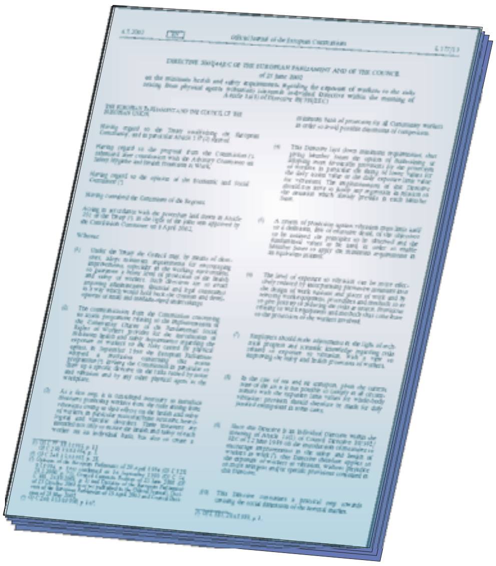
Work that involves exposure to whole-body vibration occurs commonly in off-road work, such as farming, construction and quarrying, but it can occur elsewhere, for example on the road in lorries and trucks, at sea in small fast boats and in the air in some helicopters. Whole-body vibration is not restricted to seated workers such as drivers, but may also be experienced during standing operations such as standing on a concrete crushing machine.

Back injury can be caused by ergonomic factors such as manual handling of the load and restricted or awkward postures. These are factors that may be at least as important as the exposure to whole-body vibration. Back injury can, of course, be caused by activities in or out of work unrelated to use of vehicles. In order to tackle successfully the problem of back injury in drivers and operators of mobile machinery it is important to identify and deal with all possible contributing factors together.

The 'Vibration Directive' (Directive 2002/44/EC - see "Further reading" box) sets minimum standards for controlling the risks from whole-body vibration. The Vibration Directive requires that member states of the European Union implement national legislation to implement the requirements of the Directive by 6th July 2005. National legislation may apply more favourable provisions than those required by the Directive, and should not reduce the protection afforded to workers by any pre-existing national legislation.

The Vibration Directive sets an exposure action value, above which it requires employers to control the whole-body vibration risks of their workforce and an exposure limit value above which workers must not be exposed[1]:

- a daily exposure action value of 0.5 m/s^2
  (or, at the choice of the EC Member State, a vibration dose value of 9.1 $m/s^{1.75}$);
- a daily exposure limit value of 1.15 m/s^2
  (or, at the choice of the EC Member State, a vibration dose value of 21 $m/s^{1.75}$);



The Vibration Directive places requirements on employers to ensure that risks from whole-body vibration are eliminated or reduced to a minimum. These responsibilities are summarised in Annex A.

The Vibration Directive is a daughter Directive of the Framework Directive (Directive 89/391/EEC - see "Further reading" box) as such many of the requirements of the Vibration Directive are derived from, and make specific reference to, the Framework Directive.

This guide will help employers comply with the Vibration Directive as it applies to whole-body vibration. The guide is intended to cover the methodology used for determining and evaluating risks; dealing with the choice and correct use of work equipment, the optimisation of methods and the implementation of protection measures (technical and/or organisational measures) on the basis of a prior risk analysis. This guide also gives details of the type of training and information to be provided to the workers concerned and proposes effective solutions for the other matters raised in the Vibration Directive. The structure for this guide is shown in the flow diagram of Figure 1.

[1] Member states are entitled (after consultation with the two sides of industry) to apply transitional periods to the exposure limit value for a period of 5 years from 6th July 2005 (Member States are entitled to extend this period for a further 4 years for agricultural and forestry machinery). The transitional periods only apply to the use of machinery supplied prior to 6th July 2007 for which (taking into account all available technical or organisational means to control the risk) the exposure limit value cannot be respected.

Further reading:

Vibration Directive:

Directive 2002/44/EC of the European parliament and of the Council of 25 June 2002 *on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) (sixteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)*

Framework Directive:

Directive of 89/391/EEC of the European parliament and of the Council of 12 June 1989 *on the introduction of measures to encourage improvements in the safety and health of workers at work*.

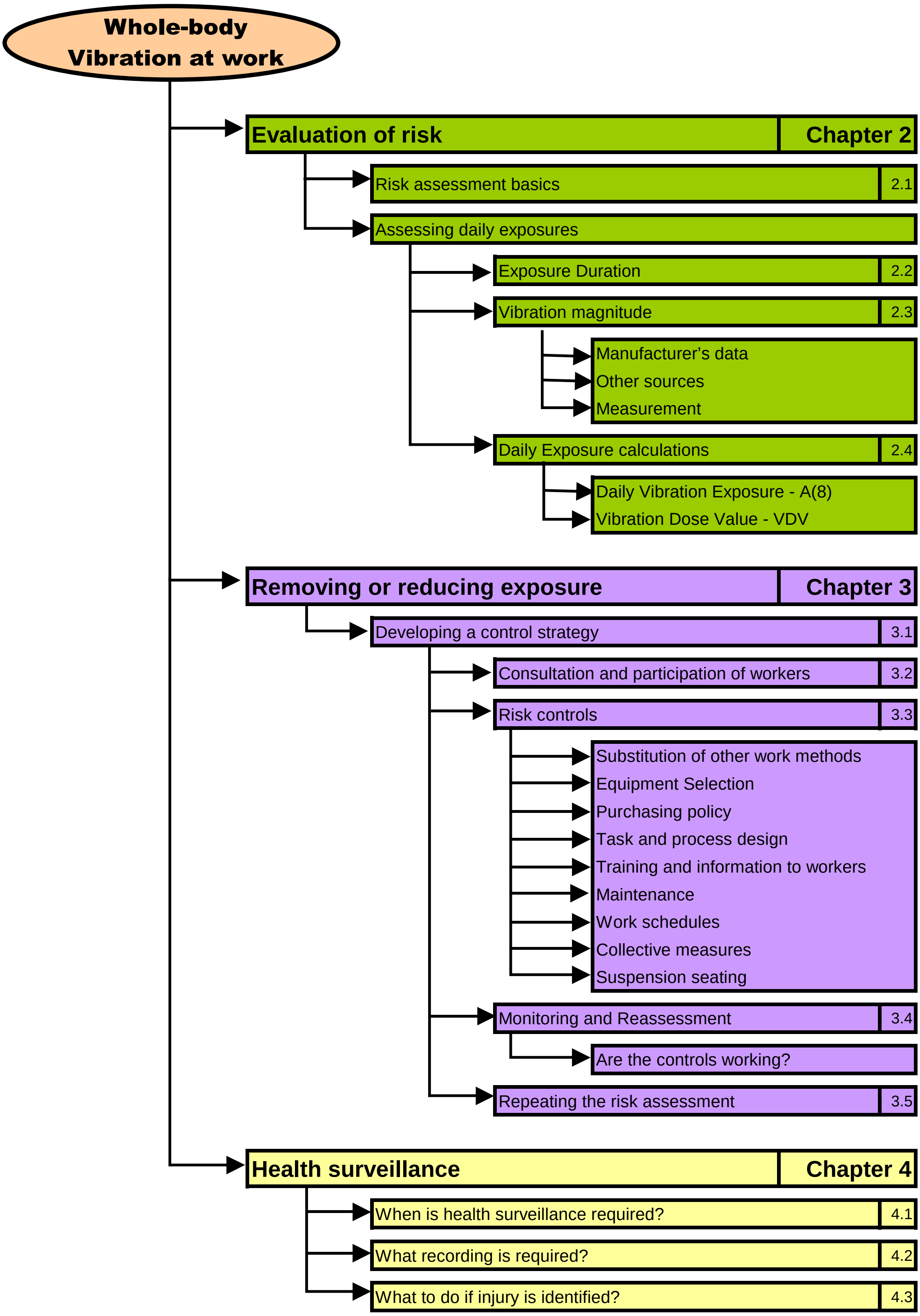


Figure 1 Whole-body vibration flow diagram

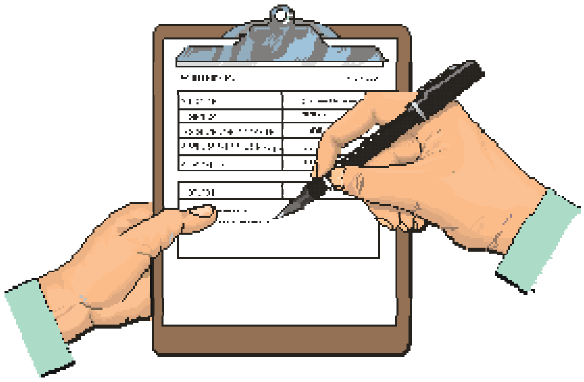
CHAPTER 2 EVALUATION OF RISK

The purpose of the whole-body vibration risk assessment is to enable you as the employer to make a valid decision about the measures necessary to prevent or adequately control the exposure of workers to whole-body vibration.

In this chapter we show how you can decide whether you may have a problem with whole-body vibration exposures in your workplace without the need for measurement or any detailed knowledge of exposure assessment

2.1 The basics of risk assessment

The risk assessment should:



- identify where there may be a health or safety risk for which whole-body vibration is either the cause or a contributory factor;
- estimate workers' exposures and compare them with the exposure action value and exposure limit value;
- identify the available risk controls;
- identify the steps you plan to take to control and monitor whole-body vibration risks; and
- record the assessment, the steps that have been taken and their effectiveness.

Along with whole-body vibration, other ergonomic factors may contribute to back pain, these include:

- poor posture while driving/operating plant;
- sitting for long periods without being able to change position;
- poorly placed control operations, which require the driver/operator to stretch or twist;
- poor visibility of the operation, which requires twisting and stretching to get an adequate view;
- manual lifting and carrying of heavy or awkward loads;
- repeatedly climbing into or jumping out of a high or difficult access cab.

All these factors can separately cause back pain. However, the risk will be increased where a person is exposed to one or more of these factors while being exposed to whole-body vibration. For example:

- being exposed to whole-body vibration for long periods without being able to change position;
- being exposed to whole-body vibration while sitting in a stretched or twisted posture (e.g. looking over your shoulder to monitor the operation of attached equipment);
- being exposed to whole-body vibration and then doing work involving manually lifting and carrying heavy loads.

Environmental factors, such as temperature may further increase the risk of back pain or injury.

All these causes must be considered together in your plans to minimise risk of back injury. Regulations and guidance on manual handling of materials should be considered where this is a factor in your workers' work.

A starting point in your risk assessment is to consider the work being carried out, the processes involved and the machinery and equipment used. Some questions to help you decide whether further action is required are shown in Table 1.

All types of vehicle, when in motion, are likely to cause the driver to experience whole-body vibration. The risks to health increase where people are regularly exposed to high levels of whole-body vibration over a long period. Some vehicles that have been associated with whole-body vibration and ergonomic risks are shown in Figure 2. Remember that whole-body vibration exposure may also arise from non-driving activities, e.g. where workers stand on vibrating platforms.

Further reading:
Manual Handling Directive: Council Directive 90/269/EEC of 29 May 1990 *on the minimum health and safety requirements for the manual handling of loads where there is a risk particularly of back injury to workers (fourth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)*

Table 1 Questions to help decide whether further action may be needed

Do you drive off-road?

High levels of whole-body vibration are most likely for people who drive vehicles over rough surfaces as part of their job, for example off-road vehicles such as tractors, quad bikes, and dumper trucks.

Do you drive or operate vibrating machinery for a long time every day?

The factors that govern a person's daily vibration exposure are the magnitude (level) of vibration and the length of time the person is exposed to it. The longer the duration of exposure, the greater will be the risk from vibration exposure.

Do you drive vehicles that are not designed for the roadway conditions?

Some industrial vehicles, such as forklift trucks, do not have wheel suspension and are fitted with solid tyres, to provide them with the necessary stability to work safely. Provided they are driven on smooth surfaces whole-body vibration levels should not be high. However, if they are driven on unsuitable surfaces (e.g. a fork-lift truck designed for warehouse use being operated in a external loading yard), they can generate high levels of whole-body vibration.

Do you drive over poorly maintained road surfaces?

Most road vehicles will generate fairly low levels of whole-body vibration provided the road surface is well maintained. Cars, vans and modern designs of suspended-cab lorries are generally unlikely to present a risk from whole-body vibration when used on well-maintained roads. However, vehicles with less effective suspension such as rigid body lorries may cause high levels of whole-body vibration, particularly when they are driven over poor surfaces, or when they are unladen.

Are you exposed to shock (or jolts)?

The greatest risk from vibration exposure is believed to come from exposure to shock vibration. Shock vibration may arise from poor road surfaces, driving too fast for the terrain, or incorrect set-up of the seat suspension. Scrapers may generate high levels of shock vibration when driving over difficult ground. Some heavily laden vehicles may transmit shocks and jolts to the driver with hard use of the brakes.

Do you need to adopt poor postures or perform manual handling tasks?

Poor cab layout or poor visibility can result in stretching and twisting, or may confine the driver to a fixed position for long periods. These poor ergonomic environments, either alone or combined with whole-body vibration exposures, can result in back and other musculoskeletal injuries.

Do the manufacturers of the machinery warn of risk from whole-body vibration?

If you are using a machine that may put the users at risk of vibration injury, the manufacturer should warn you about it in the handbook.

Do workers report back disorders?

Evidence of back injury means that ergonomic risks and vibration exposures need to be managed.

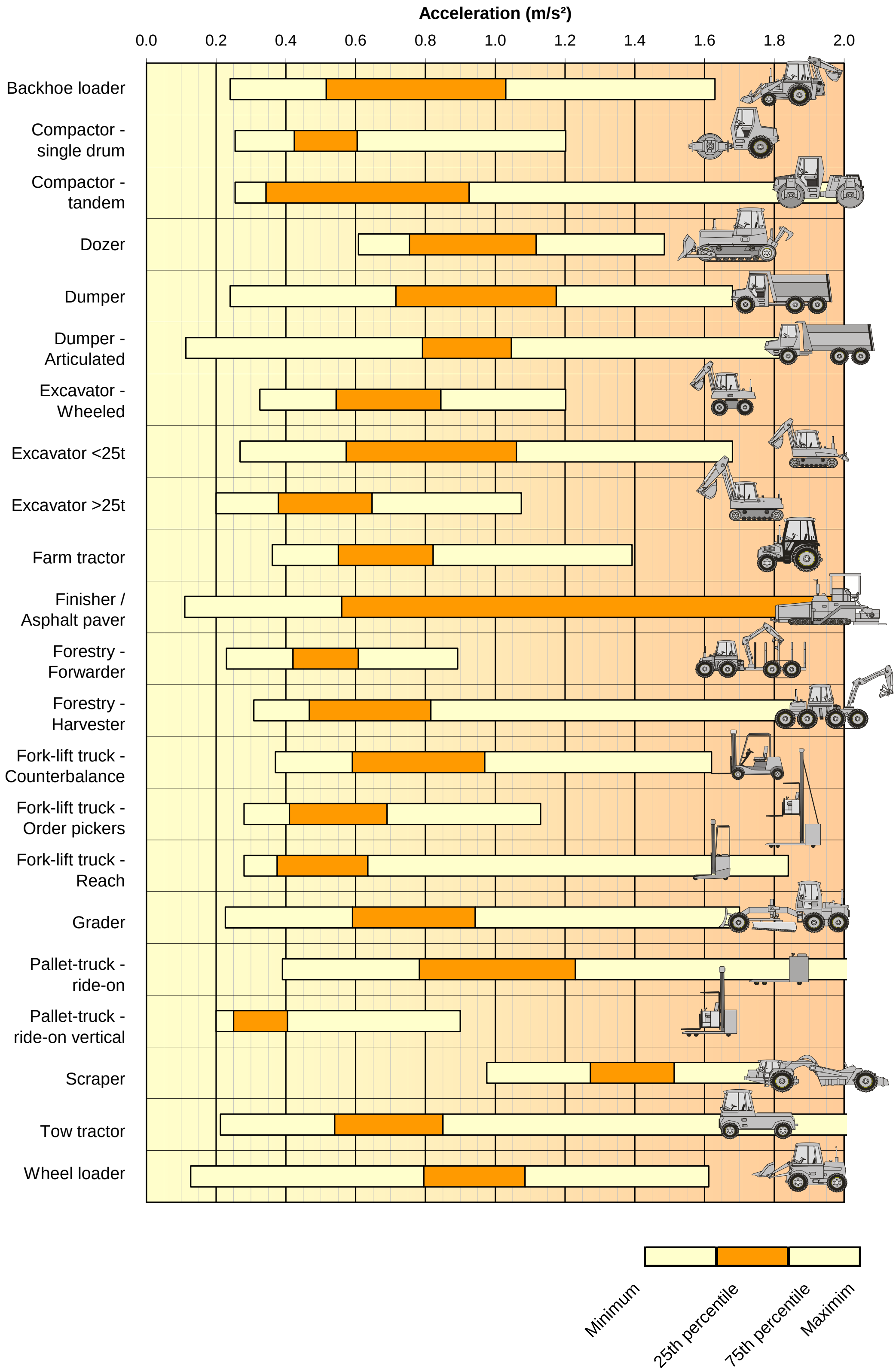


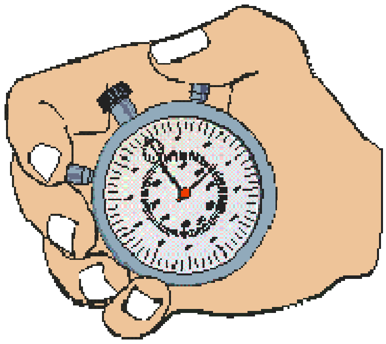
Figure 2 Examples of vibration magnitudes for common tools

Ranges of vibration values for common equipment on the EU market. These data are for illustration only. For more details see Annex B.

2.2 Determining exposure duration

To assess the daily vibration exposure of workers, we need an estimate of the time machine operators are exposed to the vibration source.

In this chapter we look at what exposure time information is needed and how it can be determined.



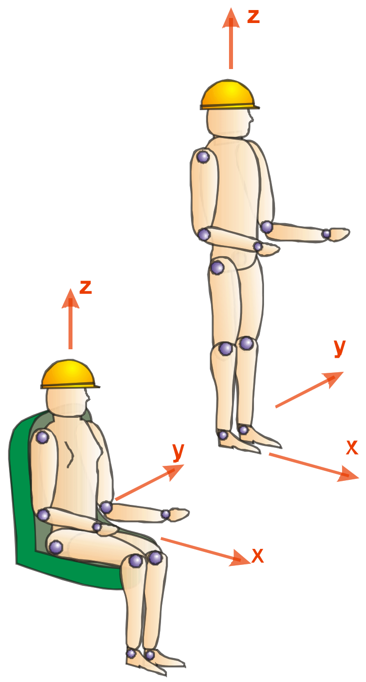
Before the daily vibration exposure ($A(8)$ or VDV) can be estimated, you need to know the total daily duration of exposure to the vibration from the vehicles or machines used. You should be careful to use data that is compatible with your vibration magnitude data, for example, if your vibration magnitude data is based on measurements when the machine was working, then count only the time that the worker is exposed to vibration. Machine or vehicle operators questioned on their typical daily duration of vibration exposure usually state a value containing periods without vibration exposure, e.g. truck loading and waiting times.

Usually, the vibration that occurs when the vehicle is travelling will dominate vibration exposures. However, some exposures are dominated by operations being performed while the vehicle is static, such as excavators and tree harvesters.

Work patterns need careful consideration. For example some workers may only operate machines for certain periods in a day. Typical usage patterns should be established, as these will be an important factor in calculating a person's likely vibration exposure.

Further reading:
EN 14253, Mechanical vibration — Measurement and calculation of occupational exposure to whole-body vibration with reference to health — Practical guidance

2.3 Determining vibration magnitude



Whole-body vibration magnitude is the frequency-weighted acceleration value in the highest of three orthogonal axes ($1.4a_{wx}$, $1.4a_{wy}$ or a_{wz}) for a seated or standing worker.

The vibration information you use for your vibration assessment needs to match closely the likely vibration performance of the machine being used (both the machine's specifications and the way the machine is operated).

In this chapter we look at how vibration can be estimated from manufacturer's data, other published data sources and from workplace measurement.

2.3.1 Use of manufacturer's emission data

The European Union's "Machinery Directive" (Directive 98/37/EC) defines essential health and safety requirements for machinery supplied within the EU including specific requirements regarding vibration.

Amongst other requirements, the Machinery Directive requires manufacturers, importers and suppliers of machines to provide information on any risks from vibration, and values for the whole-body vibration emissions of mobile machinery. This vibration emission information should be given in the information or instructions that accompany the machine.

Vibration emission data is usually obtained according to harmonised European vibration test codes produced by European or international standards bodies. However, very few machine specific standards are currently (in 2005) available and where standards do exist such as for industrial trucks, the differences between directly competing machines are often less than 50%.

Further reading:

EN 1032:2003 Mechanical vibration — Testing of mobile machinery in order to determine the vibration emission value

EN 12096:1997 Mechanical vibration — Declaration and verification of vibration emission values.

CEN/TR First committee draft Munich (March 2005) — Mechanical vibration - Guideline for the assessment of exposure to whole-body vibration of ride on operated earth-moving machines. Using harmonised data measured by international institutes, organisations and manufacturers.

2.3.2 Use of other data sources

There are other sources of information on vibration magnitudes, which are often sufficient to allow you to decide whether either the exposure action value or the exposure limit values are likely to be exceeded.

Your trade association or equivalent may have useful vibration data and there are international vibration databases on the Internet, which may meet your needs. This may be suitable for some employers to make an initial vibration exposure assessment.

Other sources of vibration data include specialist vibration consultants, trade associations, manufacturers and government bodies. Some data can also be found in various technical or scientific publications and on the Internet. Two European websites that hold manufacturers' standard vibration emission data along with some values measured in "real use" for a range of machines are:

http://vibration.arbetslivsinstitutet.se/eng/wbvhome.lasso

http://www.las-bb.de/karla/index_.htm

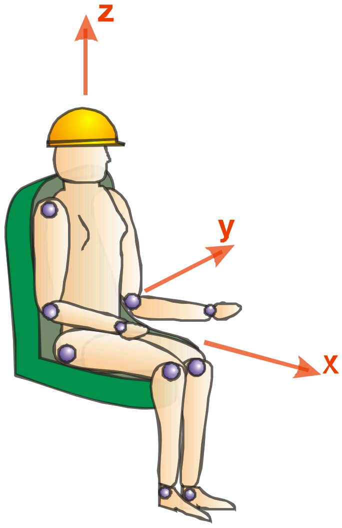
Ideally you should use vibration information for the machine (make and model) you plan to use. However, if this is not available you may need to use information relating to similar equipment as a starting point, replacing the data with more accurate values when this becomes available.

When choosing published vibration information the factors you need to take account of in making your choice include:

- the type of equipment (e.g. fork-lift truck),
- the class of equipment (e.g. power or size),
- the power source (e.g. electric or combustion engine)
- any anti-vibration features (e.g. suspension systems, suspended cab, seats),
- the task the vehicle was used for when producing the vibration information,
- the speed it was operated at,
- the type of surface it was run on.

When using published vibration data it is good practice to try to compare data from two or more sources.

2.3.3 Measurement of vibration magnitude

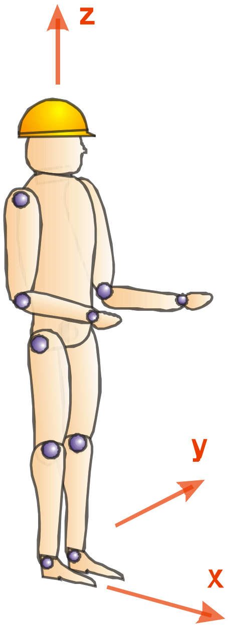


In many situations it will not be necessary to measure vibration magnitudes. However, it is important to know when to conduct measurements.

In this chapter we look at what is measured, where vibration is measured and how it is reported.

Manufacturer's data and information from other information sources may give a useful indication of the vibration exposure of machine operator's. However, whole-body vibration exposure is very dependent on the quality of road surfaces, vehicle speeds and other factors such as how the vehicle is operated. Therefore, it may be necessary to confirm your initial exposure assessment by having measurements of vibration magnitudes made.

You may choose to make the vibration measurements in-house, or to employ a specialist consultant. In either case, it is important that whoever makes the vibration measurements has sufficient competence and experience.



What is measured?

Human exposure to whole-body vibration should be evaluated using the method defined in International Standard ISO 2631-1:1997 and detailed practical guidance on using the method for measurement of vibration at the workplace is given in EN 14253:2003.

The *root-mean-square* (*r.m.s) vibration magnitude* is expressed in terms of the frequency-weighted acceleration at the seat of a seated person or the feet of a standing person (see Annex B), it is expressed in units of *metres per second squared* (m/s^2). The *r.m.s vibration magnitude* represents the average acceleration over a measurement period. It is the highest of three orthogonal axes values ($1.4a_{wx}$, $1.4a_{wy}$ or a_{wz}) that is used for the exposure assessment.

The *vibration dose value* (or VDV) provides an alternative measure of vibration exposure. The VDV was developed as a measure that gives a better indication of the risks from vibrations that include shocks. The units for VDV are *metres per second to the power 1.75* ($m/s^{1.75}$), and unlike the *r.m.s vibration magnitude*, the measured VDV is cumulative value, i.e. it increases with measurement time. It is therefore important for any measurement of VDV to know the period over which the value was measured. It is the highest of three orthogonal axis values ($1.4VDV_{wx}$, $1.4VDV_{wy}$ or VDV_{wz}) that is used for the exposure assessment.

Making vibration measurements

Measurements should be made to produce vibration values that are representative of the vibration throughout the operator's working period. It is therefore important that the operating conditions and measurement periods are selected to achieve this.

It is recommended that wherever practical, measurements should be made over periods of at least 20 minutes, where shorter measurements are unavoidable they should normally be at least three minutes long and, if possible, they should be repeated to give a total measurement time of more than 20 minutes (see EN 14253 for further advice). Longer measurements, of 2 hours or more are preferable (half or full working day measurements are sometimes possible).

Further reading:
EN 14253, Mechanical vibration — Measurement and calculation of occupational exposure to whole-body vibration with reference to health — Practical guidance CEN/TR First committee draft Munich (March 2005) — Mechanical vibration - Guideline for the assessment of exposure to whole-body vibration of ride on operated earth-moving machines. Using harmonised data measured by international institutes, organisations and manufacturers.

2.4 Calculating daily vibration exposures

Daily vibration exposure depends on both the level of vibration and the duration of exposure.

In this chapter we look at how daily vibration exposure is calculated from the exposure times and either the vibration magnitude information or from vibration dose values.

Some tools for simplifying the calculation of daily exposures and managing exposure times are given in Annex D.

Worked examples of how daily vibration exposures and VDVs can be calculated are given Annex E

2.4.1 A(8) and VDV daily exposure evaluation

Daily exposure to vibration may be assessed using either or both of the two exposure measures:

(a) Daily vibration exposure, A(8), or

(b) Vibration dose value, VDV.

Both measures are dependent on a measured vibration value. The A(8) also requires an exposure time. Like vibration magnitude, the daily vibration exposure has units of *metres per second squared* (m/s^2).

If the VDV is measured over a measurement period that is shorter than the full working day (as it usually will be), then the resulting measurement will need to be scaled up.

Instructions and worked examples showing how to calculate A(8) and VDV exposures are given in Annex E.

2.4.2 Uncertainty of daily exposure evaluations

The uncertainty of vibration exposure evaluation is dependent on many factors, see EN 14253:2003, including:

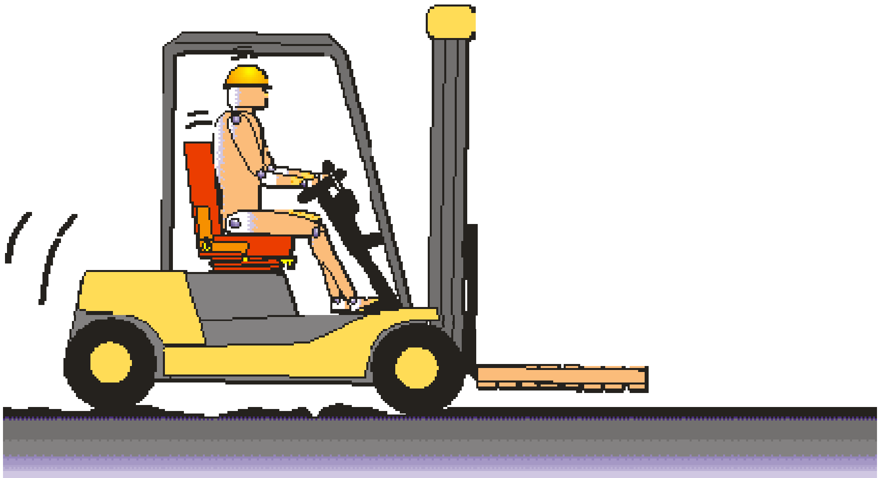
- Instrument / calibration uncertainty,
- Accuracy of source data (e.g. manufacturer's emission data),
- Variation of machine operators (e.g. experience, driving speeds or styles),
- Ability of the worker to reproduce typical work during measurements,
- Repeatability of the work task,
- Environmental factors (e.g. rain, wind, temperature),
- Variations in the machine and suspension systems (e.g. is there a need for maintenance, has the machine been warmed-up?).

Where vibration magnitude and exposure time are measured the uncertainties associated with the evaluation of *A*(8) and VDV can mean that the calculated value can be as much as much 20% above the true value to 40% below. Where either the exposure time or the vibration magnitude is estimated — e.g. based on information from the worker (exposure time) or manufacturer (magnitude) — then the uncertainty in the evaluation of daily exposure can be much higher.

CHAPTER 3 AVOIDING OR REDUCING EXPOSURE

To control exposure we must have a strategy that can effectively deliver reduced exposures to whole-body vibration.

In this chapter we look at the process of developing a control strategy, including how to prioritise your control activities.



3.1 Developing a control strategy

A risk assessment should enable methods for controlling exposure to be identified. While you are assessing the vibration exposures, you should be thinking about the work processes that cause them. Understanding why workers are exposed to high vibrations and ergonomic risks will help identify methods for reducing or eliminating the risks.

The important stages in this management process are:

- identifying the main sources of vibration,
- identifying the main sources of shock vibration,
- ranking them in terms of their contribution to the exposure,
- identifying and evaluating potential solutions in terms of practicability and cost,
- establishing targets which can be realistically achieved.
- allocating priorities and establishing an 'action programme';
- defining management responsibilities and allocating adequate resources;
- implementing the programme;
- monitoring progress;
- evaluating the programme.

The approach you take to reduce risks from whole-body vibration will depend on the practical aspects of your particular processes and on the current levels of exposure.

You may also need to adapt your controls for workers who are at particular risk of injury, e.g. those workers who are more susceptible to vibration injury and show signs of developing injury at exposures below the exposure action value.

The Framework Directive provides the following hierarchy for implementing a programme of preventative measures:

(a) avoiding risks;

(b) evaluating the risks which cannot be avoided:

(c) combating the risks at source;

(d) adapting the work to the individual, especially as regards the design of work places, the choice of work equipment and the choice of working and production methods, with a view, in particular, to alleviating monotonous work and work at a predetermined work-rate and to reducing their effect on health.

(e) adapting to technical progress;

(f) replacing the dangerous by the non-dangerous or the less dangerous;

(g) developing a coherent overall prevention policy which covers technology, organization of work, working conditions, social relationships and the influence of factors related to the working environment;

(h) giving collective protective measures priority over individual protective measures;

(i) giving appropriate instructions to the workers.

3.2 Consultation and Participation of Workers

The successful management of risks relies on the support and involvement of workers, and in particular their representatives. Representatives can provide an effective channel of communication with the workforce and assist workers in understanding and using health and safety information.

Lower-back pain may be caused by a combination of factors, including whole-body vibration exposure, so a variety of different solutions may be necessary. Some solutions may be quite straightforward. Other solutions will require modifications to the way in which work is organised. These issues can often only be effectively dealt with in consultation with workplace representatives.

Effective consultation relies on:

- the sharing of relevant information about health and safety measures with workers;
- workers being given the opportunity to express their views and to contribute in a timely fashion to the resolution of health and safety issues;
- the views of workers being valued and taken in to account.

Consultation can result in better control solutions being identified that are well understood by the workers. You will be relying on workers to make the control measures effective. Subject to adequate training and supervision, workers have a duty to make correct use of machinery and to cooperate with the employer to enable them to ensure that their environment and working conditions are safe, such that risks to safety and health are minimised and where possible eliminated. The process of consultation encourages worker involvement and co-operation with control measures and so ensures that controls are more likely to be successfully implemented.

3.3 Risk controls

To control exposure you must avoid or reduce exposure to whole-body vibration. It may also be possible to take actions that reduce the likelihood of developing or aggravating injury. It is likely that effective control will be based on a combination of several methods.

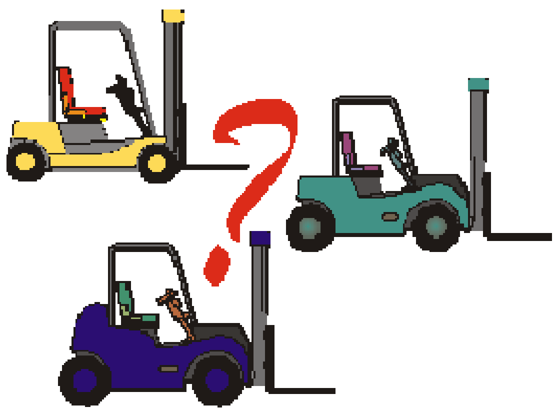
In this chapter we look at the engineering, management and other methods that should be considered when looking for control solutions.

3.3.1 Substitution of other working methods

It may be possible to find alternative work methods that avoid or reduce exposure to vibration, e.g. by transporting materials by conveyor rather than using mobile machinery. To keep up-to-date on the methods available you should check regularly with:

- your trade association;
- other industry contacts;
- equipment suppliers;
- trade journals.

3.3.2 Equipment selection



You should make sure that equipment selected or allocated for tasks is suitable and can do the work efficiently. Equipment which is unsuitable or of insufficient capacity is likely to take much longer to complete the task and expose workers to more vibration for longer than is necessary.

Choose machines with cab layouts and control levers arranged so that the operator is able to maintain a comfortable upright posture and will not need to twist the body excessively, or maintain twisted postures for any length of time.

Selection of tyres can be important; tyres will absorb some effects of uneven ground. However, tyres cannot absorb the vibration from larger lumps and potholes, and soft tyres on undulating ground can amplify a vehicle's vertical motions. Tyres need to be selected so that the vehicle can handle rougher terrain.

3.3.3 Purchasing policy

Make sure your purchasing department has a policy on purchasing suitable equipment, that takes into account health and safety issues, including: vibration emission, ergonomic factors, driver vision and your operating requirements.

Anyone supplying machinery for use in Europe must comply with the Machinery Directive (Directive 98/37/EC). According to this Directive, machinery must be so designed and constructed that risks resulting from vibrations produced by the machinery are reduced to the lowest level, taking account of technical progress and the availability of means of reducing vibration, in particular at source. This Directive also states that the seat must be designed to reduce vibrations transmitted to the driver to the lowest level that can be reasonably achieved.

The supplier should advise you of any risks presented by the machine, including those from whole-body vibration. The information about vibration should include:

- the vibration emission (as reported in the instruction handbook);
- how has the emission value been obtained;
- any circumstances under which the machine can generate whole-body vibration exposures above the exposure action value;
- any circumstances under which the machine can generate whole-body vibration exposures above the exposure limit value;
- any special training (of drivers, maintenance crew, etc.) recommended to control whole-body vibration exposures;
- how to maintain the machine in good condition;
- information showing that the seat provided in the vehicle reduces the vibration exposure to the lowest level that can reasonably be achieved;
- any options that are available that are recommended for control of whole-body vibration in specific applications of the machine.

For mobile machinery, the Machinery Directive requires that manufacturers or suppliers of machinery provide in the instruction handbook:

- *the weighted root mean square acceleration value to which the body (feet or posterior) is subjected, if it exceeds 0.5 m/s^2, should it not exceed 0.5 m/s^2, this must be mentioned."*

3.3.4 Task and process design

Work tasks should be designed so that:

- whole-body vibration exposures are as low as practicable,
- the daily period of exposure to excessive vibration is as short as possible,
- the exposure to severe shocks is avoided and
- the working posture does not increase the risks of back injury.

In many cases, travelling over rough or uneven ground is the main contributor to the vibration exposure. Vibration exposure may be reduced and controlled by:

- minimising the travelling distances,
- limiting the vehicle speeds,
- improving the road surfaces (removing obstacles, filling potholes, levelling surfaces over which vehicles are driven, etc),
- providing a suitable suspended seat which is set correctly for the driver's weight.

A good posture is vital for minimising the risks of back injury when driving. Posture can be improved by:

- improving the drivers vision from the cab (to minimise twisting of the back and neck),
- relocating machine controls (to minimise repeated stretching),
- providing a seat, that fits all the drivers that will use the vehicle, fits the space available within the cab and is suitable for the task being carried out,
- using seat-belts to maintain the driver in the best position, providing support for the back.

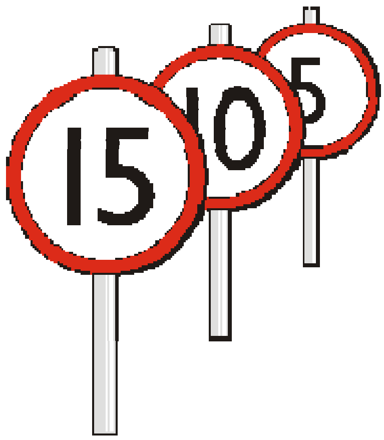
3.3.5 Collective measures

Where several undertakings share a work place, the various employers are required to cooperate in implementing the safety, and health and occupational hygiene provisions. This may mean, for example, ensuring that a road surface is adequately maintained, so that vibration exposure of workers from another company operating at the same location may be controlled.

3.3.6 Training and information to workers

It is important that you provide operators and supervisors with information on:

- the potential injury arising from the work equipment in use;
- the exposure limit values and the exposure action values;
- the results of the vibration risk assessment and any vibration measurements;
- the control measures being used to eliminate or reduce risks from whole-body vibration;
- safe working practices that minimise exposure to vibration;
- why and how to detect and report signs of injury;
- the circumstances in which workers are entitled to health surveillance.



Workers must be trained in driving techniques that minimise vibration exposure. They must be made aware of the effect of driving speed, and if speed limits are imposed, the reasons for imposing them.

Where seat suspension systems are fitted, drivers should be shown how to adjust them for their own weight. They also need to be shown how to set other seat controls (fore-aft position, height, back-rest inclination etc…) to achieve the best posture.

Drivers and maintenance technicians need to be trained to recognise when machine components that affect vibration exposure and posture, such as the seat suspension system, need maintenance or replacing.

Workers should also be advised on the impact of non-work activities on the risks to their health. To reduce the risks of developing lower-back pain workers should be encouraged to maintain their general fitness, and to consider the risks to their backs from non-work activities, for example using poor lifting techniques or adopting poor postures for long periods.

3.3.7 Work schedules

To control the risks from whole-body vibration you may need to limit the time workers are exposed to vibration from some vehicles or machines.

3.3.8 Maintenance

Regular servicing of vehicles, attachments and the roadways they use will help keep vibration magnitudes and shocks down to the a minimum necessary, so:

- maintain road surfaces;
- replace worn parts (including any seat suspension);,
- check and replace defective vibration dampers, bearings and gears;
- tune engines;
- maintain tyres and ensure they are inflated to the correct pressures for the surface and load conditions;
- lubricate seat and other suspension systems.

3.3.9 Suspension seats

The machine supplier should provide information on appropriate seats for their vehicles. Suspension seats are not always appropriate, but the machine manufacturers must provide a seat designed to reduce vibration transmitted to the driver to the lowest level that can reasonably be achieved.

Where suspension seats are provided, it is important that the seat suspension is appropriate for the vehicle. Poor choice of seat suspension systems can easily result in a higher vibration exposure than would be given without the suspension. All seat suspension systems have a range of frequencies that they amplify. If the dominant frequencies of the vehicle vibration fall within this amplification range, the seat suspension will make the driver’s vibration exposure worse. ISO EN 7096:2000, ISO EN 5007 and EN 13490:2001 provide performance criteria for earth moving machinery, agricultural wheeled tractors and industrial trucks respectively that are designed to ensure appropriate performance of seat suspension.

The seat suspension system must also be selected so that, in typical use, it is unlikely to hit its top or bottom end-stops. Striking the end-stops creates shock vibrations, so increasing the risk of back injury.

The seat suspension must be readily accessible and easy to adjust for the operator's weight and body size. Height, fore-aft and backrest adjustments are especially important. The seat cushions should be ergonomically designed

Further reading:
CEN/TR 15172-1, Whole-body vibration – Guidelines for vibration hazards reduction – Part 1: Engineering methods by design of machinery. CEN/TR 15172-2, Whole-body vibration – Guidelines for vibration hazards reduction – Part 2: Management measures at the workplace.

3.4 Vibration monitoring and reassessment

Management of vibration exposure is an ongoing process, you need to ensure that the control systems are being used and that they are giving the expected results

In this chapter we look at how to monitor the vibration controls and when to repeat the risk assessment.

3.4.1 How do I know if my whole-body vibration controls are working?

You will also need to review your whole-body vibration controls periodically to ensure they are still relevant and effective. You should:

- Check regularly that workers (including managers and supervisors) are still carrying out the programme of controls you have introduced;
- Talk regularly to all workers, safety personnel and worker representatives about any vibration or postural problems with the vehicles or machines or the way they are being used;
- Check the results of health surveillance and discuss with the health service provider whether the controls appear to be effective or need to be changed.

3.4.2 When do I need to repeat the risk assessment?

You will need to reassess risks from vibration, and how you control them, whenever there are changes in the workplace that may affect the level of exposure, such as:

- the introduction of different machinery or processes,
- changes in the work pattern or working methods,
- changes in the number of hours worked with the vibrating equipment,
- the introduction of new vibration control measures.

You will also need to reassess the risks if there is evidence (e.g. from health surveillance) that your existing controls are not effective.

The extent of the reassessment will depend on the nature of the changes and the number of people affected by them. A change in hours or work patterns may require a recalculation of the daily exposure for the people affected, but will not necessarily alter the vibration magnitudes. The introduction of new vehicles or machinery may require a full reassessment.

It is good practice to review your risk assessment and work practices at regular intervals, even if nothing obvious has changed. There may be new technology, machine designs or ways of working in your industry that would allow you to reduce risks further.

CHAPTER 4 HEALTH SURVEILLANCE

Health surveillance is about putting in place systematic, regular and appropriate procedures for the detection of work-related ill health, and acting on the results. The aims are primarily to safeguard the health of workers (including identifying and protecting individuals at increased risk), but also to check the long-term effectiveness of control measures.

It is impossible to provide definitive guidance on health surveillance in this guide, due to the differences in health surveillance practices across the European Union. In this chapter we re-state the requirements for health surveillance given in the vibration directive and review some of the assessment techniques available.

Some health surveillance techniques related to whole-body injury are described in *Annex F*.

4.1 When is health surveillance required?

Member States shall adopt provisions to ensure the appropriate health surveillance of workers where the whole-body vibration risk assessment indicates a risk to their health. The provision of health surveillance, including the requirements specified for health records and their availability, shall be introduced in accordance with national laws and/or practice.

Employers should provide appropriate health surveillance where the risk assessment indicates a risk to workers' health. Health surveillance should be instituted for workers who are at risk from vibration injury, where:

- the exposure of workers to vibration is such that a link can be established between that exposure and an identifiable illness or harmful effects on health,
- it is probable that the illness or the effects occur in a worker's particular working conditions, and
- there are tested techniques for the detection of the illness or the harmful effects on health.
- In any event, workers whose daily vibration exposure exceeds the daily exposure action value are entitled to appropriate health surveillance.

4.2 What recording is required?

Member States shall establish arrangements to ensure that, for each worker who undergoes health surveillance individual health records are made and kept up-to-date. Health records shall contain a summary of the results of the health surveillance carried out. They shall be kept in a suitable form so as to permit any consultation at a later date, taking into account any confidentiality.

Copies of the appropriate records shall be supplied to the competent authority on request. The individual worker shall, at their request, have access to the health records relating to them personally.

4.3 What to do if injury is identified?

Where, as a result of health surveillance, a worker is found to have an identifiable disease or adverse health effect that is considered by a doctor or occupational health-care professional to be the result of exposure to mechanical vibration at work:

Information for the worker

The worker shall be informed, by the doctor or other suitably qualified person, of the results of their own personal health surveillance. In particular, workers shall be given information and advice regarding any health surveillance that they should undergo following the end of exposure.

Information for the employer

The employer shall be informed of any significant findings from the health surveillance, taking into account any medical confidentiality.

Employer actions

- Review the whole-body vibration risk assessment,
- Review the measures provided to eliminate or reduce risks from whole-body vibration exposure,
- Take into account the advice of the occupational healthcare professional or other suitably qualified person or the competent authority in implementing any measures required to eliminate or reduce risks from whole-body vibration exposure, including the possibility of assigning the worker to alternative work where there is no risk of further exposure, and
- Arrange continued health surveillance and provide for a review of the health status of any other worker who has been similarly exposed. In such cases, the competent doctor or occupational health care professional or the competent authority may propose that exposed persons undergo a medical examination.

ANNEX A SUMMARY OF RESPONSIBILITIES DEFINED BY DIRECTIVE 2002/44/EC

Table A.1 Summary of responsibilities defined by Directive 2002/44/EC

Directive Article	Who	When	Requirement
Article 4	Employer	Potential risk from whole-body vibration	***Determination and assessment of risk:*** ▪ Use someone who is competent to assess the whole-body vibration risk. ▪ Be in possession of the risk assessment. ▪ Identify measures required for control of exposure and worker information and training. ▪ Keep the risk assessment up to date.
Article 5	Employer	Risks from vibration	***Removing or reducing exposure:*** ▪ Take general actions to eliminate risks or reduce them to a minimum
		Exposures above the **exposure action value**	▪ Establish and implement programme of measures to eliminate, or reduce to a minimum, exposures to whole-body vibration
		Exposures above the **exposure limit value**	▪ Take immediate action to prevent exposure above the limit value ▪ Identify why the exposure limit value has been exceeded
		Workers at particular risk	▪ Adapt to requirements of workers at particular risk
Article 6	Employer	Workers at risk from whole-body vibration	***Worker information and training:*** ▪ For all workers exposed to whole-body vibration risks.
Article 7	Employer	Workers at risk from whole-body vibration	***Worker consultation and participation:*** ▪ To consult, in a balanced way and in good time, workers and their representatives on risk assessment, control measures, health surveillance and training.
Article 8	Doctor or suitably qualified person	Where ill-health is identified	***Health Surveillance:*** ▪ Inform worker of results of health surveillance ▪ Provide information and advice to worker on health surveillance necessary when exposure to whole-body vibration has finished. ▪ Provide significant findings of health surveillance to employer
	Employer	Where ill-health is identified	▪ Review risk assessment ▪ Further eliminate or reduce risks ▪ Review the health status of similarly exposed workers.
	Employer	Exposures above the **exposure action value**	▪ Workers entitled to appropriate health surveillance

ANNEX B WHAT IS VIBRATION?

B.1 What is vibration?

Vibrations arise when a body moves back and forth due to external and internal forces, Figure B.1. In the case of whole-body vibration, it may be the seat of a vehicle or the platform on which a worker is standing that vibrates, and this motion is transmitted into the body of the driver.

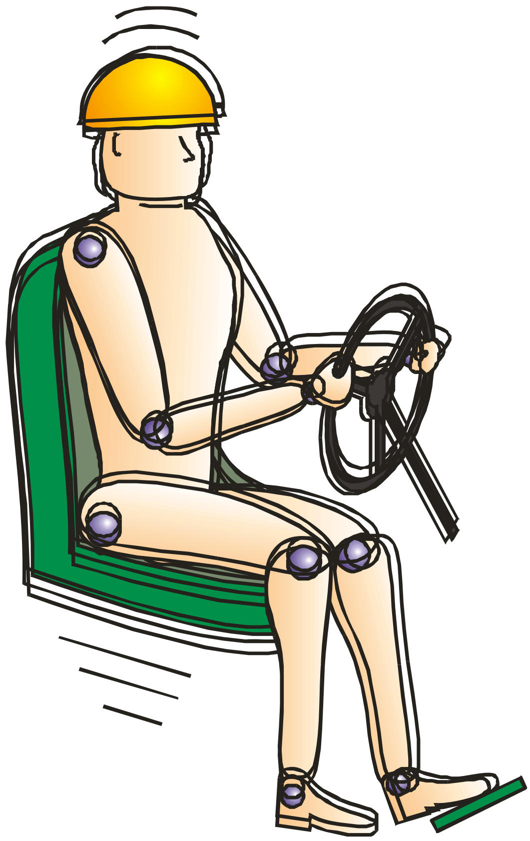


Figure B.1 Whole-body vibration

B.2 What is measured?

Vibration is defined by its magnitude and frequency. The magnitude of vibration could be expressed as the vibration displacement (in metres), the vibration velocity (in metres per second) or the vibration acceleration (in metres per second per second or m/s^2). However, most vibration transducers produce an output that is related to acceleration (their output is dependent on the force acting on a fixed mass within the transducer and, for a fixed mass, force and acceleration are directly related); so acceleration has traditionally been used to describe vibration.

The vibration transducer measures acceleration in one direction only, so to get a more complete picture of the vibration on a surface, three transducers are needed: one in each axis as illustrated in Figure B.2.

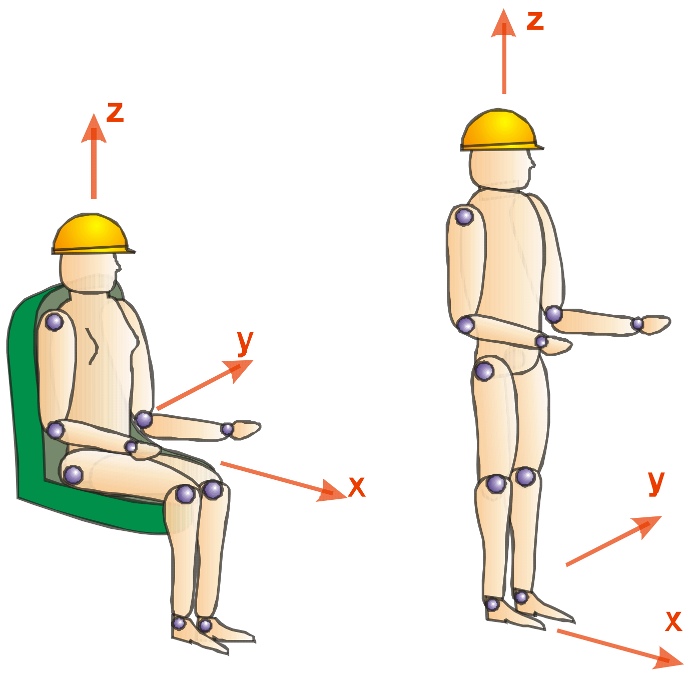


Figure B.2 Vibration measurement axes

B.3 What is frequency and frequency weighting?

Frequency represents the number of times per second the vibrating body moves back and forth. It is expressed as a value in cycles per second, more usually known as hertz (abbreviated to Hz).

For whole-body vibration, the frequencies thought to be important range from 0.5Hz to 80Hz. However, because the risk of damage is not equal at all frequencies a *frequency-weighting* is used to represent the likelihood of damage from the different frequencies. As a result, the weighted acceleration decreases when the frequency increases. For whole-body vibration, two different frequency weightings are used. One weighting (the *Wd weighting*) applies to the two lateral axes: x and y, and another (the *Wk weighting*) applies to the vertical, z-axis vibration.

When considering the risks to health from whole-body vibration an additional multiplying factor must be applied to the frequency weighted vibration values. For the two lateral axes (x and y) the acceleration values are multiplied by 1.4. For the vertical, z-axis vibration the factor is 1.0.

B.4 What parameters are used for exposure assessment?

The vibration directive allows for two vibration assessment methods:

- the daily exposure, A(8) - the continuous equivalent acceleration, normalised to an 8 hour day, the A(8) value is based on root-mean-square averaging of the acceleration signal and has units of m/s^2; and
- the vibration dose value (VDV) is a cumulative dose, based on the 4^{th} root-mean-quad of the acceleration signal with units of $m/s^{1.75}$.

Both parameters A(8) and VDV are defined in ISO 2631-1:1997.

Some examples of vibration magnitudes for common machines are shown in Figure B.3.

B.5 What instrumentation should be used?

Whole-body vibration measuring equipment should comply with the ISO 8041:2005 specifications for whole-body vibration measuring instruments.

Further reading:
ISO 2631-1:1997 Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General requirements EN 14253:2003 Mechanical vibration — Measurement and calculation of occupational exposure to whole-body vibration with reference to health — Practical guidance.

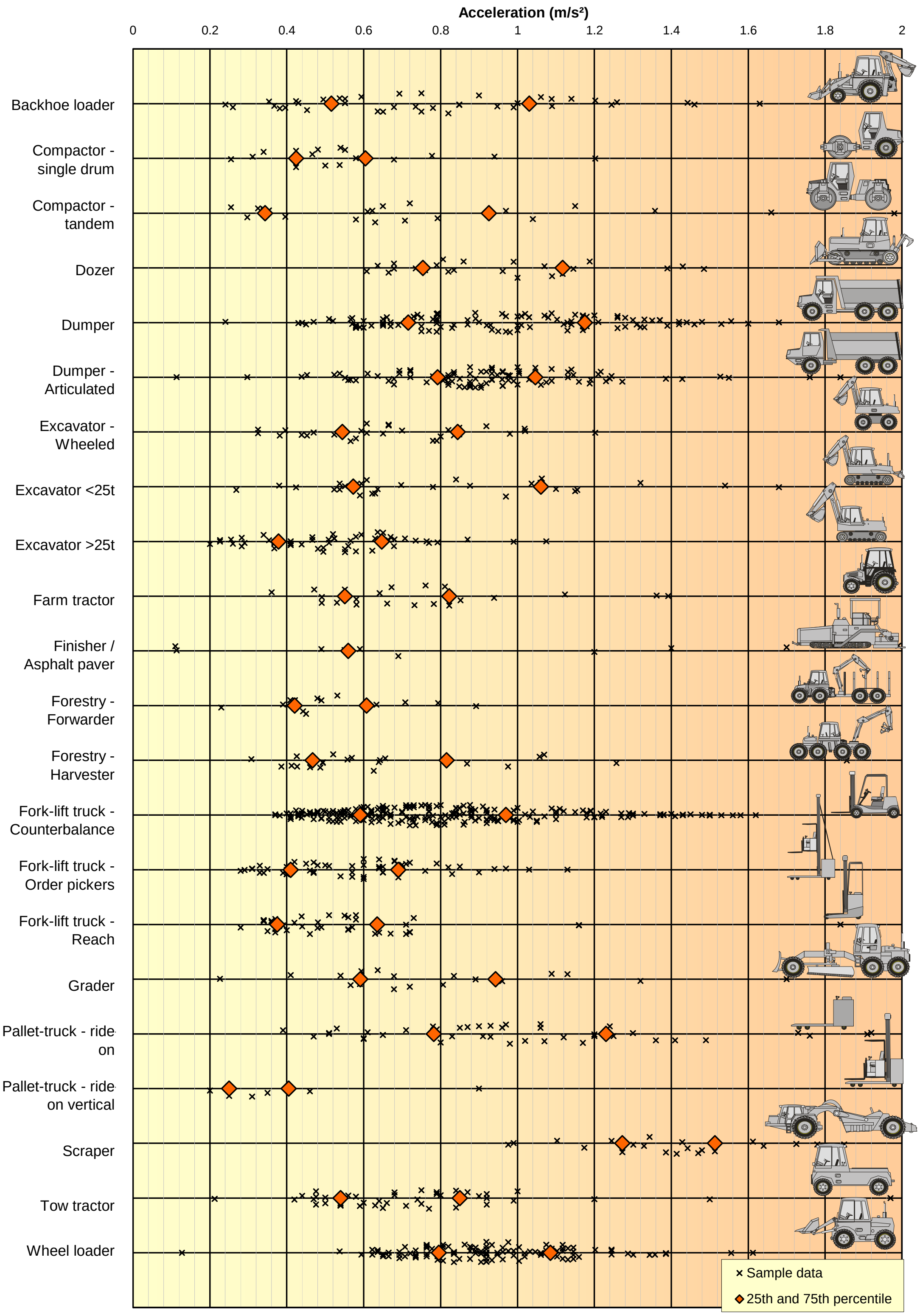


Figure B.3 Examples of vibration magnitudes for common machines

Sample data based on workplace vibration measurements of highest axis vibration values by INRS INRS (with the assistance of CRAM and Prevencem), HSL and RMS Vibration Test Laboratory between 1997 and 2005. These data are for illustration only and may not be representative of machine use in all circumstances

The 25th and 75th percentile points show the vibration magnitude that 25% or 75% of samples are equal to or below.

ANNEX C HEALTH RISKS, SIGNS AND SYMPTOMS

C.1 Effects of whole-body vibration on the human body

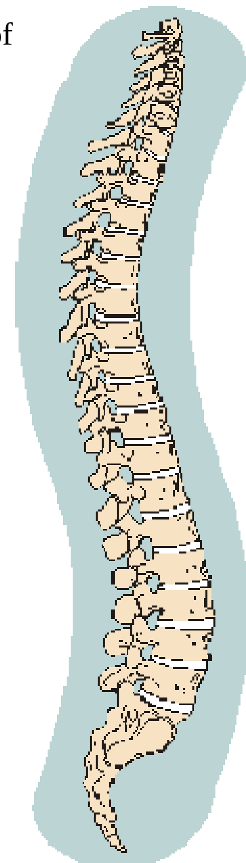
The transmission of vibration to the body is dependent on body posture. The effects of vibration are therefore complex. Exposure to whole-body vibration causes motions and forces within the human body that may:

- cause discomfort,
- adversely affect performance.
- aggravate pre-existing back injuries and
- present a health and safety risk.

Low-frequency vibration of the body can cause motion sickness.

Epidemiological studies of long-term exposure to whole-body vibration have shown evidence for an elevated risk to health, mainly in the lumbar spine but also in the neck and shoulder. Some studies have reported evidence of effects on the digestive system, the female reproductive organs and the peripheral veins.

C.2 Lower-back pain and back, shoulder or neck disorders



The results of epidemiological studies show a higher prevalence rate of low-back pain, herniated disc and early degeneration of the spine in whole-body vibration exposed groups. Increased duration of vibration exposure and increased intensity are assumed to increase the risk, while periods of rest reduce the risk. Many drivers complain also about disorders in the neck-shoulder although epidemiological researches are inconclusive on this effect.

Low-back pain and back, shoulder or neck disorders are not specific to vibration exposures. There are many confounding factors such as working posture, anthropometric characteristics, muscle tone, physical workload, and individual susceptibility (age, pre-existing disorders, muscle force, etc.).

Driving of mobile machines does not only involve exposure to whole-body vibration but also to several other factors that put strains on the back, shoulder or neck. The most important being:

- prolonged sitting in constrained postures,
- prolonged sitting in poor postures,
- frequent twisting of the spine
- needing to adopt twisted head postures,
- frequent lifting and material handling (e. g. drivers of delivery trucks),
- traumatic injuries,
- unexpected movements,

- unfavourable climatic conditions and
- stress.

In some countries and under certain conditions, lumbar disorders occurring in workers exposed to whole-body vibration are considered to be an occupational disease.

C.3 Other disorders

The question of whether whole-body vibration exposure might lead to digestive or circulatory disorders or adverse affects on the reproductive system remains open. In some cases an increased prevalence of gastro-intestinal complaints, peptic ulcer and gastritis have been reported in drivers of vibrating vehicles. Whole-body vibration seems to be a factor that in combination with the long-term sitting posture of drivers contributes to the occurrence of varicose veins and haemorrhoids. Some studies have reported evidence of effects on the digestive system, the female reproductive organs and the peripheral veins. One study showed a greater than expected incidence of stillbirth among women exposed to vibration in the transport sector.

ANNEX D TOOLS FOR CALCULATING DAILY EXPOSURES

D.1 Web-based tools

Some web-based calculators are available that simplify the process of doing daily vibration exposure calculations, e.g.:

www.hse.gov.uk/vibration/calculator.htm

http://vibration.arbetslivsinstitutet.se/eng/wbvcalculator.lasso

D.2 Daily exposure graph

The graph in Figure D.1 gives a simple alternative method for looking up daily exposures or partial vibration exposures without the need for a calculator.

Simply look on the graph for the A(8) line at or just above where your vibration magnitude value $(ka_w)_{max}$ and exposure time lines meet (the factor *k* is either 1.4 for the x- and y-axes or 1.0 for the z-axis i.e. vertical direction).

The green area in Figure D1 indicates exposures likely to below the exposure action value. These exposures must not be assumed to be “safe”. There may be a risk of whole-body vibration injury for exposures below the exposure action value, and so some exposures within the green area may cause vibration injury in some workers, especially after many years of exposure.

D.3 Daily exposure nomogram

The nomogram in Figure D.2 provides a simple alternative method of obtaining daily vibration exposures, without using the equations:

(a) On the left hand line find the point corresponding to the vibration magnitude (use the left scale for x- and y-axis values; the right scale for z-axis values).

(b) Draw a line from the point on the left hand line (representing the vibration magnitude) to a point on the right hand line (representing the exposure time);

Read off the partial exposures where the line crosses the central scale.

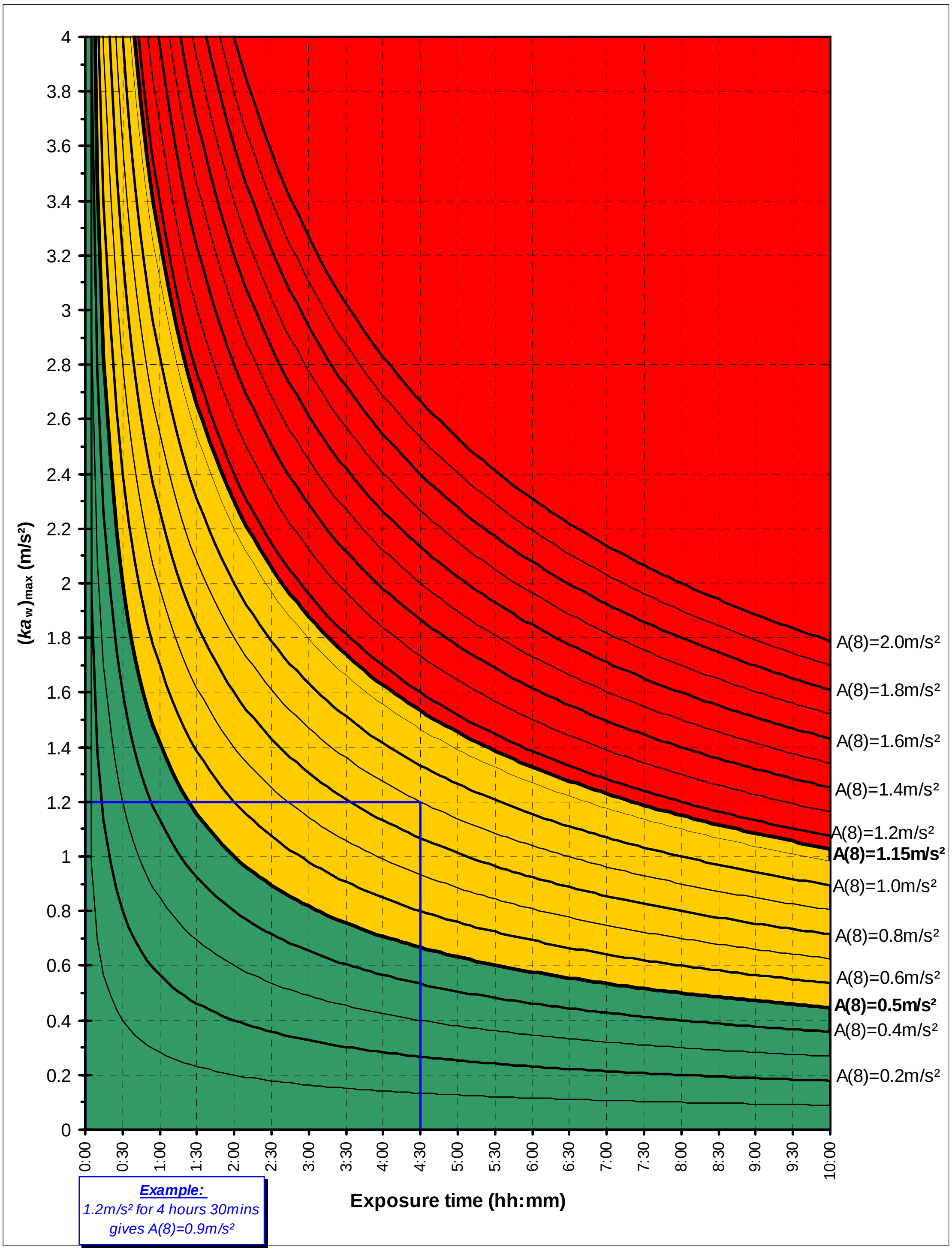
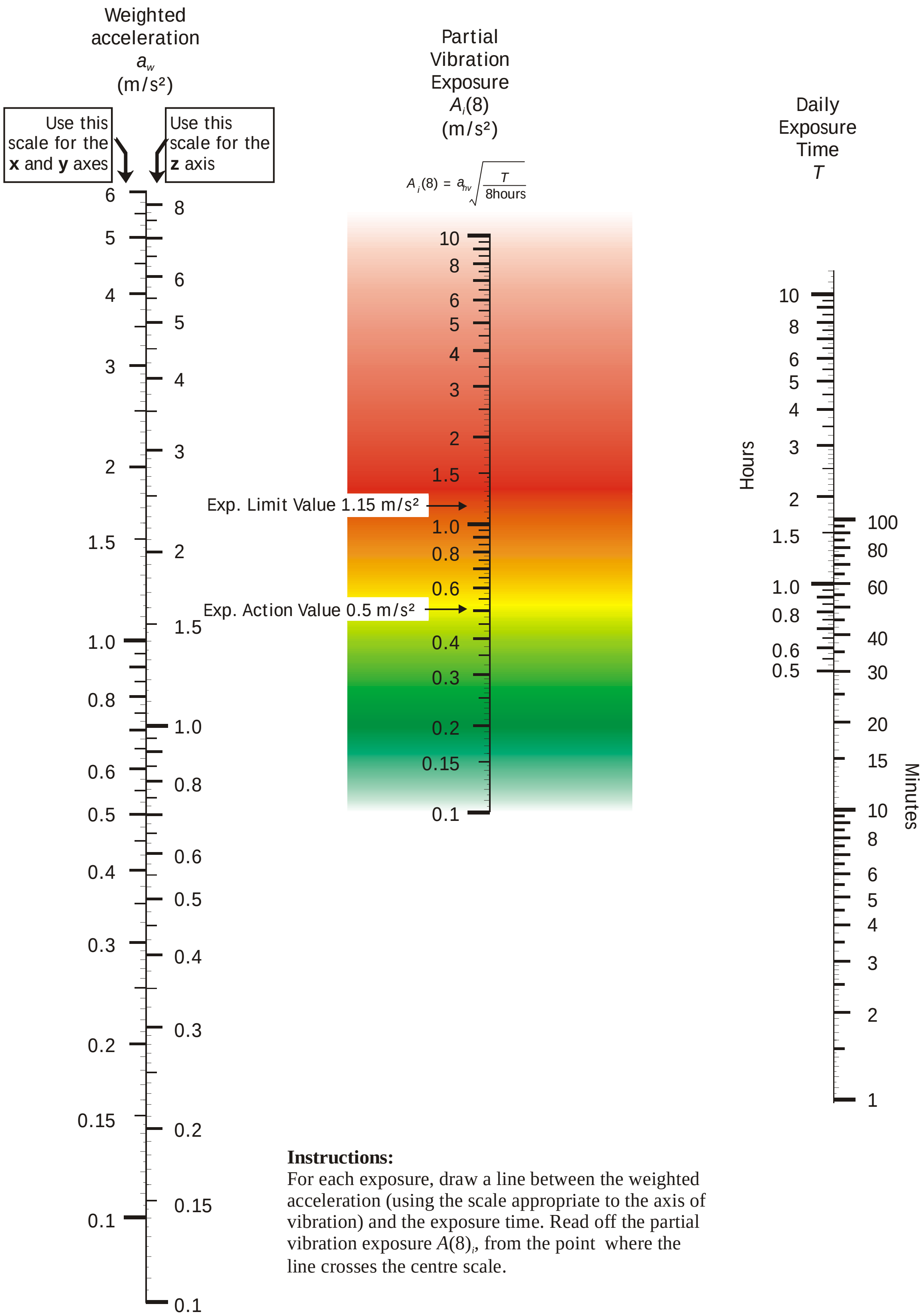


Figure D.1 Daily exposure graph



Instructions:
For each exposure, draw a line between the weighted acceleration (using the scale appropriate to the axis of vibration) and the exposure time. Read off the partial vibration exposure $A(8)_i$, from the point where the line crosses the centre scale.

Figure D.2 Nomogram for A(8) values

D.4 Exposure points system

Whole-body vibration exposure management can be simplified by using an exposure "points" system. For any vehicle or machine operated, the number of exposure points accumulated in an hour ($P_{E,1h}$ in points per hour) can be obtained from the vibration magnitude a_w in m/s² and the factor k (either 1.4 for x- and y-axes or 1.0 for the z-axis) using:

$$P_{E,1h} = 50\left(ka_w\right)^2$$

Exposure points are simply added together, so you can set a maximum number of exposure points for any person in one day.

The exposure scores corresponding to the exposure action and limit values are:

- exposure action value (0.5 m/s²) = 100 points;
- exposure limit value (1.15 m/s²) = 529 points.

In general the number of exposure points, P_E, is defined by:

$$P_E = \left(\frac{ka_w}{0.5\text{m/s}^2}\right)^2 \frac{T}{8\text{hours}} 100$$

Where a_w is the vibration magnitude in m/s², T is the exposure time in hours and k is the multiplying factor of either 1.4 for x- and y-axes or 1.0 for the z-axis.

Alternatively Figure D.3 gives a simple method for looking up the exposure points.

The daily exposure $A(8)$, can be calculated from the exposure point using:

$$A(8) = 0.5\text{m/s}^2 \sqrt{\frac{P_E}{100}}$$

Acceleration × *k* (m/s²)											
2	50	100	200	400	600	800	1000	1200	1600	2000	2400
1.9	45	90	180	360	540	720	905	1100	1450	1800	2150
1.8	41	81	160	325	485	650	810	970	1300	1600	1950
1.7	36	72	145	290	435	580	725	865	1150	1450	1750
1.6	32	64	130	255	385	510	640	770	1000	1300	1550
1.5	28	56	115	225	340	450	565	675	900	1150	1350
1.4	25	49	98	195	295	390	490	590	785	980	1200
1.3	21	42	85	170	255	340	425	505	675	845	1000
1.2	18	36	72	145	215	290	360	430	575	720	865
1.1	15	30	61	120	180	240	305	365	485	605	725
1	13	25	50	100	150	200	250	300	400	500	600
0.9	10	20	41	81	120	160	205	245	325	405	485
0.8	8	16	32	64	96	130	160	190	255	320	385
0.7	6	12	25	49	74	98	125	145	195	245	295
0.6	5	9	18	36	54	72	90	110	145	180	215
0.5	3	6	13	25	38	50	63	75	100	125	150
0.4	2	4	8	16	24	32	40	48	64	80	96
0.3	1	2	5	9	14	18	23	27	36	45	54
0.2	1	1	2	4	6	8	10	12	16	20	24
	15m	**30m**	**1h**	**2h**	**3h**	**4h**	**5h**	**6h**	**8h**	**10h**	**12h**
	Daily Exposure time										

Figure D.3 Exposure points table (rounded values)

ANNEX E DAILY EXPOSURE WORKED EXAMPLES

E.1 Daily exposure: A(8), where there is just one task

Step 1: Determine the three frequency weighted r.m.s acceleration values a_{wx}, a_{wy} and a_{wz}., from manufacturer's data, other sources, or measurement.

Step 2: Find the daily exposures in the three directions, x, y and z from:

$$A_x(8) = 1.4 a_{wx} \sqrt{\frac{T_{exp}}{T_0}}$$

$$A_y(8) = 1.4 a_{wy} \sqrt{\frac{T_{exp}}{T_0}}$$

$$A_z(8) = a_{wz} \sqrt{\frac{T_{exp}}{T_0}}$$

Where

- T_{exp} is the daily duration of exposure to the vibration and
- T_0 is the reference duration of eight hours.

Step 3: The highest value of $A_x(8)$, $A_y(8)$ and $A_z(8)$ is the daily vibration exposure.

Example

A tree harvester driver operates the vehicle for 6½ hours a day.

Step 1: The vibration values on the seat are:

- x-axis: 0.2 m/s²
- y-axis: 0.4 m/s²
- z-axis: 0.25 m/s²

Step 2: The x, y and z axis daily exposures are then:

$$A_x(8) = 1.4 \times 0.2 \sqrt{\frac{6.5}{8}} = 0.25 \text{ m/s}^2$$

$$A_y(8) = 1.4 \times 0.4 \sqrt{\frac{6.5}{8}} = 0.5 \text{ m/s}^2$$

$$A_z(8) = 0.25 \sqrt{\frac{6.5}{8}} = 0.23 \text{ m/s}^2$$

Step 3: Daily vibration exposure, A(8) is the highest of these values. In this case it is the y-axis: 0.5m/s² (i.e. at the exposure action value)

E.2 Daily exposure: A(8), where there is more than one task

If a person is exposed to more than one source of vibration (perhaps because they use two or more different machines or activities during the day) then a *partial vibration exposure* is calculated from the magnitude and duration for each axis and for each exposure. The partial vibration values are combined to give the overall daily exposure value, $A(8)$, for that person, for each axis. The daily vibration exposure is then the highest of the three single axis values.

Step 1: Determine the three frequency weighted r.m.s acceleration values a_{wx}, a_{wy} and a_{wz}, for each task or vehicle, from manufacturer's data, other sources, or measurement.

Step 2: For each vehicle or task, find the partial daily exposures in the three directions, x, y and z using:

$$A_{x,i}(8) = 1.4 a_{wx} \sqrt{\frac{T_{exp}}{T_0}}$$

$$A_{y,i}(8) = 1.4 a_{wy} \sqrt{\frac{T_{exp}}{T_0}}$$

$$A_{z,i}(8) = a_{wz} \sqrt{\frac{T_{exp}}{T_0}}$$

Where

- T_{exp} is the daily duration of exposure to the vibration and
- T_0 is the reference duration of eight hours.

Each partial vibration exposure represents the contribution of a particular source of vibration (machine or activity) to the worker's total daily exposure. Knowledge of the partial exposure values will help you decide on your priorities: the machines or activities or processes with the highest partial vibration exposure values are those that should be given priority for control measures.

Step 3: For each axis (j), the overall daily vibration exposure can be calculated from the partial vibration exposure values, using:

$$A_j(8) = \sqrt{A_{j1}(8)^2 + A_{j2}(8)^2 + A_{j3}(8)^2 + \ldots}$$

where $A_{j1}(8)$, $A_{j2}(8)$, $A_{j3}(8)$, etc. are the partial vibration exposure values for the different vibration sources.

Step 4: The highest value of $A_x(8)$, $A_y(8)$ and $A_z(8)$ is the daily vibration exposure.

Example

A delivery driver spends 1 hour loading his lorry using a small forklift truck, followed by 6 hours driving the delivery lorry each day.

Step 1: The vibration values on the seat are:

Forklift truck	Delivery lorry
▪ x-axis: 0.5 m/s² ▪ y-axis: 0.3 m/s² ▪ z-axis: 0.9 m/s²	▪ x-axis: 0.2 m/s² ▪ y-axis: 0.3 m/s² ▪ z-axis: 0.3 m/s²

Step 2: The x, y and z axis daily exposures are then:

Forklift truck	Delivery lorry
$A_{x,\,forklift}(8) = 1.4 \times 0.5\sqrt{\frac{1}{8}} = 0.25$ m/s² $A_{y,\,forklift}(8) = 1.4 \times 0.3\sqrt{\frac{1}{8}} = 0.15$ m/s² $A_{z,\,forklift}(8) = 0.9\sqrt{\frac{1}{8}} = 0.32$ m/s²	$A_{x,lorry}(8) = 1.4 \times 0.2\sqrt{\frac{6}{8}} = 0.24$ m/s² $A_{y,lorry}(8) = 1.4 \times 0.3\sqrt{\frac{6}{8}} = 0.36$ m/s² $A_{z,lorry}(8) = 0.3\sqrt{\frac{6}{8}} = 0.26$ m/s²

Step 3: Daily vibration exposure, for each axis are:

$$A_x(8) = \sqrt{0.25^2 + 0.24^2} = 0.3 \text{ m/s}^2$$

$$A_y(8) = \sqrt{0.15^2 + 0.36^2} = 0.4 \text{ m/s}^2$$

$$A_z(8) = \sqrt{0.32^2 + 0.26^2} = 0.4 \text{ m/s}^2$$

Step 4: The driver’s daily whole-body vibration exposure is the highest axis A(8) value, in this case the value for the y or z-axes: 0.4 m/s², i.e. just below the exposure action value.

E.3 Daily exposure: VDV, where there is just one task

Step 1: Determine the three frequency weighted VDVs VDV_x, VDV_y and VDV_z.
(Note – VDV data less widely reported than r.m.s data and is not required to be reported by manufacturers, so VDV values are likely to come from measured rather than published data).

Step 2: Find the daily exposures in the three directions, x, y and z from:

$$VDV_{\exp,x,i} = 1.4 \times VDV_x \left(\frac{T_{\exp}}{T_{meas}} \right)^{1/4}$$

$$VDV_{\exp,y,i} = 1.4 \times VDV_y \left(\frac{T_{\exp}}{T_{meas}} \right)^{1/4}$$

$$VDV_{\exp,z,i} = VDV_z \left(\frac{T_{\exp}}{T_{meas}} \right)^{1/4}$$

Where:

- T_{meas} is the measurement period, and
- T_{exp} is the daily duration of exposure to the vibration.

Step 3: The highest value of $VDV_{\exp,x}$, $VDV_{\exp,y}$ and $VDV_{\exp,z}$ is the daily VDV.

Example

A tree harvester driver operates the vehicle for 6½ hours a day.

Step 1: The VDVs measured on the seat during a 2 hour measurement period are::

- x-axis: 3 $m/s^{1.75}$
- y-axis: 5 $m/s^{1.75}$
- z-axis: 4 $m/s^{1.75}$

Step 2: The x, y and z axis VDV exposures are then:

$$VDV_{\exp,x} = 1.4 \times 3 \left(\frac{6.5}{2} \right)^{1/4} = 5.6\ m/s^{1.75}$$

$$VDV_{\exp,y} = 1.4 \times 5 \left(\frac{6.5}{2} \right)^{1/4} = 9.4\ m/s^{1.75}$$

$$VDV_{\exp,z} = 4 \left(\frac{6,5}{2} \right)^{1/4} = 5,4\ m/s^{1,75}$$

Step 3: Daily VDV is the highest of these values. In this case, the y-axis: 9.4 $m/s^{1.75}$ i.e. just above the VDV exposure action value.

E.4 Daily exposure: VDV, where there is more than one task

If a person is exposed to more than one source of vibration (perhaps because they use two or more different machines or activities during the day) then a *partial VDV* is calculated from the magnitude and duration for each axis and for each exposure. The partial VDVs are combined to give the overall daily VDV for that person, for each axis. The daily VDV is then the highest of the three single axis values.

Step 1: Determine the three frequency weighted VDVs VDV_x, VDV_y and VDV_z, for each task or vehicle.

Step 2: Find the partial VDVs in the three directions, x, y and z from:

$$VDV_{\exp,x} = 1.4 \times VDV_x \left(\frac{T_{\exp}}{T_{meas}} \right)^{1/4}$$

$$VDV_{\exp,y} = 1.4 \times VDV_y \left(\frac{T_{\exp}}{T_{meas}} \right)^{1/4}$$

$$VDV_{\exp,z} = VDV_z \left(\frac{T_{\exp}}{T_{meas}} \right)^{1/4}$$

Where:

- T_{meas} is the measurement period, and
- T_{exp} is the daily duration of exposure to the vibration.

Step 3: For each axis (j), the overall daily VDV can be calculated from the partial vibration exposure values, using:

$$VDV_j = \left(VDV_{j1}{}^4 + VDV_{j2}{}^4 + VDV_{j3}{}^4 + \ldots \right)^{1/4}$$

where VDV_{j1}, VDV_{j2}, VDV_{j3}, etc. are the partial vibration exposure values for the different vibration sources.

Step 4: The highest value of VDV_x, VDV_y and VDV_z is the daily VDV.

Example

A delivery driver spends 1 hour loading his lorry using a small forklift truck, followed by 6 hours driving the delivery lorry each day.

Step 1: The vibration values on the seat, measured for 1 hour on the forklift and 4 hours on the delivery truck, are:

Forklift truck	Delivery lorry
▪ x-axis: 6 m/s$^{1.75}$ ▪ y-axis: 4 m/s$^{1.75}$ ▪ z-axis: 12 m/s$^{1.75}$	▪ x-axis: 4 m/s$^{1.75}$ ▪ y-axis: 5 m/s$^{1.75}$ ▪ z-axis: 6 m/s$^{1.75}$

Step 2: The x, y and z axis partial VDVs are then:

Forklift truck	Delivery lorry
$VDV_{\exp,x,\,flt} = 1.4 \times 6\left(\frac{1}{1}\right)^{1/4} = 8\ \text{m/s}^{1.75}$ $VDV_{\exp,y,\,flt} = 1.4 \times 4\left(\frac{1}{1}\right)^{1/4} = 6\ \text{m/s}^{1.75}$ $VDV_{\exp,z,\,flt} = 12\left(\frac{1}{1}\right)^{1/4} = 12\ \text{m/s}^{1.75}$	$VDV_{\exp,x,lorry} = 1.4 \times 4\left(\frac{6}{4}\right)^{1/4} = 6\ \text{m/s}^{1.75}$ $VDV_{\exp,y,lorry} = 1.4 \times 5\left(\frac{6}{4}\right)^{1/4} = 8\ \text{m/s}^{1.75}$ $VDV_{\exp,z,lorry} = 6\left(\frac{6}{4}\right)^{1/4} = 7\ \text{m/s}^{1.75}$

Step 3: Daily vibration exposure, for each axis are:

$$VDV_x = \left(8^4 + 6^4\right)^{1/4} = 9\ \text{m/s}^{1.75}$$

$$VDV_y = \left(6^4 + 8^4\right)^{1/4} = 9\ \text{m/s}^{1.75}$$

$$VDV_z = \left(12^4 + 7^4\right)^{1/4} = 12\ \text{m/s}^{1.75}$$

Step 4: The driver's daily whole-body vibration exposure is the highest axis VDV, in this case the value for the z-axis: 12 m/s$^{1.75}$ i.e. between the VDV exposure action and exposure limit values.

E.5 Daily exposure: A(8), using the exposure points system

(Note: this is the same worked example as Annex E.2 using the exposure points method)

If you have acceleration values in m/s²:

Step 1: Determine points values for each task or vehicle, using Figure D.3 to look-up the exposure points based on the acceleration value, k-factor and the exposure time.

Step 2: For each axis add the points per machine to give a total daily points per axis.

Step 3: The highest value of the three axis values is the daily vibration exposure in points

Example

A delivery driver spends 1 hour loading his lorry using a small forklift truck, followed by 6 hours driving the delivery lorry each day.

Step 1: The x, y and z axis daily exposures are:

Forklift truck	Points after 1 hours use (from Figure D.3)
▪ x-axis: 0.5 *x* 1.4 = 0.7 ▪ y-axis: 0.3 *x* 1.4 = 0.42 ▪ z-axis: 0.9	▪ 0.7 m/s² for 1 hour = 25 points ▪ 0.5* m/s² for 1 hour = 13 points ▪ 0.9 m/s² for 1 hour = 41 points

** 0.42 m/s² is not shown in Figure D.3, therefore nearest higher value of 0.5 m/s² is used.*

Delivery lorry	Points after 6 hours use (from Figure D.3)
▪ x-axis: 0.2 *x* 1.4 = 0.28 ▪ y-axis: 0.3 *x* 1.4 = 0.42 ▪ z-axis: 0.3	▪ 0.3* m/s² for 6 hours = 27 points ▪ 0.5* m/s² for 6 hours = 75 points ▪ 0.3 m/s² for 6 hours = 27 points

** the exact vibration values are not shown in Figure D.3, therefore nearest higher values are used.*

Step 2: Daily vibration exposure points, for each axis are:

x-axis = 25 + 27 = 52 points
y-axis = 13 + 75 = 88 points
z-axis = 41 + 27 = 68 points

Step 3: The driver's daily whole-body vibration exposure is the highest axis points value, in this case the value for the y-axis: 83 points, i.e. below the 100 point exposure action value.

If you have points-per-hour data:

Step 1: Determine points-per-hour values for each task or vehicle, from manufacturer's data, other sources, or measurement.

Step 2: For each vehicle or task, find the daily points for by multiplying the number of points-per-hour by the number of hours use of the machine:

Step 3: For each axis add the points per machine to give a total daily points per axis.

Step 4: The highest value of the three axis values is the daily vibration exposure in points.

Example

A delivery driver spends 1 hour loading his lorry using a small forklift truck, followed by 6 hours driving the delivery lorry each day.

Step 1: The points per hour values on the seat are:

Forklift truck	Delivery lorry
▪ x-axis: 25 ▪ y-axis: 9 ▪ z-axis: 41	▪ x-axis: 4 ▪ y-axis: 9 ▪ z-axis: 5

Notes:
- *The k factors are included in the points per hour values (see Annex D.4).*
- *The points per hour values have been rounded up to the nearest whole number.*

Step 2: The x, y and z axis daily exposure points are then:

Forklift truck *(1 hour use)*	Delivery lorry *(6 hours use)*
▪ x-axis: 25 *x* 1 = 25 ▪ y-axis: 9 *x* 1 = 9 ▪ z-axis: 41 *x* 1 = 41	▪ x-axis: 4 *x* 6 = 24 ▪ y-axis: 9 *x* 6 = 54 ▪ z-axis: 5 *x* 6 = 30

Step 3: Daily vibration exposure points, for each axis are:

x-axis = 25 + 24 = 49 points
y-axis = 9 + 54 = 63 points
z-axis = 41 + 30 = 71 points

Step 4: The driver's daily whole-body vibration exposure is the highest axis points value, in this case the value for the z-axis: 71 points, i.e. below the 100 point exposure action value.

ANNEX F HEALTH SURVELLANCE TECHNIQUES

Health surveillance may consist of an evaluation of the case history for a worker in conjunction with a physical examination conducted by a doctor or suitably qualified health-care professional.

Questionnaires for whole-body vibration health surveillance are available from various sources (e.g. the VIBGUIDE section of: http://www.humanvibration.com/EU/EU_index.htm).

The case history

The case history should focus on:

- family history;
- social history, including smoking habit and alcohol consumption and involvement in physical activities;
- work history, including past and current occupations with exposure to whole-body vibration, working posture, lifting tasks and other work-related back stressors; and
- personal health history.

The physical examination

The physical examination might include:

- examination of the back function and evaluation of the effects on pain of forward and lateral flexion and extension;
- straight leg raising test;
- peripheral neurological examination (knee and Achilles tendon reflexes and the sensitivity in leg and foot);
- signs of muscle weakness (extension quadriceps, flexion/extension big toe/foot);
- back endurance test;
- Waddel's signs of non-organic pain.

ANNEX G GLOSSARY

Whole-body vibration ... The mechanical vibration that, when transmitted to the whole body, entails risks to the health and safety of workers, in particular lower-back morbidity and trauma of the spine.

Vibration emission .... The vibration value provided by machine manufacturers to indicate the vibration likely to occur on their machines. The vibration emission value should be obtained using standardised test code, and has to be included in the machine's instructions.

Frequency-weighting .... A filter applied to vibration measurements to mimic the frequency dependence of the risk of damage to the body. Two weightings are used for whole-body vibration:

- Wd for vibration in both the fore-aft (x) and side-to-side (y) axes, and
- Wk for the vertical (z) axis.

Daily vibration exposure, *A*(8)
The 8-hour energy equivalent vibration total value for a worker in meters per second squared (m/s^2), including all whole-body vibration exposures during the day.

Vibration dose value, VDV
"A cumulative dose, based on the fourth root of the fourth power of the acceleration signal. VDV has units of $m/s^{1.75}$.

Health surveillance........ A programme of health checks on workers to identify early effects of injury resulting from work activities.

Exposure action value ... A value for either a workers daily vibration exposure, *A*(8) of $0.5 m/s^2$, or a workers daily VDV of $9.1 m/s^{1.75}$, above which the risks from vibration exposure must be controlled.[2]

Exposure limit value ..... A value for either a workers daily vibration exposure, *A*(8) of $1.15 m/s^2$, or a workers daily VDV of $21 m/s^{1.75}$, above which workers should not be exposed.[2]

Exposure time .... The duration per day that a worker is exposure to a vibration source.

[2] Member States have a choice of using either A(8) or VDV for the exposure action and limit values

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Directive of 89/391/EEC of the European parliament and of the Council of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work

Directive 98/37/EC of the European parliament and of the Council of 22 June 1998 on the approximation of the laws of the Member States relating to machinery

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http://www.las-bb.de/karla/index_.htm	Vibration emission data
www.hse.gov.uk/vibration/calculator.htm	Exposure calculator
http://vibration.arbetslivsinstitutet.se/eng/wbvcalculator.lasso	Exposure calculator

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