European Agency for Safety and Health at Work

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Workplace exposure to vibration in Europe:
an expert review

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CONTENTS

Summary

The vibration directive (2002/44/EC) ([1]) introduces minimum protection requirements for workers when they are exposed to risks arising from vibration. National measures transposing the directive have been taken by all 27 Member States since it came into force across Europe on 6 July 2005. The objective of this report is to provide an overview of the challenges facing the occupational safety and health (OSH) community in this field in the context of the application of the vibration directive. The situation in six Member States — Belgium, Germany, Spain, Finland, France and Poland — is examined, and research information is presented covering all Member States.

Although it is a long-standing and well-known risk, vibration has increased in importance since the application of the directive. Enterprises, regulators and legislators face important new challenges; measurement is complicated and risk assessment and reduction are not simple.

The report is based on contributions from specialists in vibration at work from seven leading European institutions. It comprises the following nine chapters:

1. Main sources of vibration and extent of workers' exposure
2. Principal groups at risk
3. Implementation of the directive
4. Evaluation of vibration risks at the workplace
5. Application of the directive in practice
6. Management of vibration risks at the workplace
7. Support for employers
8. Prevention measures
9. Research perspectives

([1]) 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).

Exposed workers are overwhelmingly male and typically either drivers of mobile machines, operators of hand-tools, or people working in the vicinity of stationary machines. The proportion of the workforce exposed to vibration varies widely between countries, from 14 % to 34 %, and is concentrated in the sectors of contruction (63 %), manufacture and mining (44 %) and agriculture and fishing (38 %) ([2]).

With respect to whole-body vibration (WBV), the authors estimate that the action levels established in the directive will be exceeded by operators of most off-road machinery and agricultural and forestry tractors when travel is frequent. In the case of fork-lift trucks, the action level is likely to be exceeded if they are driven for longer than three to four hours and in the case of trucks and lorries if they are driven all day long. However, the limit value is likely to be reached only rarely, except in the case of scrapers and some conventional finishers.

As regards hand-arm vibration (HAV), the action level is likely to be exceeded by operators of most main percussive and roto-percussive tools (such as chipping hammer, demolition hammer, rock drill, breaker, impact drill, scabbler, rammer, vibratory rammer), of main rotative tools (e.g. grinder, impact wrench, sander) and main alternative tools (e.g. jig-saw, file). The limit value for exposure to vibration may be exceeded if percussive and roto-percussive tools are used for more than one to two hours a day, or in the case of some rotative tools if used for more than four hours.

The report examines how the requirements of the vibration directive are practically implemented in six European countries. In accordance with the provisions of the directive, the daily dose is taken as a starting criterion in all national legislation. In some countries, however, national law has set stricter requirements than those of the directive (e.g. Finland and Poland have fixed short-term exposure limit values and Germany has an exposure limit value of 0.8 m/s^2 for vertical axis whole-body vibration). Many complementary methods for controlling exposure to vibration are found in the legislation, including maintenance requirements and limitation of exposure duration.

An efficient way of managing the risks related to vibration is to adopt a strategy based on the evaluation of risks. The basis for this strategy can be found in the vibration directive itself, whereby employers are required to assess vibration magnitudes. In the authors' experience, very few employers actually take measurements (approximately 5 % in Finland) and many do not even evaluate the risk (around 55 % in Belgium). Evaluation is usually based on data provided by the equipment manufacturer or obtained from online databases. In order to assist employers with their risk evaluation, some countries (e.g. Poland, Spain) have trained many laboratories in how to carry out measurement of vibration, while other countries have favoured the management of risks by users themselves (Belgium). Overall, however, the number of accredited organisations in the field of vibration assessment is still small whatever the country. Regardless of the management methods in place, some employers are likely to start a programme to reduce exposure to vibration based simply on the presence of vibrating work equipment.

A strategy to control vibration can be based on actions at different levels. Anti-vibration techniques or low-vibration alternatives can be efficient at reducing the risks, but eradication of vibration syndrome needs action at several different levels: introduction of low-vibration tools, organisation of work, medical surveillance, etc.

([2]) Data from the fourth European working conditions survey: reported exposure to vibrations a quarter of the time or more.

The vibration directive proposes a strategy to employers on how to deal with risks related to vibration at the workplace. In practice, various approaches can be taken to deal with these risks and experience shows that it is possible to implement effective solutions. However, while technical solutions to reduce vibration are relatively well-known, they are under-used by machine or tool manufacturers and by operators. Key factors which may contribute to the success of a prevention programme include an integrated step-by-step approach, effective guidance, implementation of a purchasing policy, collaboration with manufacturers, implementation of a range of measures, information and awareness-raising.

In the authors' view, the extent to which technical solutions are adopted varies considerably between countries. Uptake is high in Finland, Germany and Poland, whereas it is relatively low in Belgium, France and Spain. These differences may be due to a general lack of awareness, high costs, users' ignorance of how to select an adequate machine/device, or insufficient awareness of OSH aspects on the part of manufacturers and distributors. Moreover, as the buyer of a machine/device is usually not the eventual user, it is often difficult to convince the buyer to take up solutions because of their ignorance of certain negative aspects. Last but not least, vibration-reduced machines/devices are sometimes considered to be a luxury rather than a health and safety requirement. This situation should change, however, thanks to the vibration directive, which makes the reduction of vibration compulsory. As the directive is fairly new, many companies are still in the process of implementing the measures and have only recently started to identify and assess the risks related to vibration. The implementation of technical measures and the adaptation of equipment will follow in due course.

Support from insurers, social partners, research organisations and manufacturers is provided mainly in the form of good practice guides for risk assessment and health surveillance. However, they may also encourage the development of low-cost dosimeters and of online calculators.

It is evident from the review of the research that is being carried out across the 27 Member States that one of the effects of the vibration directive has been to encourage research in countries which were previously not very active in this field. Overall, however, the authors conclude that there are still insufficient data concerning exposure to vibration in different sectors, use of machinery under various working conditions, or the effects of maintenance and age of machinery. Therefore, further field study measurements are required. Additionally, there is a need for joint scientific efforts to clarify the prerequisite for an adequate risk assessment in the case of WBV. The evaluation methods concerning health risks, comfort and performance due to WBV, described in ISO 2631-1 and -5 (frequency weighting, multiplying factors) and used in application of the EU directive, are currently under critical discussion. Moreover, in the field of HAV, there is a need to develop standardised and reproducible measurement methods for several classes of machines and working conditions, including the use of anti-vibration gloves.

INTRODUCTION

Vibrations arise when a body oscillates due to external and internal forces. Vibration may be transmitted to the human body through the part in contact with the vibrating surface: the handle of a machine, the surface of a piece of equipment, or the seat of a mobile machine.

Directive 2002/44/EC of the European Parliament and of the Council on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) lays down minimum requirements for the protection of workers from risks to their health and safety arising, or likely to arise, from exposure to mechanical vibration during their work.

Two forms of exposure may be distinguished: **whole-body vibration** (WBV), which is transmitted by mobile or fixed machines where the operator is standing or seated, and **hand-arm vibration** (HAV), which is transmitted by hand-held or guided tools. The directive defines the terms as follows:

- '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;
- 'hand-arm vibration': the mechanical vibration that, when transmitted to the human hand-arm system, entails risks to the health and safety of workers, in particular, vascular, bone or joint, neurological or muscular disorders.

Human exposure to WBV should be evaluated using the method defined in International Standard ISO 2631-1:1997, together with the detailed practical guidance on using the method for measurement of vibration at the workplace, which is given in EN 14253:2003. In the case of human exposure to HAV, the method that should be used is defined in European Standard EN ISO 5349-1:2001, together with the detailed practical guidance on using the method for measurement of vibration at the workplace, which is set out in EN ISO 5349-2:2001.

In simple terms, vibration is defined by its magnitude (traditionally described using acceleration, expressed in m/s^2) and frequency (the number of times per second the vibrating body moves back and forth, expressed in cycles per second, or hertz (Hz)). The risk of damage is not equal at all frequencies; therefore, when calculating exposure, a **frequency weighting** is used. Furthermore, vibration must be evaluated in three axes (vertical, fore and aft, and lateral axes in the case of WBV). From each vibration axis a frequency-weighted root-mean-square average acceleration is measured. This is referred to as a_{hw}. Since the risk of damage is not equal in all axes, a multiplying factor must be applied to the frequency-weighted vibration values. In the case of WBV, the acceleration values for the two lateral axes (*x* and *y*) are multiplied by 1.4, whereas for the vertical (*z* axis) they are multiplied by 1.0. In the case of HAV no multiplying factors are used.

In the case of WBV, the equivalent acceleration is obtained from the highest of three orthogonal axes' values ($1.4a_{wx}$ $1.4a_{wy}$ or a_{wz}) that are used for the exposure assessment. HAV risk, on the other hand, is based on the frequency-weighted acceleration total value a_{hv} given by the root sum of squares of the frequency-weighted acceleration from the three orthogonal axes, *x*, *y* and *z*:

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2}$$

The vibration directive defines the daily exposure, A(8), as:

HAV: the equivalent continuous acceleration, normalised to an eight-hour day; the A(8) value is based on root-mean-square averaging of the acceleration signal and has units of m/s^2;

$$A(8) = a_{hv}\sqrt{\frac{T}{T_0}}$$

where T is the daily duration of exposure to the vibration magnitude a_{hv} and T_0 is the reference duration of eight hours;

WBV: the equivalent continuous acceleration over an eight-hour period, calculated as the highest (rms) value, or the highest vibration dose value (VDV) of the frequency-weighted accelerations, determined on three orthogonal axes (1.4*awx*, 1.4*awy*, *awz* for a seated or standing worker).

The directive sets **exposure action values**, above which it requires employers to control the vibration risks to their workforce, and **exposure limit values**, above which workers shall not be exposed:

- a daily exposure action value of 0.5 m/s^2 (WBV) or 2.5 m/s^2 (HAV);
- a daily exposure limit value of 1.15 m/s^2 (WBV) or 5 m/s^2 (HAV).

The directive also: explains employers' obligations with regard to determining and assessing risks; sets out the measures to be taken to reduce or avoid exposure; and explains how to provide information and training for workers. Any employer that intends to carry out work involving risks arising from exposure to vibration must therefore implement a series of protection measures before and during actual operations.

The vibration directive has been transposed through national measures in all European Member States since it came into force on 6 July 2005. It has resulted in many questions from employers, hygienists and exposed persons on, for example, how to evaluate vibration, what are the situations at risk, what are the effects of vibration, how to reduce vibration, and how to develop an action plan for prevention.

The objective of this report is to provide an overview of various aspects of prevention of vibration hazards to workers following the entry into force of the vibration directive. It will show that vibration is increasingly important on account of the vibration directive, increasing exposure of women, ageing of exposed persons, and the development of new tools for prediction.

Focusing on six countries, it presents a picture of the risks associated with vibration, highlighting the influence of other hazards (such as poor posture and muscular work); describes prevalence and groups particularly at risk; and discusses likely trends in the coming years and ways in which they are being addressed across Europe. In particular, it emphasises how the vibration directive is being applied by Member States in practice and the different strategies developed. It examines a broad range of initiatives and considers the issues affecting their likelihood of success. Examples of initiatives include practical solutions, guides, actions and strategies at national and sector levels, including actions by social partners. The description of vibration effects and listing of technical reduction systems have been widely covered elsewhere and are beyond the scope of this project.

Geographical coverage

Within the limits of the project, it was considered that rather than attempt an overview of the topics in all 27 Member States, best use of resources could be achieved by in-depth coverage of a selection of countries for topics one to eight. In the case of topic nine, concerning research, a questionnaire was sent to experts from all Member States via the focal point network of the European Agency for Safety and Health at Work.

The selection of countries chosen for the in-depth review aims to be representative of Europe as a whole, with one country (Germany) very active in the field of vibration reduction, one Nordic country (Finland), one member of the Benelux countries (Belgium), one representing eastern Europe (Poland) and two Mediterranean countries (France and Spain).

1.

MAIN SOURCES OF VIBRATION AND EXTENT OF WORKERS' EXPOSURE

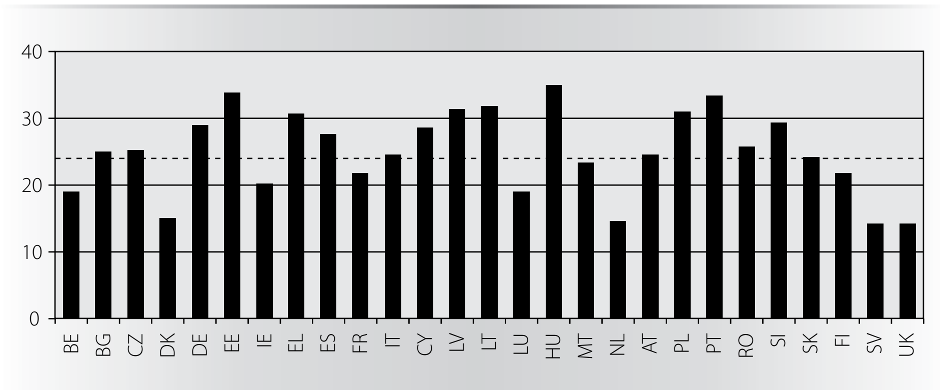
1.1. Extent of exposure

According to Eurofound's ([1]) fourth European working conditions survey (EWCS), an average of one in three workers in Europe is exposed to some kind of vibrations whatever the source, tools or machinery and one in four is exposed at least a quarter of the time (see Table 1.1). These figures have remained constant over the last three surveys (1996, 2000 and 2005).

Table 1.1: Percentage of workers exposed to vibration from hand-tools, machinery, etc. according to duration of exposure and by country (Eurofound, fourth EWCS) ([2])

Duration of exposure	Belgium	Germany	Spain	France	Poland	Finland	EU-27
All of the time	5.7 %	4.5 %	4.6 %	7.3 %	10.1 %	3.5 %	5.5 %
Almost all of the time	2.7 %	4.9 %	10.0 %	4.7 %	4.3 %	3.5 %	5.0 %
Around 3/4 of the time	2.0 %	3.9 %	3.3 %	1.7 %	3.4 %	2.1 %	2.8 %
Around half of the time	1.8 %	6.1 %	3.8 %	2.4 %	4.8 %	4.2 %	4.0 %
Around 1/4 of the time	6.5 %	9.4 %	5.2 %	5.7 %	8.7 %	8.3 %	7.0 %
Almost never	13.1 %	11.6 %	10.7 %	10.7 %	11.0 %	16.6 %	11.1 %
Never	68.3 %	59.6 %	62.5 %	67.5 %	57.8 %	61.9 %	64.7 %

Figure 1.1: Percentage of workers exposed to vibration from hand-tools, machinery, etc., at least a quarter of the time by country (Eurofound, fourth EWCS)



Unfortunately, this unique European survey does not distinguish between WBV and HAV, which are fundamentally different in nature and have very different effects on the human body. In an effort to provide a fuller picture, the authors have drawn on national sources of data to estimate levels of occupational exposure to WBV.

([1]) European Foundation for the Improvement of Living and Working Conditions (www.eurofound.europa.eu).

([2]) Question: Are you exposed at work to vibrations from hand-tools, machinery, etc.?

Data on occupational exposure to vibration usually distinguishes between drivers of mobile machines, operators of hand-tools and people working in the vicinity of stationary machines. Data from national surveys was only available from four of the six countries focused on in this report (see Table 1.2). It is evident from this data that the majority of exposed workers are operators of mobile machines or hand-tools. The wide variations between the countries are probably due, in part at least, to differences in the survey methodologies. Regarding WBV exposure, one can hypothesise that, for example, the considerable difference between Finland and Germany is due to inclusion of van drivers by the former, whereas the latter restricts the sample to operators of off-road machines, fork-lift trucks, agricultural tractors and large road lorries. Furthermore, since the national surveys were carried out under different conditions to the EWCS, it is not possible to compare the values given in Table 1.1 with those of Table 1.2.

Table 1.2: Percentage of workers exposed to vibration according to the type of exposure and countries

	Germany (1)	Spain (1)	France (2)	Finland (1) (3)
Mobile machines	5 %	10 %	10.6 %	25 %
Hand-tools	4.6 %	5.6 %	10.9 %	8.3 %
Stationary machines	1-2 %	2.6 %	1.5 %	N/A

(1) Values provided respectively by the German Federal Institute for Occupational Safety and Health (BAuA), the Finnish Institute of Occupational Health (FIOH) and Spain's Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT).

(2) Surveillance médicale des risques professionnels (SUMER).

(3) Alternative data from Finland's 2006 'Work and health' survey (2 226 respondents) indicate that exposure to HAV is twice as common as exposure to WBV. Approximately 20 % of respondents had been exposed to vibration of any origin and about 10 % reported that vibration is a burden.

1.2. Exposure of men and women

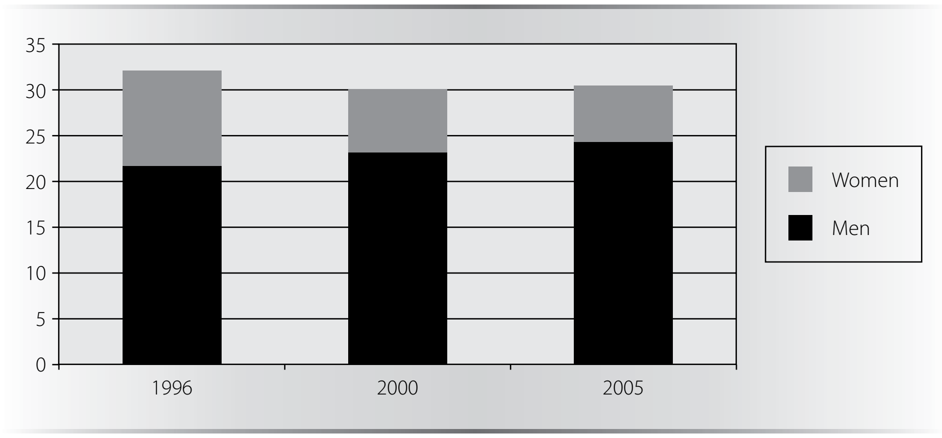
Surveys at national and European level indicate that many more men are exposed to vibration than women. According to the EWCS, the figure is approximately three and a half times more men than women. National surveys confirm the predominance of exposed men to varying extents, with the differences between the surveys varying significantly according to the methodology used.

- According to the Flemish Workability Monitor 2004, approximately 26.4 % of male workers report being exposed all or almost all of their working time compared to 5.3 % of women workers.
- In Germany, 7.4 % of men state that they often work with strong vibration compared to 1 % of female respondents (*Source:* BIBB/IAB survey 2005/06).
- According to Finnish 'Work and health' surveys, exposure to vibration is clearly more common among men (about 21 % of respondents) than among women (slightly above 3 % of respondents). This is mainly because those occupations and economic activities where vibration most frequently occurs (agriculture, forestry, manufacturing, construction and transport) are male-dominated.

- In France, exposure to WBV and HAV, except in the service sector, concerns mainly men (only 5 % of mobile machine drivers or hand-tool operators are female in France). Exposure to vibration from stationary machines concerns both men and women (in France 33 % of exposed operators are female); however, this category accounts for just a few per cent of all exposed workers.
- In Spain, 7.8 % of men are exposed to HAV compared to 1.8 % of women (*Source:* Encuesta Nacional de Condiciones de Trabajo, 2003).

With respect to changes in exposure to vibration at work over time, data from the EWCS in 1996, 2000 and 2005 (see Figure 1.2 below) show that while overall exposure has remained reasonably constant, the proportion accounted for by women has decreased. Women accounted for 45 % of the workers exposed for half of the time or more in 1996, 30 % in 2000 and 26 % in 2005.

Figure 1.2: Proportion of women and men exposed to vibration at work at least half of the time (Eurofound figures for the EU-15 according to the last three EWCS)



Over the same period, the rate of women's participation in the European workforce increased (from 50 % in 1995 to 54 % in 2000 and 58 % in 2005. For purposes of comparison, all figures are quoted for the EU-15. This trend is accounted for in large part by the fact that 40 % of the women exposed to vibration are in the manufacturing sector. While this sector is strongly associated with vibration exposure (see Section 1.4 below), it accounts for progressively fewer workers in Europe. At the same time, the construction sector, which also accounts for high rates of vibration exposure, but which employs very few women, has undergone a period of growth in recent years.

1.3. Main sources of vibration

The number of potential vibration sources can be used to estimate exposure levels and is particularly useful in relation to WBV, where reliable information on exposure is relatively hard to find.

In many cases, figures for sources of vibration can be estimated from yearly sales or registration of machinery, but reliable data is once again not easy to find. The information presented in this section is based on the authors' expert estimates and on national data.

1.3.1. Mobile machines

The estimations in Table 1.3, below, show clearly that the most common vehicles which result in exposure to vibration are lorries and agricultural tractors.

For each country, total numbers may be comparable to the number of employees that state they are exposed to vibration due to mobile machines. However, a great number of agricultural tractor drivers are self-employed and thus are not normally taken into account in these surveys. On the other hand, it is estimated that, on average, three drivers will drive the same fork-lift truck. The majority of fork-lift trucks in use are small counterbalance trucks with load capacity below or equal to 2.5 tonnes. Off-road machines sold today are mainly compact machines, backhoe loaders, excavators, and wheel loaders.

Table 1.3: National estimation of mobile machine distribution

Types of mobile machine	Germany (1)	Spain (1)	France (1) (2)	Poland (1)	Finland (1)
Off-road machines	150 000	106 000	130 000	N/A	100 000
Tractors	700 000	856 000	1 000 000	1 400 000	300 000
Fork-lift trucks	35 000 (3)	N/A	200 000	300 000	7 500
Lorries	N/A	4 400 000 including vans	5 772 000 including vans 214 000 articulated trucks	2 400 000	45 000
Others	N/A	57 000 buses, pavers, finishers, vibratory rollers	82 000 buses	1 300 airport trucks, 5,000 locomotives	10 000 4-wheel cross-country, snow scooters, fast boats, etc.

(1) Estimations provided respectively by BAuA and the German Institute for Occupational Safety (BIA), INSHT, France's National Research and Safety Institute (INRS), Poland's Central Institute for Labour Protection—National Research Institute (CIOP–PIB) and FIOH.
(2) French sources for lorries and buses (2003): DAEI/SES, CCFA.
(3) The figure for fork-lift trucks in Germany is probably an underestimate.

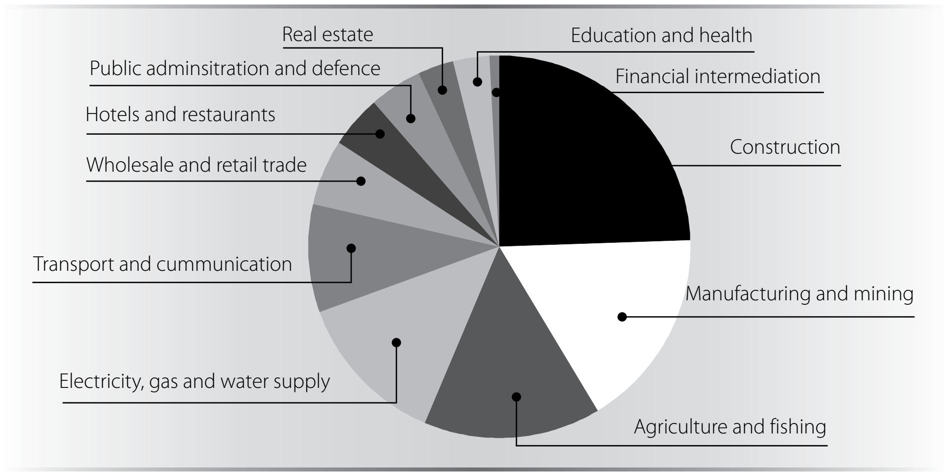
1.3.2. Hand-held or guided tools

It is difficult to obtain national figures for tools in use at the workplace. Vibration exposure is mainly accounted for by rotative tools (grinders, saws, etc.), of which there are estimated to be 4.5 million in use in Germany and 200 000 in Finland. The estimations for percussive (chipping hammers, breakers, etc.) and roto-percussive (perforators, etc.) tools are 600 000 for Germany and 70 000 for Finland.

1.4. Main sectors of activities with vibration

According to the fourth EWCS, about 24 % of all EU-27 workers reported being exposed to vibration at work at least a quarter of the time (see Table 1.1). Figure 1.3 below shows exposure by sector, from which it is evident that most exposure is found in construction (63 % of workers), manufacturing and mining (44 %), agriculture and fishing (38 %), electricity, gas and water supply (34 %) and transport and communication (23 %).

Figure 1.3: Exposure to vibration by sector of economic activity (Eurofound, fourth EWCS)



With respect to construction, the greatest concern is posed by the use of vibrating hand-held tools, while in agriculture a high percentage of employees have to operate mobile machines, which principally give rise to WBV.

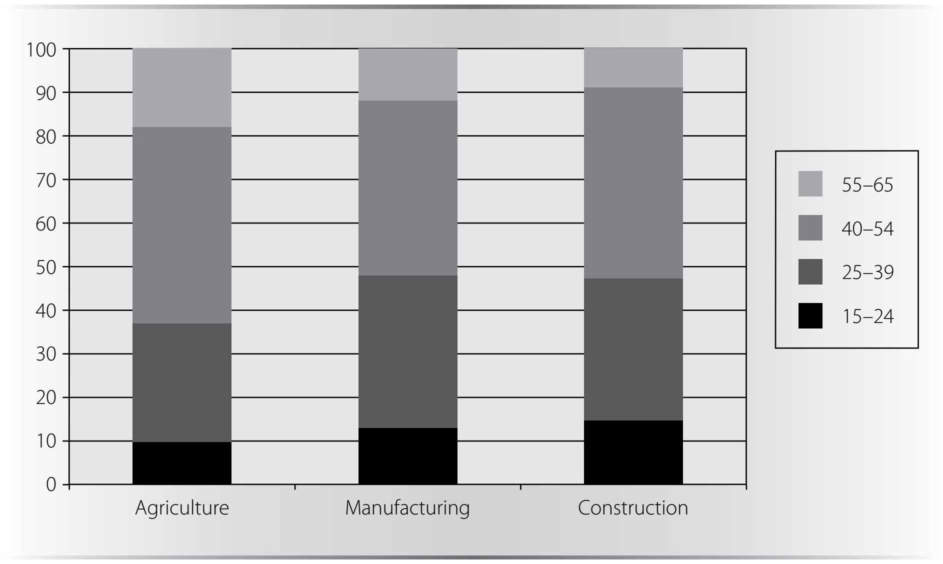
The results of the EWCS are broadly supported by national surveys.

- According to the Finnish 'Work and health' surveys (1997–2006), the economic sectors with the most common exposure to burdensome vibration are agriculture and construction. Manufacturing and transport have also been associated with fairly frequent exposure.
- In France, according to the SUMER survey, the largest numbers of operators of mobile vehicles are found in service and industry whereas operators of hand-tools are mostly found in construction and services.
- In Germany, the BIBB/IAB 2005/06 survey leads to similar conclusions, with 17.8 % of people working frequently with strong vibration in agriculture and forestry, 15.2 % in construction, and 4.6 % in mining and the electricity, gas and water industries. The total number of exposed people is estimated to be about 3 million.
- In Poland, the highest numbers of workers exposed to vibration levels which exceed limit values are found in manufacturing, mining and construction. Also, a large number of the exposed workers are employed in agriculture, hunting, forestry and fishing, and transport and communication (Polish national statistical data in 2001–05).
- In Spain, where the survey was more orientated towards HAV, unsurprisingly, construction emerges as the main sector for this kind of exposure.

Exposure according to age 1.5.

As shown by Eurofound's 2005 EWCS data presented in Figure 1.4 below, occupational exposure to vibration by age varies to some extent according to sector. In broad terms, the distribution of age range in each of the sectors is similar to that of the workforce in general. However, it is worth noting that older workers (55+ years) make up twice as large a proportion of exposed workers in agriculture compared with construction. While the difference is not so great in the case of younger workers (15–24 years), this group makes up a larger proportion of exposed workers in construction compared with manufacturing or agriculture.

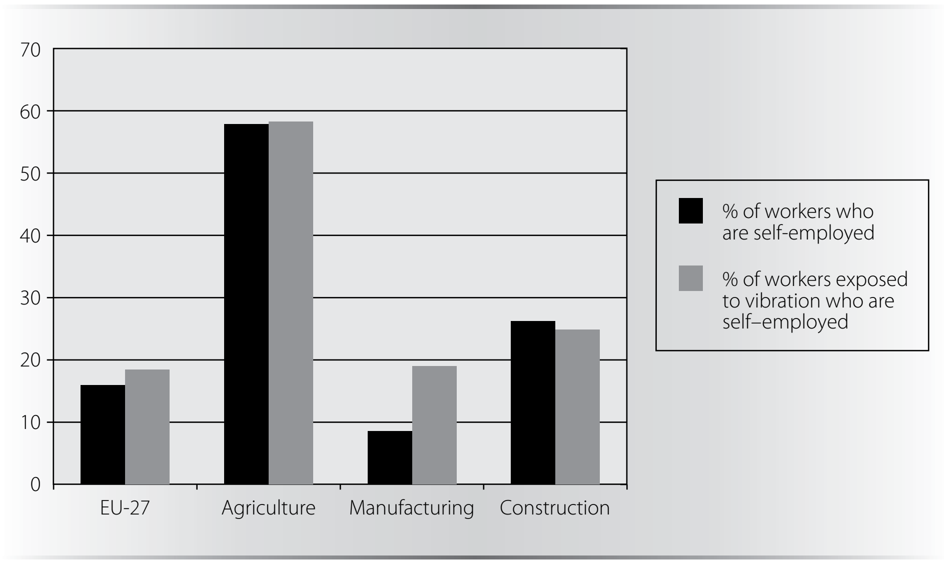
Figure 1.4: Exposure according to age group by sector (Eurofound, fourth EWCS)



Exposure according to economic status 1.6.

The data from the last EWCS indicates that a worker's economic status is not associated with greater or lesser exposure with the exception of the manufacturing sector. Whereas the self-employed account for just over 8 % of workers in manufacturing (compared with 17 % of the EU-27 workforce), they account for nearly 20 % of those workers in manufacturing who report being exposed to vibration at least a quarter of the time. As can be seen from Figure 1.5 below, this difference according to economic status is not evident in the workforce as a whole, or in either of the other two most exposed sectors: agriculture and construction.

Figure 1.5: Exposure according to economic status by sector (Eurofound, fourth EWCS)



2.

PRINCIPAL GROUPS AT RISK

The analysis described in this chapter is not based on data from registers of recognised occupational diseases because the different national practices in recognition render direct comparison impossible. Furthermore, the numbers of medical cases are influenced by legal definition and by economic considerations, which means that they do not provide a reliable basis for identification of the principal groups at risk.

2.1. Mobile machines

2.1.1. Expert opinion

Between them, the authors of this report have a long experience in the measurement of vibration at work emitted by mobile machines. In the context of Vibrisks, a joint European project on good practice ([1]), their data were put together with those of the UK Health and Safety Executive and published as practical guidance on WBV (see Table 2.1).

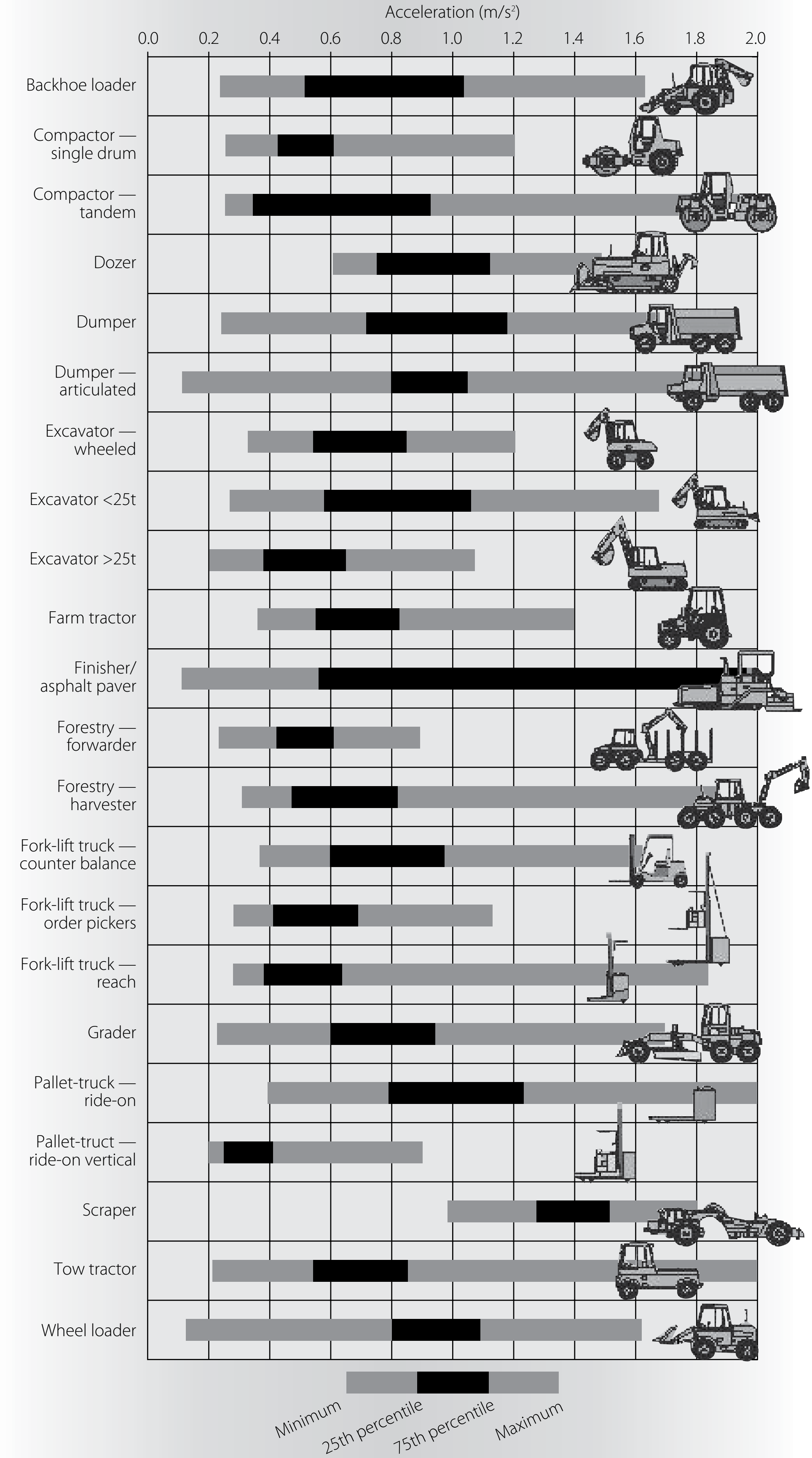
Based on the available data and on the authors' expert opinion, it is anticipated that the action level for WBV set in the directive will be exceeded by operators of most off-road machines and agricultural and forestry tractors when travelling frequently. In contrast, the limit value is likely to be reached only rarely, except in the case of scrapers and some conventional finishers. Additionally, workers may be exposed above the limit value if driving fork-lift trucks for longer than eight hours a day, or on a rough surface, or if driving trucks and lorries all day long.

([1]) Vibrisks (http://www.humanvibration.com/vibrisks/).

Table 2.1: Expert opinion on mobile machines that may expose operators above action or limit values

Is operators' exposure to vibration likely to be above action or limit values?		Prevent	FIOH	INRS	BGIA	CIOP-PIB	INSHT
Off-road machines not working at a stationary place **Excavators working in mine or digging a frozen surface**	**Action ($0.5\ m/s^2$)**	Yes	Yes	Yes	Yes	Yes	Yes, also compaction tandem roller
Scrapers >5 hours **Finishers without anti-vibration platform >5 hours** **Dozers and dumpers when used under bad conditions** **Some loaders on very rough surface**	**Limit ($1.15\ m/s^2$)**	Yes, but unknown for finishers. Buses when driving over badly designed sleeping policemen. All equipment with suspension seat when bottoming or topping out.	Yes, except loaders	Yes	Yes	Yes, except scrapers, finishers	Yes, except finishers
Agricultural and forestry tractors	**Action ($0.5\ m/s^2$)**	Yes, also combines, self-driving spray machines, potato harvesters	Yes	Yes	Yes	Yes	Yes
	Limit ($1.15\ m/s^2$)						Olive vibrator
Industrial and airport trucks	**Action if running over 3 to 4 hours ($0.5\ m/s^2$)**	Yes	Yes	Yes	Yes or no – both possible	Yes	No
	Limit ($1.15\ m/s^2$)			Fork-lift truck on rough surface		Fork-lift truck on rough surface	Fork-lift truck on rough surface
Lorries and some vans	**Action ($0.5\ m/s^2$)**	Some lorries, vans less	No	If run more than 8 hours	If run all day long, but most cases no	Sometimes if used on poor surface	No

Figure 2.1: Examples of vibration magnitudes for common mobile machines (Vibrisks)

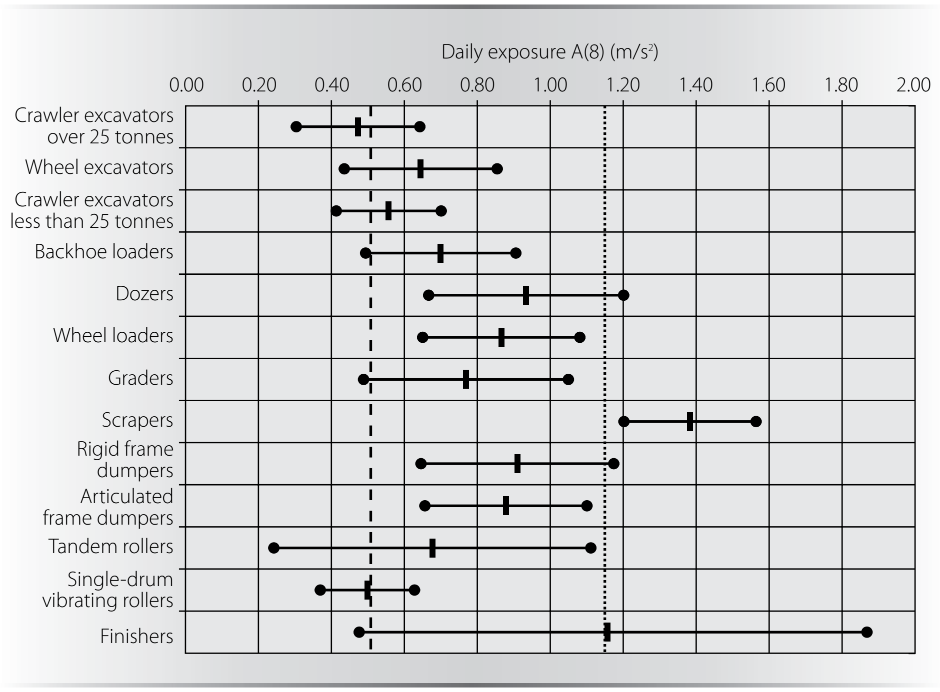


2.1.2. Surveys on mobile machinery operator exposure

Surveys on mobile machinery operators' exposure to vibration have been carried out in many countries, although only those from Finland, Belgium and France are discussed here. Their results confirm the experts' conclusions presented above.

- Finland: A survey by FIOH on forest harvesting and agricultural tractors concluded that these vehicles may exceed the action value by 50 %.
- Belgium: A survey was carried out in the framework of a European project in four countries for truck, combine and agricultural machinery ([2]). Some 47 % of drivers complained about back pain and all of them rated the suspended seat as poor (4.5/10); the back pain was caused by vibration and prolonged sitting.
- Belgium: Measurements were carried out by the Fund of Occupational Diseases (Fonds des Maladies Professionnelles — Fonds voor Beroepsziekten) for fork-lift trucks, lorries and vehicles used on construction sites. The results show that, in most cases, driving these types of vehicle generates vibration levels above 0.5 m/s² and, exceptionally, above 1.15 m/s²; levels depend on factors such as speed, surface, power source and condition of the vehicle.
- France: Off-road machines were measured mainly in quarries and earthworks. Figure 2.2 below gives the mean exposure value A(8) for each family of plant, plus or minus one standard deviation. It can be seen that the limit value of 1.15 m/s² was exceeded by 90 % of the scrapers measured, 50 % of finishers, 29 % of bulldozers, 28 % of dumpers, 14 % of tandem rollers, 10 % of articulated dumpers, 9 % of loaders, 8 % of graders, and only rarely on power shovels. The mean value was greater than 0.5 m/s² for all the types of plant except for power shovels of more than 25 tonnes and single-roller vibrating compactors.

Figure 2.2: Mean daily values A(8) of exposure to vibration and standard deviations for the main families of off-road machines (action value marked as --- and limit value as…)



([2]) http://www.iop.org/EJ/abstract/0957-0233/15/9/010

2.2. Hand-held or guided tools

2.2.1. Expert opinion

As above for mobile machines, this section draws on the authors' substantial experience in the measurement of vibration at work emitted by hand-held or hand-guided tools and uses data that was put together with those of the UK Health and Safety Executive and published in practical guidance on HAV as part of the Vibrisks project (Figure 2.3).

Based on the available data and on the authors' expert opinion, it is likely that operators of most main percussive and roto-percussive tools (e.g. chipping hammer, demolition hammer, rock drill, breaker, impact drill, scabbler, rammer, vibratory rammer), of main rotative tools (e.g. grinder, impact wrench, sander) and main alternative tools (e.g. jig-saw, file) will be exposed to vibration above the action level. If percussive and roto-percussive tools are used for more than one or two hours a day the limit value will be exceeded and this might also be the case for some rotative tools if used for more than four hours (see Table 2.2).

In the authors' view there is a high probability that negative health effects will result from working with vibratory rams, as well as with rock drills and road breakers. In addition, demolition hammers, chipping hammers, grinders and chainsaws/saws can be regarded as risk factors in the world of work. In contrast, activities related to sanders, as well as work associated with drills, may be considered to be safe, with a low risk of possible negative health effects.

Other vibration-reduced machines/devices identified by the authors, such as wood finishers and windscreen knives, were also rated highly with regard to their possible negative health effects.

It is worth noting that a worker follow-up study carried out in Finland [3] found that modern chainsaws are below the action value and no longer cause vibration-induced white finger (VWF), although they still cause musculoskeletal disorders.

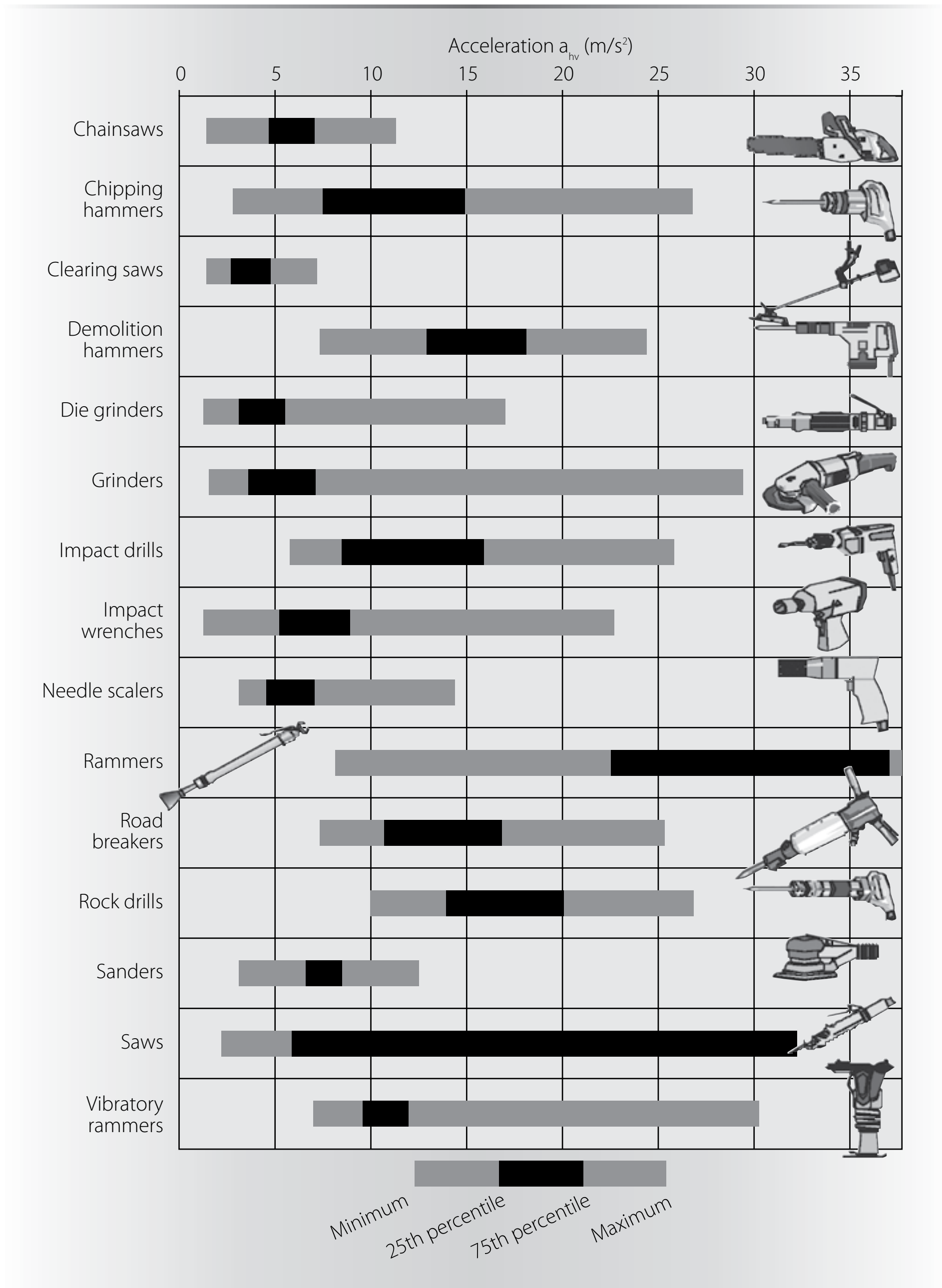
Table 2.2: Expert opinion on hand-tools that may expose operators above action or limit values

Is operators' exposure to vibration likely to be above action or limit values?		Belgium	Finland	INRS	BIA	CIOP-PIB	Spain
Percussive and roto-percussive tools	Action ($2.5\ m/s^2$)	Yes	Yes	Yes	Yes	Yes	Yes
	Limit ($5\ m/s^2$) if used more than 1 to 2 hours a day		Yes	Yes	Yes	Yes, except for tools with anti-vibration device	Yes

[3] Koskimies, Kaija, Pyykkö, Ilmari, Starck, Jukka and Inaba, Ryoichi, 'Vibration syndrome among Finnish forest workers between 1972 and 1990', *International Archives of Occupational and Environmental Health*, Vol. 64, No 4, November, 1992, pp. 251–256.

Is operators' exposure to vibration likely to be above action or limit values?		Belgium	Finland	INRS	BIA	CIOP-PIB	Spain
Rotative tools	Action (2.5 m/s²)	Yes	No	Yes	Yes	Yes	Yes
	Limit (5 m/s²) some rotative tools if used more than 4 hours		No	Yes	Yes	Sometimes	Yes
Alternative tools	Action (0.5 m/s²)	Yes	Yes	Yes	Yes	Yes	

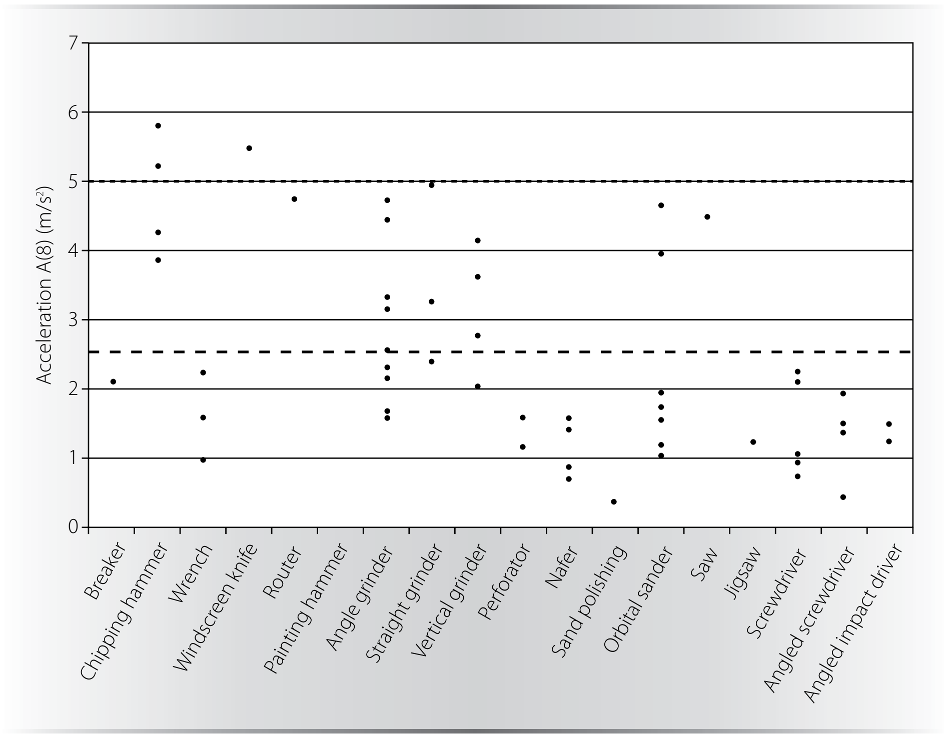
Figure 2.3: Examples of vibration magnitudes for common tools (Vibrisks)



2.2.2. Surveys on hand-tool operator exposure

The results of a first survey carried out in France on 53 hand-held tool operators confirm the expert conclusions presented above (see Figure 2.4).

Figure 2.4: Daily exposure values A(8) measured at the workplace of 53 operators using one hand-held tool



The dotted line in the table above indicates the limit value (5 m/s²) and the dashed line the action level (2.5 m/s²) from which it can be seen that three of the 53 operators are exposed above the limit value and 17 above the action level.

3.

IMPLEMENTATION OF THE DIRECTIVE

3.1. Implementation of Directive 2002/44/EC

On 25 June 2002, the European Parliament and the Council of the European Union, taking into consideration the opinion of the Advisory Committees, adopted Directive 2002/44/EC on the minimum health and safety requirements regarding 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).

To date, all 27 Member States have taken measures transposing Directive 2002/44/EC since it came into force across the EU on 6 July 2005, although an overall assessment of its implementation at national level is yet to be carried out by the European Commission.

In the light of the directive, the protection of workers from risks to their health and safety arising, or likely to arise, from exposure to mechanical vibration should be achieved by clearly specified actions. These actions depend strictly on the level of workers' exposure to mechanical vibration.

The directive lays down minimum requirements, thus giving Member States the option of maintaining or adopting more favourable provisions for the protection of workers, in particular the fixing of lower values for the daily action value or the daily exposure limit value for vibrations.

Implementation measures taken by each of the countries focused on in this report are listed in Table 3.1 below, together with a description of any additional or stricter requirements that have been set.

Table 3.1: Additional or stricter national requirements in comparison with the directive's provisions

Country	Implementing measures	Additional or stricter requirements
Belgium	Royal Decree of 7 July 2005	No additional or stricter requirements.
Finland	VNa 48/2005 Decree of the Council of the State on the provisions to protect workers against the harmful effects of vibration. *Valtioneuvoston asetus työtekijöiden suojelemiseksi tärinästä aiheutuvilta vaaroilta* http://www.finlex.fi/fi/laki/alkup/2005/20050048	Temporary maximum value for HAV 35 m/s^2 and for WBV 7 m/s^2.
France	Decree No 2005-746 of 4 July 2005 and orders of 6 July 2005 and 4 May 2007. http://admi.net/jo/20050705/SOCT0511142D.html	No additional or stricter requirements.

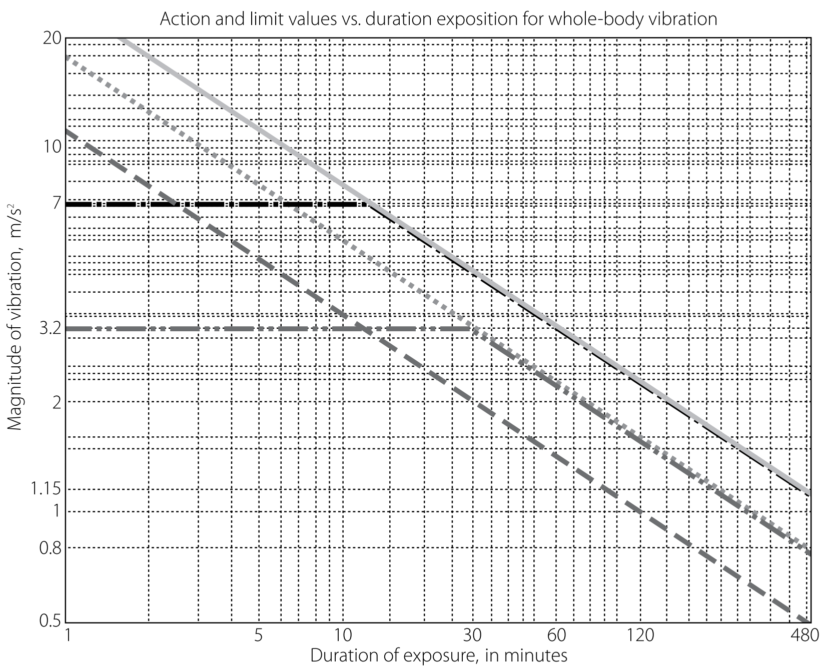
Country	Implementing measures	Additional or stricter requirements
Germany	VDI 2057 Part 1. Human exposure to mechanical vibrations. Whole-body vibration. September 2002. *Einwirkung mechanischer Schwingungen auf den Menschen. Ganzkörper-Schwingungen* Available from Beuth Verlag, D-10772 Berlin. http://www.vdi.de/en/7636.0.html	The German guideline VDI 2057 Part 1 contains an area of increased health risk for WBV with an upper limit of $a_{w(8)} = 0.8$ ms^{-2}, i.e. a value in agreement with ISO 2631-1 and considerably lower than the A(8) value of the EU directive. The energy-equivalent dependence for the calculation of dose values is limited to daily exposure duration equal to or longer than two hours. In agreement with ISO 2631-1, the guideline permits the application of alternative dose calculations that agree much better with the real health risk in the case of short-term and high-magnitude exposures, thus avoiding the fundamental misjudgement that is possible with the application of the EU guide for such conditions.
Poland	Ordinance of the Minister of Labour and Social Policy of 29 November 2002 on maximum admissible concentrations and intensities of agents harmful to health in the working environment. *w sprawie najwyższych dopuszczalnych stężeń i natężeń czynników szkodliwych dla zdrowia w środowisku pracy* Dziennik Ustaw 2002, No 217, item 1833. http://isip.sejm.gov.pl/servlet/Search?todo=file&id=WDU20022171833&type=2&name=ATTHK6FN Amended by the Ordinance of the Minister of Labour and Social Policy of 10 October 2005, Dziennik Ustaw 2005, No 212, item 1769. http://isip.sejm.gov.pl/servlet/Search?todo=file&id=WDU20052121769&type=2&name=D20051769.pdf	There are stricter/additional limit values for exposure to vibration: WBV: – daily exposure limit value A(8) = 0.8 m/s^2, – short-term exposure limit value A(0.5) = 3.2 m/s^2 HAV: – daily exposure limit value A(8) = 2.8 m/s^2, – short-term exposure limit value A(0.5) = 11.2 m/s^2 A(0.5) is a new limit value established in Poland and is defined as: for WBV – maximum, frequency-weighted rms value of acceleration in dominant direction with applied multiplying factor *k*, for an exposure period of 30 minutes or shorter. Multiplying factor k is as follows: *x* axis: $k = 1.4$ *y* axis: $k = 1.4$ *z* axis: $k = 1$ for HAV – maximum root sum of squares of frequency-weighted rms values of acceleration in three orthogonal directions, *x*, *y*, *z*, for an exposure period of 30 minutes or shorter.

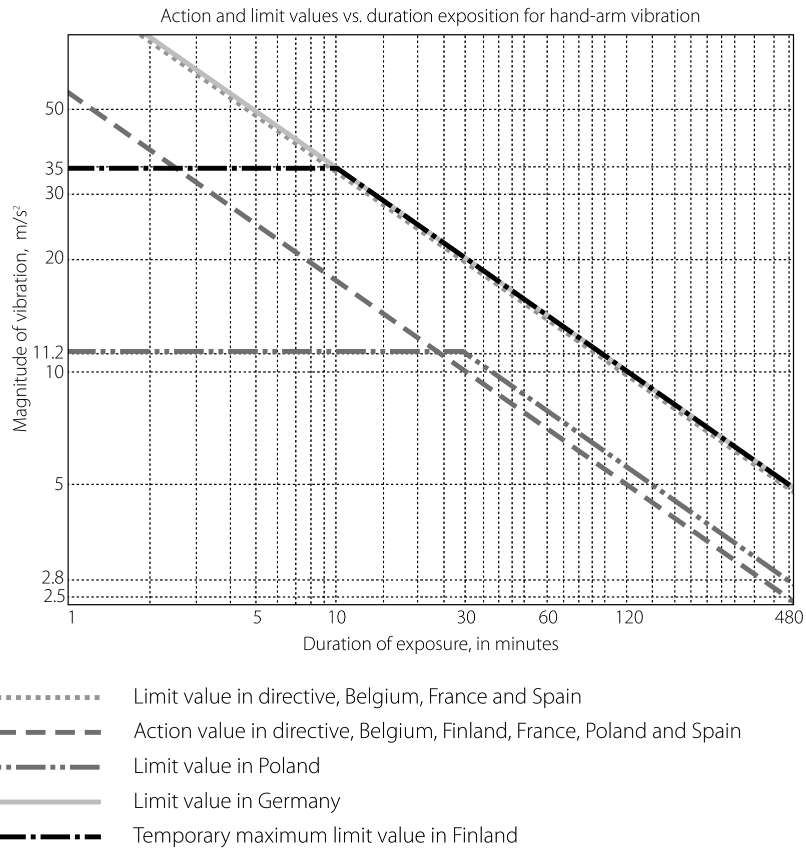
Country	Implementing measures	Additional or stricter requirements
	Ordinance of the Council of Ministers of 10 September 1998 on the register of work prohibited for women. w sprawie wykazu prac wzbronionych kobietom Dziennik Ustaw 1996, No 114, item 545. http://isip.sejm.gov.pl/servlet/Search?todo=file&id=WDU19961140545&type=2&name=D19960545.pdf Amended by the Ordinance of the Council of Ministers of 30 July 2002, Dziennik Ustaw 2002, No 127, item 1092. http://isip.sejm.gov.pl/servlet/Search?todo=file&id=WDU20021271092&type=2&name=D20021092.pdf	For pregnant women, work in exposure to WBV is prohibited and for exposure to HAV the stricter/additional limit values are as follows: – daily exposure limit value A(8) = 1.0 m/s^2, – short-term exposure limit value A(0.5) = 4.0 m/s^2 where A(0.5) is as described above.
	Ordinance of the Council of Ministers of 24 August 2004 on a register of work prohibited for young people and on conditions of employing them in some of that work. w sprawie wykazu prac wzbronionych młodocianym i warunków ich zatrudniania przy niektórych z tych prac) Dziennik Ustaw 2004 No 200, item 2047. http://isip.sejm.gov.pl/servlet/Search?todo=file&id=WDU20042002047&type=2&name=D20042047.pdf Amended by the Ordinance of the Council of Ministers of 5 July 2005, Dziennik Ustaw 2005, No 136, item 1145. http://isip.sejm.gov.pl/servlet/Search?todo=file&id=WDU20051361145&type=2&name=D20051145.pdf	For workers between 16 and 18 years old the additional limit values are: WBV: – daily exposure limit value A(8) = 0.19 m/s^2, – short-term exposure limit value A(0.5) = 0.76 m/s^2 HAV: – daily exposure limit value A(8) = 1.0 m/s^2, – short-term exposure limit value A(0.5) = 4.0 m/s^2 where A(0.5) is as described above. People below 16 are not allowed to work.

Country	Implementing measures	Additional or stricter requirements
Spain	Royal Decree 1311/2005, of 4 November 2005, on the protection of the health and safety of workers from risks that result or may result from exposure to vibration. Real Decreto 1311/2005, de 4 de noviembre, sobre la protección de la salud y la seguridad de los trabajadores frente a los riesgos derivados o que puedan derivarse de la exposición a vibraciones mecánicas. BOE núm. 265 de 5 noviembre Official Gazette BOE No 265 of 5 November 2005. http://empleo.mtas.es/insht/legislation/tl_hig.htm#Vibraciones	Stricter transitional periods have been adopted while INSHT is carrying out a survey related to vibration. The results will show, within the transitional periods established in the directive, whether the legislation has to be changed.

3.2. National procedures for the assessment of vibration exposure

Figure 3.1: Action and limit values in different countries for exposure to WBV (above) and HAV (below)





There exist at national level in some countries legal or widely recommended risk assessment methods for exposure to vibration other than those specified in the standards mentioned in the directive. Examples are given in Table 3.2 below.

Table 3.2: National methods recommended for assessment of vibration exposure

France
Order of 6 July 2005 from Minister of Employment, Journal de la république française, 6 July 2005, Application of R 231-118, R 231-120 and R 231-121 Articles of work code (Arrêté du 6 juillet 2005 pris pour l'application des articles R 231-118, R 231-120 et R 231-121 du code du travail). ISO 2631-1:1997, Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General requirements mentioned in Directive 2002/44/EC have not been transposed into French legislation because in France European standards take precedence over international standards. Currently, measurement and evaluation of human exposure to WBV is conducted using the method from European Standard EN 14253:2003.
Germany
For WBV, guidance for occupational physicians summarises the current knowledge with respect to the relationship between exposure and the probability of long-term effects on the lumbar spine. Decree on occupational diseases. Guidance concerning occupational diseases. Bek. des BMGS vom 1. Juni 2005 – 414-45222-2110. Berufskrankheiten-Verordnung. Merkblätter zu Berufskrankheiten. Bek. des BMGS of 1 June 2005 – 414-45222-2110. This document contains a table with ranges of daily exposure data according to VDI 2057 Part 1 and the EU guideline, together with corresponding verbal risk assessments for exposure durations (i) between 5 and 10 years as well as (ii) longer than 10 years.

Poland
ISO 2631-1:1997, Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General requirements, mentioned in Directive 2002/44/EC, have not yet been transposed into Polish legislation because in Poland European standards take precedence over international standards. Currently, measurement and evaluation of human exposure to WBV is conducted following the method from Polish Standard PN-EN 14253:2005 (U) *Drgania mechaniczne. Pomiar i obliczanie zawodowej ekspozycji na drgania o ogólnym działaniu na organizm człowieka dla potrzeb ochrony zdrowia.* (Mechanical vibration – Measurement and evaluation of occupational exposure to whole-body vibration with reference to health – Practical guidance.) Standard PN-EN 14253:2005 (U) has been developed on the basis of the new European standard EN 14253:2003.
Spain
ISO 2631-1:1997, Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General requirements, mentioned in Directive 2002/44/EC, have not yet been transposed into Spanish legislation because in Spain European standards take precedence over international standards. Currently, measurement and evaluation of human exposure to WBV is conducted following the method from national standard UNE EN 14253:2004, Mechanical Vibration. Measurement and calculation of occupational exposure to whole-body vibration with reference to health. Practical guidance.

In some of the countries focused on in this report there are derogations connected with the provisions of the directive.

- In Finland these concern maritime activities and aviation, within the limits set in the directive (VNa 48/2005).
- In France, the requirement not to expose workers above the limit values is subject to a transition period which applies where equipment was used from before 6 July 2007, which does not permit the exposure limit values to be respected, taking into account the latest technical advances and/or the organisational measures taken. The transition period will end after a period of five years on 6 July 2010. With regard to equipment used in the agriculture and forestry sectors, an order from the Ministry of Forestry and Agriculture extends the maximum transition period by up to four years.
- In Germany, the following temporary arrangements exist with regard to noise and vibration (§17 of ordinance on OSH).
  - The regulation applies to the music and entertainment sector since 15 February 2008.
  - According to the ordinance of the German federal armed forces, as from 1 July 2007, workers are subject to exposure limit values of A(8) = 1 15 m/s² with regard to ***z*** direction WBV until 1 July 2011.
  - In the case of activities related to construction machinery and equipment manufactured before 1997, which despite all preventive means exceeds the limit values, workers must not be exposed to ***z*** direction whole-body vibrations exceeding A(8) = 0.8 m/s² to 1.15 m/s² on more than 30 days per year. This derogation expires on 31 December 2011.
- In other countries (Poland, Spain, Belgium) no such derogations exist.
- None of the countries examined identified any specific branches of activity (e.g. artists, farmers, therapists, etc.) which are commonly subject to recommended requirements on exposure to vibration.
- Additionally, in Germany, the decree on protection of health in the mining industry Gesundheitsschutz-Bergverordnung ([1]) contains provisions concerning vibration.

([1]) http://bundesrecht.juris.de/gesbergv/BJNR017510991.html

3.3. Enforcement of the directive's provisions at national level

Among the countries studied, labour inspectors have the task of ensuring that employers follow the legal or generally recommended requirements, including those of the directive.

- Finland — This is done mainly as part of general inspections of working conditions, where vibration is known to be a problem. Usually the inspector checks whether the risk assessment is carried out adequately.
- France — When visiting a factory, inspectors may ask employers to show that they have actually assessed the vibration exposure of operators using vibrating tools or machines. If this has not been done, the employer may be required to pay a notified body to carry out this assessment. To assist them in their task, inspectors use a list of tools and machines likely to expose operators to vibration above limit values, which was produced by INRS at the request of the Ministry of Labour.

  In addition, the CRAM (French insurance system) has trained its eight regional laboratories to assess vibration exposure at work. They take measurements and, when necessary, advise factories on ways to reduce vibration.
- Poland — Labour inspectors monitor working conditions to ensure that they meet minimum requirements concerning workers' health and safety. Inspectors analyse measurement reports which are required by regulations that specify precisely the content of the report. If there are no such reports, they order a risk assessment to be carried out. When any irregularity is found, they issue the employer with an administrative fine and when serious infringements are discovered, or the law has been broken, they can refer the case to court or the public prosecutor's office.
- Spain — The labour inspectors examine the risk assessment, which includes the vibration level measurements according to Royal Decree 1311/2005 of 4 November 2005. If the requirements of the legislation have not been met, the inspector will request that the employers implement the necessary measures. As the legislation on vibration is still recent, the labour inspectorate has made few regulations related to the application of action and limit levels.

4.

EVALUATION OF VIBRATION RISKS AT THE WORKPLACE

The vibration directive requires vibration exposure to be assessed by employers. Critics of the directive claimed that this would be impossible because of the high cost of measurement and the small number of laboratories able to carry them out. In fact, the directive does not explicitly ask employers to measure vibration, but rather to assess it, and European guides have been developed to facilitate these assessments. Nevertheless, direct measurements are often necessary and it is interesting to know how countries will ensure that there is adequate capacity to undertake the task.

4.1. Who carries out vibration measurements?

Table 4.1 shows clearly the two different strategies adopted at national level among the countries studied in this report. The Polish and Spanish governments' approach centres on assisting companies directly by equipping a large number of health and safety organisations with vibrometers. Other countries, such as France, have taken the view that private enterprise will provide the capacity needed and employers must either undertake the assessment themselves or pay private laboratories to carry out the measurements.

Setting up many new establishments for the measurement of vibration represents a significant challenge. Generally, metrology technicians have previous experience in noise and, while measuring WBV is relatively straightforward, this is certainly not the case for HAV. Measurement of exposure to vibration from percussive tools is especially difficult and significant errors are common. To avoid this, precautions have to be taken (e.g. to solve dc-shift ([1])); however, vibrometer manufacturers do not always address these issues. As a result, widespread difficulties can be expected in ensuring the quality of measurements and this is likely to result in authorities developing a common procedure.

It must be emphasised that it is not sufficient for employers to be assisted only in measuring vibration, but that they will also require assistance in the reduction of vibration hazards. In the authors' opinion, this issue has, to date, not been sufficiently addressed in some of the countries under study. Where this is the case, a lack of good advice is likely to result in conflict between, for example, buyers and users. In this context, the provision of adequate training for technicians is also essential.

Table 4.1: National arrangements for carrying out human vibration exposure measurement

	Belgium	Germany	Spain	France	Poland	Finland
Employers	A survey showed that not all employers assess the risk of vibration at the workplace (55 %, n = 56).	Yes, by using emission measurements (VDI 2057-1/2:2002)	No	Very few	Yes ([2])	5 % with a subcontractor

([1]) A distortion in electronic devices also known as 'offset'.

([2]) Employers assess the exposure to vibration only on the basis of measurements carried out directly at the workplace. It is performed by comparing results of measurements with established maximum permissible values and action values. Under Polish law no other approach is permitted to assess occupational exposure to vibration.

	Belgium	Germany	Spain	France	Poland	Finland
Number of laboratories	2 universities (3)	20 to 30 laboratories 8 OSH organisations	139 OSH organisations	9 OSH organisations Some consultants (5 to 10)	4 OSH organisations 50 national labour inspectorates 150 employers with capacity to measure vibration 150 consultants	2 OSH organisations
Accredited organisations	Laboratories certified by the Ministry of Labour (4) Specialists in environmental effects report (milieu effect rapport – MER) (5) Fund of Occupational Diseases: measurements requested by companies (6)	TÜV (technical surveillance association) BGen (German institutions for statutory accident insurance and prevention) Consulting engineers Bergämter (mining offices)	OSH organisation	None today but some in preparation (Apave, Socotec etc.)	24 laboratories accredited by Polish Centre for Accreditation (7)	None

Methods to assess vibration at work used by employers 4.2.

The daily vibration exposure to be assessed depends on both the magnitude of vibration at the surface in contact with the body and the total daily duration for which an employee is in contact with that vibration. In practice very few employers take measurements and their vibration assessment is based on figures provided by manufacturers, guides and standardised technical reports, etc., as indicated in Table 4.2, below.

(3) http://mech.vub.ac.be/avrg and http://www.wtcm.be

(4) http://www.emploi.belgique.be/defaultTab.aspx?id=573

(5) Specialised in noise and vibrations and certified by the Flemish government (http://www.mervlaanderen.be).

(6) Arrêté Royal 19 April 1999, Moniteur Belge, 23 July 1999.

(7) http://www.pca.gov.pl/english/ Laboratories performing measurements at the workplace should be certified according to the Ordinance of the Minister of Health of 20 April 2005 (Dziennik Ustaw 2005 No. 73, item 645 http://isip.sejm.gov.pl/servlet/Search?todo=file&id=WDU20050730645&type=2&name=D20050645.pdf).

Table 4.2: Strategies used by employers to assess vibration exposure

	Belgium ([8])	Germany ([11])	Spain	France ([10])	Poland	Finland ([9])
Manufacturer declarations re. WBV	Sobane method	According to ISO/TR 2539 8 (earth-moving machines) and VDI 2057-1/2:2002	No manufacturer declaration available for some conditions and duration assessment	Manufacturer guides (e.g. Caterpillar, etc.) and according to ISO/TR 2539 8	ISO/TR 2539 8 not translated into Polish May use manufacturer's guide	Not widely used
Manufacturer declarations re. HAV	Based on figures given by the manufacturer (see above)	According to DIN V 45694; Informationsblatt Nr. 008 des Fachausschusses MFS	As above	Using manufacturer guide according to CEN/TR 15350: 2005	Used mainly to compare devices' value for money rather than to assess vibration	Using manufacturer guide according to CEN/TR 15350: 2005
EU guides to good practice	Information from guides through (e)magazine articles, seminars, websites and extra information by phone	Used widely and information from guides on Internet	Not widely used INSHT guides on WBV and HAV in preparation	To some extent. INRS guides are in preparation	Not widely used	Not widely used
Data bank on Internet	Widely used e.g.: Umea University databases http://www.vibration.db.umu.se Standards (CEN, ISO, etc.) Legislative texts www.meta.fgov.be Manufacturers' guides	Several data banks developed ([12])	Not widely used	Widely used	Used just for comparison	FIOH website and national focal point website including: - good practices - research reports - risk assessment methods. Tools for exposure assessment

([8]) A company survey (n = 56) showed that a global approach is needed to tackle vibration at work, starting with identification of hazards. Often these actions are accompanied by a multidisciplinary team or working group involving several people, e.g. from production management, purchasing department, OSH service, medical service, industrial hygienist. After the identification of potential risks, an assessment is made, based on information such as manufacturers' data or, in some cases, measurements. Vibrations de l'ensemble du corps et mains-bras, Stratégie Sobane, SPF Emploi, Travail et Concertation du Travail, 2005, fiche 9, pp. 65-66, http://www.emploi.belgique.be/WorkArea/showcontent.aspx?id=3862, Johan Cardinaels, Vibrations, Sécurité au travail de A à Z, 123, October 2005.

([9]) In Germany, a study was done to check the quality of prediction. Kaulbars, Uwe, 'Risk assessment of hand-arm-vibration by estimate, taking the example of hand-guided stone-working machines'. Proceedings of the First American Conference on Human Vibration, http://www.cdc.gov/niosh/docs/2006-140/

([10]) The nine health and safety organisations in France have developed three internal procedures for measuring vibration at the workplace. Most are certified in accordance with ISO 9000: 2000. They are also developing an internal data bank named Colphy.

([11]) Finnish survey on the quality of declarations on forestry and agricultural tractors and other road machines.

([12]) KARLA (Katalog Repräsentativer Lärm- und Vibrationsdaten am Arbeitsplatz): http://www.las-bb.de/karla, DLG – http://www.dlg.org/de, Potsdam – http://www.las-bb.de/karla, Umea – http://www.vibration.db.umu.se/

Use of manufacturers' emission data 4.3.

The European machinery directive (98/37/EC) ([13]) defines essential health and safety requirements for machinery supplied within the European Union, including specific requirements regarding vibration.

Annex 1 — Essential health and safety requirements relating to the design and construction of machinery and safety components

1. ESSENTIAL HEALTH AND SAFETY REQUIREMENTS:

1.5 Protection against other hazards: 1.5.9 Vibration – 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.

1.7 Indicators – 1.7.4 Instructions – (d) The technical documentation describing the machinery must give [. . .] in the case of hand-held and/or hand-guided machinery, information regarding vibration as referred to in 2.2. (e) Where necessary, the instructions must give the requirements relating to installation and assembly for reducing noise or vibration (e.g. use of dampers, type and mass of foundation block, etc.).

2. ESSENTIAL HEALTH AND SAFETY REQUIREMENTS FOR CERTAIN CATEGORIES OF MACHINERY:

2.2 Portable hand-held and/or hand-guided machinery – The instructions must give the following information concerning vibrations transmitted by hand-held and hand-guided machinery: the weighted root mean square acceleration value to which the arms are subjected, if it exceeds 2.5 m/s^2 as determined by the appropriate test code. Where the acceleration does not exceed 2.5 m/s^2, this must be mentioned.

3. ESSENTIAL HEALTH AND SAFETY REQUIREMENTS TO OFFSET THE PARTICULAR HAZARDS DUE TO THE MOBILITY OF MACHINERY:

3.2 Work stations – 3.2.1 Driving position – Where the machinery is fitted with a cab, this must be designed, constructed and/or equipped to ensure that the driver has good operating conditions and is protected against [. . .] excessive noise and vibration... 3.2.2 Seating – The seat must be designed to reduce vibrations transmitted to the driver to the lowest level that can be reasonably achieved.

3.6 Indications – 3.6.3 Instruction handbook – Apart from the minimum requirements set out in 1.7.4, the instruction handbook must contain the following information:

(a) regarding the vibrations emitted by the machinery, either the actual value or a figure calculated from measurements performed on identical machinery:

([13]) 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.

– the weighted root mean square acceleration value to which the arms are subjected, if it exceeds 2.5 m/s², should it not exceed 2.5 m/s², this must be mentioned,

– the weighted root mean square acceleration value to which the body (feet or posterior) is subjected, if it exceeds 0.5 m/s², should it not exceed 0.5 m/s², this must be mentioned.

Where the harmonised standards are not applied, the vibration must be measured using the most appropriate method for the machinery concerned.

The manufacturer must indicate the operating conditions of the machinery during measurement and which methods were used for taking the measurements…

Manufacturers' **declared vibration emission** values are usually obtained according to harmonised European vibration test codes produced by European or international standards bodies. EN ISO 20643:2005 provides the basis for the drafting of vibration test codes for hand-held and hand-guided power-driven machinery. Examples of these codes are the EN ISO 8662 series for pneumatic and other non-electric tools and the EN 60745 series for electric tools.

Declared emission values allow purchasers to compare machines tested to the same standardised test code. They can show up large differences between machines, allowing high-vibration tools to be avoided.

Emission data from manufacturers can also indicate how much vibration is likely to enter a person's hands when using a particular power tool. This may be useful to help make an estimate of daily exposure and an assessment of the risk.

At present, vibration test codes are usually based on measurements in a single vibration axis and they tend to underestimate the vibration from tools when they are being used in the workplace. CEN/TR 15350:2006 ([14]) advises that for estimating risk, the manufacturer's declared emission value should, in most cases, be multiplied by a factor depending on the type of tool. Many harmonised European vibration test codes are currently under review to incorporate modifications required by the new machinery directive. The revised test codes should result in improved emission values that will not be directly comparable with older emission data, but which should provide a more accurate guide to the vibration experienced at the workplace.

([14]) CEN/TR 15350: 2006 Mechanical vibration — Guideline for the assessment of exposure to hand-transmitted vibration using available information including that provided by manufacturers of machinery.

5.

APPLICATION OF THE DIRECTIVE IN PRACTICE

In risk assessment and when applying control measures, an employer has to consider exposure, impulsiveness of exposure, combined effects, possible increase in the number of accidents and the effect of personal protective equipment (PPE). Furthermore, the employer has to evaluate and consider the possible effects on sensitive risk groups.

5.1. Criteria to start a vibration control programme (Directive Article 5 — Provisions aimed at avoiding or reducing exposure)

In all of the countries under study, the daily dose A(8), as specified by the directive, is the most commonly used criterion to start a vibration control programme for both HAV and WBV. Additionally, for HAV, the equivalent acceleration and/or peak or shock are used in Belgium and Spain, and for WBV, the equivalent acceleration is used in Finland, Spain and Germany and peak or shock in Belgium and Spain.

The different countries have tried to simplify the task for employers mainly by promoting the evaluation of the daily dose expressed in m/s^2. Two of the countries have established stricter national limit values for short-time exposure: Finland has set the maximum peak values as 7 m/s^2 for WBV and 35 m/s^2 for HAV and Poland has established a short-term exposure limit value of A(0.5).

In practice, the directive does not require employers to carry out measurements: 'The employer shall assess and, if necessary, measure the levels of mechanical vibration to which workers are exposed.' European good practice guides have been developed to assist employers, which provide lists of machines likely to expose operators above the action level, and in practice many employers are likely to start a programme of actions based simply on the presence of such vibrating machines. This approach is being reinforced for instance in France, where the Ministry of Labour is planning new legislation to provide these lists officially to employers and factory inspectors.

Article 3 of the vibration directive defines exposure limit values and action values:

1. For HAV:

(a) the daily exposure limit value standardised to an eight-hour reference period shall be 5 m/s^2;

(b) the daily exposure action value standardised to an eight-hour reference period shall be 2.5 m/s^2.

2. For WBV:

(a) the daily exposure limit value standardised to an eight-hour reference period shall be 1.15 m/s^2 or, at the choice of the Member State concerned, a vibration dose value of 21 $m/s^{1.75}$;

(b) the daily exposure action value standardised to an eight-hour reference period shall be 0.5 m/s^2 or, at the choice of the Member State concerned, a vibration dose value of 9.1 $m/s^{1.75}$.

Once the above exposure action values are exceeded, the employer must establish and implement a programme of technical and/or organisational measures intended to reduce to a minimum exposure the mechanical vibration and the attendant risks. If, despite the measures taken by the employer, the exposure limit value is exceeded, the employer must take immediate action to reduce exposure below the exposure limit value.

5.2. Combined effects (Article 4 of the vibration directive, determination and assessment of risks)

The vibration directive and ISO standards (ISO 2631 or ISO 5349) for the assessment of vibration effects specify a number of co-factors (cold, smoking, poor posture, etc.) which may amplify the consequences of vibration exposure. These combined factors are well known and have been described many times in the scientific literature (e.g. Griffin (1990)). However, although the literature and standards raise the issue, they rarely provide a method to quantify the importance of these co-factors. The recommendations given are generalities such as 'use gloves to keep hands warm' or 'avoid smoking while working with vibrating tools'.

The effect of impulse vibration is also well known through scientific literature, but the dose-response relationship is not yet well defined. As a consequence, no practical measures in respect of impulse vibration were identified as part of this study. A similar lack of understanding and consequent measures applies to the evaluation of accident risk and combined effects of several harmful agents.

With respect to HAV, the authors generally agree that working at low temperatures and primary Raynaud's phenomenon are the most important risk factors, followed by smoking. Other factors identified include awkward postures and static muscle forces, and the use of certain drugs or medication. In the authors' opinion, grip and feed forces, and factors for neuropathy such as diabetes and joint problems, should also be taken account of. In this context, it should be noted that progress in force-measurement equipment (see Vibtool report ([1])) has led to the development of a new standard (ISO 15230:2007).

The authors highlight awkward postures and static workload as the most important risk factors for WBV, but also mention the use of certain drugs or medication, smoking, and work at low temperature. The importance of age and morphology is also recognised, together with the existence of previous lumbar problems or frequent manual handling of loads (particularly if over 15 kg and exceeding 10 % of working time). Other factors to be considered include low satisfaction at work, musculoskeletal diseases, life-style, obesity and exposure to shocks. Seidel et al. (2007) developed a biomechanics model to predict spinal stress in drivers at work, which incorporates data on body posture, vibration input and driver characteristics.

([1]) Vibtool: 'Grip-force mapping for characterisation of hand-held vibrating tools' (http://mm.univpm.it/vibtool/).

In the light of existing knowledge and ongoing developments, we may expect that vibration experts will soon be better equipped to take account of combined effects. It is, however, unlikely that these tools will be simple enough to be used by employers in the near future.

5.3. Criteria in medical examination (Directive Article 8 — Health surveillance)

Many tests have been developed to assist medical examinations (see Griffin, 2000).

HAV criteria for medical examination

The most commonly used criteria are numbness or pain in the hand-arm area, presence of vibration white finger (VWF) and nerve conduction tests. Carpal tunnel examination and cold provocation tests are also used and, to a lesser extent, effect of grip force and measurement of tactilometry in fingertips. Occasionally, pregnancy is also considered.

Other less common criteria include use of aesthesiometry and capillaroscopy. Also, bone and joint disorders may be considered, in addition to neurological disorders and problems of the vascular system. Therefore, musculoskeletal and vascular tests are recommended.

There are many diagnostic tools for HAV and a combination of them is used in all countries. (Generally, at least two symptoms are required for recognition of vibration disease.)

- Cold provocation tests serve for diagnosis of HAVS, but are more usually used to assess severity or to evaluate legal criteria for compensation, or for screening purposes. Peripheral blood circulation measurements (i.e. using plethysmography) are also recommended.
- As regards quantitative sensory testing, thermal and vibrotactile sense measurement is more often used in monitoring exposed workers or for evaluation of compensation (ISO 13091-1:2001 ([2]) and ISO 14835-2:2005 ([3])).

Other approaches are more useful for severe or complex cases:

- echo Doppler of upper limb with dynamic tests,
- arteriography or, more usefully, angioscanner with dynamic tests, although the risk of digital vasospasm limits the use of these methods,
- maximum voluntary force to assess signs of severity,

([2]) Mechanical vibration — Vibrotactile perception thresholds for the assessment of nerve dysfunction — Part 1: Methods of measurement at the fingertips.

([3]) Mechanical vibration and shock — Cold provocation tests for the assessment of peripheral vascular function — Part 2: Measurement and evaluation of finger systolic blood pressure.

- manual dexterity (picking up and gathering of tiny objects) for severe cases,
- skin biopsy for differential diagnosis from scleroderma,
- electroneurography for differential diagnosis from carpal tunnel syndrome or cervical entrapment,
- semi-quantitative test of tactile sense with Von Frey or Semmes-Weinstein filaments.

In practice, the use of these tests varies considerably and none is used systematically across the countries focused on in this study. Tests that require significant medical intervention are the least practical and procedures such as arteriography or skin biopsy are clearly not suitable for country-wide screening purposes, for example.

WBV criteria for medical examination

Approaches to diagnosis of WBV vary among the countries under study, but pregnancy is a widely considered criterion. Other criteria used include hernia (L4-L5 or L5-S1) or crural pain (L2-L3, L3-L4, L4-L5) in France and musculoskeletal tests, spinal column, lumbar and neck regions in Spain.

Spinal disorders and vibration exposure are the only symptoms recognised as an occupational disease in some European countries, such as Belgium, Germany and France. As these are common diseases not specific to vibration exposure, there is no specific test.

Assessment of vibration syndrome/health hazard 5.4.

Assessment of HAV vibration syndrome is based widely on the Stockholm Workshop scale [4] (e.g. in France, Spain and Germany), but many also use alternative assessment criteria.

X-ray examination to identify bone and joint disorders is used as a criterion in medical evaluation of HAV and pain below the knee is used for assessment of WBV.

Generally, assessment of vibration syndrome/health hazards is to some extent an estimate, especially for WBV. A recent study in Finland highlighted the pitfalls associated with assessing vibration syndrome/health hazards, even in evaluation of exposure. The study showed that even the affected workers themselves did not recognise that they had typical VWF symptoms. The workers did not refer to their working conditions, nor did they mention their symptoms to the occupational health service. This underlines the need for effective implementation of the directive at workplace level. The same study also indicated that the effects of VWF on workers' quality of life are underestimated.

Health surveillance guidance for HAV and WBV, recently produced under the Vibrisks project, will help occupational health workers to minimise risk, screen exposed individuals and manage individuals with symptoms of vibration injuries (Bovenzi and Hulshof, 2007).

(4) The Stockholm Workshop scale for the classification of cold-induced Raynaud's phenomenon in the hand-arm vibration syndrome (revision of the Taylor-Pelmear scale).

5.5. Use of personal protective equipment (HAV only) (Directive Article 5 — Provisions aimed at avoiding or reducing exposure)

Anti-vibration gloves are the most commonly used item of personal protective equipment (PPE), followed to a lesser extent by special clothing.

Reduction of vibration from low-frequency percussive tools requires suspension with several centimetres of travel. Therefore, it is not technically possible to develop efficient anti-vibration gloves adapted to this family of tools. Tests carried out according to ISO standard 10819:1996 ([5]) show that no vibration reduction is achieved below 150–200Hz. In the view of the authors, this means that most anti-vibration gloves are both expensive and inefficient as PPE. Their main benefit is that they keep the operator's hands warm.

5.6. Control of WBV

Engineering solutions to minimise the effects on operators of vibrating mobile machinery can be grouped into three areas (Donati, 2002):

- reduction of vibration at source as a result of improvement in the quality of the terrain, careful selection of vehicle or machine, correct loading, proper maintenance, etc;
- reduction of vibration transmission through incorporation of suspension systems (tyres, vehicle suspension, suspension cab and seat) between the operator and the source of vibration;
- improvement of cab ergonomics and seat profiles to optimise operator posture.

The authors highlight the importance of special seats, the quality of the terrain and the use of suspension systems, such as those with active attenuation, in reducing exposure to WBV.

Additionally, driving behaviour (e.g. reducing speed) and purchasing policy also contribute to control of WBV (Malchaire, 2001).

Technically effective tools and methods exist for control of WBV and they are fairly well known, as shown by the two technical reports published by the CEN vibration technical committee (CEN/TR 15172-1:2005; CEN/TR 15172-2:2005 ([6])).

([5]) Mechanical vibration and shock — Hand-arm vibration — Method for the measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand.

([6]) Whole-body vibration. Guidelines for vibration hazards reduction — Part 1: Engineering methods by design of machinery; Part 2: Management measures at the workplace.

Other control methods 5.7.

Common control measures identified by the authors include an effective maintenance programme for tools and machines to control exposure not only to HAV, but also to WBV (e.g. the maintenance of a good access route to off-road sites and the proper preparation of the terrain may significantly reduce vibration on off-road machines).

Suspension inserted between the source of HAV and operator can be very efficient. There are many successful applications of anti-vibration handles (e.g. chainsaws, grinders, breakers, chipping hammers, rammers) (see CR 1030-1:1995; CR 1030-2:1995 ([7])).

It is important to limit the force that the operator exerts on tools so as to minimise the coupling. In the case of grinders and polishers, balancers play an important role in this respect.

Interrupted or limited exposure is also an important means of reducing exposure to both HAV and WBV. However, this measure often meets with resistance because, as shown by the formula below, in order to halve the daily exposure, A(8), the duration of exposure must be reduced to a quarter.

Heated handles or grips are a common measure, as is, to a much lesser extent, the use of warm rest cabins, warm transport and warm meals as a means of control for HAV. Since cold and wet are co-factors of HAV syndrome, heating systems for hand grips of motor chainsaws proved to be a very effective prevention measure in forestry work, provided the operator's whole body is also kept warm.

([7]) Hand-arm vibration. Guidelines for vibration hazards reduction — Part 1: Engineering methods by design of machinery; Part 2: Management measures at the workplace.

6.

MANAGEMENT OF VIBRATION RISKS AT THE WORKPLACE

Controlling the risks from WBV and HAV requires a set of prevention measures. Directive 2002/44/EC sets out the measures that have to be taken by employers to reduce and avoid exposure to vibration based on a risk assessment. The question arises of how enterprises can deal with these issues in practice. Therefore, the first part of this chapter discusses the elements of a control strategy, providing an overview of the prevention measures, and the second part discusses good practices.

6.1. Control strategy and measures for preventing risks related to vibration

6.1.1. Legal basis

The only effective way to deal with the risks related to WBV and HAV is to set up a strategy based on their assessment and evaluation. The basis for this strategy can be found in the legislation, whereby the directive obliges employers 'to assess and, if necessary, measure the levels of mechanical vibration to which workers are exposed' (Article 4.1). The risk assessment:

- can be made by observing specific working practices and/or reference to relevant information on the probable magnitude of vibrations;
- should contain, if necessary, measurements carried out using specific apparatus and appropriate methodology;
- must be carried out by competent services;
- must be recorded on a suitable medium and kept up to date;
- must consider several aspects such as specific working conditions (see Box 6.1).

Box 6.1: Elements to consider while carrying out the risk assessment (Article 4.4)

The employer shall give particular attention, when carrying out the risk assessment, to the following:

(a) the level, type and duration of exposure, including any exposure to intermittent vibration or repeated shocks;

(b) the exposure limit values and the exposure action values laid down in Article 3 of this directive;

(c) any effects concerning the health and safety of workers at particularly sensitive risk;

(d) any indirect effects on worker safety resulting from interactions between mechanical vibration and the workplace or other work equipment;

(e) information provided by the manufacturers of work equipment in accordance with the relevant Community directives;

(f) the existence of replacement equipment designed to reduce the levels of exposure to mechanical vibration;

(g) the extension of exposure to WBV beyond normal working hours under the employer's responsibility;

(h) specific working conditions such as low temperatures;

(i) appropriate information obtained from health surveillance, including published information, as far as possible.

Based on the risk assessment, measures must be taken. The EU directive stipulates that priority must be given to elimination at source (Article 5). Other measures described are:

- other working methods that require less exposure to mechanical vibration;
- choice of appropriate work equipment, and of appropriate ergonomic design;
- provision of auxiliary equipment that reduces the risk;
- appropriate maintenance programmes for work equipment, the workplace and workplace systems;
- design and layout of workplaces and work stations;
- adequate information and training to instruct workers;
- limitation of the duration and intensity of the exposure;
- appropriate work schedules with adequate rest periods;
- provision of clothing to protect exposed workers from cold and damp.

Although the strategy, as described in the directive, already provides a firm basis, the information about how to implement this strategy requires further guidance.

6.1.2. Guidance

Guidance on how to implement the control strategy to prevent risks related to vibration at work can be found in several documents. The most important guides at European level are described below.

Standards

The European Committee for Standardisation, or CEN (www.cen.eu), has published two standards that provide practical guidance for tackling the risks related to vibration. The first is CR 1030-2:1995, HAV — Guidelines for vibration hazards reduction — Part 2: Management measures at the workplace. This guideline outlines measures for the reduction and control of health hazards associated with exposure to HAV at work in order to provide a practical, professional aid to managers and health and safety officers. The document covers four principal aspects:

- identification of main sources of HAV within the firm;
- vibration reduction by reconsidering task, product, and process and redesign;
- how to select low vibration machinery, anti-vibration systems and personal protection;
- management measures for the control of HAV exposure.

The second standard covers WBV: CEN/TR 15172-2:2005, Whole-body vibration — Guidelines for vibration hazards reduction — Part 2: Management measures at the workplace. This technical report outlines measures for the reduction and control of exposure to WBV at workplaces in order to provide a practical, professional aid to workplace managers and health and safety officers. Topics covered are:

- identification of main sources of WBV at the workplace;
- formulation of a strategy for minimisation and control of vibration exposure;
- implementation of the strategy.

Guides to good practice

Two guides to good practice have been developed within the framework of the Vibguide project (see Box 6.2). The project aimed to draw up non-binding guides to good practice with a view to the implementation of Directive 2002/44/EC. One guide deals with WBV and the other with HAV. Aimed at employers, including small and medium-sized enterprises (SMEs), the guides offer information on the evaluation of risks, how to determine if action is needed and how to assess daily exposure. To control the risks, a strategy is proposed based on a management process and on participation of workers. The guides also discuss the subject of health surveillance.

This guidance may be taken up at national level — for example, the Belgian High Council on Safety and Health at Work is discussing transposition of the guides as they stand and France is working on simplified versions.

Box 6.2: Vibguide

The objective of the Vibguide project is to produce accessible, comprehensive and achievable non-binding guidance to assist both employers and workers in meeting the requirements of Directive 2002/44/EC, and to ensure that the risks arising from vibration exposure are controlled. The outputs of the project are two separate guides, one on WBV and the other on HAV. The guides are available in English, French and German. Four organisations are involved in this project funded by the European Commission: the Human Factors Research Unit of the ISVR (University of Southampton) and three national occupational health and safety organisations: HSE (Health and Safety Executive in the UK); INRS (National Research and Safety Institute in France); and BGIA (Institute for Occupational Health in Germany).

http://www.humanvibration.com/EU/VIBGUIDE.htm

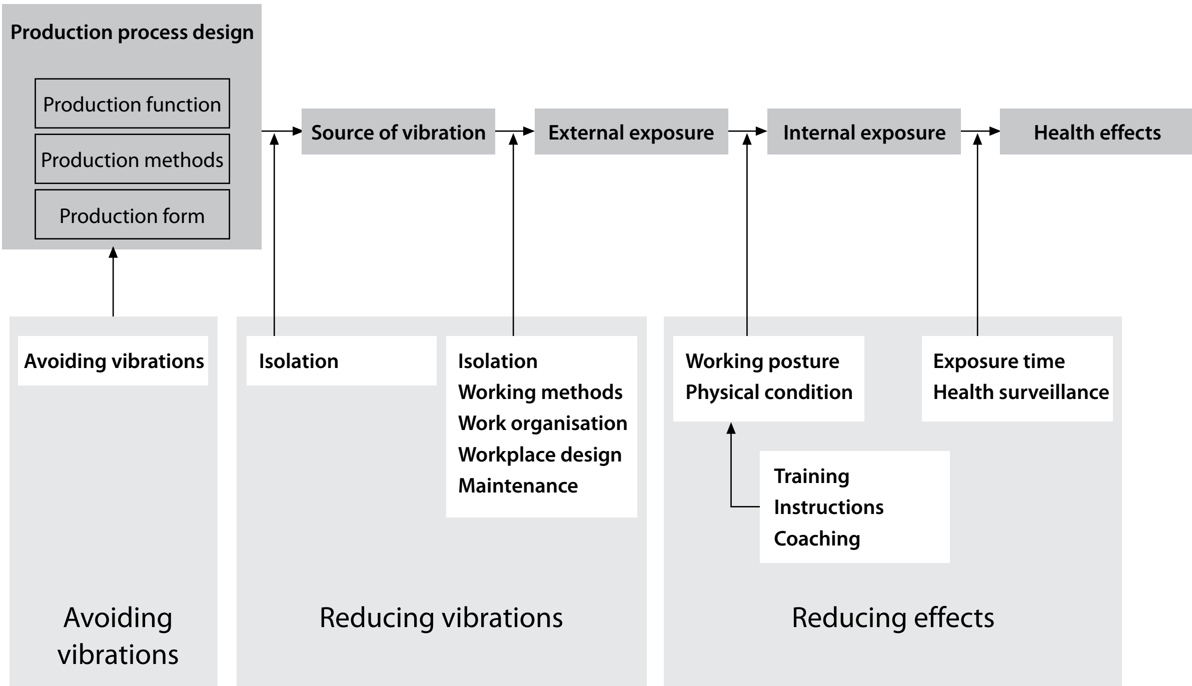
6.1.3. Measures to control the risks related to vibration

A wide range of measures exist for controlling the risks related to vibration, but the selection of the most appropriate depends very much on the precise situation. By classifying control measures, all possible approaches can be considered before deciding on specific measures. Furthermore, it guarantees that appropriate priority will be given to each of the measures. Figure 6.1 links control measures to the process of vibration control. Vibrations arise within a production process (design) and are linked with specific sources. These sources affect exposed workers and generate health effects. Measures can be taken at each stage of this process, but should preferably be taken at the earliest stage. Based on this figure, measures can be divided into three groups:

- avoiding vibration;
- reducing vibration;
- reducing the effects of vibration.

Based on these three categories, two tables are presented below. Table 6.1 gives an overview of measures for WBV and Table 6.2 of those for HAV. Practical examples and guidance for these measures can be found in various publications and other sources (see Chapter 11).

Figure 6.1: Categorising control measures



Regarding the problem of WBV for professional drivers, a measure that is often recommended is the use of an appropriate seat. Research suggests that the effects of seat suspension on exposure to vibration might be limited (Burdorf, A. et al. 1993; Wilder, D. et al, 1994; Swuste, P. et al. 1992, INRS, 1992 and 1998). In order to be effective, this measure must be accompanied by other measures such as training of drivers, adapting the speed and adapting the terrain. Furthermore, it is very important to select the appropriate seat, so that it is adapted to both the vehicle and driver. In Annex I, several examples are given that can give assistance in making the right choice. Moreover, technical solutions and improvements to develop better seating systems are the subject of ongoing research and technical innovation. Examples can be found in Chapter 9 and at: http://www.iop.org/EJ/abstract/0957-0233/15/9/010 and http://akseli.tekes.fi/opencms/opencms/OhjelmaPortaali/ohjelmat/MASINA/en/etusivu.html

Table 6.1: Control measures for WBV

1. Avoiding WBV	
1.1. Alternative work methods	1.1.1. Automating the work

	1.1.2. Using conveyors for transportation instead of mobile machinery	
1.2. Selection of machinery (Selecting the appropriate machinery with the lowest vibration)	1.2.1. Using machines with assistance system for work	Loader: mechanism for loading
	1.2.2. Selecting machinery with appropriate suspension systems	Cabin, engine, etc. (e.g. sulky with efficient suspension, loader with suspension bucket, scraper with suspension between tractor and cart, suspended agricultural tractor)
	1.2.3. Selecting appropriate tyres	Pneumatic tyres when fork-lift trucks are used outside
1.3. Purchasing policy	1.3.1. Replacing old machines	
	1.3.2. Testing machinery before buying	
	1.3.3. Asking manufacturers for information on declared vibration	
2. Reducing WBV		
2.1. Isolation	2.1.1. Using an appropriate suspended seat (adapted to the vehicle and the driver)	Ask manufacturers for seat performance, check if the seat is tested for the class of machine, seat test code
	2.1.2. Using remote-controlled machinery	
	2.1.3. Isolation of the floor between vibrating machines and operators	Finisher with suspended platform for the operator at the back. Compactor with suspended floor. Isolated worker platform in crushing plants and rock drills
2.2. Working methods	2.2.1. Minimising travelling distances	
	2.2.2. Minimising speed	Select lower speed on fork-lift truck
2.3. Workplace design	2.3.1. Improving road surfaces	Prepare good access facility to off-road work site
2.4. Maintenance	2.4.1. Maintaining vehicle suspension systems	
	2.4.2. Maintaining (correct pressures) and replacing tyres (before wear limits)	

	2.4.3. Maintaining road surfaces	Minimise obstacles for fork-lift trucks (e.g. door seals, man-hole/drain covers, rails, loading ramps). Maintain access track to work site with a grader
3. Reducing the effects of WBV		
3.1. Working posture	3.1.1. Adjusting seat to driver	Buy seats with adjustable backrest angle, swivelling mechanism, sloping seat or cab when forks lift on truck
	3.1.2. Using safety belt to maintain driver in the seat	
	3.1.3. Instruction and training of the drivers in order to minimise vibration	Prepare terrain prior to work with an excavator, brake before obstacles and then accelerate on a dumper
3.2. Physical condition	3.2.1. Physical exercises	
3.3. Work organisation	3.3.1. Limiting exposure time and/or adapting work schedules	
	3.3.2. Job design	E.g. avoid static work
3.4. Health surveillance	3.4.1. Introducing health monitoring	

Table 6.2: Control measures for HAV

1. Avoiding HAV		
1.1. Alternative work methods	1.1.1. Automating the work	Finishing with NC machines ([1]), automatic welding and better foundry technique all reduce finishing required
	1.1.2. Using alternative equipment	Replace breakers with excavators Replace hammer drills by perforators Use harvesters instead of chainsaws Use rotating instead of percussive tools
	1.1.3. Using alternative work processes	Cutting with laser or water
1.2. Equipment selection	1.2.1. Selecting the lowest vibration tool that is suitable	
	1.2.2. Selecting equipment with appropriate suspension	Rammer, grinder with auto balancer, balanced sander, etc.

([1]) Numerically controlled machines.

1.3. Purchasing policy	1.3.1. Replacing old equipment	
	1.3.2. Testing equipment before buying	
	1.3.3. Asking manufacturers to provide the declared vibration value	
2. Reducing HAV		
2.1. Isolation	2.1.1. Using vibration-isolating handles	Breaker, grinder, chainsaw, rammer, chipping hammer
	2.1.2. Using vibration-isolating gloves	
2.2. Reducing impulsiveness	2.2.1. By product selection	Grinding wheels and circular blade straightening
2.3. Work methods	2.3.1. Using equipment appropriate for the job	
2.4. Workplace design	2.4.1. Improving workplace design to limit the load on hands, wrists, etc.	
	2.4.2. Suspending tools to balance weight	
2.5. Maintenance	2.5.1. Setting up of maintenance programme to keep the equipment in good order	
	2.5.2. Sharpening the tools (blunt tools do not work efficiently)	
3. Reducing the effects of HAV		
3.1. Working posture	3.1.1. Appropriate working posture (Avoiding static muscle force and complex postures)	
	3.1.2. Training of operators	
3.2. Physical condition	3.2.1. Physical exercises	
3.3. Equipment	3.3.1. Gloves to warm hands	
	3.3.2. Heated handles	Chainsaws, pneumatic tools, snow scooters
3.4. Work organisation	3.4.1. Limiting exposure time and/or adapting work schedules	
	3.4.2. Organisational measures to maintain normal body temperature, especially in extreme conditions	Warm rest cabins, transport and meals, and appropriate clothing (forest workers)
3.5. Health surveillance	3.5.1. Health monitoring	

Good practice — Success factors 6.2.

The vibration directive proposes a strategy to employers on how to deal with risks related to vibration at the workplace (see Section 6.1). In practice, various approaches and programmes can be set up to deal with these risks and Annex II gives descriptions of a selection of case studies, which show that it is possible to implement effective solutions to deal with WBV and HAV in the workplace. Furthermore, various factors can be identified that have contributed to the success of these cases, including:

- an integrated, step-by-step approach;
- provision of guidance;
- implementation of a purchasing policy;
- collaboration with manufacturers;
- implementation of a range of measures;
- provision of information and awareness-raising.

6.2.1. An integrated step-by-step approach

Dealing with vibration at the workplace is not an easy task for companies. It requires a control strategy and a management process, as set out in the EU directive and in the EU guides. Faced with this obligation, one might conclude that companies are once more obliged to carry out extra duties and to meet extra costs; however, this is not necessarily the case. Practice shows that it is possible to integrate risk analysis on vibration into existing schemes for risk analysis (e.g. case 7, Annex II). This integration makes it possible to keep the resources needed to carry out a risk assessment and to implement preventive measures at an acceptable level.

Furthermore, if the risk analysis focuses first on determining which jobs/activities/workstations could present vibration-related problems, it reduces the number of in-depth analyses (e.g. expert measurements) that must be carried out. An example of a small checklist that can be used to determine if further action is needed can be found in the guides to good practice (e.g. Vibguide).

Furthermore, in selecting the appropriate preventive measures, a step-by-step approach proves to be the most successful as it offers the possibility of making evaluations, performing tests and determining costs/benefits, etc. (e.g. cases 4 and 6, Annex II).

6.2.2. Providing guidance

Practice shows that sometimes it is not a matter of convincing people to take measures, but of offering guidance. The French project on WBV (case 1, Annex II) showed that if farmers were provided with practical information on how to select a suspension seat, they were ready to implement this measure. This example illustrates the need for guidance and shows that it is useful to offer specific guidance (e.g. to sector or job), in addition to the general guidance that is already available.

6.2.3. Involvement of workers

In several of the cases described in Annex II, workers were involved both in making risk assessments and in selecting the appropriate measures (cases 2, 3, 4, 6 and 7). The involvement of the people on the shop floor is essential for success because without the support of the operators, measures will not be carried out properly and all preventive efforts are likely to be in vain. Various practices should be considered when involving workers.

- Ask workers about the hazards, work methods, and work environment when carrying out a risk assessment (participative risk analysis, e.g. based on a questionnaire).
- Consult the workers' representatives.
- Inform workers about the results of the risk analysis, and the results of measurements.
- Involve workers in discussions about appropriate measures (e.g. in a working group).
- Test various measures before deciding and ask the opinion of the workers.
- Inform workers about the measures that have been or will be implemented.
- Provide information or training about correct work procedures.
- Provide information on health effects and health surveillance.

6.2.4. Implementing a purchasing policy

Buying the right equipment and machinery is an important factor in tackling vibration at work successfully. Case 6 (Annex II) demonstrates that by involving the purchasing department in a project to reduce WBV for fork-lift truck drivers, it was possible to establish clear criteria for the purchase of new fork-lift trucks, which in turn resulted in a reduction in exposure to WBV for the drivers.

Points to consider in setting up a purchasing policy are to:

- establish a procedure in which it is obligatory to seek advice on health and safety;
- include health, safety and ergonomics requirements on the order form (making reference to legislation, standards, etc);
- request offers from several suppliers and ask for sufficient information (e.g. when buying tools ask about the frequency-weighted acceleration, under different conditions, etc).

6.2.5. Collaborating with manufacturers and suppliers

Manufacturers and suppliers play an important role in preventing vibration at the workplace by offering reasonably priced low-vibration equipment, which companies are more likely to purchase. This is especially true in the case of small companies that do not always have the resources to make in-depth analyses prior to their buying decisions. Case 2 (Annex II) describes a French campaign to reduce vibration exposure from breakers, which was run in close collaboration with the manufacturer. In the first phase, a suspension system was developed together with the manufacturer to reduce exposure. In the second phase of the campaign, information was disseminated and incentives were given to companies to buy the low-vibration equipment. As a result of this campaign, low-vibrating breakers are now more widely used.

Also at company level, a close collaboration with suppliers can be very useful; often they are able to provide assistance in selecting the most appropriate tool or equipment and in its correct use, installation and maintenance.

6.2.6. Implementing a range of measures

Managing vibration at the workplace often requires a set of complementary measures; one measure alone is seldom effective. This is illustrated by the cases described in Annex II, such as case 3, which show that, for instance, provision of alternative means of transportation will not be effective if it is not accompanied by an adequate procedure and clear information to the workers.

6.2.7. Information and awareness-raising

Informing workers and raising awareness is an important success factor. Case 2 shows, on a supra-company level, that by disseminating information on low-vibrating breakers companies can become aware of the risks and of the advantages of reducing vibration. However, information is also needed at company level. The companies in cases 3 and 6 (Annex II) invested in informing their workers (e.g. via toolbox meetings) and as a result the workers successfully adopted new work methods and procedures.

7.

SUPPORT FOR EMPLOYERS

This chapter describes policies and tools provided by insurance companies, social partners, research organisations, manufacturers and authorities at national and European level that contribute to effective implementation of the directive by providing support for employers.

7.1. Guides for risk assessment

Despite the existence of a recognised methodology to assess vibration risks in all of the countries studied in this report, many employers do not know how to carry out this evaluation and many believe that they have to carry out or pay for measurements. Even if measurement were necessary, it would not be possible at present because of the scarcity of vibration experts compared to the number of companies needing to carry out assessment. The fact that employers cannot get results from measurements means that they are less inclined to take preventive action. As the directive merely asks employers to make an assessment of the situation in order to determine whether they have to start taking action, insurance companies and other players in the field have a role to develop tools that facilitate employers' vibration assessment. Online exposure calculators of A(8), such as those provided by several European OSH institutes (e.g. HSE's HAV ([1]) and WBV ([2]) calculators or those of Umeå University, Sweden ([3])) are a good example of such tools. Others include a guide with examples of vibration emissions, or a procedure to estimate the A(8) using these data (e.g. HSE's exposure points system and ready-reckoner ([4]) and WBV and ergonomics toolkit ([5])).

At present, risk assessment procedures related to vibration do not take sufficient account of other hazards, such as poor posture, muscular work, noise, and force coupling. These factors are mentioned, but not quantified in the calculation of the daily exposure value normalised to an eight-hour reference period A(8). As mentioned in Chapter 5, tentative efforts are under way to combine the evaluation of vibration effect with co-factors such as forces exerted by the operator, or postural constraint (ISO 15230:2007; Seidel et al., 2007), but more research and development is needed before these techniques are used for assessment in the field.

([1]) http://www.hse.gov.uk/vibration/hav/vibrationcalc.htm
([2]) http://www.hse.gov.uk/vibration/wbv/wholebodycalc.htm
([3]) http://www.vibration.db.umu.se/
([4]) http://www.hse.gov.uk/vibration/hav/readyreckoner.htm
([5]) http://www.hse.gov.uk/research/rrpdf/RR612.pdf

Guides for health surveillance 7.2.

Health surveillance is specific to each country. At present, no official protocol for health surveillance specifically related to vibration exists in any of the countries covered in this study with the exception of Germany. However, the main elements are briefly described in two good practice guides (on HAV and WBV), which were developed by a consortium of European experts at the request of the European Commission in 2006. Currently the guides are available in English, French, and German (see Vibguide ([6])). Furthermore, some protocols are under development by medical vibration experts in Holland, Italy and the UK through the European Vibrisks (2007) project.

Examples of national guides and non-official protocols

Finland

- HAV: guidance book for health examinations in occupational healthcare (FIOH, 2006).
- Handbook on occupational hygiene (FIOH, 1990, second edition, 2006).
- WBV: guidance book for health examinations in occupational healthcare (FIOH, 2006). This considers qualitative rules for sensitive persons and criteria for exclusion from vibration work.

France

- HAV: apart from two or three French medical laboratories, the tests used to diagnose VWF or vibration syndrome are not widely known in France. This may explain why very few cases of VWF are declared in France in comparison to other countries (Lasfargues, 1990).
- WBV: yearly (or six-monthly) medical examination is compulsory in France in all jobs and the medical physician will examine the employee's back. However, there is no official protocol relating to WBV.

Germany

- For HAV, two guides summarise the current knowledge on occupational diseases of bones and joints (BK 2103) and vascular and/or neurological disorders (BK 2104).
- For WBV, guidance for occupational physicians summarises current knowledge on the relationship between exposure and the probability of long-term effects on the lumbar region of the spine.
- Guideline G 46 'Strain on the musculoskeletal system (including vibrations)' (in *Prophylaxis in occupational medicine*, DGUV 2007, ISBN 978-3-87247-691-3) deals with occupational medical examinations. It takes into consideration a medical anamnesis of WBV and also contains a specific part on HAV. The guideline is supplemented with an appendix on the diagnosis of musculoskeletal disorders in occupational medical examinations.

([6]) http://www.humanvibration.com/EU/VIBGUIDE.htm

- In addition, WBV and HAV can be found in the second part of the 'Berufsgenossenschaftliche Information BGI 504-46' published in 2005. It provides information on applicable regulations, occupational medical examinations, risk assessment as well as other helpful references (HVBG. Auswahlkriterien: Belastungen des Muskel- und Skelettsystems, 2005 ([7]).
- Decree on occupational diseases. Guidance concerning occupational diseases. The document contains a table with ranges of daily exposure data according to VDI 2057 Part 1 and the EU guideline, along with corresponding verbal risk assessments for exposure durations between 5 and 10 years and for longer than 10 years.

7.3. Actions

7.3.1. Initiatives for an innovative approach on vibration

Various innovative approaches on reduction of exposure to vibration exist and they are different in each of the countries studied. Assessment of risks without measurement is an innovative approach in itself and it must be further developed.

Belgium

Efforts are concentrated on development of overall risk assessment procedures, namely the Sobane risk management strategy and the Déparis method (funded and promoted by the Federal Public Service for Work and Employment) and the PRA method with specific modules (Malchaire and Piette, 2001).

The aim of the Sobane risk management strategy is to make risk prevention faster, more cost-effective, and more effective in coordinating the contributions of the workers themselves, their management, the internal and external occupational health (OH) practitioners and the experts. Sobane consists of four levels: screening, observation, analysis and expertise. At the screening level are the risk factors detected by the workers and their management, and obvious solutions are implemented. At the observation level, the remaining problems are studied in depth and the reasons and solutions are discussed in detail. At the analysis level, an OH practitioner is called upon to carry out appropriate measurements to develop specific solutions when necessary. At the expertise level, the assistance of an expert is called upon to solve a particular problem. The software tool, Sobane, was developed by the Catholic University of Louvain (UCL).

The PRA method guarantees the active involvement of all employees in the company in the identification and assessment of hazards and risks within their own work activities and for their own working area. Attention is not only paid to traditional safety risks, but also to health risks, ergonomic aspects, psychosocial aspects, and other risks.

([7]) http://www.hvbg.de/d/bgz/praevaus/amed/bg_grund/g46/index.html

France

The institute for occupational accident prevention, INRS, is preparing a good practice guide for off-road machine operators. This will cover assessment and technical or organisational measures for vibration reduction.

INRS has carried out feasibility demonstrations for the reduction of vibration from fork-lift trucks, road finishers, breakers, chipping hammers, and grinders (Bitsch, 1998 and 2001; Boulanger, 1998; Galmiche, 2006).

Finland

Since 2003 FIOH has carried out the following initiatives:

- development of an animal model of the biological effects of HAV on blood circulation and neurons;
- definition of impulse vibration effects on blood cells and definition of criterion value for peak level;
- development of a measuring device to make long-term, online recordings.

An epidemiological study has been planned to compare the needs of WBV-exposed and non-exposed workers to use occupational health services.

Germany

Comprehensive research is being carried out on the effects of WBV on health and well-being (see Chapter 9 for a detailed description). Research and development is also being carried out by manufacturers, principally investigating technical measures for the reduction of vibration at source (mainly vibrating tools) and vibration isolation (suspended seats for drivers) (BIA, 1998a).

Spain

INSHT is carrying out a review based on measurement of vibration levels of machinery used in the construction, agriculture and forestry sectors, according to ISO 2631-1, UNE EN ISO 5349-1 and UNE EN ISO 5349-2. Based on the results, Spain will decide whether it has to change the vibration regulation within the transitional periods established by the directive.

IAPRL (Instituto Asturiano de Prevención de Riesgos Laborales) has undertaken studies on actual exposure levels to HAV in portable machinery for manual work and on exposure levels to WBV from machinery and vehicles used in civil engineering. The conclusions of these studies will be a good starting point from which to carry out the study at national level.

7.3.2. Developing computer tools to evaluate the risk

Most software tools evaluate exposure based on two main factors: equivalent vibration value and duration of exposure. There are several, mostly similar, kinds of computer tools to evaluate vibration risks and it is a well-developed field.

Belgium

Different kinds of computer tools are available to evaluate the vibration risk and it is an advanced area. The Federal Public Service for Work and Employment funded and promoted the software tool, Sobane.

Finland

FIOH, within the Ministry of Social Affairs, provides an Internet-based dose calculator for HAV and WBV.

France

Assessment of vibration for non-experts is a difficult task, so INRS is funding the development of a low-cost, whole-body dosimeter. INRS is also promoting guidance on how to assess vibration without measurement.

Germany

An assessment has been made of the health risks for the lumbar region of the spine. This was based on calculations of static and dynamic intra-spinal forces (six lumbar levels from T12/L1 to L5/S1) with finite element (FE) models adapted to representative anthropometry and postures of European drivers and using WBV measurements at the seat, feet and backrest in three axes (*x, y, z*) as input. The risk assessment considers the age of the drivers and the individual size of their vertebral endplates. The computer tools were developed by BAuA within the framework of the Vibrisks (2007) project.

Spain

An exposure calculator is being developed for HAV and WBV, which is very similar to the tool provided by the Health and Safety Executive in the UK. Once the level of vibration and the exposure time are entered, the tool returns the value of A(8) and the result is compared with the limit and action values. The tool covers four cases: WBV, one source of vibration and several sources of vibration; and HAV, one source of vibration and several sources of vibration. It will be accessible on the INSHT website.

7.4. Strategies

7.4.1. Keeping up to date with developments in vibration control

It is important to ensure effective dissemination of information about developments in technology that allow better control of vibration exposure. Dissemination activities in this area are generally not well developed, but they are especially important for raising awareness among employers.

In Finland, trends in exposure to the main agents of vibration at work and reasons for changes are published every three years in a book, *Occupational health and occupational exposure to various agents*.

In Spain, a report is published on technological surveillance related to vibration by sector.

In France, INRS regularly monitors the availability of new technology and holds demonstrations of the latest technical solutions for reducing vibration (e.g. suspension cabs for industrial trucks, suspended floors for finishers, low-frequency suspension seats, low-vibration rammers, breakers, files) and may assist manufacturers in the development of low-vibration equipment (see INRS publications).

7.4.2. National–level strategies, policies, action plans or campaigns on exposure to vibration

Development of strategies or campaigns to reduce human vibration exposure requires large amounts of effort and time. Campaigns are most effective when they are maintained over several years and concentrate on specific situations. A key success factor is the use of tailored communication tools to reach each of the different target groups: not only the employer, but also the buyer, the physician, the manufacturer, the distributor, etc.

The following example of a national strategy is from France.

As a first step, the INRS trained nine laboratories in measuring vibration and proposing solutions to reduce vibration exposure (Centre de Mesure Physique, three guides to evaluate vibration at work (1998, 2000 and 2004)). Subsequently, INRS and these nine laboratories formed the Vibration CRAM/INRS group, which meets on a regular basis and has undertaken the following activities:

- drafting three procedures on how to take measurements and certification of the nine laboratories to ISO 9001;
- development of a repository of collected vibration data;
- measurement campaigns covering off-road machinery and hand-held tools;
- systematic presentation of the directive to occupational physicians across France;
- provision of two guides of good practice (on WBV and HAV), based on corresponding European guides ([8]);
- sponsoring development of cheap and easy-to-use instrumentation;
- publication of a list of working places which may expose operators above limit values;
- assistance to manufacturers who are interested in developing anti-vibration systems;
- distributing lists of anti-vibration breakers or adapted suspension seats to CRAM inspectors for advice.

In the past, INRS has run campaigns to promote adapted suspension seats for fork-lift trucks or the choice of anti-vibration breakers.

([8]) http://www.humanvibration.com/EU/VIBGUIDE.htm

8.

PREVENTION MEASURES

8.1. Technical measures for the reduction of vibration

Efforts to reduce occupational exposure to WBV and HAV have increased substantially over the last 15 years.

8.1.1. WBV

The effect of WBV may be transmitted through the buttocks when sitting or through the feet when standing (e.g. in road or construction vehicles) or over the entire body when lying down (e.g. in ships).

In vehicles, vibration magnitude depends on the function of the vehicle, the terrain and the driving style. Reduction in exposure has focused on seat suspension for drivers, but the vibration of vehicles that is caused by a rough or bumpy terrain can also be reduced by the selection of appropriate tyres and shock absorbers on the vehicle and by provision of suspension cabs.

Each suspension system is designed to reduce vibration over a specific frequency range, so selection of the correct device is especially important. All suspension devices have a frequency range over which they amplify rather than reduce vibration and an incorrect choice could easily result in increased exposure to vibration.

Vehicle damping and seat decoupling

All three principal vehicle damping systems — undercarriage damping, suspension cabs and seat suspension — must be adjusted in such a way that vehicle stability is not compromised. Suspension travel must strike a compromise between ensuring driving stability (short travel) and achieving effective reduction in vibration across all frequencies (long travel). Short suspension travel results in a low range of damping, covering only the higher frequencies. In general, undercarriage suspension is tuned to reduce only higher–level frequencies, so as to maintain vehicle stability, whereas cabin suspension is tuned to lower frequencies and the suspended seat is tuned to the lowest frequencies of vibration in the system. It should be noted, however, that the seat's suspension travel is limited by the operation of pedals, steering wheel and adjusting levers (BIA, 1998a).

Adjustment of the seat suspension

In the first generation of air-sprung vehicles fitted with air-sprung suspension seats, the damping characteristics of the seats did not match the lower-frequency tuning of the more conventional steel springing of the vehicle air suspension with the result that low–level chassis vibrations were substantially amplified by the seat suspension. Seats with adjustable suspension make it easier to find the right balance between soft springing to reduce low–frequency vibrations and sufficient suspension for high peaks caused by e.g. a railway crossing. The problem, however, is that the effectiveness of the system depends on the driver adjusting the seat according to the causes of the vibration — and often this does not happen. This problem should be solved with the development of 'semi-active' dampers which adjust absorption to a set of variable-speed algorithms, but avoid the high costs associated with fully active springing systems.

8.1.2. HAV

A significant reduction in exposure to HAV has been achieved as a result of five principal measures: use of vibration-reduced working procedures, design of vibration-reduced machinery and tools, use of anti-vibration grips, use of elastic material and grip coatings, and the use of anti-vibration gloves.

Vibration-reduced working procedures

Already in the planning of work processes, the use of vibrating hand-tools can be avoided or reduced by adapting product manufacture. For example, the high levels of HAV exposure resulting from manual surface treatment with chisel hammers or grinders can be avoided or the exposure time be considerably reduced through the use of high-precision moulds. On building sites, architects and engineers can help reduce vibration exposure through the use of prefabricated modules.

Other examples of low-vibration alternative work processes include the use of hydraulic presses instead of hammers in the manufacture of steel tanks, or adoption of rivet devices driven hydraulically or by compressed air that eliminate the need for a counter holder and reduce exposure for the riveter.

The use of drill-screwers instead of impact wrenches results in less noise as well as no vibration exposure. In practice, when this change was implemented in the process of lorry construction, the frequency-weighted vibration magnitude decreased from a_{hv} = 5.8 m/s^2 to a_{hv} = 2.0 m/s^2 and productivity and ergonomics also improved (BIA, 1998b).

Design of vibration-reduced machinery and tools

Figure 8.1 below shows three designs of low-vibration road-breaker, which achieve their effect either by pneumatic decoupling, the use of steel springs in the grips, or decoupling using rubber elements.

For drilling stone and concrete, the use of new technology has reduced the vibration exposure. The main developments have been the change from reversing hammer drills with a ratchet striking mechanism to rock drills with an electro-pneumatic striking mechanism and more recently to diamond drill technology. Rock drill vibration can be further reduced through additional grip suspension.

For grinders, a special auto-balancing system (see Figure 8.2) uses balls to compensate for the imbalance of the grinding disk. This retro-fittable system can reduce vibration by 10 % to 70 %.

Figure 8.3 shows an example of vibration reduction in rivet hammers using an air-cushion as suspension. A servo valve controls the air pressure according to the feed force. Other anti-vibration systems improve the motor and the damping elements between motor and tool.

Figure 8.1: Examples of different road-breakers with vibration reducing systems (BIA, 1998b)

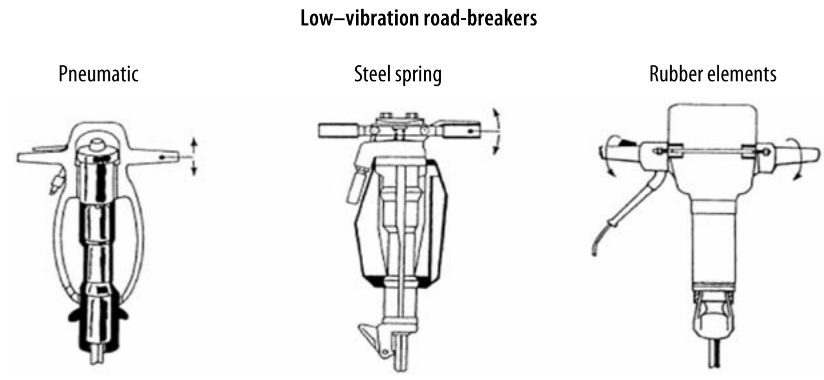


Figure 8.2: Auto-balancing system for grinders (Donati and Bitsch, 1991)

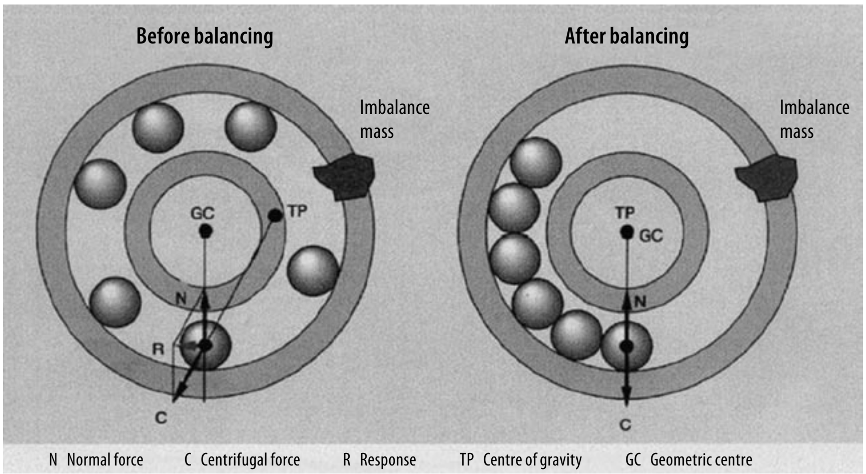
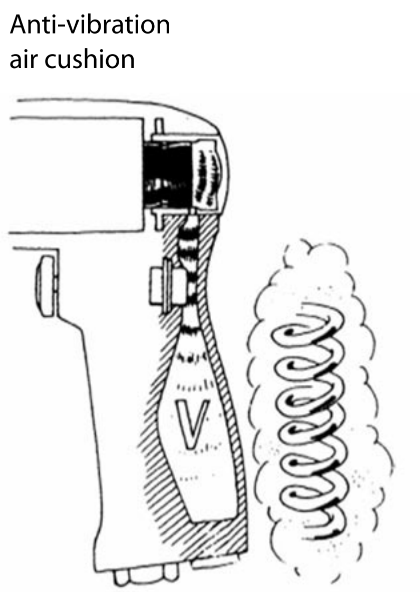


Figure 8.3: The working principle of a rivet hammer with recoil reduction (SKF Auto-Balancing-Systems, Gothenburg, Sweden)



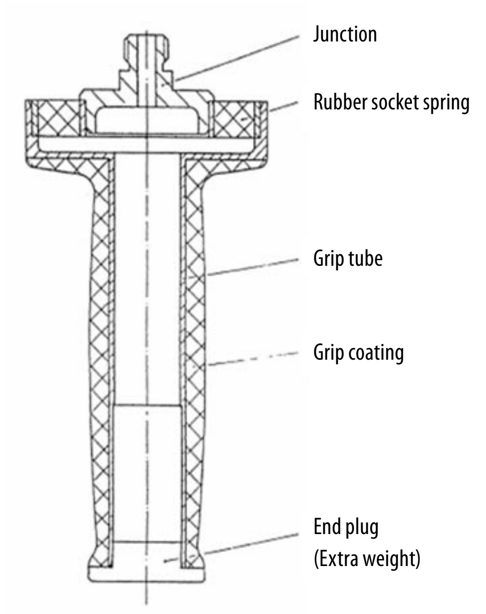
Use of anti-vibration grips

Anti-vibration grips reduce the transmission of the vibration to the user's hands. In order to be effective, the resonant frequency of the grip must be a factor of 1.4 lower than the excitation frequency. Therefore, large grip mass or low spring stiffness is necessary, which may influence the handling and control of the tool. Successful anti-vibration grips can be found for chainsaws and pneumatic chisels. Several manufacturers offer vibration-reduced chisels with $a_{hv} \leq 5$ m/s^2.

Use of elastic material and grip coatings

Grip coatings made of rubber or of special elastic material can reduce the vibration transmission at the point of contact in a similar way to anti-vibration grips, but due to limits of material thickness, only high-frequency vibration can be reduced significantly (above 200 Hz). In practice, a side grip with gum jacket and integrated socket spring (see Figure 8.4) has been shown to reduce the frequency-weighted acceleration of hammer drills by 20 % compared to stiff grips without a jacket (BIA, 1998b). However, this successful combination of the two measures was primarily due to the grip suspension.

Figure 8.4: Vibration-reduced hammer drill grip, a combination of grip coating and socket spring (BIA, 1998b)



Use of anti-vibration gloves

In the early 1980s, so-called 'anti-vibration' gloves became available and a laboratory test procedure was developed that provides a uniform and reproducible basis for evaluating the vibration-insulation effects of such gloves (EN ISO 10819). For frequency ranges higher than 150 Hz, a vibration transmission factor of $TR_H \leq 0.6$ is typical for an effective glove, but for lower frequencies, anti-vibration protection gloves are not useful.

Use of certified anti-vibration gloves may be recommended in the following cases (Kaulbars, 1997; Kaulbars, 2007):

- machines with exclusive as well as mainly high-frequency proportions greater than 150 Hz (e.g. polishers);

- machines for which no precise guidance or no especially high docking forces are necessary (e.g. vibratory stampers);
- machines for which the wearing of gloves is recommended for reasons of protection against cold and mechanical risks (e.g. chainsaws).

However, it should be noted that generally valid statements about the degree of risk reduction possible through the use of anti-vibration gloves for practical use cannot be made at present.

8.2. Negative health effects

8.2.1. WBV

Demand for vibration protection and prevention is increasing despite continued improvement in vehicles, machines and devices. However, many factors are at the same time increasing vibration exposure, as described below. Additionally, owing to the ageing of the population, employees will have to work until later in life and will be exposed for longer overall.

Regarding negative health and safety effects due to WBV, the authors consider dumpers, farm tractors and scrapers to be among the most critical machines. Dozers, pallet-trucks and asphalt pavers are less critical, but are still not considered safe. In comparison to all of these machines, wheel and backhoe loaders, excavators (both above and below 25 tonnes), tow tractors, heavy trucks and graders are to a lesser extent associated with possible negative health effects. Finally, additional machines related to possible negative health effects due to WBV include all-terrain trucks, compactors and road trucks.

This categorisation does not in all cases correspond to the objective values of acceleration for the machines listed (see Figure 2.1). According to the authors, machines such as dumpers, farm tractors and scrapers are strongly related to possible negative health effects, whereas according to the EU guide to good practice on WBV, scrapers, asphalt pavers, dozers and wheel loaders have the highest acceleration rates. However, negative health effects are not due to vibration acceleration alone, but also to the adjustment between man and machine, including factors such as:

- incorrect adjustment by the driver of the seat position and hand and foot controls, so that it is necessary to continually twist, bend, lean and stretch to operate the machine;
- poor design of controls, making it difficult for the driver to operate the machine or vehicle easily;
- sitting for long periods without being able to change position.

Moreover, there is great variation across Europe in the machines used in agriculture, road-building and other sectors (different manufacturers, different age, maintenance, etc.). These factors together explain the apparent discrepancy mentioned above between the authors' expert opinion and the acceleration values available.

8.2.2. HAV

Regarding negative health and safety effects due to HAV, working with vibratory rams, as well as with rock drills and road breakers can be regarded as the most critical activities. In addition, demolition hammers, chipping hammers, grinders and chainsaws/saws put workers at risk. In contrast, activities related to sanders and drills are considered to be relatively safe, with a comparatively lower risk of possible negative health effects. Additional machines identified as posing possible negative health effects include wood finishers (last step of wood treatment) and gluing of car windscreens.

As in the case of WBV, there are some discrepancies when compared to the table of acceleration values. In the authors' opinion, machines such as vibratory rams, rock drills and road-breakers have the highest possible negative health effects, followed by demolition hammers, chipping hammers, grinders and chainsaws/saws; whereas, according to the EU guide to good practice on HAV, vibratory rams, rock drills and demolition hammers have the highest acceleration rates followed by road-breakers, chipping hammers, sanders and chainsaws. In fact, the negative health effect is a combined result of acceleration values and handling of the devices. The acceleration value effect may be minimised by professional handling and this can explain the apparent discrepancy.

Prevention in the field of vibration 8.3.

8.3.1. Success factors

Over the past 15 years, the principal factors leading to a reduction in exposure to vibration have been:

- the development of different kinds of anti-vibration machinery, driven in large part by decisions to stop using the conventional kinds of machinery;
- reduction in workers' exposure to WBV by improving suspension systems on vehicles, seats or cabs;
- reduction in workers' exposure to HAV through adoption of anti-vibration systems such as damped grips, balance systems, diamond-fitted tools and machines in the construction sector;
- insertion of bogies to improve suspension and reduction of machines' impulsiveness;
- adoption of organisational approaches, such as work automation and job rotation, especially in manufacture and production processes associated with negative health effects;
- decoupling of man and machine, such that rotating tools are preferred to percussive tools where applicable;
- systematic medical check-ups as well as temporarily limited exposure to machines;
- information for employers and workers on the risks and developments in the field of vibration.

All of these interventions have improved workers' performance at work and have become progressively cheaper to implement as, for instance, anti-vibration machines work more efficiently and effectively than conventional ones.

8.3.2. Barriers to prevention

As well as the positive developments, however, the last 15 years have also seen the appearance and persistence of a number of barriers to reduction of occupational exposure to vibration.

- Adoption of just-in-time production methods and the ever greater pressure on rates of productivity have reduced the effectiveness of interventions to tackle occupational vibration.
- The increasing number and use of motorised tools, such as impact or nailing hammers, has led to greater efficiency and higher productivity, but is frequently associated with an increase in vibration exposure at work when compared with the previous working methods.
- Anti-vibration systems do not always take account of basic ergonomic requirements, such as workers' preference for light rather than heavy tools. Furthermore, reduction of a tool's power does not necessarily reduce vibration because the decrease in force (e.g. in the case of hammers) usually leads to an increase in the duration of its use.
- In some cases vibration-reduction devices, such as suspended handles for grinders, are rejected by workers because they result in a loss of precision. This underlines the importance of effective application of standards for developing vibration-reduced devices: poor design or false or exaggerated claims result in unfair competition, with reduced motivation for manufacturers to design lower vibration equipment.

8.4. Success of specific preventive activities

8.4.1. WBV

Technology that reduces exposure to WBV is available in particular on farm tractors and compactors and to a lesser extent in the form of vibration-reduced dumpers and wheel loaders. Vibration-reduced backhoe loaders, dozers and excavators (both above and below 25 tonnes) can also be found on the market. However, vibration-reduced versions of asphalt pavers, graders, pallet-trucks, tow tractors and heavy trucks account for only a small proportion of sales.

The authors estimate the market share of WBV-reduced machines to be between 50 % and 70 % for farm tractors, dumpers and heavy trucks and between 30 % and 50 % for excavators (both above and below 25 tonnes), wheel and backhoe loaders, dozers, tow tractors and scrapers. The market share for asphalt pavers, graders and pallet-trucks is below 30 %.

Suspension seats, if appropriately selected and properly maintained, may reduce vertical WBV effectively on machines such as fork-lift trucks, dumpers and bulldozers

(BIA, 1998a). However, measurements of seat suspension performance of off-road mobile machines carried out by INRS in the 1980s showed that many machines were equipped with seats that were not properly adapted. Unfortunately, similar measurements carried out more recently show that very little has changed in 25 years, despite several campaigns promoting the correct use of suspension seats.

Further reduction in exposure to WBV results from the use of systems to assist loading, improved vehicle suspensions, as well as suspended buckets for loaders and attachments for scrapers. Additionally, anti-vibrating bogie constructions and suspended axles (which can be fixed during working periods) help in lowering the occupational exposure to WBV.

8.4.2. HAV

Regarding HAV, vibration-reduced chainsaws/saws, chipping hammers and vibratory rams can easily be found for sale. Also widely available are anti-vibration devices for demolition hammers, drills, grinders and road-breakers. Vibration-reduced sanders are less widespread and vibration-reduced versions of rock drills are seldom found.

The market share for HAV-reduced machines such as chainsaws/saws lies between 50 % and 70 %. However, for road-breakers, vibratory rams, drills, sanders, chipping hammers and grinders, the market share is only between 30 % and 50 %. Moreover, machines such as demolition hammers and rock drills have a market share below 30 %.

The authors highlight that, while rock drills pose a significant hazard in standard form, vibration-reduced versions are scarcely available and their market share is very low. Employers and manufacturers need to focus on the prevention of HAV to reduce the risks due to rock drills. Furthermore, the market share needs to be increased for vibration-reduced vibratory rams, road-breakers, demolition hammers, chipping hammers and grinders.

8.4.3. General prevention in the field of vibration

It is generally accepted that vibration exposure can be reduced successfully through engineering solutions, such as elimination at source and/or the use of anti-vibration measures or personal protective equipment (PPE). However, the extent to which technical solutions are adopted varies greatly from one country to another. In workplaces where such solutions are ignored, this is usually due either to a lack of awareness or for reasons of cost. Lack of awareness implies poor knowledge on the part of users and employers regarding how to select an adequate machine, as well as ignorance on the part of manufacturers and distributors regarding occupational health and safety aspects. Moreover, as in most cases the buyer of a machine is not the end user, it is hard to convince the buyer, who is not aware of certain negative aspects, to take the correct decisions.

Occasionally, low-vibration versions of equipment are even regarded as an optional luxury rather than as an essential health and safety measure. However, this attitude is becoming rarer thanks to the vibration directive (2002/44/EC), which makes the reduction of vibration compulsory. Given that the directive is relatively recent, many companies are still in the process of implementing the measures and have only recently started to identify and assess the risks related to vibration. The implementation of technical measures and the adaptation of equipment will follow soon after.

Besides engineering and technical solutions, awareness-raising campaigns are another means whereby the risk from vibration at work could be reduced. However, the authors emphasise that the extent to which campaigns can reduce exposure, where it has not been possible to eliminate it, is far from certain. To help ensure success, campaigns should be integrated into a policy on vibration in particular and into a health and safety strategy in general. Campaigns can be cost-effective and simple solutions, which can be set up in a short period, but doing so without first implementing a policy on vibration (assessing the risks, introducing controls, removing or reducing exposure, etc.) will have minimal impact. Awareness-raising must be seen as only one of several approaches and should be clearly linked to a policy. Last, but not least, it is important that the campaign and its approach are available to and accepted by the workers — their involvement is a key success factor.

Training for workers on how to reduce exposure to HAV is rare. If it is to be effective, the trainer must explain how to use the vibration-reduced devices correctly, e.g. how to set up the suspension of breakers, and practical hands-on training helps enormously in this respect. With respect to WBV, research carried out by the UK's HSE shows that adequate information and appropriate training in best practice are the most important factors in controlling/reducing operator exposure (HSE, 2005). Videos are regarded as an effective training aid in this respect. In addition, training should focus on adoption of good working methods that reduce the effects of vibration and show, with real-time measurements, how working conditions influence the transmission of vibration.

Assistance to manufacturers in promoting anti-vibration devices (at national level) can raise the awareness of users. Additionally, unions can be assisted in writing specific guides of good practice with lists of technical solutions. In order to enable the users to adopt successful solutions, the state of the art as well as the latest research results need to be disseminated both at national and European level. So long as there is a lack of personal dosimeters, employers can base their assessments on approximate indications of personal perception to a range of overall vibration emission values. According to ISO 2631-1:1997, the exposure level 0.5–1 m/s^2 is identified as 'fairly uncomfortable' and the level rising from 0.8 m/s^2 to 1.6 m/s^2 as 'uncomfortable'.

8.5. Barriers to adoption of successful solutions

In the authors' opinion, a lack of know-how is the most important barrier to users' adoption of successful solutions; however, there are differences between SMEs and large enterprises.

SMEs' lack of know-how, measuring equipment and training is generally the main challenge, but to a lesser extent, workers are not able to adopt successful solutions owing to a lack of tools to support decision-making, as well as a lack of support and money. In comparison with SMEs, fewer deficits exist in large enterprises, although a lack of know-how is still the main problem with regard to users' failure to adopt successful solutions. It is not clear whether the lack of decision-support tools is important for larger companies, however, neither a lack of measuring equipment nor a lack of training adequately describes the situation in large enterprises. Nonetheless, a lack of support and money also results in workers not adopting successful solutions in large enterprises. As stated earlier, some suppliers and users seem to regard items such as ergonomic seats or grips in vehicles as a luxury and are not willing to pay for them.

Besides these obstacles the authors highlight the importance of multifactorial risks. Exposure to vibration combined with, for example, awkward or static postures — especially in the context of an ageing workforce — present a further challenge to the success of interventions. Although increasingly common, it is as yet unclear whether obesity presents a problem for preventive effects.

The price of measuring equipment such as dosimeters is also a significant barrier, particularly for SMEs.

While warnings on equipment about the risks from exposure to WBV are required under the machinery directive (2006/42/EC), in practice they are rarely included in operating instructions since very few emission values are available. A similar situation arises with respect to HAV, on account of either incomplete information or because the given vibration levels are inaccurate. Moreover, in some cases the transmission of vibration is not only due to the type of machine, but to the complex result of certain working conditions such as sustained effort, static or awkward postures, and certain types of drill. Some manufacturers do publish comprehensive written guides of good practice, but many users do not use the information simply because they do not read the instructions.

Diversity of the workforce exposed to vibration 8.6.

The authors highlight the increasing participation of women in occupations involving exposure to vibration. These jobs are mainly associated with WBV exposure through vehicle driving and include (fork-lift) trucks, tractors, buses, trams, cranes, lifts, locomotives and off-road machines such as dumpers. However, women are also exposed to HAV, particularly in industrial sectors such as cleaning activities, where they use hand-driven machinery and motorised hand-tools, as well as in the metal and construction sectors. In spite of this increase, women's exposure is only very rarely addressed specifically in preventive actions. Therefore, the authors emphasise the need to inform occupational physicians about women's exposure to vibration and the need to take specific measures to limit women's exposure and to prohibit it during pregnancy.

A steady increase is expected in the average age of exposed workers. This change is likely to be greater with respect to WBV, given that only workers who are relatively young are able to exert the effort needed to control hand-held tools. Workers who suffer from back problems will be affected by exposure to WBV and will not be able to continue such activities.

8.7. Future implications

8.7.1. Preventive effects related to the implementation of Directive 2002/44/EC

Directive 2002/44/EC seeks to introduce minimum protection requirements for workers exposed to vibration of all types, which have to be observed by employers. Some steps have been taken to assist in the implementation of the directive in the daily business of enterprises through, for instance, the EU good practice guides on WBV and HAV. These are non-binding guides to good practice with the objective of facilitating the assessment of risks in relation to vibration exposure, the identification of controls to eliminate or reduce exposure, and the introduction of systems to prevent the development and progression of injury. These guides contain a summary of responsibilities for employers defined by Directive 2002/44/EC: determination and assessment of risk; removing or reducing exposure (controlling exposure action value and exposure limit value); workers' information, consultation and training; and health surveillance.

The authors consider that the implementation of Directive 2002/44/EC will result in more vibration-reduced devices, as well as in greater awareness. However, an increase in the use of personal protective equipment cannot be regarded as a primary preventive effect of the implementation. The increasing number of employers that are interested in assessing vibration can also be seen as a consequence of the implementation. Furthermore, there are clear signs that enterprises' purchasing and engineering departments are actively involved in combating the risk from vibration. This has a positive effect on employers' attitudes towards occupational health and safety and also on integrating them into day-to-day business.

Besides these primary effects, the authors are confident that a secondary effect of the implementation of Directive 2002/44/EC will be that more measurements are carried out. Another secondary effect of implementation is that acoustic consultants will increasingly develop a means of measuring vibration as the field becomes more financially attractive. Demand for devices associated with vibration is increasing and should drive down the price of measurement equipment such as dosimeters. This will help employers and occupational physicians apply the directive more effectively. A similar effect on the price of low-vibration equipment should encourage the renewal of old equipment in companies.

8.7.2 Changes in the world of work

Changes in the world of work will always lead to changes in the occupational health and safety situation. Increasing workload, fewer breaks and longer shifts, as well as increasing productivity, higher efficiency and short-term production, combined with greater mechanisation exposes workers to greater doses of vibration. There are branches where the number of people that are exposed is rising, e.g. in airport transport and city traffic. Additionally, poorly qualified workers and heavy traffic can be seen as changes in the world of work which cause additional vibration exposure. The authors consider that the effect of globalisation is contributing to this tendency in Europe.

9.

RESEARCH PERSPECTIVES

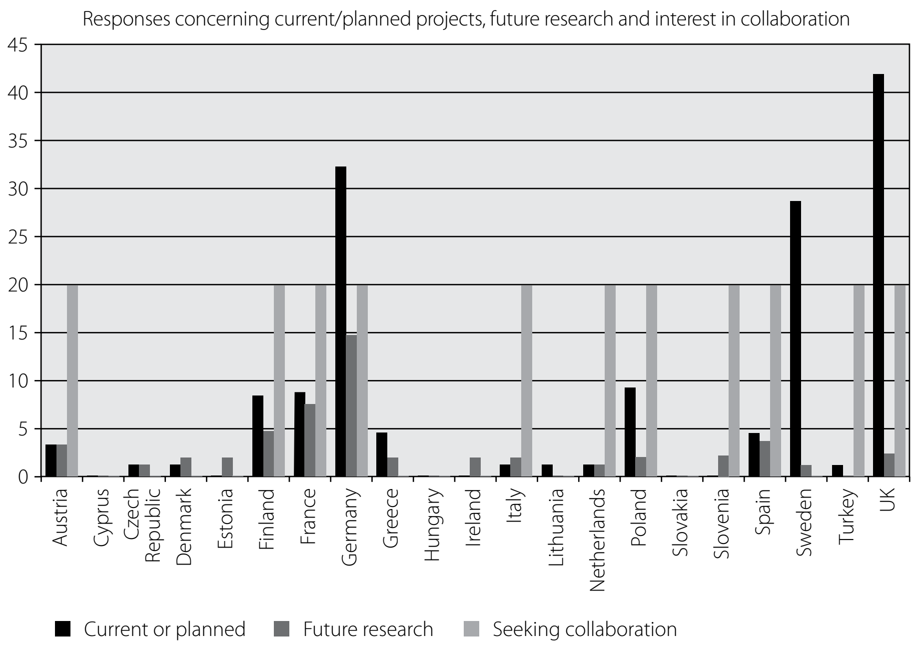
9.1. Current or planned research projects

This chapter is based on information provided by the EU-OSHA's network of focal points ([1]) regarding recent, ongoing, or planned research in the field of human exposure to vibration.

Approximately 150 projects were submitted, covering 20 Member States and Turkey. Full information is available through a Microsoft Access database which incorporates the fields shown in Figure 9.1. The database is available as a separate file for download at the BAuA's homepage, under the topic 'Vibration':
http://www.baua.de/de/Themen-von-A-Z/Vibration/Vibration/EU-Forschung.html?__nnn=true&__nnn=true

For each of the countries that submitted information, Figure 9.1 shows the number of current or planned projects, the number of proposals regarding future research and the interest in collaboration within the EU. Subsequent sections summarise responses concerning priorities for research on vibration, categorised by topic area, which should provide an idea about the main topics of future research. A total of about 50 proposals were delivered.

Figure 9.1: Number of current or planned projects, number of proposals regarding future research, interest in collaboration within the EU (yes/no)



As well as information obtained from EU-OSHA's network of focal points, this chapter also presents the main conclusions of a meeting on vibration research between nine

([1]) http://osha.europa.eu/about/partners/focal_points

European institutions working in the field of risk prevention at work (2). At the meeting, organised by the Kommission Arbeitsschutz und Normung (KAN) (3) in March 2007, the participants defined their main priorities and possibilities for research and research cooperation.

Research priorities — WBV 9.2.

9.2.1. Focal point information

Many countries propose carrying out measurement of vibration exposure for different sectors and machinery under various working conditions, taking into consideration maintenance and the age of machinery (field studies). The measurements should contribute to the identification of sectors, machines and conditions with the most detrimental health effects. A further development of existing databases or the establishment of new databases is needed.

Also widely recommended is a verification of the evaluation methods concerning health risks, comfort and performance described in ISO 2631-1 and -5 (frequency weighting, multiplying factors) based on laboratory experiments using subjects. Detrimental effects of horizontal WBV in *x* and *y* axes are of growing significance and the real exposure conditions, as well as controversial opinions on the evaluation, support the need for research in this area. A European research project, e.g. within the seventh framework programme of the European Community for research, technological development and demonstration activities, would facilitate joint efforts by putting results into practice. An existing and improved finite element (FE) model (BAuA) should be used for verification regarding health. The posture, anthropometric data, age and gender of the subjects should be considered.

Table 9.1: Categorised focal point responses regarding WBV research priorities

Field studies	
Exposure measurements, database, identification of problem sectors, machines and conditions (including age of machines)	Austria, Denmark, Germany, Slovenia
Testing of new measurement equipment (dosimeter)	Germany, Poland
Laboratory studies	
ISO 2631, health, comfort, performance, frequency weightings, multiplying factors, multi-axial exposure	Finland, Germany, Italy, Netherlands, UK
Determination of evaluation values (aside from acceleration)	Italy

(2) Meeting in the framework of Euroshnet — the European network for occupational safety and health experts involved in standardisation, testing/certification and/or related research (http://www.euroshnet.org/fora_open.php?k_a=11&board=4&board=4&view=threaded).

(3) Commission for Occupational Health and Safety and Standardisation (http://www.kan.de)

Field studies	
Seat tests, verification of seat–adjusting guidelines	Spain
Epidemiological studies	
Association between WBV and health effects considering posture, age, length of rest periods, repeated shocks	Austria, Finland, Germany, Netherlands
Modelling	
Further development and application of an existing FE model of the human body (BAuA)	Germany
Modelling the effects of vibration on cells (muscle, blood, neuronal) by means of animal studies	Finland

More detailed information about future research needs by type of research and country is given in Sections 9.2.3. to 9.2.8. below.

9.2.2. KAN meeting

Table 9.2: WBV research priorities according to the specialists from 10 organisations in Euroshnet

Interest in research and current research projects	
Effect of interval breaks – ISO 2631 specifies that it is preferable to have interval breaks during vibration exposure. This needs to be validated.	Germany
Database (exposure, emission) – Database would help employers to assess vibration, as required by the directive. They do not have the necessary resources to carry out measurements.	Austria, France, Germany, Italy, Spain, Turkey, UK
Frequency dependence (weighting) – Weighting curves should depend on vibration magnitude. More research is needed to make proposals.	Germany, UK
Equipment (dosimeter) measurement – Vibration measurement equipment is too complex and expensive for many employers. Affordable dosimeters are needed.	France, Italy, UK
Shock – Root mean square averaging probably underestimates shock consequences. ISO 2631-5 needs to be validated.	Germany, Italy, Turkey, UK
Directions – According to the vibration magnitude (comfort, health risk), equivalent acceleration along the horizontal axes must be multiplied by 1 or 1.4. Why?	Germany, UK
Posture – It is widely assumed that back pain results from excessive pressure between lumbar vertebrae. Poor posture is the first cause of high pressure. How to quantify posture?	France, Germany, UK
Modelling – Predictive models that combine the effect of posture, operator characteristics and vibration are being developed, but they are complex and need further development.	Germany, Turkey, UK

9.2.3. WBV — Field studies

Austria

Evaluation of all those affected industries not yet evaluated:

- Provide a general overview and identify the most relevant sectors.
- Provide a comprehensive list of work equipment giving significant figures of generated vibration.
- Measure vibration and exposure using tools under working conditions.

Denmark

WBV exposure profiles:

- Produce a profile of WBV exposure for heavily exposed occupations/sectors.
- Identify potential practical remedies to address these problems.

Germany

Evaluate the exposure of drivers of forestry and horticultural equipment:

- For the maintenance of green spaces, sit-on lawnmowers with almost no seat suspension are used increasingly (schools, hospitals, sports grounds, etc.), exposing the driver to unknown levels of WBV. A qualified risk assessment is not possible.
- Drivers of forwarders, harvesters and tractors with cable winch are exposed to high intensity WBV.
- Measure exposure under typical working conditions and place data in a database.
- Investigate the influence of machine deterioration on WBV exposure.
- Test vibration dosimeter in practice:
  — comparison with traditional measuring equipment,
  — 'round-robin' test.

Poland

Practical vibration dosimeter:

- Develop a simple dosimeter and procedure for initial assessment of exposure to vibration at the workplace for use at different workplaces and during different tasks.

Slovenia

Assess and analyse the situation regarding exposure to vibration at work:

- Collect data regarding exposure of workers to WBV and HAV.
- Assess and analyse the situation in enterprises to determine the exposure of workers to vibration, the use of work equipment that produces harmful vibration, and duration of exposure.
- Determine the sectors and work activities (workplaces) where the problems regarding vibration are most critical in order to prioritise the measures required to reduce vibration exposure.
- Determine the means of executing the measures stipulated by Directive 2002/44/EC, where values exceed limit values.
- From gathered information (collected data), identify which sectors and work activities are the most critical, and perform sample measurements and compare them with action and limit values.

- Perform analysis of the execution of measurements (who performs them and how), the use of personal protective equipment (PPE) and other measures applied.
- On the basis of the results, analyse workers' exposure with a view to proposing measures to reduce exposure.

9.2.4. WBV — Laboratory studies

Finland

Validation of a standardised method for evaluating WBV effects on health and comfort:

- The current ISO 2631-1 ([4]) standard defines a method to evaluate the effects of WBV on health and comfort. The evaluation methods, however, are based on perception and comfort studies rather than directly on health studies. Furthermore, these have been based on single-axis studies, whereas the method itself is applied in multi-axis environments.
- The standardised method has not been properly evaluated in multi-axis environments and compared to health effects. There should be specific laboratory studies to evaluate the method in multi-axis environments. In addition, multiplying factors and frequency weightings have not been validated separately or together.
- The first objective is to gain more information about the subjective effects of different directions in multi-axis environments. The second objective is to use the current method and validate the results. Then it is likely that improvements or a completely new method will be developed.
- Laboratory measurements with test subjects.

Germany

Effect of WBV in the horizontal directions on health, comfort and performance:

- The frequency weighting curves (ISO 2631-1) — curves of equal health effects and equal comfort — were developed on the basis of investigations with sinusoidal signals. They should be validated with sinusoidal signals (e.g. dependence of the shape of the curves on vibration magnitude) and verified for narrow band and broadband vibration signals.
- In ISO 2631-1:1997, the multiplying factors for *x*, *y* and *z* direction are 1.4, 1.4 and 1 respectively for the assessment of health effects, 1, 1, 1 for comfort — are these factors justified?
- Verification of frequency weightings and multiplying factors for sinusoidal signals and real power density spectra of mobile machines.
- Use of the FE model (BAuA) for verification concerning health.
- Consideration of posture, anthropometric data, age and gender of the subjects.

Italy

Identification of new exposure limits not only related to the acceleration rms values:

- To find a simplified model of energy absorption and damage mechanism in both WBV and HAV exposure.
- Laboratory studies with electromyography and absorbed power in order to determine the exact form of the transfer function.

([4]) Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 1: General requirements.

The Netherlands

Occupational health intervention studies:

- Evaluating the effects of intervention measures aimed at reduction or avoidance of exposure and exposure-related adverse effects, leading to evidence-based practice in vibration issues in the field of occupational health and safety.
- Randomised controlled trials or other robust (controlled) study designs to evaluate the effects of interventions supported and prepared by laboratory studies to test the efficacy of these interventions.

Spain

Optimisation of materials and proper adjustment guidelines in seats of machinery and vehicles:

- Study on construction materials and user–adjustment rules in order to avoid vibration amplification in seats.
- Laboratory testing, with different available seat models, of the attenuating effect in vibration transmission across various simulated working conditions.
- Verification of the results by means of trying out the seats on machines and vehicles, running in real working conditions and with diverse workers.

UK

Prioritisation of the 'worst' axis of vibration in WBV:

- Subjectively, vertical vibration and shocks are the most severe in many machines, yet most measurements of vibration show peaks in vibration in horizontal directions. Seats with vertical suspensions are practical in most high-exposure situations and well optimised. The project should use modelling techniques combined with field and laboratory data to identify whether the methods required according to PA(V)D and ISO 2631 are optimal.

9.2.5. WBV — Epidemiological studies

Austria

Medical investigations regarding WBV:

- Identification of a definite correlation between WBV and certain diseases.

Finland

Long-term WBV measurements and analyses with an epidemiological study:

- There is a need to link vibration exposure history to an epidemiological questionnaire and medical history. This can only be achieved if a group of people are continuously measured for the evaluation period and an epidemiological study is made.
- The goal of the research is to link medical problems with vibration exposure history. Normally, vibration exposure history is not available and only estimated, which has proved to be difficult.
- VTT [5] has developed a method and equipment to continuously measure and analyse WBV.
- Field study incorporated with epidemiological study.

[5] Technical research centre of Finland (http://www.vtt.fi/).

Germany

Assessment of the acute risk resulting from repeated shocks in WBV:

- Risk assessment of repeated shocks during typical operations, e.g. with mining locomotives, aircraft towing equipment, loading passenger cars or railway cars, and industrial trucks.

Influence of posture and WBV

- Quantitative assessment of the combination of the risks from posture and WBV.

Effect of different length of rest periods in long-term WBV exposures:

- Influence of different lengths of rest periods on health risk associated with long-term exposure.

WBV – relevance of age:

- Relevance of age of young people (< 25 years) and older people exposed to WBV (in young people, the bone structure is not developed completely; in older people the bone structure may work under limited pressure).

The Netherlands

Occupational health intervention studies:

- Evaluating the effectiveness of intervention measures aimed at reduction or avoidance of exposure and exposure-related adverse effects, leading to evidence-based practice in vibration issues in the field of occupational health and safety.
- Randomised controlled trials or other robust (controlled) study designs to evaluate the effectiveness of interventions supported and prepared by laboratory studies to test the efficacy of these interventions.

9.2.6. WBV — Modelling

Finland

Modelling the mechanisms causing vibration disease:

- To find out the possible effects of different vibration types on cells such as muscle, blood vessels and neuronal cells in order to fulfil the requirements of the vibration directive.
- Animal studies and verification with epidemiological studies.

France

Evaluation of risk to the spine, taking into account vibration, posture, BMI, etc.:

- To be able to improve working conditions for mobile machine drivers taking into account multi-factor characteristics.
- Use of the BAuA human model to look for the optimum position and vibration level to minimise spine internal force. Check that ergonomic redesign and cab anti-vibration system will minimise the internal forces on the spine.

Germany

Further development of BAuA's finite element (FE) model of the human body:

- Anatomical extension (muscles, more detailed model of the lumbar spine, material characteristics).

- Including results of *in vitro* investigations of functional spinal segments from bodies of different age (mechanical behaviour under dynamic loading).
- Adaptation to real conditions (posture, anthropometrics).

9.2.7. WBV — Development of methods for measurement and assessment

France

Development of methods for assessment of the uncertainty in field vibration measurements.

Greece

Measurement and assessment of WBV and HAV is a complex and difficult task, so it is important to have a standardised method to ensure consistent results are obtained by different laboratories.

Ireland

Investigate methods for ensuring reproducible measurements of both WBV and HAV.

Spain

Development of test procedures for evaluating vibration emission values in specific machines:

- Development of standard vibration measurement procedures that give comparable results between machines. The results could allow the vibration exposure to be assessed more accurately using values given in instruction manuals.
- Identification of types of machine with higher vibration emission levels that still do not have a standard measurement procedure.
- Field study of vibration levels produced by machines, analysing the influence of different typical working conditions on the levels of vibration.
- Development of standard test procedures, taking into consideration the influence of different working conditions.

9.2.8. WBV — Development of technical measures to avoid or reduce vibration exposure

Estonia

Development of methods and technical measures to avoid and reduce vibration exposure.

Finland

Continuous measurement and reduction of vibration:

- Development of a measurement device pertinent to continuous field measurement.
- Development of effective active attenuation systems for self-propelling vehicles or work machinery.
- Wireless data transfer, fast hydraulic valves.

France

Development of suspension systems, in particular for pallet truck (fork-lift truck) floors.

9.3. Research priorities — HAV

9.3.1. Focal point information

As in the case of WBV, many countries propose systematic measurements of vibration exposure for different sectors and machinery under various working conditions. The measurements should contribute to the identification of those workplaces which are likely to suffer the most detrimental health effects.

Additionally, many countries advocate development of standardised and reproducible measurement methods for several classes of machines and working conditions. In particular, the effectiveness of anti-vibration gloves should be determined using standardised methods.

Table 9.3: Categorised responses regarding HAV

Field studies	
Exposure measurements, database, identification of problem sectors, machines and conditions (including age of machines, effects of anti-vibration gloves)	Austria, Denmark, Germany, Slovenia
Comparison of measured and predicted A(8)	France
Testing of new measurement equipment (dosimeter)	France, Germany, Poland
Laboratory studies	
Anti-vibration gloves (effectiveness, eligibility criteria), effects of HAV reduction techniques	Germany, Netherlands
Cold water provocation test	Austria
Determination of evaluation values (aside from acceleration)	Italy, Poland
Epidemiological studies	
Association between HAV and health effects considering HAV-frequency, coupling forces, age, length of rest periods, repeated shocks, intervention studies	Germany, Netherlands
Modelling	
Modelling the effects of vibration on cells (muscle, blood, neuronal) by means of animal studies	Finland
Measurement methods	

Field studies	
Standardisation, reproducibility (classes of machines, working conditions, anti-vibration gloves), measuring uncertainty (incertitude)	Czech Republic, France, Greece, Ireland, Spain, UK
Measurement of coupling forces	France
Reduction techniques/measures	
Active attenuation, wireless data transfer, fast hydraulic valves	Finland
Development of low-vibration tools	France

9.3.2. KAN meeting

Table 9.4: HAV research priorities according to the specialists from 10 organisations in Euroshnet

Interest in research and current research projects	
Effect of breaks – ISO 5349 specifies that it is preferable to have breaks during vibration exposure. This needs to be validated.	Austria, Germany, Turkey, UK
Coupling forces – The higher the coupling between hand and tools, the more hazardous should be the exposure. We need more information on this topic.	France, Germany, Italy
Frequency dependence – There is significant doubt about the validity of the frequency weighting curve developed in the 1960s using a subjective method.	Germany, UK
Equipment (dosimeter) measurement – Vibration measurement equipment is too complex and expensive for many employers. Affordable dosimeters are needed.	Austria, France, Germany, Italy, Spain, Turkey, UK
Effectiveness of PPE – Are anti-vibration gloves effective?	Germany, Turkey, UK
Evaluation without measurement (database) – Database would help employers to assess vibration, as required by the directive. They do not have the necessary resources to carry out measurements.	Austria, France, Germany, Italy, Spain, UK
Strategy for prevention – Effectiveness of the advice that prevention organisations give to employers to reduce vibration.	Austria, France, Germany, Spain, Turkey, UK

9.3.3. HAV — Field studies

Austria

Evaluation of all those concerned industries not yet evaluated:

- Provide a general overview and identify the most relevant sectors.
- Provide a comprehensive list of work equipment giving significant figures of generated vibration.
- Measure vibration and exposure using tools under working conditions.

Denmark

HAV exposure profiles:

- Produce a profile of HAV exposure for heavily exposed occupations/sectors.
- Identify potential practical remedies to address these problems.

France

Survey of HAV to facilitate assessment by employers:

- Carry out many measurements under real conditions to compare measured A(8) with predicted values using values declared by manufacturers.
- Apply ISO 5349-1 and 2 and the CEN technical report on using values declared by manufacturers to predict vibration exposure.

Germany

- Evaluate the exposure to relevant HAV through the use of power saws.
- Measurement of the vibration intensity (acceleration) in wrist-elbow direction by using a power saw, including frequency analysis.
- Investigation of the association between operating a power saw and observed diseases.
- Influence of machine deterioration and of maintenance on HAV exposure.
- Influence of deterioration on the effectiveness of anti-vibration gloves and of damping materials.
- Lowering of HAV risks by anti-vibration gloves: identification of eligibility criteria.
- Frequency content of machines, HAV intensity, environmental conditions.
- HAV with single shocks: signal characteristics, measurement and assessment.
- Characterisation of typical HAV time histories with single shocks — groups of machines.
- Measurement procedures: identification of important variables and assessment of health risks.

Poland

Practical vibration dosimeter:

- Develop a simple dosimeter and procedure for initial assessment of exposure to vibration at the workplace for use at different workplaces and during different tasks.

Slovenia

Assessment and analysis of the situation regarding exposure to vibration at work:

- Collect data regarding exposure of workers to WBV and HAV.
- Assess and analyse the situation in enterprises to determine the exposure of workers to vibration, the use of work equipment that produces harmful vibration, and duration of exposure.
- Determine the sectors and work activities (workplaces) where the problems regarding vibration are most critical and prioritise measures required to reduce vibration exposure.
- Determine the means of executing the measures stipulated by Directive 2002/44/EC, where limit values are exceeded.
- From collected data, identify which sectors and work activities are the most critical, and perform sample measurements and compare them with action and limit values.
- Perform analysis of the execution of measurements (who performs them and how), the use of personal protective equipment (PPE) and other measures applied.
- On the basis of the results, workers' exposure should be analysed with a view to proposing measures to reduce exposure.

9.3.4. HAV — Laboratory studies

Austria

Determination of the significance of the cold water provocation test.

Germany

- Influence of deterioration on the effectiveness of anti-vibration gloves and of damping materials.
- Lowering of HAV risks by anti-vibration gloves — eligibility criteria.
- Frequency content of machines, HAV intensity, environmental conditions.

Italy

Identification of new exposure limits not only related to the acceleration rms values:

- Find a simplified model of energy absorption and damage mechanism in both WBV and HAV exposure.
- Laboratory studies with electromyography and absorbed power in order to determine the exact form of the transfer function.

Poland

Simultaneous human exposure to shock and vibration:

- Laboratory studies of absorbed power by human body during exposure to shock, repeated shocks and vibration.

The Netherlands

Occupational health intervention studies:

- Evaluating the effects of intervention measures aimed at the reduction or avoidance of exposure and exposure-related adverse effects, leading to evidence-based practice in vibration issues in the field of occupational health and safety.
- Randomised controlled trials or other robust (controlled) study designs to evaluate the effects of interventions supported and prepared by laboratory studies to test the efficacy of these interventions.

9.3.5. HAV — Epidemiological studies

Germany

Effects and assessment of combined HAV with lower and higher frequency content:

- Differentiation of hand-held and hand-guided machines in relation to their health risk according to vibration-induced bone and joint disorders on the one hand and vascular disorder on the other.
- This differentiation interferes with the extent of the costs for prevention.

Effects of HAV from hand-guided machines with high intensities of coupling forces and high emission values of the machines:

- High intensities of coupling forces result — especially for high emission values of the machines — in higher rates of energy input in the hand-arm system, yielding a greater health risk. Investigation of the quantitative relationship for different groups of machines.

Effect of different length of rest periods on long-term HAV exposure:

- Influence of different lengths rest periods on health risks in long-term HAV.

HAV — relevance of age:

- Relevance of age of young people (< 25 years) and older people exposed to HAV (in young people, the bone structure is not developed completely, in older people the bone structure is able to work under limited pressure).

HAV with single shocks — signal characteristics, measurement, assessment:

- Characterisation of typical HAV time histories with single shocks — groups of machines; measurement procedure, important variables, assessment of health risks.

The Netherlands

Occupational health intervention studies:

- Evaluating the effects of intervention measures aimed at the reduction or avoidance of exposure and exposure-related adverse effects, leading to evidence-based practice in vibration issues in the field of occupational health and safety.
- Randomised controlled trials or other robust (controlled) study designs to evaluate the effects of interventions supported and prepared by laboratory studies to test the efficacy of these interventions.

9.3.6. HAV — Modelling

Finland

Modelling the mechanisms causing vibration disease:

- Finding out the possible effects of different vibration types on cells such as muscle, blood vessels and neuronal cells in order to fulfil the requirements of the vibration directive.
- Animal studies and verification with epidemiological studies.

9.3.7. HAV — Development of methods for measurement and assessment

Czech Republic

Segmental hand-transmitted vibration:

- Generally, an advanced measuring method for finger vibration is needed. Investigation of whether vibration measurements performed in the palm location correspond to real finger exposure.
- The method should be in accordance with European standard series EN 5349.

France

- Development of methods for the assessment of uncertainty in field vibration measurements.
- Measurement of coupling forces between tools and hand.
- Combining HAV with coupling forces to improve prediction of risk.
- Use of the Novel pressure mats.

Greece

Measurement and assessment of WBV and HAV is a complex and difficult task, so it is important to have a standardised method to ensure consistent results are obtained by different laboratories.

Ireland

Investigate methods for ensuring reproducible measurements of both WBV and HAV.

Spain

Development of test procedures for evaluating vibration emission values in specific machines:

- Developing standard vibration measurement procedures that give comparable results between machines. The results could allow the vibration exposure to be evaluated more accurately using values given in instruction manuals.
- Identification of types of machine with higher vibration emission levels that still do not have a standard measurement procedure.
- Field study of vibration levels produced by machines, analysing the influence of different typical working conditions on the levels of vibration.
- Development of standard test procedures, taking into consideration the influence of different working conditions.
- Assessment of effectiveness of protective gloves in workers' hand-arm system health:
- Development and validation of standard method for measuring glove response at low frequencies.
- Optimisation of materials in the manufacture of anti-vibration gloves, and improvement of attenuation patterns at the most harmful frequencies for workers' health.
- Development and validation of a proper procedure that allows evaluation of the effectiveness of anti-vibration gloves in the prevention of hand-arm damage.
- Using the check and search procedure, for a better attenuated response at low-frequency range in available commercial models of gloves.

UK

Development of test procedures for evaluating vibration emission values in specific machines:

- Developing standard vibration measurement procedures that give comparable results between machines. The results could allow the vibration exposure to be evaluated more accurately with the instruction manual values.
- Identification of types of machine with higher vibration emission levels that still do not have a standard measurement procedure.
- Field study of vibration levels produced on machines, analysing the influence of different typical working conditions of the machine at the vibration levels.
- Development of standard test procedures, taking into consideration the influence of different working conditions.

9.3.8. HAV — Development of technical measures to avoid or reduce vibration exposure

Estonia

Development of methods and technical measures to avoid and reduce vibration exposure.

Finland

Continuous measurement and reduction of vibration:

- Development of measurement devices pertinent to continuous field measurement.
- Development of effective active attenuation systems for self-propelling vehicles or work machinery.
- Wireless data transfer, fast hydraulic valves.

France

Development of new, low-vibration tools (e.g. small rammer) so as to comply with the directive limit value.

10.

GENERAL CONCLUSIONS

Is vibration an increasingly important hazard?

Clearly not, if we look at the risk in isolation focusing only on the number of people exposed to high levels of vibration. As early as the 18th century, Ramazini described adverse effects (back pain) of whole-body vibration (WBV) resulting from the development of high-speed horse-drawn coaches. Since Ramazini's time, the number of people exposed to hand-arm vibration (HAV) or WBV increased considerably with the advent of widespread mechanisation and by the beginning of the 20th century vibration syndrome (Raynaud's vascular disease) was first described. Exposure to vibration is always closely associated with the effort needed to operate tools or the poor posture imposed by tasks, especially when driving mobile machines. However, epidemiological and physiological research has not allowed definitive conclusions to be drawn on the respective contribution of each of these specific hazards to the genesis of what is called vibration syndrome. In general, modern machines emit less vibration, are lighter and generally better designed ergonomically. Therefore, it is likely that the number of people exposed to severe vibration is decreasing overall, as is the number of workers who have to exert high levels of physical effort to operate tools and machines.

Certainly yes, if we consider the total number of people exposed. According to the latest figures ([1]), one in four European workers report exposure to vibration at least a quarter of the time. Based on national data, the authors estimate that between 5 % and 25 % of workers are exposed to WBV and 5 % to 11 % are exposed to HAV. More people are being affected because of the systematic mechanisation of manual tasks and the increasing use of road transport in construction, agriculture, industry and services. An additional factor to consider is that the population in Europe is ageing and older workers are more likely to complain of vibration exposure and to suffer from musculoskeletal or neurovascular problems. Although men still account for the great majority of vibrating machine users, the percentage of women users is clearly increasing as the physical effort demanded by many machines decreases. Very little is known about the health consequences of exposure to vibration while pregnant, but common sense demands the highest levels of precaution.

Certainly yes, if we consider legal requirements. The vibration directive (2002/44/EC) ([2]) has boosted the demand for information from employers who have, up to now, generally neglected vibration hazards. In many cases, actual vibration levels are likely to be above the action values established in the directive, which came into force across the EU on 6 July 2005. Therefore, a large number of employers are obliged to develop a control strategy. For many, the first step is to replace equipment with a low-vibration alternative, which in turn focuses the attention of manufacturers on developing low-vibration products. For their part, manufacturers need the help of vibration consultants to improve their machines. All of these parties require new measuring instruments, tools and standards so as to be able to better assess vibration at the workplace, or evaluate the performance of a device to cut vibration emissions. In parallel, more research into vibration is being carried out and developments in technology have opened up new areas of research, e.g. dynamic modelling of human or machine response to vibration excitation.

In summary, if it cannot be said that vibration is an increasing hazard, it is definitely an increasing priority for decision-makers and is an emerging issue for business, with the

([1]) Fourth European working conditions survey (EWCS) 2005 (www.eurofound.europa.eu).

([2]) 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).

hope that this will result in a significant improvement in machine operators' conditions of work.

Who is at risk?

According to the fourth European working conditions survey (EWCS), 63 % of workers who reported exposure to vibration at least a quarter of the time were employed in the construction sector; 44 % in manufacture and mining; 38 % in agriculture and fishing; 34 % in electricity, gas and water supply; and 23 % in transport and communication. Exposed workers are predominantly men, with 36 % exposed to vibration at least a quarter of the time as opposed to 10 % of women.

WBV exposure is experienced by operators of most off-road machines, and agricultural and forestry tractors when travel is frequent. The same applies to fork-lift trucks if the duration of running is longer than three to four hours, and trucks and lorries if they are driven all day long. However, the limit value is seldom attained, except in the case of scrapers and some conventional finishers.

The action level for HAV is exceeded by operators of most main percussive and roto-percussive tools (such as chipping hammer, demolition hammer, rock drill, breaker, impact drill, scabbler, rammer, or vibratory rammer), of main rotative tools (e.g. grinder, impact wrench, sander) and of main alternative tools (jig saw, file). If percussive and roto-percussive tools are used for more than one or two hours a day, the limit value may be exceeded.

Who is carrying out vibration measurements?

The vibration directive requires vibration assessment on the part of employers; critics claim this is impossible due to the high cost of measurements and the small number of laboratories able to make them. In fact, the directive does not explicitly ask employers to **measure** vibration, but rather to **assess** it, and this does not necessarily require measurement.

Nevertheless, direct measurements are often a necessity and it is of interest to know how countries will meet the challenge of ensuring that there are sufficient resources available to undertake the task. Whereas some governments have decided to assist companies directly, by equipping a large number of health and safety organisations with vibrometers, others have taken the view that the market will meet the challenge. In this latter case, companies must either establish the capacity to carry out vibration measurement themselves or outsource the service.

The development of sufficient resources for the measurement of vibration, whether in the form of qualified technicians or specialist organisations, represents a real challenge. Metrology technicians are generally experienced in noise rather than vibration and whereas WBV measurements are relatively straightforward, this is certainly not the case for HAV. Vibration measurement in the use of percussive tools is particularly susceptible to large errors.

In the authors' opinion, many companies are likely to take the view that they are not able to assess exposure to vibration, which in practice means that many of them will not respect the directive's provisions. This highlights the importance of providing enterprises with appropriate support, both in the form of guidelines, such as those developed at European level to facilitate vibration assessment by employers, and in the form of measurement equipment that is cheaper and simpler to use.

Can we reduce vibration successfully?

Besides the elimination of vibration at its source, the development of vibration-reduced machines and devices has successfully reduced workers' exposure to WBV as well as to HAV in recent decades. Nevertheless, the market share of certain machines and devices needs to increase further. In addition to technical solutions, organisational means such as work automation, job rotation, temporarily limited exposure and systematic medical check-ups must be implemented more widely in order to further improve the working conditions of workers exposed to vibration.

A lack of awareness regarding vibration-reduced machines and devices and their generally higher cost are the principal reasons for the relatively low levels of adoption for such technical solutions. Indeed, the level of knowledge is such that vibration-reduced machines and devices are sometimes thought of as luxury options rather than as an important part of a risk-reduction strategy. Most of the time, however, poor take-up of technical solutions results from the lack of awareness and knowledge, which is due in large part to the scarcity of information about vibration risks. Operating instructions, for example, only very rarely include sufficient information of this type. There is therefore an urgent and important need for more information on occupational safety and health to be passed on to workers in the form of good practice guides, awareness-raising campaigns and practical training. Particularly in small and medium enterprises (SMEs), the lack of know-how, training and measuring equipment can be seen as a major obstacle to the adoption of effective vibration control measures. Moreover, the authors consider that many companies tend to give excessive priority to those risks which may lead to severe accidents, thereby paying less attention than they should to occupational health issues.

Nevertheless, the authors emphasise the long-term contribution of Directive 2002/44/EC to driving the development as well as the wider use of vibration-reduced machines and devices.

How to assist employers to follow the directive's provisions

Across Europe there is a broad variety of approaches to assisting employers to meet the requirements of the Directive. The assessment of risks without measurement, which does not require the use of specific apparatus and an appropriate methodology, is an innovative approach that must be developed further using, for example, interactive website resources.

Most software tools are based on exposure to vibration, which is calculated using two main factors: equivalent vibration value and exposure time. Several similar types of computer tool exist to evaluate the risk from vibration and it is a well-developed field. Nonetheless, there is still a clear need for low-cost and easy-to-use dosimeters for both HAV and WBV.

It is important for countries to keep activities on vibration up to date and this will need the elaboration of clear national strategies, policies, action plans and campaigns, as well as sharing of information between Member States.

The dissemination of information about technological trends in vibration control is an important action to be considered as assistance to employers in selecting low-vibration equipment. This can take the form of, for example, websites where the latest innovations to control exposure to vibration and their effectiveness can be checked.

What kind of research is needed?

In many countries there seem to be insufficient data concerning levels of vibration exposure in different sectors and types of machinery, under various working conditions, and considering maintenance and the age of machinery. Measurements through field studies are required that will contribute to the identification of those sectors, machines and conditions that are associated with the most detrimental effects.

Additionally, the evaluation methods concerning health risks, comfort and performance due to WBV, described in ISO 2631-1 and -5 (frequency weighting, multiplying factors) and used in the application of the EU directive, are currently under critical discussion. A greater research effort is needed to clarify this important prerequisite for an adequate risk assessment, such that body posture, anthropometrics, age and gender are taken account of adequately.

Concerning HAV, some countries advocate the development of standardised and reproducible measurement methods for several classes of machines and working conditions. In particular, the effectiveness of anti-vibration gloves should be determined, along with development of standardised methods. More research is needed to check the validity of the frequency weighting network and to take into account co-factors such as the coupling between hand and tool.

Joint projects between EU Member States should be encouraged to combine scientific resources in this field.

11.

REFERENCES

11.1. EU directives and standards

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, OJ L 207, 23.7.1998.

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), OJ L 177, 6.7.2002.

Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on the approximation of the laws of the Member States relating to machinery, OJ L 157, 9.6.2006.

European Committee for Standardisation (1995). Hand-arm vibration — Guidelines for vibration hazards reduction — Part 1: Engineering methods by design of machinery. CEN/CR 1030-1:1995.

European Committee for Standardisation (1995). Hand-arm vibration — Guidelines for vibration hazards reduction — Part 2: Management measures at the workplace. CEN/CR 1030-2:1995.

European Committee for Standardisation (2001). Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 1: General requirements. EN ISO 5349-1:2001.

European Committee for Standardisation (2001). Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 2: Practical guidance for measurement at the workplace. EN ISO 5349-2:2001.

European Committee for Standardisation (2003). Mechanical vibration — Measurement and calculation of occupational exposure to whole-body vibration with reference to health — Practical guidance. EN 14253:2003.

European Committee for Standardisation (2005). Mechanical vibration — Guideline for the assessment of exposure to hand-transmitted vibration using available information including that provided by manufacturers of machinery. CEN/TR 15350:2005.

European Committee for Standardisation (2005). Whole-body vibration — Guidelines for vibration hazards reduction — Part 1: Engineering methods by design of machinery. CEN/TR 15172-1:2005.

European Committee for Standardisation (2005). Whole-body vibration — Guidelines for vibration hazards reduction — Part 2: Management measures at the workplace. CEN/TR 15172-2:2005.

European Committee for Standardisation (2006). 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. CEN/TR 25398 (October 2006).

International Organisation for Standardisation (1992). Mechanical vibration — Laboratory method for evaluating vehicle seat vibration — Part 1: Basic requirements. EN ISO 10326-1:1992.

International Organisation for Standardisation (1996). Mechanical vibration and shock — Hand-arm vibration — Method for the measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand. ISO 10819:1996.

International Organisation for Standardisation (1997). Guide to the evaluation of human exposure to whole-body mechanical vibration and shock. ISO 2631-1:1997.

International Organisation for Standardisation (2001). Mechanical vibration — Vibrotactile perception thresholds for the assessment of nerve dysfunction — ISO 13091:2001 (parts l and 2).

International Organisation for Standardisation (2005). Mechanical vibration — Cold provocation tests for the assessment of peripheral vascular functions. ISO 14835:2005 (parts l and 2).

International Organisation for Standardisation (2007). Mechanical vibration — Definition and guidelines for the measurement of the coupling forces for operators exposed to hand-arm-vibration. ISO 15230:2007.

Guidance and publications 11.2.

BIA (1998a). 230301 Technischer Vibrationsschutz bei Ganzkörper-Schwingungseinwirkungen. BIA-Handbuch 31. Lfg. I/98.

BIA (1998b). 230302 Technischer Vibrationsschutz bei Hand-Arm-Schwingungseinwirkung. BIA-Handbuch 33. Lfg. XII/98.

BGIA's work No 0241 2005 'Whole-body vibration exposure during fork-lift truck travel over ramps'.

BGIA's work No 0120 2003 'Ganzkörper-Schwingungseinwirkungen eines Niederhubwagens' (Whole-body vibration on a pallet-truck).

Bitsch, J. and Poirot, R. 'Something new regarding ramming: anti-vibration rammers'. *Hommes et Fonderies*, March 1998 in French.

Bitsch, J. 'Anti–vibration lime at ARC International. The Cristal d'Arques factory chases vibration'. *Travail et Sécurité*, February 2001.

Bitsch, J. 'The assembling of an electric motor with a pneumatic tool'. *Travail et Sécurité*, March 2001.

Bongers, P. and Boshuizen, H. 'Back disorders and whole-body vibration at work'. Thesis, University of Amsterdam, Amsterdam, 1990, ISBN 90-9003668-7.

Bovenzi, M. 'Medical aspects of the hand-arm vibration syndrome'. *International Journal of Industrial Ergonomics*, 6, 1990, pp. 61–73.

Bovenzi, M. (UTRS) and Hulshof, C. T. J. (AMC) 'Common procedures that can be applied by occupational health workers across Europe for minimising risk, screening exposed individuals and management of individuals with symptoms of mechanical vibration injuries' http://www.vibrisks.soton.ac.uk/reports/Annex21 %20UTRS_AMC %20 WP1_3_ %204_3 %20070307.pdf Vibrisks Final technical report http://www.vibrisks.soton.ac.uk/reports/VIBRISKS %20Final %20Technical %20 Report %20080307.pdf, February 2007.

Boulanger, P. 'Antivibration floor for road finishers'. *Travail et Sécurité,* January 1998.

Burdorf, A. and Swuste, P. 'The effects of seat suspension on exposure to whole-body vibrations', *The Annals of Occupational Hygiene*, 1993, 1, pp. 45–55.

Centres de Mesure Physique (CMP) and Institut National de Recherche et de Sécurité (INRS). 'Guide to evaluate vibration at work. Part 1: Whole-body vibration transmitted by mobile machines'. Edited by INRS, 1998 (in French).

Centres de Mesure Physique (CMP) and Institut National de Recherche et de Sécurité (INRS). 'Guide to evaluate vibration at work. Part 2: Hand arm vibration'. Edited by INRS, 2000 (in French).

Centres de Mesure Physique (CMP) and Institut National de Recherche et de Sécurité (INRS). 'Guide to evaluate vibration at work. Part 3: Whole-body vibration transmitted by fixed machinery'. Edited by INRS, 2004 (in French).

Cheyns, P., Geenens, L., Jansen, P., Peeters, D. and Staessens, G. 'Het KB Mechanische trillingen: actuele implementatieproblematiek, projectwerk', 2005–06.

Christ, E. et al. *Vibration at work*. (ISSA brochure). Published by the International Section Research of ISSA, Institut National de Recherche et de Sécurité (INRS), 30, rue Olivier-Noyer, F-75680 Paris Cedex 14, 1989.

Donati, P. 'Survey of technical preventative measures to reduce whole-body vibration effects when designing mobile machinery'. *Journal of Sound and Vibration*, 253(1), 2002, pp. 169–183.

Donati, P. and Bitsch, J. 'Prévention des vibrations engendrées par les machines portatives'. Communication présentée au XXIIième Journées Nationales de Médicine du Travail B.T.P. La Main Pathologique, Marseille, 8–11 May 1991.

Dupuis, H. and Zerlett, G. *The effects of whole-body vibration*. Springer-Verlag, Berlin, Heidelberg, New York, Tokyo, 1986, ISBN 0-387-16584-3.

European Commission (2006). '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)'.

European Commission (2006). 'Guide to good practice on 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)'.

Galmiche, J. P. and Tisserand, X. 'When the seat has a good back'. *Travail et Sécurité*, June 2006.

Griffin, M. J. *Handbook of human vibration*. Academic Press, London, 1990, ISBN 0-12-303040-4.

Griffin, M. 'Recommendations for diagnosis of the vibration netWork (VINET)', European Community project conducted by University of Southampton. The final report was published in 2000/01, and includes Annex X5B 'International Workshop – Diagnosis of injuries caused by hand-transmitted vibration', September 2000. This English text can be downloaded at http://www.humanvibration.com/EU/VINET/pdf_files/Appendix_X5B.pdf

Health and Safety Executive (HSE) (1997). 'Vibration solutions. Practical ways to reduce the risk of hand-arm vibration injury'.

Health and Safety Executive (HSE) (2005). 'Advice for employers on the control of vibration at work, regulations 2005'. INDG242(rev1).

Hulshof, C. T. J. and Veldhuijzen van Zanten, O. B. A. 'Whole-body vibration and low-back pain — A review of epidemiological studies'. *International Archives of Occupational and Environmental Health*, 59, 1987, pp. 205–220.

INRS (1991). 'Smooth impact. Use an anti-vibration concrete breaker'. Edition INRS, ED 1346. (In French).

INRS (1992). 'Driving smoothly. How to adjust your suspension seat. Lift truck and seat manufacturers'. Edition INRS, ED1372 (in French).

INRS (1993). 'Driving smoothly. Choosing and maintaining suspension seats for fork-lift trucks'. Edition INRS, ED1373 (in French).

INRS (1994). 'Driving without shocks. Film for the training of fork —lift truck drivers'. Editions INRS VS0275 (in French).

INRS (1998). 'Driving smoothly. A suspension seat to ease your back. Farmers'. Edition INRS, ED 1493 (in English and French).

INRS (1998). 'Driving smoothly. Help your customers to stay fit. Distributors of farm machinery seat'. Edition INRS, ED 1494 (in English and French).

INRS (1998). 'Driving smoothly. Selection and replacement of tractor and farm machinery seats. Farm inspectors'. Edition INRS, ED 1492 (in English and French).

INRS (2001). 'The spine in danger'. Edition INRS, ED 864 (in English and French).

INRS (2001). 'The hand in danger'. Edition INRS, ED 863 (in French and English).

Kaulbars, U. 'Geprüfte Antivibrations-Handschuhe. Einheitliche Schutzanforderungen im europäischen Binnenmarkt. Schwingungstagung '97, Schwingungen am Arbeitsplatz und in der Umwelt'. VDI-Berichte 1345, VDI-Verlag GmbH, Düsseldorf (1997).

Kaulbars, U. 'Antivibrations-Handschuhe – Positivliste'. BGIA – Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung. BGIA-Handbuch. Sicherheit und Gesundheit am Arbeitsplatz. 2. Auflage. Sicherheitstechnisches Informations und Arbeitsblatt. Kennzahl 450110. ISBN: 978-3-503-07417-4. 2007.

Lasfargues, G. 'Effets vasculaires et neurologiques des vibrations transmises au système main-bras'. *Etudes et enquêtes*. TF 21. INRS, 1990, 10 p. PDF.

Lenaerts, L. 'Evaluatie van de blootstelling aan lichaamstrillingen bij heftruckchauffeurs in functie van de Europese richtlijn 2002/44/EG', eindwerk, 2002–03.

Luts, J. Fonds des maladies professionnelles. 'Mesurer et interpréter les vibrations mécaniques, *PreventActua*', No 17, 2006.

Malchaire, J. and Piette, A. (2001). 'Stratégie de prévention des risques dus à l'utilisation de machines vibrantes'. Recueil des résumés du 9ème congrès international sur les vibrations mains-bras, Nancy, France, 5 to 8 June. Malchaire, J., Piette, A. and Cock, N. 'Associations between hand-arm musculoskeletal and sensorineural complaints and biomechanical and vibration work constraints'. *The Annals of Occupational Hygiene*, 45, 6, 2001, pp. 479–491.

Ministère fédéral de l'Emploi et du Travail (Belgique). 'Vibrations corps total. Stratègie d'évaluation et de prévention des risques'. D/1998/1205/72 (in French).

Ministère fédéral de l'Emploi et du Travail (Belgique). Vibrations main bras. Stratègie d'évaluation et de prévention des risques. D/1998/1205/70 (in French).

Ministère français de l'emploi, de la cohésion sociale et du logement et le ministre de l'agriculture et de la pêche du travail et de la cohésion sociale. 'Projet d'arrêté déterminant les catégories d'équipements de travail susceptibles de ne pas permettre de respecter les valeurs limites d'exposition fixées au i de l'article r. 231-119 du code du travail'. (In preparation 2007).

Morilla, E. G., Santurio, J. M., Carballido, J. R. and Argüelles, E. 'Proyecto de estudio de vibraciones mano-brazo en máquinas manuales' (Primera parte). Asturias Prevencion; D.L. As/3908-2001; No 8, June 2006; pp. 16–20. (This article is available on the IAPRL website through the menu: 'Instituto de Prevencion —> Area de formación y Acreditaciones' and then clicking on 'revista').

Paoli, P. and Merllié, D. 'Third European survey on working conditions'. European Foundation for the Improvement of Living and Working Conditions. Dublin, 2001.

Pelmear, P. L., Taylor, W. and Wasserman, D. E. (eds). 'Hand-arm vibration — A comprehensive guide for occupational health professionals'. Van Nostrand Reinhold, New York, 1992, ISBN 0-442-01250-0.

Piette, A., Malchaire, J., Huberlant, J. M. (1999). 'Guide de formation au travail de meulage'. Ministère fédéral de l'Emploi et du Travail, p. 32.

Piette, A., Cock, N. and Malchaire, J. (1999). 'Pathologies du membre supérieur liés et non liés à l'utilisation de machines vibrantes'. *Médecine du Travail et Ergonomie*, XXXVI, 1, pp. 11–24.

'Protection against vibration: a problem or not?' Leaflet of the Federal Institute for Occupational Safety and Health (BAuA).

Saint Eve, P. and Donati, P. 'Prevention of spine disorders at the driving place of fork-lift trucks'. Document pour le médecin du travail No 54, 2nd term 1993 (In French).

Seidel, H. 'Selected health risk caused by long-term whole-body vibration'. *American Journal of Industrial Medicine*, 23, 1993, pp. 589–604.

Seidel, H., Hinz, B., Blüthner, R., Menzel, G., Hofmann, J., Gericke, L., Schust, M., Kaiser, H. and Mischke, C. (BAuA). 'Prediction of spinal stress in drivers from field measurements' http://www.vibrisks.soton.ac.uk/reports/Annex19 %20FIOSH %20WP6_2 %20300107.pdf

Vibrisks 'Risks of occupational vibration exposures, final technical report', February 2007, (http:www.vibrisks.soton.ac.uk/reports/VIBRISKS %20Final %20Technical %20 Report %20080307.pdf)

Stockholm Workshop 86, 'Symptomatology and diagnostic methods in the hand-arm vibration syndrome'. *Scandinavian Journal of Work, Environment and Health*, 4, 1987, pp. 271–388.

Swuste, P., Burdorf, A. and van Drimmelen, D. 'De invloed van afgeveerde bestuurdersstoelen op de trillingsbelasting, Arbowetenschap', 1992, 2, pp. 22–28.

Vibtool project. Progress report, year 2, reporting period from 1.12.2003 to 30.11.2004, 72 pp. This work (pressure mapping) has been financed by the European Commission, within the research contract VIB-TOOL (Contract No G6RD-CT-2002-00843), coordinated by Univ. Politecnica delle Marche and having as partners the National Research Council of Italy-CNR, INRS, Novel GmbH, the University of Southampton, Berufsgenossenschaftliches Institut für Arbeitsschutz and Breakers AS.

Wilder, D., Magnusson, M. and Fenwick, J. 'The effect of posture and seat suspension design on discomfort and back muscle fatigue during simulated truck driving', *Applied Ergonomics*, 25(2), 1994, pp. 66–76.

Websites 11.3.

General

www.humanvibration.com (General information, including links to various human vibration websites).

http://eur-lex.europa.eu/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=en&numdoc=32002L0044&model=guichett Directive 2002/44/EC

http://www.vibrisks.soton.ac.uk/reports/VIBRISKS %20Final %20Technical %20 Report %20080307.pdf, Final Technical Report, February 2007

Vibration emission data base

http://www.vibration.db.umu.se/
http://www.las-bb.de/karla/, http://www.hvbg.de/d/bia/pub/ada/index.html

Exposure calculator: WBV — values

http://www.hse.gov.uk/vibration/wbv/wholebodycalc.htm
http://www.vibration.db.umu.se/
http://www.bgmetallsued.de/fachausschuss/wbv_rechner_de.xls

Exposure calculator: HAV — values

http://www.hse.gov.uk/vibration/hav/vibrationcalc.htm
http://www.vibration.db.umu.se/

Reduction of vibration

http://www.humanvibration.com/EU/VIBGUIDE.htm (Guides to good practice).
http://www.emploi.belgique.be/WorkArea/showcontent.aspx?id=3862 WBV (SOBANE strategy), SPF Emploi, Travail et Concertation du Travail, 2005, fiche 9, pp. 65-66
http://www.hvbg.de/d/bia/pub/ada/index.html

www.hse.gov.uk/pubns/indg242.pdf
http://www.hse.gov.uk/vibration/hav/campaign/index.htm
http://www.iop.org/EJ/abstract/0957-0233/15/9/010 and at http://akseli.tekes.fi/opencms/opencms/OhjelmaPortaali/ohjelmat/MASINA/en/etusivu.html
http://www.arbouw.nl/werkgever/risicos/trillingen/

The diagnostic tools and health surveillance procedures

Common procedures that can be applied by occupational health workers across Europe for minimising risk, screening exposed individuals and management of individuals with symptoms of mechanical vibration injuries http://www.vibrisks.soton.ac.uk/reports/Annex21 %20UTRS_AMC %20WP1_3_ %204_3 %20070307.pdf (VIBRISKS Final technical report http://www.vibrisks.soton.ac.uk/reports/VIBRISKS %20Final %20Technical %20Report %20080307.pdf)

Combined effect

WBV and posture: Prediction of spinal stress in drivers from field measurements http://www.vibrisks.soton.ac.uk/reports/Annex19 %20FIOSH %20WP6_2 %20300107.pdf (VIBRISKS Final Technical Report http://www.vibrisks.soton.ac.uk/reports/VIBRISKS %20Final %20Technical %20Report %20080307.pdf)

HAV and force measurement:

Germany: http://www.baua.de/en/Research/Research.html?__nnn=true
http://www.baua.de/en/Practical-experience/Practical-solutions/ISOMAG/ISOMAG.html__nnn=true
HSE: http://www.hse.gov.uk/research
Greek research project (in Greek) — HAV field study http://www.elinyae.gr
Lithuanian research project (in Lithuanian) — HAV field study: http://www.socmin.lt/index.php?1514675562
Spanish research project (published in 2007) — HAV field study: www.cfnavarra.es/insl & www.iaprl.es

European Agency for Safety and Health at Work

EUROPEAN RISK OBSERVATORY REPORT

ANNEXES

Annex I — Guidance and practices for control measures

Measure	1.1.2. Selecting mobile machinery for construction sites (cabins)
Description	Working with mobile machinery on construction sites can cause various complaints, injuries and diseases. Selecting the right cabin to avoid these problems is important. These factsheets provide guidance in selecting the right cabin in general, and for some specific machines such as excavators.
Reference	Cabines van mobiele machines in de bouwnijverheid. Arbouw http://www.arbouw.nl/pdf/a-bladen/a-blad-cabines-bulldozers.pdf

Measure	1.2. Technical vibration protection
Description	KAMIN: Catalogue of proven practical measures for technical vibration protection and for elements for vibration reduction. Examples include HAV and WBV reduction.
Reference	Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (BAuA), Research Report Fb 981 http://www.baua.de/nn_34490/en/Publications/Research-reports/2003/Fb981.html__nnn=true

Measure	1.2.1 Isomag — Computer-aided vibration isolation of machines and devices
Description	Isomag 1.2 is a user-friendly, self-explanatory program for the calculation and design of vibration isolation, based on a rigid-body model. It permits calculation of the double vibration isolation and the dynamic characteristics of the environment. A graphic-user interface is used for program operation, model description, and data input and output. The user is assisted by implemented wizards.
Reference	Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (BAuA), Research Report Fb 944 Uhlig, A. Schreiber, U. Blochwitz, T. http://www.baua.de/en/Practical-experience/Practical-solutions/ISOMAG/ISOMAG.html__nnn=true

Measure	1.2.1.1. Fork-lift trucks: selection and maintenance of suspended seats and driver training
Description	The use of an appropriate suspended seat that is adapted both to the vehicle and to the driver can halve the vibration exposure. Selection of the seat must take account of both the ergonomic and dynamic properties of the trucks. A technician must maintain and change the seats regularly and drivers must be trained to adjust the seats correctly.
Reference	Saint Eve, P., Donati, P. 'Prevention of spine disorders at the driving place of fork lift trucks'. *Document pour le médecin du travail* No 54, 2nd term 1993 (in French). INRS (1992). 'Driving smoothly. How to adjust your suspension seat. Lift truck and seat manufacturers'. Edition INRS, ED1372 (in French). INRS (1993). 'Driving smoothly. Choosing and maintaining suspension seats for fork-lift trucks'. Edition INRS, ED1373 (in French).

Measure	1.2.1.1. Off-road machines and fork-lift trucks: selection of an appropriate suspended seat (adapted to vehicle and driver)
Description	The use of an appropriate suspended seat that is adapted both to the vehicle and to the driver can reduce the exposure to vibration. Selection of the seat must take into account both ergonomic criteria and criteria for the suspension. INRS bought a number of suspension seats for loan to companies. If there is a need to change seats in a factory, the CRAM will let the factory use INRS seats (after checking that they are correct for the vibration) for a couple of months to compare them, so as to provide a choice which satisfies the users.
References	Galmiche, J. P. and Tisserand, X. 'When the seat has a good back'. *Travail et Sécurité*, June 2006. Driving without shocks. Film for the training of fork-lift truck drivers. INRS VS0275 (in French).

Measure	1.2.1.1. Using appropriate suspended seats (adapted to vehicle and driver)
Description	The use of an appropriate suspended seat that is adapted both to the vehicle and to the driver can reduce the exposure to vibration. Selection of the seat must take into account both ergonomic criteria and criteria for the suspension (e.g. frequencies).
References	An information card providing guidance for selecting an appropriate suspended seat. 'Globale lichaamstrillingen, Sobane strategie', FOD voor Werkgelegenheid, Arbeid en Sociaal overleg, 2005, fiche 9, pp. 65–66. http://www.werk.belgie.be/publicationDefault.aspx?id=3704 'Vibrations de l'ensemble du corps Stratégie Sobane', SPF Emploi, Travail et Concertation du Travail, 2005, fiche 9, pp. 65–66 http://www.emploi.belgique.be/publicationDefault.aspx?id=3704

Measure	1.2.1.3. Pallet trucks with on-board standing drivers
Description	When running over obstacles, pallet trucks transmit severe peaks of vibration to drivers, which may exceed the directive action levels. A solution is to equip these vehicles with an anti-vibration floor. Vibration was measured on different models and results show a reduction of 50 % on some recent models.
Reference	Galmiche, J. P. 'Measurements of vibration exposure at the driving place of pallet trucks''. INRS internal report 2006.

Measure	1.2.1.3. Reduce vibration transmitted to operators standing at rear of finishers
Description	Fresh tarmac must be vibrated to be levelled on the road. An operator generally stands on a platform at the back of the finisher to adjust the thickness of tarmac. He stands directly on the vibrators and is exposed to a vibration magnitude which may be above the directive limit value. A suspension floor, developed by INRS, was installed in a number of finishers in Brittany and vibration exposure was reduced to a quarter.
Reference	Boulanger, P. 'Anti–vibration floor for road finishers'. *Travail et Sécurité,* January 1998

Measure	**2.1. Avoiding HAV**
Description	The Health and Safety Executive (UK) offers practical guidance online for methods to avoid WBV in three specific sectors: foundries, heavy steel fabrication and construction. For each industry, information is given on alternative processes to avoid/reduce the use of vibrating equipment. In HSE's experience, these are reasonably practicable in many circumstances. There are also links to further information and case studies.
Reference	Web pages with practical information and links. Health and Safety Executive (HSE) http://www.hse.gov.uk/vibration/hav/campaign/index.htm

Measure	**2.2. Solutions to reduce the risk of HAV injury**
Description	This book, aimed at managers, shows that vibration problems can be solved in many ways. It offers real examples of how some companies have reduced vibration at work. Forty-five case studies are presented. For each example, the problem, the solution and the results are discussed.
Reference	'Vibration solutions. Practical ways to reduce the risk of HAV injury', HSE, 1997. ISBN 0717609545 Health and Safety Executive (HSE) http://www.hsebooks.com/Books/product/product.asp?catalog %5Fname =HSEBooks&category %5Fname=&product %5Fid=2020

Measure	**2.1.2. Selection of low vibrating grinders for a foundry**
Description	In this foundry, six people use grinders for four hours a day to smooth welding imperfections. They were exposed to vibration above the action level as defined by the vibration directive. With the assistance of INRS, tests were done with different grinders equipped with an automatic balancer system and a suspended handle. The machine selected not only fits the task but also necessitates less effort, which economises the grinding wheels.
Reference	Bitsch, J. 'Kuhn is equipped with low vibration grinders'. *Travail et Sécurité*, January 2005 http://www.travail-et-securite.fr/archivests/archivests.nsf/(allDocParRef)/TS647page2_1/$File/TS647page2.pdf

Measure	**2.2.1.1. Rammers: reduction of vibration**
Description	Rammers expose users to very high levels of vibration. A suspension system was developed by INRS with the assistance of a German manufacturer. The solution takes into account the vibration characteristics, the task and the ergonomics of the tool. It was adapted to several sizes of rammers. The product is on sale and promoted by INRS.
Reference	Bitsch, J. and Poirot, R. 'Something new regarding ramming: anti-vibration rammers' (in French). *Hommes et Fonderies*, March 1998

Measure	2.2.1.1. Selecting an appropriate suspension system
Description	Various suspension systems exist in order to reduce exposure to HAV from tools. When selecting the appropriate system, it is important to consider elements such as weight, frequency and work environment.
References	Information card providing guidance for selecting appropriate suspension. 'Hand-arm trillingen, Sobane strategie', FOD voor Werkgelegenheid, Arbeid en Sociaal overleg, 2004, fiche 7, pp. 58–59. http://www.werk.belgie.be/publicationDefault.aspx?id=3708 'Vibrations mains-bras, Stratégie Sobane', SPF Emploi, Travail et Concertation du Travail, 2004, fiche 7, pp. 58–59. http://www.emploi.belgique.be/publicationDefault.aspx?id=3708

Measure	2.2.2.1. Polishing of moulds for manufacture of crystal glasses
Description	A factory preparing moulds employed 60 people who used small files which transmit high levels of vibration and necessitate high gripping forces. Operators complained of pain in shoulders and numbness in fingers. INRS demonstrated to the manufacturers that the tool could be significantly improved by a better balance of internal pressure forces and better choice of end-stop springs. Vibration exposure was reduced to a third.
Reference	Bitsch, J. 'Anti vibration lime at ARC International. The Cristal d'Arques factory chases vibration'. *Travail et Sécurité*, February 2001

Measure	2.2.3.1. An anti-vibration chipping hammer for the manufacture of motors
Description	In the assembly of components of large electric motors, workers used a hammer while maintaining a difficult posture and they developed MSD at the elbow level. An anti-vibration chipping hammer was adapted to replace the manual hammer and this solution allowed workers to carry out the task while adopting a correct posture.
Reference	Bitsch, J. 'The assembling of an electric motor with a pneumatic tool'. *Travail et Sécurité*, March 2001

Annex II – Description of good practices

Case 1: Driving smoothly

Identification

Company/institution/ organisation	Mutualité Social Agricole, Cemagref, Ministry of Agriculture, INRS
Sector	Agriculture
Number of employees	1 million
Country	France
Contact person	P. Donati
Contact details	Patrice.donati@inrs.fr
References	INRS (1998). 'Driving smoothly. A suspension seat to ease your back. Farmers'. Edition INRS, ED 1493. (In English and French) INRS (1998). 'Driving smoothly. Help your customers to stay fit. Distributors of farm machinery seats'. Edition INRS, ED 1494. (In English and French) INRS (1998). 'Driving smoothly. Selection and replacement of tractor and farm machinery seats. Farm inspectors'. Edition INRS, ED 1492. (In English and French)

Short description

Farming exposes operators to high levels of vibration, poor posture, long exposure and manual loading. Back disorders are common. Epidemiological studies show significant correlation between lumbar problems and the driving of tractors. However, farmers have no choice: with or without back pain they have to carry out the work. Often seats are poor and will tend to amplify vibration. This situation has been known for many years but there is no procedure for advising distributors to propose good seats. Farm inspectors were convinced they could do nothing without measurement equipment, and the direct assistance of experts. On the other hand, good seats do exist. The purpose of this campaign was to develop a procedure to enable farm inspectors to advise farmers when replacing seats.

Preventive measures

Type of measures	Helping the farmers to keep their backs in good health by using appropriate seats
Implementation process	A chart of vibration magnitudes according to machine and tasks was made. The results showed that seats were often insufficient to reduce vibration despite a law which states that seats should be tested according to the category of tractor. It was shown that seats must be changed and that distributors were ignorant of the problem. Low-cost seats with untested suspension were proposed. The measures consisted of: – preparation and wide distribution of three guides: one for farmers, one for distributors, and one for farm inspectors; – drafting of a four-step procedure for assessment of risk and choice of solution; – training of about 50 farm inspectors.

Type of measures	Helping the farmers to keep their backs in good health by using appropriate seats
Persons involved	The initiative was undertaken simultaneously by the Ministry of Agriculture and Mutuelle social agricole, with the assistance of Cemagref and INRS. A multidisciplinary group met monthly for two years. The guides were tested by samples.

Results

Results	The daily exposure to vibration of tractor drivers could be reduced by more than 30 % on machines correctly equipped with adapted seats.
Pitfalls	It was not possible to equip most inspectors with vibrometers to measure vibration exposure and to check seat performance.
Success factors	Nowadays, agriculture has become a modern industry using state-of-the-art equipment. The fact that it is important to have an appropriate seat is more accepted in this climate. On the other hand, the population of farmers is ageing. This means that farmers are often faced with back pain and are more susceptible to this problem. Furthermore, it proved to be an advantage that the people who use the equipment are also those who have to pay for it, so it is possible to convince them to invest in the correct equipment. They often need assistance in choosing the right equipment but this project could offer an answer.

Case 2: Smooth impact

Identification

Company/institution/ organisation	INRS, Caisse Nationale d'Assurance Maladie (CNAM), 16 caisses régionales d'assurance maladie (CRAM)
Sector	Road and building construction
Number of employees	100 000
Country	France
Contact person	P. Donati
Contact details	Patrice.donati@inrs.fr
References	INRS (1991). 'Smooth impact'. Use an anti-vibration concrete breaker. INRS, ED 1346. (In French and English) French Ministry of Social Affairs, advice to manufacturers, importers, distributors, hirers and users of breakers (Avis aux fabricants, importateurs, distributeurs, loueurs et utilisateurs de brise béton), *Journal officiel de la république française*, 13 January 2004. www.inrs.fr dossier brise béton

Short description

Use of breakers often results in HAV. Despite this equipment exposing users to high levels of vibration, it was sold without suspension. In 1973, INRS, along with some manufacturers, invented suspension breakers and vibration was more than halved. The product was commercialised, had some success and then progressively disappeared. Twenty years after an enquiry showed that breakers were the origin of many cases of bone and joint disorders on upper limbs, the French institute of prevention decided to launch a campaign for the promotion of anti-vibration breakers. Ten years later, market surveillance showed that most breakers sold were equipped with suspension. The Ministry of Social Affairs published advice defining what is a suspension breaker.

Preventive measures

Type of measures	Breakers were equipped with suspension to reduce the vibration exposure of users.
Implementation process	An enquiry on occupational disease cases was carried out at the end of the 1980s. The conclusions showed the necessity of promoting anti-vibration breakers. With the assistance of manufacturers, three benches to compare anti-vibration breakers with conventional ones were constructed. They were presented in more than 20 French towns to thousands of users. Several presentations were made on TV and in newspapers. More than 4 000 anti-vibration breakers were sponsored by the CRAM. At the beginning of the 1990s, only three manufacturers sold anti-vibration breakers, but at the end of 1990s, all manufacturers promoted them. At the request of the Ministry of Social Affairs, INRS made a series of vibration measurements using the standardised test code for this kind of tool. This was done on all tools proposed for the French market. All suspension tools were below 8 m/s2, except some electric ones. This value became a reference value to consider the validity of the suspension.
Persons involved	INRS and CNAM, with the assistance of CRAM.

Results

Results	Anti-vibration breakers replace conventional breakers. Significant reduction in vibration transmitted to users.
Pitfalls	Today, an increasing number of breakers use electricity. They are all suspended, but some suspensions are poor.
Success factors	Breakers were an unacceptable symbol of bad tools. The technical solution was excellent, not only to reduce vibration but also to facilitate the work. The campaign was warmly welcomed everywhere, and the manufacturers were highly motivated. The CNAM invested heavily, since 4 000 tools were sponsored (at that time the market was 5 000 breakers sold annually!).

Case 3: Redesigning transportation

Identification

Company/institution/organisation	
Sector	Supermarket (retail sale, NACE 52)
Number of employees	420 (number of fork-lift drivers in three logistic centres)
Country	Belgium
Contact person	
Contact details (address, tel. or e-mail)	
Reference	

Short description

As in all businesses, the transportation of goods is an important area of activity in this company. Fork-lift trucks are used to load and unload palletised goods from trucks into several warehouses. Clear segregated ways ensure efficient transportation as well as good maintenance procedures (regular check-ups of the fork-lift trucks, maintenance of the transportation roads, lighting, and signage). However, the company is situated over a large area and consists of several centres and departments. This means that drivers sometimes use fork-lift trucks to drive long distances without loading or unloading goods, exposing them unnecessarily to WBV. This became obvious during a risk analysis that was carried out. Based upon this risk analysis, measures were developed in order to reduce the WBV. These measures mainly concerned awareness-raising and changes in working methods.

Preventive measures

Type of measures	Reduction of WBV by changing the work method (1.2.2.)
Implementation process	Drivers of fork-lift trucks can be exposed to WBV transmitted through the seat. Following the new regulation on vibration ([1]), this company carried out a risk analysis of the exposure of its workers to vibration. One of the observations made was that fork-lift truck drivers were exposed to WBV (daily exposure levels above the action level of 0.5 m/s^2). The risk analysis also revealed that the drivers often used fork-lift trucks in situations where other means of transportation were more appropriate (only for transportation, not for loading or unloading). Based on this risk analysis, preventive measures were developed, presented and implemented. The measures consist of: – making other means of transportation available (car, bicycle); – creating extra parking areas for fork-lift trucks (easier to change vehicles); – limiting areas for fork-lift trucks (they may not be used outside these areas, signs); – drafting of a procedure (appropriate use of the fork-lift truck); – instruction and awareness-raising of the fork-lift truck drivers; – integration of procedure/instruction in training of fork-lift truck drivers (new workers/refreshment).

([1]) Belgian legislation transposing Directive 2002/44/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from vibration (Koninklijk besluit van 7 juli 2005 betreffende de bescherming van de gezondheid en de veiligheid van de werknemers tegen de risico's van mechanische trillingen op het werk, BS 14 July 2005).

Type of measures	Reduction of WBV by changing the work method (1.2.2.)
Persons involved	The initiative was taken by the safety and health advisor. Assistance was given by the external service for occupational safety and health at work (measurements). The committee on prevention and protection (workers' delegation) was consulted. The team leaders and logistics manager were involved in drafting and implementing the new procedure. The instructions were given via toolbox meetings (team leaders). The awareness-raising was organised via a communication campaign.

Results

Results	The daily exposure of fork-lift truck drivers to WBV could be reduced. However, measurements are necessary to establish if other measures are needed in order to further reduce the exposure to vibration. The benefit of this preventive measure was that all the people involved reflected on their working methods and became more aware of the impact of their way of work.
Pitfalls	The introduction of these kinds of working methods depends not only on clear procedures, but also on the involvement of all drivers and on the monitoring of the implementation.
Success factors	Success factors of this good practice were the awareness-raising and the fact that all the people involved reflected on their working methods.

Case 4: New seats on fork-lift trucks

Identification

Company/institution/organisation	
Sector	
Number of employees	
Country	Germany
Contact person	
Contact details (address, tel. or e-mail)	
Reference	Focus on BGIA's work No 0120 'Ganzkörper-Schwingungseinwirkungen eines Niederhubwagens' (WBV on a pallet-truck) http://www.hvbg.de/d/bia/pub/ada/index.html

Short description

In a factory, the fork-lift trucks had to transport pallets with goods over ramps. The fork-lift truck driver complained of low back pain. The mounted seats met the demands of the seat testing standard.

Measurements and simulation of the exaltation in the seat test laboratory showed that the stroke of the mounted seats was too small for the excitation at the beginning and the end of the ramps. In the test laboratory, two seats with longer strokes were identified as appropriate. Both seats were brought to the factory where the drivers selected one which also satisfied their ergonomic demands.

Preventive measures

Type of measures	Changing the seats of industrial trucks
Implementation process	
Persons involved	

Results

Results	
Pitfalls	
Success factors	

Case 5: Fork-lift truck travel over ramps

Identification

Company/institution/organisation	
Sector	
Number of employees	
Country	Germany
Contact person	
Contact details (address, tel. or e-mail)	
Reference	Focus on BGIA's work No 0241 'WBV exposure during fork-lift truck travel over ramps' http://www.hvbg.de/d/bia/pub/ada/index.html

Short description

The drivers of pallet-trucks complained of low back pain. However, the manufacturer of the pallet-trucks declared — according to the machinery directive — an emission value of 0.44 m/s^2.

The frequency weighted acceleration during operation of a pallet-truck was 0.33 m/s^2. However, during the transport of goods in the truck over a ramp, the ramp inclination changed according to the degree of loading — caused by the small wheels of the pallet-truck — and resulted in shocks and jolts. The solution was height adaptation of the ramp.

Preventive measures

Type of measures	Height adaptation of a ramp for pallet-trucks.
Implementation process	
Persons involved	

Results

Results	
Pitfalls	
Success factors	

Case 6: Tackling vibration of fork-lift trucks

Identification

Company/institution/organisation	
Sector	Pharmaceutical industry
Number of employees	700 workers
Country	Belgium
Contact person	
Contact details (address, tel. or e-mail)	
Reference	Lenaerts, Luc. 'Evaluatie van de blootstelling aan lichaamstrillingen bij heftruckchauffeurs in functie van de Europese richtlijn 2002/44/EG', eindwerk, 2002–03

Short description

Measurements of WBV showed that drivers of fork-lift trucks who drove on site were often exposed to values above the action limit of 0.5 m/s^2 (but lower than the exposure limit of 1.15 m/s^2). Based on these measurements, various measures were proposed and evaluated by a multidisciplinary task-force. An action plan was drafted to carry out the most appropriate measures.

Preventive measures

Type of measures	
Implementation process	Based on the risk analysis and measurements, a multidisciplinary task-force looked at all possible measures to limit the exposure to WBV. Various measures were proposed: – work organisation: separate internal from external transportation (between warehouses, plants) and using appropriate transportation means for external transportation; – testing of alternative tyres (the testing was not successful and this solution was rejected); – testing of an alternative surface; – maintenance programme including controls; – purchasing policy (criteria for fork-lift trucks); – awareness-raising (toolbox meeting); – job rotation (limiting the exposure duration).

Type of measures	
Persons involved	In order to select and implement the best measures, a multidisciplinary task-force was set up. This task-force consisted of: – an industrial hygienist; – an occupational nurse; – a production coordinator; – a coordinator of purchasing and stock; – two fork-lift truck drivers.

Results

Results	New measurements show that for new fork-lift trucks (based on the revised purchasing policy with severe ergonomic criteria), the values are always below the action limit of 0.5 m/s^2. This measure, together with the other measures that were taken such as a maintenance programme and awareness-raising, was successful.
Pitfalls	
Success factors	An important success factor was that the project was carried out by a task-force that involved several people. The involvement of drivers (this made it possible to test several solutions before implementation) and the purchasing department (introduction of purchasing policy) particularly contributed to the success of this project.

Case 7: Step by step

Identification

Company/institution/organisation	
Sector	Chemical industry
Number of employees	
Country	Belgium
Contact person	
Contact details (address, tel. or e-mail)	
Reference	Cheyns, Patrick, Geenens, Luc, Jansen, Patrick, Peeters, Dirk, Staessens, Geert. 'Het KB Mechanische trillingen: actuele implementatieproblematiek', projectwerk, 2005–06.

Short description

In this company, a strategy was developed to deal with vibration at work. Based on a company-wide risk analysis (every three years the company carries out a risk analysis on every workstation), possible jobs/activities/workstations were identified where workers might be exposed to vibration. On these workstations, measurements are executed and, based on the results, measures are implemented. The workers are informed about the results of the analysis and the measures.

Preventive measures

Type of measures	
Implementation process	
Persons involved	A working group consisting of the OSH advisor, the occupational physician and a maintenance specialist evaluate the results of the measurements and decide upon the necessary measures.

Results

Results	
Pitfalls	
Success factors	Step-by-step approach. Integrated in the company-wide risk analysis.

European Agency for Safety and Health at Work

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