Risks of Occupational Vibration Exposures

VIBRISKS

FP5 Project No. QLK4-2002-02650
January 2003 to December 2006

Annex 21 to Final Technical Report

Title: Common procedures that can be applied by occupational health workers across Europe for minimizing risk, screening exposed individuals and management of individuals with symptoms of mechanical vibration injuries

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European Commission

Quality of Life and Management of Living Resources Programme
Key Action 4 - Environment and Health

4th January 2007

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Summary

Article 2 of the 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), defines “hand-arm vibration” as “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”, and “whole-body vibration” as “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”. According to the European Directive 2002/44/EC on mechanical vibration (article 8, para. 1), “health surveillance, the results of which are taken into account in the application of preventive measures at a specific workplace, shall be intended to prevent and diagnose rapidly any disorder linked with exposure to mechanical vibration. Such surveillance shall be appropriate where: (i) the exposure of workers to vibration is such that a link can be established between that exposure and an identifiable illness or harmful effects on health; (ii) it is probable that the illness or the effects occur in a worker’s particular working conditions; (iii) there are tested techniques for the detection of the illness or the harmful effects on health. In any event, workers exposed to mechanical vibration in excess of the values stated in Article 3(1)(b) and (2)(b) shall be entitled to appropriate health surveillance”. The values reported in Article 3(1)(b) and (2)(b) of the EU Directive are the daily exposure action values for HTV and WBV expressed in terms of A(8). Health surveillance of vibration-exposed workers consist of pre-employment medical screening and subsequent clinical examinations at regular intervals. Medical preventive programs shalld be managed by certified occupational health personnel. One of the objectives of the VIBRISKS project is the development of common procedures for HTV and WBV health surveillance, including the development of improved methods for the detection and diagnosis of disorders. In this context, protocols for the health surveillance of workers exposed to either HTV or WBV have been developed. The protocols are to provide tools for assessing health effects in the upper limbs (HTV exposed workers) or the lower back (WBV exposed workers) that can be used for health surveillance in the workplace, and in epidemiological research. The tools that have been developed include guidelines for health

surveillance, questionnaires for initial assessment and periodic medical examinations at regular intervals, and the definition of a battery of objective tests for the assessment of vibration-induced disorders. The program of health surveillance for vibration-exposed workers developed in the VIBRISKS project has been designed to fulfil the following aims: (i) to inform the workers on the potential risk associated with vibration exposure; (ii) to assess worker's health status and fitness for work; (iii) to diagnose vibration-induced disorders at an early stage; (iv) to give preventive advice to employers and employees; (v) to control the long-term effectiveness of preventive measures.

1. General

Mechanical vibration arises from a wide variety of processes and operations performed in industry, mining and construction, forestry and agriculture, and public utilities. ***Hand-transmitted vibration*** occurs when the vibration enters the body through the hands, e.g. in various work processes where rotating or percussive power tools or vibrating workpieces are held by the hands or fingers. ***Whole-body vibration*** occurs when the human body is supported on a surface which is vibrating, e.g. in all forms of transport and when working near some industrial machinery [Griffin, 1990].

Article 2 of the 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), defines "hand-arm vibration" as "*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*", and "whole-body vibration" as "*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*".

According to the 3rd European Survey on Working Conditions [Paoli and Merllié, 2001], about 23.6% of all workers interviewed during the survey reported being exposed to mechanical vibration in the workplaces of the European Union. Of them, 10.3% were exposed all or almost of the time, 6.5% around ¾ or ½ of the time, and 6.8% around ¼ of the time.

In Europe, craft workers, machine operators, agricultural workers, work force involved in elementary occupations, and armed forces are the occupations with the greatest exposure to vibration from hand tools, machinery, and vehicles [Paoli and Merllié, 2001].

Exposure to harmful vibration at the workplace can induce several complaints and health disorders, mainly in the upper limbs and the lower back [Griffin, 1990; Bernard, 1997; CEN TR 12349, 1996].

The VIBRISKS project has developed and refined questionnaires and objective test procedures for diagnosis of injuries caused by hand-transmitted vibration and whole-body vibration. The diagnostic tools have been tested and validated in multi-national epidemiological (cross-sectional and longitudinal) surveys.

The diagnostic tools and health surveillance procedures developed in the VIBRISKS project are available at http://www.humanvibration.com. In the context of the implementation of the European Directive 2002/44/EC on mechanical vibration, the VIBRISKS materials can provide a valuable resource for (i) occupational health personnel, (ii) occupational safety and health organisations who are involved in long-term monitoring of vibration-induced disorders, and (iii) acadaemic researchers with expertise in the field of injuries caused by occupational exposure to mechanical vibration.

In sections 2 and 3 of this report, a brief review is dedicated to the evaluation and assessment of vibration exposure at the workplace, and to the long-term health effects caused by occupational exposure to hand-transmitted vibration and whole-body vibration, respectively.

In section 4, the aims of health surveillance in general and in case of exposure to mechanical vibration are discussed.

In sections 5 and 6, this report provides a detailed description of the medical procedures that should be implemented for the protection and health surveillance of workers exposed to hand-transmitted vibration or whole-body vibration, respectively. Moreover, criteria for fitness for work with vibratory machinery and for avoidance of vibration exposure in injured workers are suggested. Advices for medical treatment in workers affected with vibration-induced disorders are offered.

Appendixes A to F provide detailed information about diagnostic tools, clinical criteria and ethical issues associated with an effective health surveillance practice to protect the worker against the risks arising from exposure to mechanical vibration.

2. Evaluation and assessment of vibration exposure

The human response to vibration depends mainly on the magnitude, frequency and direction of the vibration signal [Griffin, 1990].

2.1 Vibration magnitude

The magnitude of vibration is quantified by its displacement (m), its velocity (ms^{-1}), or its acceleration (ms^{-2}).

For practical convenience, the magnitude of vibration is expressed in terms of an average measure of the acceleration, usually the root mean square value (ms^{-2} r.m.s.). The r.m.s. magnitude is related to the vibration energy and hence the vibration injury potential.

2.2 Frequency of vibration

The frequency of vibration is expressed in cycles per second and it is measured in Hertz (Hz).

Biodynamic investigations have shown that the response of the human body to vibration is frequency-dependent [Griffin, 1990]:

- The adverse health effects of whole-body vibration can occur in the low frequency range from 0.5 to 80 Hz.
- For hand-transmitted vibration, frequencies from 5 to 1500 Hz can provoked disorders in the upper limbs.
- Frequencies below about 0.5 Hz can cause motion sickness.

To account for these differences in the response of the body to vibration frequency, current standards for human vibration recommend to weight the frequencies of the measured vibration according to the possible deleterious effect associated with each frequency [ISO 2631-1, 1997; ISO 5349-1, 2001]. Frequency weightings are required for three orthogonal directions (*x*-, *y*- and *z*-axes) at the interfaces between the body and the vibration.

2.3 Evaluation of vibration exposure

2.3.1 Hand-transmitted vibration

For the health effects of hand-transmitted vibration on the upper limbs, the evaluation of vibration exposure is based on the vibration total value (a_{hv}), a quantity defined as the square root of the sum of the squares (r.m.s.) of the frequency weighted acceleration values (a_{hw}) determined on the three orthogonal axes *x*, *y*, *z*, i.e. $a_{hv}=(a_{hwx}^2+a_{hwy}^2+a_{hwz}^2)^{½}$, ($ms^{-2}$ r.m.s.).

2.3.2 Whole-body vibration

The vibration total value has been also proposed for the evaluation of the health effects of whole-body vibration if no dominant axis of vibration exists [ISO 2631-1, 1997]. For a seated or standing worker, the vibration total value (a_v) for the frequency-weighted accelerations (a_w) of whole-body vibration is calculated as $a_v=(k_x^2 a_{wx}^2+ k_y^2 a_{wy}^2+k_z^2 a_{wz}^2)^{½}$, where k=1.4 for *x*- and *y*-axes and k=1 for *z*-axis.

Since it is believed that the health effects of whole-body vibration are influenced by shocks or vibration peaks, the international standard ISO 2631-1 [1997] suggests to use the fourth power vibration dose method instead of the second power of the acceleration time history (i.e. r.m.s.) as the basis for averaging. The fourth power vibration dose value (VDV) is expressed in metres per second to the power of 1.75 (i.e. $ms^{-1.75}$).

2.4 Assessment of vibration exposure

According to the European Directive 2002/44/EC, the assessment of exposure to hand-transmitted "*is based on the calculation of the daily exposure value normalised to an eight-hour reference period A(8), expressed as the square root of the sum of the squares (r.m.s.) of the frequency weighted acceleration values, determined on the three orthogonal axes* a_{hwx}, a_{hwy}, a_{hwz}" as defined in the international standard ISO 5349-1 [2001].

The assessment of exposure to whole-body vibration "*is based on the calculation of daily exposure A(8) expressed as continuous equivalent acceleration over an eight-*

*hour period, calculated as the highest (r.m.s.) value, or the highest vibration dose value (VDV) of the frequency-weighted accelerations, determined on three orthogonal axes (1.4*a_{wx}*, 1.4*a_{wy}*,* a_{wz}*)*" in accordance with the international standard ISO 2631-1 [1997].

The EU Directive 2002/44/EC specifies "daily exposure action values" and "daily exposure limit values" for both hand-transmitted vibration and whole-body vibration, above which administrative, technical and medical measures have to be implemented by employers with the aim to protect workers against the risks arising from vibration exposure (Table 1).

Table 1. Daily exposure action values and daily exposure limit values for hand-transmitted vibration (HTV) and whole-body vibration (WBV) according to the European Directive 2002/44/EC on mechanical vibration. *A*(8) is the daily vibration exposure value normalised to an eight-hour reference period, and VDV is the Vibration Dose Value (see text for definitions).

	HTV	WBV
Daily exposure action value	*A*(8)=2.5 ms^{-2} (r.m.s.)	*A*(8)=0.5 ms^{-2} (r.m.s.) VDV=9.1 $ms^{-1.75}$
Daily exposure limit value	*A*(8)=5 ms^{-2} (r.m.s.)	*A*(8)=1.15ms^{-2} (r.m.s.) VDV=21 $ms^{-1.75}$

2.5 OTHER FACTORS INFLUENCING HUMAN RESPONSE TO VIBRATION

In addition to the physical characteristics of vibration, some other factors are believed to be related to the injurious effects of vibration, such as the duration of exposure (daily, yearly, and lifetime cumulative exposures), the pattern of exposure (continuous, intermittent, rest periods), the type of tools, processes or vehicles which produce vibration, the environmental conditions (ambient temperature, airflow, humidity, noise), the dynamic response of the human body (mechanical impedance, vibration transmissibility, absorbed energy), and the individual characteristics (method of tool handling or style of vehicle driving, body posture, health status, training, skill, use of personal protective equipment, individual susceptibility to injury).

Consistently with these notions, Article 4 of Directive 2002/44/EC establishes that the employer shall assess and, if necessary, measure the levels of mechanical vibration to which workers are exposed, giving particular attention to the following items:

(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 whole-body vibration 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.

Article 5 of the EU Directive establishes that workers shall not be exposed above the exposure limit values. If the exposure action values are exceeded, "*the employer shall establish and implement a programme of technical and/or organisational measures intended to reduce to a minimum exposure to mechanical vibration and the attendant risks, taking into account in particular:*

(a) other working methods that require less exposure to mechanical vibration;

(b) the choice of appropriate work equipment of appropriate ergonomic design and, taking account of the work to be done, producing the least possible vibration;

(c) the provision of auxiliary equipment that reduces the risk of injuries caused by vibration, such as seats that effectively reduce whole-body vibration and handles which reduce the vibration transmitted to the hand-arm system;

(d) appropriate maintenance programmes for work equipment, the workplace and workplace systems;

(e) the design and layout of workplaces and work stations;
(f) adequate information and training to instruct workers to use work equipment correctly and safely in order to reduce their exposure to mechanical vibration to a minimum;
(g) limitation of the duration and intensity of the exposure;
(h) appropriate work schedules with adequate rest periods;
(i) the provision of clothing to protect exposed workers from cold and damp".

In addition to the determination and assessment of risks at the workplace (article 4), further obligations of employers include workers' information and training relating to the outcome of the risk assessment (article 6). Moreover, consultation and participation of workers and/or of their representatives shall take place in accordance with Article 11 of Directive 89/391/EEC on the matters covered by the EU Directive on mechanical vibration (article 7).

3. Health effects of vibration on the human body

3.1 Hand-transmitted vibration

3.1.1 General

Prolonged exposure to hand-transmitted vibration (HTV) from powered processes or tools is associated with an increased occurrence of symptoms and signs of disorders in the vascular, neurological and osteoarticular systems of the upper limbs [Griffin 1990; Bernard, 1997; Bovenzi, 1997]. The complex of these disorders is called *hand-arm vibration syndrome*. The *vascular component* of the HAV syndrome is represented by a secondary form of Raynaud's phenomenon known as vibration-induced white finger; the *neurological component* is characterised by a peripheral, diffusely distributed neuropathy with predominant sensory impairment; the *osteoarticular component* includes degenerative changes in the bones and joints of the upper extremities, mainly in the wrists and elbows. An increased risk for upper limb muscle and tendon disorders, as well as for nerve trunk entrapment syndromes, has also been reported in workers who use hand-held vibrating tools [Bernard, 1997; Hagberg *et al.*, 1995]. The vascular and osteoarticular disorders caused by HTV are included in a European schedule of recognised occupational diseases [2003/670/CE, Annex I, items 505.01 e 505.02] It is estimated that 1.7 to 5.8% of the workers in the European Countries, U.S. and Canada are exposed to potentially harmful HTV [ISSA, 1989].

3.1.2 Neurological disorders

There is epidemiologic evidence for a greater occurrence of digital tingling and numbness, deterioration of finger tactile perception, and loss of manipulative dexterity in occupational groups using vibrating tools than in control groups not exposed to HTV [Bovenzi, 1998]. In epidemiologic surveys of vibration-exposed workers, the prevalence of peripheral sensorineural disorders was found to vary from a few percent to more than 80% [CEN TR 12349, 1996].

Neurophysiological studies have suggested that sensory disturbances in the hands of vibration-exposed workers are likely due to vibration-induced impairment to various skin mechanoreceptors (Meissner's corpuscles, Pacinian corpuscles, Merkel cell neurite complexes, Ruffini endings) and their afferent nerve fibres. Electron microscopic studies of human finger biopsy specimens suggest that hand-transmitted vibration can provoke perineural fibrosis, demyelination, axonal degeneration and nerve fibre loss.

The neurological component of the HAV syndrome is currently staged according to the scale proposed at the Stockholm Workshop 86 [Brammer *et al.*, 1987]. The sensorineural (SN) scale consists of three stages (SN1, SN2, SN3) according to the symptoms complained and the results of clinical examination and objective tests (Table 2).

Clinical and epidemiologic surveys have revealed an increase in sensorineural disorders with the increase of daily vibration exposure, duration of exposure, or lifetime cumulative vibration dose. The currently available epidemiologic data, however, are insufficient to outline the form of a possible exposure-response relationship for vibration-induced neuropathy.

Table 2. The Stockholm Workshop scale for the sensorineural stages of the hand-arm vibration syndrome.

Stage	Symptoms and signs
SN0	Exposed to vibration but no symptoms
SN1	Intermittent numbness, with or without tingling
SN2	Intermittent or persistent numbness, reduced sensory perception
SN3	Intermittent or persistent numbness, reduced tactile discrimination and/or manipulative dexterity

Some cross-sectional and case-control studies have shown an increased occurrence of symptoms and signs of entrapment neuropathies, mainly carpal tunnel syndrome (CTS), in occupations involving the usage of vibrating tools [CEN TR 12349, 1996]. CTS is also common in job categories whose work tasks involve high-force and repetitive hand wrist movements [Hagberg *et al.*, 1992]. The independent contribution of vibration exposure and physical work load (forceful gripping, heavy manual labour, wrist flexion and extension), as well as their interaction, in the etiopathogenesis of CTS have not yet been established in epidemiologic studies of workers who handle vibratory tools. It has been suggested that ergonomic risk factors are likely to play the dominant role in the development of CTS. As a result, to date it is hard to draw a specific relation between CTS and exposure to HTV.

3.1.3 Bone and joint disorders

Vibration-induced bone and joint disorders are a controversial matter [Bovenzi, 1998; CEN TR 12349, 1996; Griffin, 1990; Gemne and Saraste, 1987]. Various authors consider that disorders of bones and joints in the upper extremities of workers using hand-held vibrating tools are not specific in character and similar to those due to the ageing process and to heavy manual work. Early radiological investigations had revealed a high prevalence of bone vacuoles and cysts in the hands and wrists of vibration-exposed workers, but more recent studies have shown no significant increase with respect to control groups made up of manual workers. An increased risk for wrist osteoarthrosis and elbow arthrosis and osteophytosis has been reported in coal miners, road construction workers and metal-working operators exposed to shocks and low frequency vibration (<50 Hz) of high magnitude from percussive tools (pick, riveting and chisel hammers, vibrating compressors). An excess prevalence of Kienbock's disease (lunate malacia) and pseudoarthrosis of the scaphoid bone in the wrist has also been reported by a few investigators. On the contrary, there is little evidence for an increased prevalence of degenerative bone and joint disorders in the upper limbs of workers exposed to mid- or high-frequency vibration arising from chain saws or grinding machines. It is thought that, in addition to vibration, joint overload due to heavy physical effort, awkward postures, and other biomechanical factors can account for the higher occurrence of skeletal injuries found in the upper limbs of users of percussive tools. A constitutional susceptibility might also play a role in the etiopathogenesis of premature wrist and elbow osteoarthrosis. At present, there are no epidemiologic studies that may suggest, even tentatively, an exposure-response relation for bone and joint disorders in vibration-exposed workers.

3.1.4 Muscle and tendon disorders

Workers with prolonged exposure to HTV may complain of muscular weakness, pain in the hands and arms, and diminished muscle force [CEN TR 12349, 1996]. Vibration exposure has also been found to be associated with a reduction of hand-grip strength. In some individuals muscle fatigue can cause disability. Direct mechanical injury or peripheral nerve damage have been suggested as possible etiologic factors for muscle symptoms. Other work-related disorders have been reported in vibration-exposed workers, such as tendinitis and tenosynovitis in the upper limbs, and Dupuytren's contracture, a disease of the fascial tissues of the palm of the hand. These disorders seem to be related to ergonomic stress factors arising from heavy manual work, and the association with HTV is not conclusive.

3.1.5 Vascular disorders (white finger)

Vibration-induced white finger (VWF) is recognised as an occupational disease in many industrialised countries. Epidemiologic studies have pointed out that the prevalence of VWF is very wide, from 0-5% in workers using vibratory tools in geographical areas with a warm climate to 80-100% in the past among workers exposed to high vibration magnitudes in northern Countries [Griffin, 1990; Bovenzi, 1998; CEN TR 12349, 1996].

It is believed that vibration can disturb the digital circulation making it more sensitive to the vasoconstrictive action of cold. To explain cold-induced Raynaud's phenomenon in vibration-exposed workers, some investigators invoke an exaggerated central vasoconstrictor reflex caused by prolonged exposure to harmful vibration, while others tend to emphasise the role of vibration-induced local changes in the digital vessels (e.g. thickening of the muscular wall, endothelial damage, functional receptor changes). It has also been suggested that vasoactive substances, immunologic factors or blood viscosity may play a role in the pathogenesis of VWF [Bovenzi, 1997].

Clinically, VWF is characterised by episodes of white fingers caused by spastic closure of the digital arteries. A blue discoloration of the fingers (cyanosis) may follow. The attacks are usually triggered by cold and last from 5 to 30-40 minutes. A complete loss of tactile sensitivity may be experienced during an attack. In the recovery phase, commonly accelerated by warmth or local massage, redness (hyperaemia) may appear in the affected fingers as a result of a reactive increase of blood flow in the cutaneous vessels. In the rare advanced cases, repeated and severe digital vasospastic attacks can lead to trophic changes (ulceration or gangrene) in the skin of the fingertips.

A grading scale for the classification of VWF has been proposed at the Stockholm Workshop 86 [Gemne *et al.*, 1987], consisting of four symptomatic stages, from mild (stage 1) to very severe (stage 4). VWF symptoms are staged according to the frequency of finger blanching attacks, the number of affected fingers and the number of affected phalanges in a given finger (Table 3).

Table 3. The Stockholm Workshop scale for the classification of cold-induced Raynaud's phenomenon in the hand-arm vibration syndrome.

Stage	Symptoms
0	No attacks of finger blanching
1	Occasional attacks affecting only the tips of one or more fingers
2	Occasional attacks affecting distal and middle (rarely also proximal) phalanges of one or more fingers
3	Frequent attacks affecting all phalanges of most fingers
4	As in stage 3, with trophic skin changes in the finger tips

In Annex C to International Standard ISO 5349-1 [2001], the following tentative relationship between vibration exposure and finger blanching (VWF) is suggested:

$$D_y = 31.8\, A(8)^{-1.06}$$

where $A(8)$ is the daily vibration exposure (8-h energy-equivalent vibration total value at a surface in contact with the hand), and Dy is the group mean total (lifetime) exposure duration, in years.

The ISO exposure-response relationship gives the values of the daily vibration exposure *A*(8) which may be expected to produce episodes of finger blanching in 10 % of workers exposed for a given number of years *D*y:

D_y, years	1	2	4	8
A(8), ms^{-2}	26	14	7	3,7

It is said that the ISO relation is derived from studies of groups of workers exposed to tool vibration magnitudes up to 30 ms^{-2} in their occupations for up to 25 years. Almost all studies involved groups of workers who performed, near-daily, work involving one type of power tool or industrial process in which vibration was coupled to the hands. The acceleration values are derived from studies in which the dominant, single-axis, frequency-weighted component acceleration was reported.

The prognosis of vibration-induced white finger (VWF) is still uncertain. Studies have reported that VWF may improve, persist or worsen in workers with current or previous exposure to hand-transmitted vibration. It has been suggested that cessation or reduction of vibration exposure may be associated with some reversibility of VWF, but the rate of remission of vasospastic symptoms over time is not well-known [CEN TR 12349, 1996]. However, since the late 1970s a decrease in the occurrence of VWF has been reported among active forestry workers in both Europe and Japan after the introduction of anti-vibration chain saws and administrative measures curtailing the saw usage time together with endeavours to reduce exposure to other harmful work environment factors (e.g. cold and physical stress). Recovery from VWF has also been reported among retired forestry workers. Nevertheless, it has been reported that the reversibility of VWF is inversely related to the stage of VWF at retirement, age and duration of exposure after the first episode of finger blanching [Futatsuka *et al.*, 1985]. In general, there is evidence for a decrease in the occurrence of VWF in the last two decades, at least among occupational groups who started to work with vibrating tools of new generation.

3.1.6 OTHER POSSIBLE VIBRATION-INDUCED DISORDERS

A few clinical and epidemiologic studies have reported that exposure to hand-transmitted vibration can aggravate the risk of noise-induced hearing loss and provoke disturbances of the central nervous system [Griffin, 1990; CEN TR 12349, 1996]. To date, no exposure-response relationship can derived from the findings of the studies which have investigated these disorders in occupational groups operating vibratory tools.

3.2 Whole-body vibration

3.2.1 General

Long-term occupational exposure to intense whole-body vibration (WBV) is associated with an increased risk for disorders of the lumbar spine and the connected nervous system [Bongers and Boshuizen, 1990; Bovenzi and Hulshof, 1999; CEN TR 12349, 1996; Dupuis and Zerlett, 1986; Hoogendoorn et al, 1999; Lings and Leboeuf-Yde, 2000; Seidel, 1993]. With a lower probability, the neck-shoulder, the gastrointestinal system, the female reproductive organs, the peripheral veins, and the cochleo-vestibular system are also assumed to be affected by whole-body vibration [CEN TR 12349, 1996; Seidel and Heide, 1986]. However, there is a weak epidemiologic support for vibration-induced disorders of organ systems other than the lower back. It has been estimated that 4 to 7% of all employees in the U.S., Canada and some European Countries are exposed to potentially harmful WBV [ISSA, 1989]. In some Countries (e.g. Belgium, France, Germany, The Netherlands, Denmark), (low) back disorders occurring in workers exposed to WBV are, under certain conditions regarding intensity and duration of exposure, considered to be an occupational disease which can be compensated [Hulshof et al, 2002].

3.2.2 Low back disorders and WBV exposure

There is epidemiological evidence that occupational exposure to WBV is associated with an increased risk of low back pain, sciatic pain, and degenerative changes in the spinal system, including lumbar intervertebral disc disorders [Hulshof and Veldhuyzen van Zanten, 1987; Bovenzi and Hulshof, 1999; CEN TR 12349, 1996; Hoogendoorn et al, 1999; Waddell and Burton, 2000].

Several epidemiological studies have also suggested a trend for an increasing risk of low back pain with increasing exposure to WBV [Bongers and Boshuizen, 1990; Bovenzi and Hulshof, 1999].

In an epidemiologic review of the long-term effects of WBV on the lumbar spine [Bovenzi and Hulshof, 1999], crane operators, bus drivers, tractor drivers, and fork-lift truck drivers were found to be the most frequently investigated occupational groups in either cross-sectional or cohort studies. The findings of these studies suggested an increased risk for LBP disorders among occupational groups exposed to WBV when compared to unexposed control groups including either sedentary workers such as administrative officers or manual workers such as maintenance operators. The results of a meta-analysis showed that after adjusting for individual characteristics and ergonomic and psychological risk factors at work, there was a significant increase in the combined prevalence odds ratio (POR) for 12-month prevalence of low back pain in occupations with exposure to WBV from industrial vehicles (summary POR: 2.3, 95% confidence interval (CI) 1.8-2.9). An excess risk for sciatic pain (summary POR: 2.0, 95% CI 1.3-2.9) and lumbar disc disorders, including herniated disc (summary POR: 1.5, 95% CI: 0.9-2.4 for cross-sectional studies; summary incidence density ratio: 1.8, 95% CI: 1.1-3.1 for cohort studies) was also found in the vibration-exposed groups compared with the control groups. These risk estimates are consistent with those of an earlier meta-analysis [Bongers and Boshuizen, 1990], which found an increase of the prevalence odds ratio for low back pain of 1.7 per one unit of increase in WBV magnitude (ms^{-2} r.m.s.). The effects of this risk can also be expressed otherwise: based on the literature mentioned above, a Markov model was applied to evaluate a hypothetical cohort of workers with follow-up of 40 years (40 cycles of 1 year) with continuous exposure to whole-body vibration. In such hypothetical cohort it can be estimated that among workers with the highest exposure to WBV on average about 47 weeks of their working life are lost due to sick leave because of low back pain, which is approximately 2.5% of their working life. When all workers on prolonged sick leave for 52 weeks would remain disabled for the rest of their working life on average about 23.4% of their working life is lost due to high WBV exposure. Among workers with a no or low exposure to WBV the corresponding losses of working time are 0.8% and 7.8%, respectively [Burdorf and Hulshof, 2006].

The role of WBV in the etiopathogenesis of low back injuries is not yet fully clarified, as driving vehicles involves not only exposure to harmful WBV but also to several ergonomic factors which can affect the spinal system, such as prolonged sitting in a constrained posture, bending forward and frequent twisting of the spine. Moreover, some driving occupations involve heavy lifting and manual handling activities (e.g. drivers of delivery trucks), which are known to strain the lower part of the back. Individual characteristics (age, anthropometric data, smoking habit, constitutional susceptibility), psychosocial factors, and previous back traumas are also recognised as important predictors for low back pain. Therefore, injuries in the lower back of professional drivers represent a complex of health disorders of multifactorial origin involving both occupational and non-occupational factors [Bovenzi and Hulshof, 1999; Burdorf and Sorock, 1998]. As a result, it is hard to separate the contribution of WBV exposure to the onset and the development of low back troubles from that of other individual and ergonomic risk factors.

Biodynamic and physiological experiments have shown that seated vibration exposure can affect the spine by mechanical overloading and excessive muscular fatigue, supporting the epidemiologic findings of a possible causal role of whole-body vibration in the development of (low) back troubles [Dupuis and Zerlett, 1986; Griffin, 1990]. Owing to the cross-sectional design of the majority of the epidemiological studies, however, this epidemiologic evidence is not sufficient to outline a clear exposure-response relationship between WBV exposure and (low) back disorders.

4. Protection and health surveillance of vibration-exposed workers

The prevention of injuries or disorders caused by mechanical vibration at the workplace requires the implementation of administrative, technical and medical procedures.

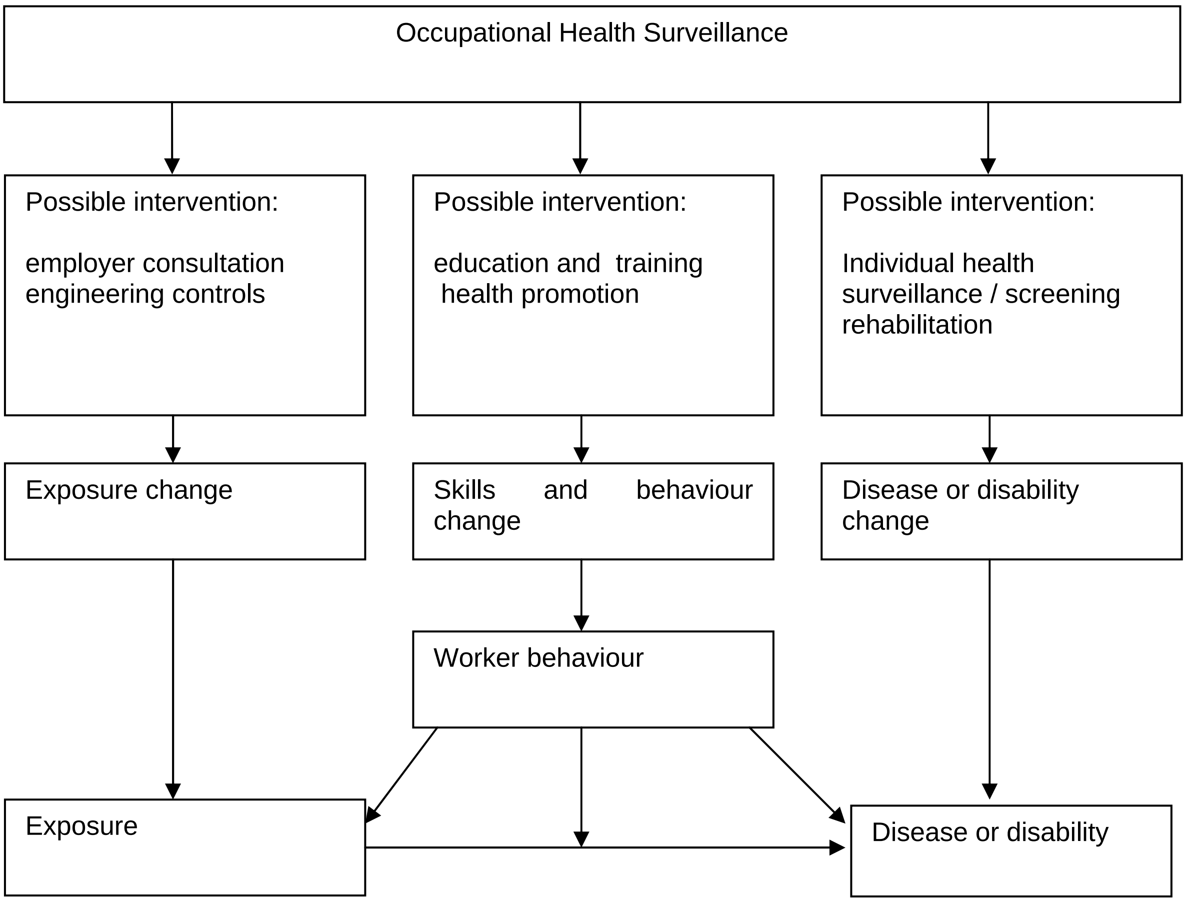
In most cases only a combination of administrative, technical and medical actions will lead to an effective prevention of vibration-induced disorders.

Administrative measures should include adequate information and advice to employers and employees, organisational changes in the work, and training to instruct the operators of vibrating machinery to adopt safe and correct work practices. Since continuous exposure to vibration is believed to increase vibration hazard, work schedules should be arranged to include rest periods.

Technical measures should include the choice of tools with the lowest vibration and with appropriate ergonomic design. According to the EC Directive for the safety of machinery [89/392/EEC], the manufacturer shall inform whether the frequency-weighted acceleration of HTV or WBV exceeds 2.5 or 0.5 ms^{-2} r.m.s., respectively. Maintenance conditions of machinery should be periodically checked and personal protective equipment, when available, should be provided to employees exposed to mechanical vibration. However, most of the research on vibration has concentrated on the ‘‘etiological pathway’’ between external exposure, internal load of the human body (physiological and biomechanical effects), and adverse health effects. Therefore, literature on the effects of occupational health interventions with respect to WBV is still scarce. In an experimental pretest/post-test control group study design, the process and outcome of a multifaceted occupational health intervention programme on whole-body vibration (WBV) in forklift truck drivers was evaluated [Hulshof et al, 2006]. The programme was found to be partially effective but more research in this area is needed. The same holds true for health surveillance in the case of exposure to vibration.

4.1 Aims of health surveillance in general

Health surveillance is mentioned as the cornerstone of occupational health services in many documents on occupational health services. The International Labour Office has defined occupational health surveillance as ‘the ongoing, systematic collection, analysis, interpretation and dissemination of data for the purpose of prevention’ (ILO, 1997). Surveillance is seen as essential to the planning, implementation and evaluation of occupational health programmes and control of work-related ill health and injuries and the protection and promotion of workers' health. Occupational health surveillance can be divided into workers' health surveillance and working environment surveillance (Kauppinen, 1999; Koh, 2003). In any case, health surveillance should lead to an intervention. Model 1 illustrates this broad concept of occupational health surveillance [Verbeek et al, 2004].



Model 1. Different aims of occupational health surveillance [adapted from Verbeek et al, 2004].

Individual health surveillance can be carried out as a health status assessment at different moments in a worker's career: pre-employment, periodical, at return to work after sick leave or at the termination of employment or retirement. In this draft, we restrict ourselves to pre-employment and periodical health examinations. Workers' health surveillance can be best defined as any medical examination that is carried out at otherwise healthy workers with the aim to maintain or improve the worker's health. The results of health surveillance should be used to protect and promote the health of the individual, collective health at the workplace, and the health of the exposed working population. Moreover, a worker’s health surveillance programme must ensure professional independence and impartiality of the health professionals, workers’ privacy and confidentiality of individual health information [see Appendix F].

According to different EU directives, it is obligatory for employers to provide health surveillance to workers in jobs with specific exposures such as noise, carcinogens, asbestos and, in the EU Directive 2002/44/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration), also on occupational vibration.

Health surveillance may consist of pre-employment medical screening and subsequent clinical examinations of vibration-exposed workers at regular intervals. Medical preventive programs should be managed by certified occupational health personnel.

Guidelines on protection and health surveillance of vibration-exposed workers are included in some ISO and European standards and reports [CEN 1030-1 and -2, 1994; CEN TR 12349, 1996; ISO 10819, 1996; ISO 5349-1, 2001], documents or reports from national and international institutions [Faculty of Occupational Medicine, 1993 and 2000; NIOSH, 1989; NVAB, 1999], and review papers and chapters of books [Bovenzi, 2004; Griffin, 1990; Pelmear *et al.*, 1992; Pope *et al.*, 2002; Staal *et al.*, 2003; Sorock *et al.*, 1997; Spitzer *et al.*, 1987; Waddell and Burton, 2000].

The European Directive 89/391/EEC (article 14, para. 1) states that: "*to ensure that workers receive health surveillance appropriate to the health and safety risks they incur at work*, *measures shall be introduced in accordance with national law and/or practices*".

According to the European Directive 2002/44/EC on mechanical vibration (article 8, para. 1), “*health surveillance, the results of which are taken into account in the application of preventive measures at a specific workplace, shall be intended to prevent and diagnose* *rapidly any disorder linked with exposure to mechanical vibration. Such surveillance shall be appropriate where:*

- *(i)* *the exposure of workers to vibration is such that a link can be established between that exposure and an identifiable illness or harmful effects on health;*
- (ii) *it is probable that the illness or the effects occur in a worker's particular working conditions;*
- (iii) *there are tested techniques for the detection of the illness or the harmful effects on health.*

In any event, workers exposed to mechanical vibration in excess of the values stated in Article 3(1)(b) and (2)(b) shall be entitled to appropriate health surveillance".

The values reported in Article 3(1)(b) and (2)(b) of the EU Directive are the daily exposure action values for HTV and WBV expressed in terms of $A(8)$, (Table 1).

One of the objectives of VIBRISKS is the development of common procedures for HTV and WBV health surveillance, including the development of improved methods for the detection and diagnosis of disorders. In this context, protocols for the health surveillance of workers exposed to either HTV or WBV have been developed. The protocols are to provide tools for assessing health effects in the upper limbs (HTV exposed workers) or in the lower back (WBV exposed workers) that can be used for health surveillance in the workplace, and in epidemiological research. The tools that have been developed include guidelines for health surveillance, questionnaires for initial assessment and periodic medical examinations at regular intervals, and the definition of a battery of objective tests for the assessment of vibration-induced disorders.

4.2 Aims of health surveillance in case of exposure to vibration

In the field of occupational exposure to mechanical vibration, the aims of health surveillance are:

- (i) to inform the workers on the potential risk associated with vibration exposure;
- (ii) to assess worker's health status and fitness for work;
- (iii) to diagnose vibration-induced disorders at an early stage;
- (iv) to give preventive advice to employers and employees;

(v) to control the long-term effectiveness of preventive measures.

The employers should provide a health monitoring program for all workers occupationally exposed to vibration according to the provisions of the EU Directive and in accordance with national laws and/or practice (Art. 8, para. 1). The EU Directive on mechanical vibration establishes that health surveillance is compulsory for workers exposed to vibration exceeding the daily exposure action values reported in Table 1. Moreover, the Directive requires that the employer shall take immediate action to reduce exposure if the daily exposure limit values have been exceeded.

Appropriate facilities for the health surveillance of the vibration-exposed workers should also be provided by the employers. The management of a health surveillance program for workers exposed to vibration should be under the supervision of a physician with a speciality in occupational medicine or at least with a certified training in occupational health ("competent doctor"). Practical routine procedures for the application of the health surveillance program may be carried out by allied health professionals with experience in occupational health problems. The workers should be informed by the health care staff that their personal and health data will be confidentially treated and preserved.

Pre-placement medical assessment and periodic clinical examinations at regular intervals shall be conducted for each worker exposed to mechanical vibration in excess of the daily exposure action values established by the EU Directive. Moreover, health surveillance is appropriate when there is evidence for the conditions listed in article 8 (para. 1) of the Directive.

It should be noted that no one sign or symptom is specific of vibration-induced injuries and that the clinical features of the disorders may be found in several other diseases. As a result, the occupational health physician should consider various clinical and laboratory tests in order to perform a differential diagnosis when the case history and the physical examination suggest the presence of symptoms or signs possibly related to occupational exposure to vibration.

5. Health surveillance for workers exposed to hand-transmitted vibration

5.1 Pre-placement medical examination

A pre-placement medical examination should be offered to each worker who will handle vibrating tools on the job. The main purposes of pre-placement health assessment are (i) to make the worker aware of the hazards connected with the use of vibrating tools, (ii) to obtain baseline health data for comparison with the findings of subsequent periodical health examinations, and (iii) to verify the presence of pathological conditions which may increase the risk of adverse health effects due to exposure to hand-transmitted vibration.

The pre-placement medical evaluation must be performed according to the principles and practice of occupational medicine and shall include the case history, a complete physical examination and, if necessary, screening tests and special diagnostic investigations according to the clinical judgement of the physician.

5.1.1 THE CASE HISTORY

The case history should focus on:

- the family history, with particular reference to vascular disorders (e.g. arterial hypertension, vasospastic syndromes, constitutional white finger), metabolic diseases (e.g. diabetes, gout), and immunologic disorders (e.g. rheumatoid arthritis);
- the social history, including smoking habit and alcohol consumption;
- the work history, with particular reference to past and current occupations with exposure to hand-transmitted vibration, details about the types of vibrating tools used, the daily and total duration of exposure to hand-transmitted vibration, and previous jobs with exposure to neurotoxic or angiotoxic agents. Leisure activities involving the usage of vibrating tools should be also investigated;
- the personal health history, with details of acute or chronic disorders in the body organs, past and present vascular, neurological and musculoskeletal disturbances in the hand-arm system, any injuries or surgery to neck and upper limbs, and use of medicines; symptoms of whiteness and/or blueness, tingling and numbness, as well as their distribution in the fingers and hands must be carefully investigated.

Note 1: information on personal, social, work, and health histories may be obtained by means of a standardised questionnaire. The questions should be validated and the answers easy to be analysed. In field surveys, a short questionnaire, including a few items to determine if exposure to hand-transmitted vibration causes health problems, may be either self-administered or administered by occupational health professionals (e.g. nurses, medical assistants). A comprehensive questionnaire including detailed personal, work and health information, may be required if the aims of the investigation are the clinical and/or medicolegal evaluation of the worker or the assessment of exposure-response relation in epidemiologic studies. Since the management of such a questionnaire requires a substantial medical background, the questionnaire should be administered by an occupational health physician.

Examples of questionnaires for hand-transmitted vibration can be downloaded at http://www.humanvibration.com.

Note 2: at the first clinical examination, particular attention should be paid to any condition which may aggravate the effects of exposure to hand-transmitted vibration (e.g. constitutional tendency to white finger, some forms of secondary Raynaud's phenomenon, past injuries of the upper limbs causing circulatory disturbances or deformity of bones and joints, neurological disorders). The use of some drugs which can affect peripheral circulation (e.g. β-blocking agents) should be recorded. Appendix A reports a list of possible medical conditions that may increase the risk of upper limb disorders in workers exposed to hand-transmitted vibration.

Note 3: as part of the employee education and health surveillance, the occupational health professional should advise the worker to wear adequate clothing to keep the entire body warm, and to avoid or minimise the smoking of tobacco. Gloves are useful to protect the fingers and hands from traumas and to maintain them warm. To be effective at attenuating vibration, gloves shall succeed the test required by the international standard ISO 10819 [1996].

5.1.2 The physical examination

A comprehensive physical examination, with special reference to the peripheral vascular, neurological, and musculoskeletal systems, should be performed by a qualified physician.

In general, the presence of skin callosities, Dupuytren's contracture, and scars from previous traumatic injuries or surgery in the hands should be described. Any abnormality of the upper limbs should be also reported.

The examination of the *vascular system* should include evaluation of skin colour, temperature and trophism in the fingers and hands; report of the presence, strength and symmetry of the brachial, radial, ulnar, and posterior tibial pulses; measurement of systolic and diastolic pressures in both arms; and measurement of pulse rate.

The integrity of the *peripheral nervous system* should be screened by a routine neurological examination including sensation (pain, light touch, temperature, and vibrotactile perception) and reflexes in the upper and lower limbs.

The physical examination of the *musculoskeletal system* in the upper limbs should include inspection for local swelling, muscle wasting or atrophy, and bone and joint deformities; palpation of muscle tendon and insertions; evaluation of range of movement and muscle strength.

5.1.3 Clinical tests

Further assessment of the anatomical and functional integrity of the peripheral vascular, neurological, and musculoskeletal systems can be performed by means of simple clinical tests (Appendix B). In general, the validity of these clinical tests is questionable and their sensitivity and specificity are reported to be low. Nevertheless, such tests may be helpful both to support the presence of disorders of the hand-arm vibration syndrome and to assess clinically their progression.

Clinical tests for the *peripheral vascular system* include the Lewis-Prusik test (for the assessment of capillary circulation), the Allen test (for the patency of the palmar arches and the digital arteries), and the Adson test (for the vascular component of the thoracic outlet syndrome).

Clinical tests for the *peripheral nervous system* include the evaluation of manual dexterity (e.g. coin recognition and pick up), the Roos test (for the neurogenic component of the thoracic outlet syndrome), the Phalen's test and the Tinel's sign (for carpal tunnel compression).

Clinical tests for the screening of the peripheral neurological and vascular systems, and standardised criteria for the clinical diagnosis of several musculoskeletal disorders of the neck and upper limbs, as well as of entrapment neuropathies, are reported in Appendix C [Harrington *et al.*, 1998; Ohlsson *et al.*, 1994; Waris *et al.*, 1979].

5.2 Periodic medical examination

The pre-placement examination should be followed by periodic health re-assessment with a regular interval according to the national legislations. Periodic medical examination shall be made available to all workers exposed to hand-transmitted vibration in excess of the daily exposure action value established by the EU Directive 2002/44/EC (i.e. $A(8)$ 2.5 ms^{-2} r.m.s.).

At the periodic medical examination, which should be conducted in the same way as described in para. 5.1.1 to 5.1.3, any change in work practices with vibrating tools should be reported in a follow-up questionnaire (see at http://www.humanvibration.com). Moreover, any illness or injury occurred since the last examination, any symptom possibly related to vibration exposure, as well as the findings of the physical examination should be also reported.

The reported findings for the individual should be compared with previous examinations.

The peripheral neurological and vascular signs and symptoms noted during the examination should reported and staged according to the Stockholm scales (Tables 2 and 3). A numerical system for symptoms of finger whiteness has been proposed as a means of scoring severity [Griffin, 1990]. This method may be useful for monitoring progression or regression of symptoms in individual fingers. It should be noted that both the Stockholm scales and the numerical scoring system have limitations. However, they are currently accepted as a pragmatic compromise and may be used in clinical work and epidemiological studies [Stockholm Workshop 94, 1995].

Grouped, anonymous, data should be compiled periodically and reported to management and representatives of employees.

Note 4: according to the report of a working group at the Stockholm Workshop 94 [1995], a medical interview is the best available method for the diagnosis of VWF. Therefore, in addition to the findings of the questionnaire investigation, the anamnestic diagnosis of VWF should be validated with a medical interview. The following minimal requisites for the anamnestic diagnosis of currently active VWF in a medical interview have been suggested:

(i) cold provoked episodes of well demarcated distal whiteness in one or more fingers [a history of cyanosis (blueness) alone is not acceptable immediately as diagnostic discolouration of VWF and further investigation for other secondary causes and/or diseases is recommended];

(ii) first appearance of white finger after start of professional exposure to hand-arm vibration and no other probable causes of Raynaud's phenomenon;

(iii) VWF is currently active if episodes have been noticed during the last two years. If no episodes have occurred for more than two years, VWF has ceased, provided there has been no significant change in cold exposure.

Note 5: observation of an attack of white finger is an important diagnostic marker. Vibration-exposed workers should be instructed to report and demonstrate white finger when it first occurs or if there is deterioration. Physicians and their staff should record these pathological events.

5.3 Special diagnostic investigations

Special diagnostic investigations should be decided by the physician on the basis of the worker's symptoms and the results of the clinical examination. Special investigations may be required (i) to establish a clinical diagnosis of the hand-arm vibration syndrome, (ii) to achieve accurate staging of the syndrome, (iii) to make differential diagnosis, and (iv) for medicolegal purposes.

These investigations may be performed by occupational health professionals with appropriate expertise or by specialists in the relevant medical disciplines.

Various laboratory diagnostics of vascular and neurological symptoms induced by hand-transmitted vibration have been discussed in the Stockholm Workshop 94 and consensus reports have been published in an issue of Arbete och Hälsa [1995].

5.3.1 Vascular investigations

The vascular assessment of the hand-arm vibration syndrome is mainly based on cold provocation tests with visual inspection of changes in finger colour, recording of recovery times of finger skin temperature, and/or measurement of finger systolic blood pressure. The cold test for the assessment of peripheral vascular function should be conducted according to the recommendations of international standard ISO 14835 – Part 1 (measurement and evaluation of finger skin temperature) and Part 2 (measurement and evaluation of finger systolic blood pressure), [2005].

The observation of a finger blanching attack after cold water immersion or the detection of an abnormal digital blood pressure after a standardised cooling procedure (e.g. zero pressure or a digital pressure at 10°C <60-70% of the pressure at 30°C) are the most supportive objective tests for a diagnosis of cold-induced Raynaud’s phenomenon [Bovenzi, 1998; Stockholm Workshop 94, 1995].

It should be noted that a negative cold test does not exclude the diagnosis of Raynaud’s phenomenon in a subject with a reliable anamnestic history of white fingers [Stockholm Workshop 94, 1995].

The use of other non-invasive diagnostic tests, such as Doppler recording of arm and digital blood flow and pressure, may be useful to detect arterial obstructions in subjects with severe finger blanching symptoms.

5.3.2 NEUROLOGICAL INVESTIGATIONS

The neurological assessment of the hand-arm vibration syndrome includes several psychophysical and neurophysiological tests. The experts of the Stockholm Workshop 94 [1995] recommend the use of vibration perception thresholds (single or multi frequency) and aesthesiometry (gap detection) for testing the function of various skin mechanoreceptors and their connected A-β myelinated fibres. Thermal perception thresholds are useful to investigate the function of unmyelinated C-fibres (hot thermoreceptors) and A-δ fibres (cold thermoreceptors).

Vibrotactile perception thresholds for the assessment of nerve dysfunction should be conducted according to the recommendations of International Standard ISO 13091 – Part 1 (methods of measurement at the fingertips) and Part 2 (analysis and interpretation of measurements at the fingertips), [2001].

The measurement of sensory and motor nerve conduction velocities in the upper and lower limbs is recommended for the diagnosis of peripheral nerve entrapments (e.g. median and ulnar nerves at the wrist and elbow) and generalised polyneuropathies. The diagnosis of carpal tunnel syndrome should be based on clinical and electrodiagnostic investigations according to the consensus criteria by Rempel *et al.* [1998] and the American Association of Electrodiagnostic Medicine [2002].

Electromyography and F-response should be also considered if proximal disorders are suspected (e.g. cervical disorders, rhizopathy).

The Purdue pegboard (assembly of pins, collars, and washers) is considered a useful testing method to measure gross movements of fingers, hands and arms and to evaluate fingertip dexterity.

5.3.3 MUSCLE STRENGTH INVESTIGATIONS

The quantitative evaluation of muscle force in the hand can be performed by means of a dynamometer to measure grip strength and a pinch gauge to measure tip, key and palmar pinch strength. Standardised testing procedures and normative data for adult males and females are available in the scientific literature [Mathiowetz *et al.*, 1985].

5.3.4 Radiological investigations

X-ray films of the shoulders, elbows, wrists and hands for a radiological diagnosis of bone and joint disorders are usually required in those countries in which vibration-induced osteoartropathy in the upper limbs is recognised as an occupational disease. Sometime, radiological examination of the cervical spine and ribs may be useful to exclude the presence of thoracic outlet syndrome or costoclavicular syndrome.

5.3.5 Laboratory tests

Haematologic assessment [total and differential blood cell counts, sedimentation rate, blood viscosity, glucose, uric acid, rheumatoid factor, autoimmune serology (anti-nuclear antibodies, anti-DNA antibodies, anti-nucleolar antibodies, anti-centromere antibodies, ENA antibodies, anti-cardiolipin antibodies), cryoglobulins, serum protein electrophoresis, immunoglobulins] and urinalysis for proteinuria and glycosuria are recommended when history or clinical findings indicate need for differential diagnosis with other vascular or neurological disorders such as some of those indicated in Appendix A.

5.4 Avoidance of HTV exposure

Avoidance or reduction of vibration exposure for workers affected with disorders of the hand-arm vibration syndrome should be decided after considering the severity of symptoms, the characteristics of the entire working process, and other aspects related to the company's medical policy and the legislation of the country. Some Institutions recommend that exposure to hand-transmitted vibration should be avoided for workers who reach either stage 2 vascular or stage 2 neurological on the Stockholm Workshop scales [Faculty of Occupational Medicine, 1993]. Since there is clinical and epidemiologic evidence that some vibration-induced disorders, mainly the vascular component of the hand-arm vibration syndrome, may be reversible when vibration exposure is ceased, the physician should discuss with the employee the possibility of his/her re-employment in working practices with vibrating tools if previous symptoms and signs have improved sufficiently according to well-established medical criteria.

It should be noted that the EU Directive on mechanical vibration (Art. 8, para. 3) establishes that "*where, as a result of health surveillance, a worker is found to have an identifiable disease or adverse health effect which is considered by a doctor or occupational health-care professional to be the result of exposure to mechanical vibration at work:*

(a) the worker shall be informed by the doctor or other suitably qualified person of the result which relates to him personally. He shall, in particular, receive information and advice regarding any health surveillance which he should undergo following the end of exposure;

(b) the employer shall be informed of any significant findings from the health surveillance, taking into account any medical confidentiality;

(c) the employer shall:

- *review the risk assessment carried out pursuant to Article 4,*
- *review the measures provided for to eliminate or reduce risks pursuant to Article 5,*
- *take into account the advice of the occupational health care professional or other suitably qualified person or the competent authority in implementing any measures required to eliminate or reduce risk in accordance with Article 5, including the possibility of assigning the worker to alternative work where there is no risk of further exposure, and*
- *arrange continued health surveillance and provide for a review of the health status of any other worker who has been similarly exposed. In such cases, the competent doctor or occupational health care professional or the competent authority may propose that exposed persons undergo a medical examination*".

5.5 Treatment

Medical treatment of the hand-arm vibration syndrome is usually of limited benefit.

No controlled clinical trial has been conducted in vibration-exposed patients to assess the effectiveness of pharmacological agents commonly used for the treatment of Raynaud's phenomenon, such as calcium channel antagonists, α_1-adrenoreceptor antagonists, antifibrinolytics, prostanoids or nitroglycerin paste applied to affected digits. In case series reports, the calcium channel blocker nifedipine was the most frequently used drug, but its long-term effectiveness on the relief of vibration-induced vasospastic symptoms is not known. Moreover, calcium channel antagonists may be associated with side effects such as hypotension, swelling, headache and blushing.

Digital sympathectomy or pharmacologically-induced regional nerve blockage are associated with temporary benefit even in patients with trophic cutaneous changes in severe Raynaud's phenomenon. These invasive practices are rarely justified in persons affected with VWF.

Workers suffering from white fingers should be instructed to wear adequate clothing and suitable gloves to keep their hands, feet and body dry and warm, mainly when travelling or working with vibrating tools. Anti-vibration gloves, as defined in ISO 10819 [1996], can be beneficial to reduce vibration exposure. Other measures (use of chemical heat packs, breaks in a warm environment, abstaining from smoking) may be also useful to reduce the frequency of finger blanching attacks.

At present, there is no specific treatment regimen for the neurological component of the hand-arm vibration syndrome.

Carpal tunnel-release surgery may be effective in vibration-exposed workers affected with CTS, even though it has been reported that the prognosis may be less favourable than in patients not exposed to HTV, mainly in those cases in which CTS symptoms coexist with other vibration-induced neurological disorders such as digital neuropathy. Conservative treatments for CTS (splinting, nonsteroidal antiinflammatory medication, local corticosteroid injection) have been proven to be effective in mild form of nerve impairment when associated with reduction of activities at home and work which can exacerbate symptoms [Katz and Simmons, 2002].

The medical management of musculoskeletal symptoms caused by working with vibrating tools is similar to that adopted for work-related neck and upper limb disorders associated with exposure to adverse ergonomic stressors at the workplace. A primary goal of treatment strategy is to avoid the development of a chronic pain syndrome which can make the worker unable or unwilling to return to work. In this context, the occupational health physician shall take into account the several individual, medical, physical, and psychosocial variables that may play a role in the etiopathogenesis of the musculoskeletal symptoms complained by the worker. Randomised trials have suggested that intensive muscular training, chiropractic treatments, learning and behavioural therapies, and/or biofeedback techniques can result in substantial improvement of pain and function in the upper limbs of workers with specific and non-specific musculoskeletal syndromes [Hagberg, 2002].

6. Health surveillance for workers exposed to whole-body vibration

6.1 Pre-placement medical examination

A pre-placement health examination should be offered to each worker who will be exposed to WBV at work. The main purposes of pre-placement health assessment are (i) to make the worker aware of the hazards connected with exposure to whole-body vibration, (ii) to obtain baseline health data for comparison with the findings of subsequent periodical health examinations, and (iii) to verify the presence of pathological conditions which could represent possible medical conditions that may increase the risk of adverse effects due to WBV.

The pre-placement health evaluation must be performed according to the principles and practice of occupational medicine and to national legislation or guidelines with respect to pre-placement examinations. It will include a case history, a physical examination and, if necessary, special diagnostic investigations according to the clinical judgement of the physician.

6.1.1 THE CASE HISTORY

The case history should focus on:

- the social personal history including use of tobacco and alcohol and being involved in physical activities;
- the work history, with particular reference to past and current occupations with exposure to whole-body vibration; details about the types of vehicles used, the daily and total duration of exposure to whole-body vibration, the working posture, lifting tasks and other work-related back stressors. Leisure activities involving driving of vehicles causing exposure to WBV should be also investigated;
- sports activities or hobbies during leisure time, which may impose high spinal loads, should be recorded;
- the personal medical history, in particular with details of past and present acute or chronic back pain complaints, disorders in the spine, any injuries or surgery to the musculoskeletal system.

Note 6: Information on personal, social, work and health histories may be obtained by means of a standardised questionnaire. The questions should be validated and the answers easy to be analysed. Examples of questionnaires for WBV can be downloaded at http://www.humanvibration.com.

The use of clinical practical guidelines for low back pain is also recommended [Bigos *et al.*, 1994; Royal College of General Practitioners, 1999].

As part of employee education and health surveillance, the occupational health professional should provide information on the possible preventative measures to avoid or minimise the risk of adverse effects due to whole-body vibration.

6.1.2 The physical examination

A physical examination on the lower back should be performed on workers who have experienced low back symptoms over the past 12 months. This physical examination should include:

- examination of the back function and evaluation of the effects on pain:
    - forward flexion
    - extension
    - lateral flexion
- straight leg raising test
- peripheral neurological examination:
    - knee and Achilles tendon reflexes
    - sensitivity in leg/foot
    - signs of muscle weakness (extension m quadriceps, flexion/extension big toe/foot)
- back endurance test (tentative extra test)
- Waddell's signs of non-organic pain [Waddell *et al.*, 1980]

Note 7: methods for physical examination of the lower back are available in Appendix C

6.1.3 Additional investigations

In the absence of positive symptoms and signs and unless indicated by clinical practice guidelines, it is in general not acceptable, for the purpose of a pre-placement examination, to perform further diagnostic clinical examinations like X-ray of the lumbar spinal column, CT-scan, myelography, or MRI. In some guidelines on the management of occupational LBP, imaging examination is restricted to cases with neurological problems (radicular symptoms) or suspected specific spinal pathology like fractures, infections, or tumors ("red flags"), [Royal College of General Practitioners, 1999].

Note 8: at the pre-placement examination, particular attention should be paid to any condition, which may aggravate the effects of exposure to WBV (e.g. poor posture, heavy and/or frequent lifting, tobacco use, and psycho-social factors). Appendix E reports a list of possible medical conditions that may increase the risk of disorders of the spine or other organs and structures in workers exposed to WBV.

6.2 Periodic medical examination

The pre-placement examination should be followed by periodic health re-assessment with a regular interval according to national legislations. Periodic medical examination shall be made available to all workers exposed to whole-body vibration in excess of the daily exposure action value established by the EU Directive 2002/44/EC (i.e. $A(8)$ 0.5 ms^{-2} r.m.s., or VDV 9.1 ms$^{-1.75}$).

At the periodic medical examination, which should be conducted in the same way as described earlier, any change in work practices with the driving of vehicles or other sources of WBV should be reported in a follow-up questionnaire (http://www.humanvibration.com). Moreover, any illness or injury listed in Appendix E and which has occurred since the last examination, any symptom possibly related to vibration exposure as well as the findings of the physical examination should be also reported.

Imaging studies should be limited to workers with LBP associated with neurological symptoms or signs, serious "red flags" conditions, or when symptoms do not improve over 4 weeks [Royal College of General Practitioners, 1999].

At the periodic health examinations of workers exposed to WBV, the occupational health physician shall investigate symptoms and signs of disorders possibly caused by excessive exposure to WBV. Since all symptoms and signs associated with these disorders may be found in several other diseases, the physician shall consider all pathological conditions which can either increase the susceptibility of the individual to the adverse health effects of WBV or worsen vibration-induced injuries to the spine or other organs.

The reported findings for the individual should be compared with previous examinations. Group data should be compiled periodically and reported to management and representatives of employees.

6.3 Avoidance of WBV exposure

Avoidance or reduction of vibration exposure for workers affected with disorders possibly related to WBV and listed in Appendix E should be decided after considering the severity of symptoms, the characteristics of the entire working process, and other aspects related to the company's medical policy and the legislation of the country.

Since (low) back symptoms may improve when vibration exposure is ceased, the physician may discuss with the employee the possibility of his/her re-placement in working practices without exposure to whole-body vibration.

According to the EU Directive on mechanical vibration (article 8, para. 3), if a worker is found to be affected with a health disorder associated exposure to mechanical vibration "*the employer shall ….. take into account the advice of the occupational health care professional or other suitably qualified person or the competent authority in implementing any measures required to eliminate or reduce risk in accordance with Article 5, including the possibility of assigning the worker to alternative work where there is no risk of further exposure*".

6.4 Treatment

The management of low back pain at workplace is one of the major challenges for the occupational health professional. Since work is only one of the component of the multifactorial origin of LBP disorders, the occupational physician should take into account the broad variety of individual, medical, physical, psychosocial and organisational risk factors which can concur to the onset and aggravation of LBP symptoms in the injured worker [Carter and Birrell, 2000; Staal *et al.*, 2003].

Imaging studies have revealed non-specific findings in the great majority of persons affected with LBP and, conversely, degenerative changes in the lumbar vertebrae and disks have been found in asymptomatic subjects. Hence, the management of the worker with LBP should include educational interventions with the aims to provide information and advice to employees and employers, to reassure the patient about the benign prognosis of LBP, to overcome fear avoidance beliefs, and to promote self-care [Carter and Birrell, 2000].

There is strong scientific evidence that "back or abdominal belts" or "back supports" do not reduce work-related low back injuries and sickness absence [Carter and Birrell, 2000].

The primary goals of treatment are to relieve pain, to restore function, and to encourage patients to become active early and gradually in ordinary and work activities in order to prevent the risk of chronic pain and disability [Verbeek, 2001]. There is strong evidence that the longer a worker is off work with LBP, the lower their chances of ever returning to work [Carter and Birrell, 2000].

Guidelines for the occupational health management and treatment of LBP suggest a combination of pharmacological therapy, active and progressive exercise and physical fitness programme, multidisciplinary rehabilitation, and organisational interventions by the employers/supervisors to facilitate return to work. There is moderate evidence that a combination of measures is more effective than a single method of treatment alone [Carragee, 2005; Carter and Birrell, 2000; Staal *et al.*, 2003].

There is general agreement that bed rest as a treatment for simple (low) back pain is not recommended [Carragee, 2005; Carter and Birrell, 2000]. For acute or recurrent LBP with or without referred leg pain, bed rest for 2-7 days is worse than placebo or ordinary activity. Prolonged bed rest may lead to chronic disability and increasing difficulty in rehabilitation.

Pharmacological treatment of LBP includes analgesics, antiinflammatory drugs, muscle relaxants, and antidepressant drugs. These pharmacological agents are effective for simple (low) back pain, while their benefits for nerve root pain are inconsistent. Adverse effects (e.g. gastrointestinal and neurological problems) should be also considered. Long-term treatment with narcotics or sedatives should be avoided because their significant adverse side effects.

Rehabilitation programmes include manipulation, some forms of “back school”, and progressive active back exercises accompanied by cognitive behavioural therapy. Manipulative treatment within the first six weeks of onset of acute or recurrent low back pain seems effective in patients who need additional help with pain relief or who are failing to return to normal activities, but the evidence is inconclusive [Carragee, 2005]. A Cochrane review of randomised trials of various exercises for persistent LBP (strengthening, general stretching, McKenzie passive stretching exercises, conventional physical therapy) showed that exercise programmes have some positive effects on the recovery of pain and disability as compared with placebo or usual care, but no difference in the outcomes of the different exercise programmes was found [van Tulder *et al.*, 2000].

Occupational health guidelines for the management of LBP recommend that workers having difficulty to return to work within 2 – 12 weeks, should refer to a gradually increasing exercise programme or a multicomponent rehabilitation programme, which should be implemented within an integrated occupational health and safety system [Carter and Birrell, 2000; Waddell and Burton, 2000].

In summary, available data suggest that intensive multidisciplinary programmes combining medical, behavioral and rehabilitative components are associated with improvement of (low) back pain, reduction of functional disability and decrease in sick leave, even though there is no clear evidence for their long-term effects. In addition to these strategies, the management of LBP in an occupational setting should require organisational interventions on several aspects of the work system (time schedules, tasks, technology, environment and industrial relations). As pointed out by a Working Group of the Faculty of Occupational Medicine [London, 2000]: “*A major feature of the occupational (as opposed to clinical) guidance is the concept that work organisation and communication between workers and supervisors/management are important elements of occupational health management; education of both workers and employers is seen as important*”.

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Appendix A

List of medical conditions that may increase the risk of upper limb disorders in workers exposed to hand-transmitted vibration. It should be noted that some of the disorders or diseases included in the table are incompatible with any work activity.

Vascular

1. **Primary Raynaud's phenomenon**
2. **Secondary Raynaud's phenomenon** caused by:
   - 2.1 Connective tissue diseases (e.g. scleroderma, systemic lupus erythematosus, dermatomyositis, polyarteritis nodosa, rheumatoid arthritis, Sjögren's disease)
   - 2.2 Occlusive vascular disease (e.g. thromboangiitis obliterans, atherosclerosis)
   - 2.3 Compression of proximal vessels (e.g. thoracic outlet syndrome, costoclavicular syndrome, hyperabduction syndrome)
   - 2.4 Trauma (e.g. following injury, fracture or surgery, frostbite)
   - 2.5 Neurogenic disorders (e.g. poliomyelitis, syringomyelia, hemiplegia)
   - 2.6 Blood abnormalities (e.g. polycythaemia vera, cryoproteinemias, macroglobulinemia, thrombocytosis)
   - 2.7 Occupational chemical agents (e.g. vinyl chloride, arsenic, nitrates)
   - 2.8 Drugs (e.g. β-adrenoceptor blocking agents, ergot preparations, clonidine, chemotherapeutic agents, cyclosporin)
   - 2.9 Miscellaneous (e.g. vasculitis, arteriovenous fistula, fibromyalgia, hypothyroidism, reflex sympathetic dystrophy, neoplasms)
3. **Peripheral vascular disorders**
   - 3.1 Arteriosclerosis obliterans
   - 3.2 Thromboangiitis obliterans (Buerger's disease)
   - 3.3 Acquired arteriovenous fistulas
   - 3.4 Erythromelalgia
4. **Vascular disorders secondary to malformations, injuries, fractures, or surgery in the hand, arm, or neck**

Neurological

1. **Peripheral nerve entrapment** (e.g. carpal tunnel syndrome, pronator syndrome, Guyon's syndrome, cubital tunnel syndrome)
2. **Peripheral neuropathy** (e.g. diabetic, alcoholic and toxic neuropathies, cervical radiculopathy)
3. **Disorders of the central nervous system** (e.g. compressive myelopathy, multiple sclerosis, degeneration of the spinal cord)
4. **Neurological disorders secondary to malformations, injuries, fractures, or surgery in the hand, arm, or neck**

Musculoskeletal

1. **Severe tendinitis or tenosynovitis in the hand-wrist, elbow, or shoulder** (e.g. de Quervain's tendinitis, lateral epicondylitis, shoulder tendinitis)
2. **Severe unspecific cervicobrachial disorders**
3. **Severe Dupuytren's contracture**
4. **Severe degenerative bone and joints disorders in the upper limbs and the neck**
5. **Severe deformities of the bone and joints of the upper limbs secondary to malformations, injuries, fractures, or surgery**
6. **Severe myopathies** (e.g. primary fibromyalgia, myofascial syndrome, alcoholic myopathy, drug-induced myopathy, muscle pain syndrome of unknown etiology)

Appendix B

Clinical tests and manoeuvres for the assessment of upper limb disorders .

- ***Lewis Prusik test***. This test is designed to assess capillary circulation. Pressure is applied to the nail bed for ten seconds and, on release, normal colour should return in two seconds or less. The method is poorly standardised.
- ***Adson's test***. This test is designed to detect the vascular component of the thoracic outlet syndrome. During deep inspiration, with the head rotated to the side being tested and the arm abducted, the radial artery at the wrist is palpated. In presence of subclavian obstruction, the radial pulse is reduced or absent.
- ***Roos's test***. This test is designed to detect the neurogenic component of the thoracic outlet syndrome. The subject sits erect and elevates both arms to the 90° abduction-external-rotation position with the elbows slightly braced back of the frontal plane ("hands up" position). The subject is then asked to open and close his/her hands slowly for three minutes. Patients with thoracic outlet syndrome develop progressive distress and reproduction of their usual symptoms such as pain in the neck, shoulder and/or arms; numbness and/or tingling of the extremities; heaviness, fatigue, and weakness of the arm and/or hand.
- ***Allen's test***. This test examines the patency of the palmar arches and the digital arteries. The examiner uses the fingers of each hand to compress the radial and ulnar arteries at the wrist and then raises the subject's hand while the subject opens and closes the hand for 20 seconds to empty the palmar arches and subcutaneous vessels. The hand is then lowered and one of the arteries released. Prompt flushing of the hand indicates a normal contribution from the tested artery. Faint and delayed flushing of the fingers (more than five seconds) indicates that either the deep palmar or the digital arteries may be occluded. The test is also used for the diagnosis of the hypothenar hammer syndrome which consists of symptoms and signs of digital ischaemia caused by thrombosis and/or aneurysm of the ulnar artery and/or the superficial palmar arch. It should be noted that normal anatomical variations may give rise to false positive results.

- ***Tinel's sign***. This test, if positive, is consistent with the presence of carpal tunnel syndrome. The subject's hand and forearm are rested horizontally on a flat, firm surface with the palm uppermost. The examiner places his/her index finger over the carpal tunnel at the wrist and applies a sharp tap to it with a tendon hammer. The complaint of pain or tingling in the subject's fingers (thumb, index, or middle finger) indicates median nerve compression at the wrist. A positive Tinel's sign over the Guyon's tunnel or the cubital tunnel suggests ulnar nerve compression at the wrist or the elbow, respectively.

- ***Phalen's test***. This test, if positive, is consistent with the presence of carpal tunnel syndrome. The subject raises his/her arms to chin level and then allows both hands to flex at the wrist by gravity. This posture should be maintained for one minute. Pain, tingling, or numbness in the median-nerve distribution of the hand is indicative of compression of the median nerve under the carpal ligament.

- ***Spurling's test***. This test, if positive, is consistent with the presence of cervical radiculopathy. The sitting patient's head is rotated and flexed laterally to the same side by the examiner. The complaint of pain and numbness in the forearm and hand of the side to which the patient's head is rotated and flexed suggests a cervical nerve root compression and irritation.

- ***Finkelstein's test***. This test, if positive, is consistent with the presence of De Quervain's disease (inflammation of the tendons to the long abductor and the short extensor muscle of the thumb). The subject makes a fist over the thumb, which is flexed into the palm, followed by ulnar deviation of the wrist. This manoeuvre increases the excursion of the first dorsal compartment tendons and leads to significant discomfort in individuals affected with De Quervain's disease.

Appendix C

Criteria for clinical diagnoses of neck and upper limb musculoskeletal disorders [Harrington *et al.*, 1998; Ohlsson *et al.*, 1994; VINET, 2001; Waris *et al.*, 1979].

Disorder	Symptoms and signs
Tension neck syndrome	Neck pain, feeling of fatigue or stiffness in the neck, headache radiating from the neck, muscle tightness, palpable hardenings and tender spots in muscles, straightening of the cervical spine.
Cervical syndrome	Neck pain radiating to one or both arms, numbness in the hands, limited neck movements, radiating pain provoked by test movements, diminished muscle force of the deltoid, triceps, and biceps muscles. Positive neck compression (Spurling's) test.
Thoracic outlet syndrome	Pain and paraesthesia radiating to an upper limb, fatigability or weakness in the arms, numbness of an upper limb while sleeping, coolness and Raynaud-like symptoms, tenderness in the shoulder pouch (Morley's sign), bruit in infraclavicular area, positive Adson's test and/or positive Roos test, drooping shoulder.
Shoulder tendinitis	Pain in the deltoid region, limited and painful resisted movements (abduction of the supraspinatus; external rotation of the infraspinatus and teres minor; internal rotation of the subscapularis).
Bicipital tendinitis	Anterior shoulder pain, pain over the long head of biceps tendon on resisted flexion of the elbow (Speed's sign) or on resisted supination of the forearm with the elbow flexed 90° (Yergason's test).
Frozen shoulder syndrome	Pain in the deltoid area (often nocturnal and related to activity), restricted and painful active and passive movements of the shoulder in a capsular pattern (external rotation > abduction > internal rotation).
Acromioclavicular syndrome	Local pain and tenderness at the acromioclavicular joint, pain at the end of abduction or in adduction of the arm over the chest.

Appendix C (*continued*)

Disorder	Symptoms and signs
Epicondylitis	Pain at the epicondyle either during rest or motion, local tenderness at the lateral or medial epicondyle, pain during resisted extension of the wrist and fingers (lateral epicondylitis), pain during resisted flexion of the wrist and fingers (medial epicondylitis).
Tenosynovitis of the wrist	Pain on movement localised to the affected tendon(s) in the wrist, palpable tenderness of the tendon(s), local swelling, pain on resisted active movement of the affected tendon(s) with the forearm stabilised, weakness in gripping.
De Quervain's disease	Pain over the radial styloid, tender swelling of the first extensor compartment, pain on resisted thumb extension or positive Finkelstein's test.
Cubital tunnel syndrome	Pain, paraesthesia, or numbness in the ulnar distribution of the hand, sensory loss in 4th and 5th fingers, positive Tinel's sign over the cubital tunnel, decreased strength in spreading the fingers and in flexion of the distal phalanx of 5th finger, loss of power grip, atrophy of hypothenar and interosseus muscles.
Guyon's syndrome	Pain, paraesthesia, or numbness in the ulnar nerve distribution of the hand, sensory loss in 4th and 5th fingers, positive Tinel's sign over the Guyon's tunnel, decreased strength in spreading the fingers.
Pronator syndrome	Pain in the proximal forearm, pain and numbness in radial side of palm and palmar side of first three and a half fingers, local tenderness over the edge of m. pronator teres, pain and decreased strength in pronation, decreased flexion strength of the wrist and/or of the distal phalanxes of 1st and 2nd fingers.

Appendix C (*continued*)

Disorder	Symptoms and signs
Carpal tunnel syndrome	Pain, paraesthesia, or numbess in the median nerve distribution of the hand, nocturnal exacerbation of symptoms, sensory loss in three and a half fingers on the radial side of the hand, positive Tinel's sign over the carpal tunnel, positive Phalen's test, weakness in pinching or gripping, atrophy of abductor pollicis brevis.
Hypothenar hammer syndrome	Paraesthesias, numbness, cold sensitivity, colour changes without cold exposure in the affected hand, positive Allen's test.
Dupuytren's contracture	Nodules, thickening or retraction of the skin, cords, and bands on the palmar surface of the hands and fingers, and, finally, progressive and irreversible flexion of the fingers, mostly the ring finger followed by the little finger.
Carpal ganglia	Firm mass or fullness over the dorsum of the wrist at the radiocarpal joint or at the palmar aspect of the wrist just radial to the flexor carpi radialis tendon, often asymptomatic, occasionally complaints of aching or discomfort of the wrist exacerbated by activity, rarely loss of wrist motion secondary to pain.
Trigger finger	Tenderness along the palmar flexor tendon sheath over the first annulary pulley in the distal palm with discomfort on repeated digital flexion, difficulty initiating extension of the fingers or thumb from a flexed position with accompanied pain, palpable nodule on the flexor tendon accentuated with active flexion and extension of the involved finger, inability to completely extend the finger ("locked" or incarcerated trigger finger).
Unspecified MS symptoms	Recurring or persistent pain, aching, numbness, stiffness or weakness across the upper limbs with concomitant headache, loss of function, muscle tenderness, slowing of fine movements unspecified findings on clinical examination and failure to meet the diagnostic criteria for other specific disorders and diseases.

Appendix D

Physical examination methods of the lower back [VINET, 2001; Pope *et al.*, 2002].

The patient should be barefoot and wear a standard patient gown that is open in back.

Patient standing

The examiner should stand behind the patient and observe the general configuration of the spine to detect any lateral curvatures, kyphosis, or excessive lordosis in the erect posture.

Forward flexion: the patient is asked to flex forward as far as possible and indicate any pain or discomfort. The examiner should observe the lumbar paraspinous muscles. Any eccentric contractions of the musculature suggest lumbosacral paraspinous spasms; limited motion without evidence of such eccentric contractions suggests lack of patient co-operation. Normal subjects should be able to nearly touch their toes. In general, pain increased by flexion suggests lumbar disc abnormalities. Pain increases with repetitive flexions in patients with discogenic pain. Forward flexion is often associated with a list to one side. Occasionally, patients with lumbosacral paraspinous spasm will be able to flex forward reasonably normally but will have difficulty returning to the erect position. Abnormal spinal rhythm is a typical feature in the clinical diagnosis of instability syndrome. In extreme examples, the patient may “climb up” his/her thighs to return from the flexed position. The range of motion is recorded as the distance of the fingertips from the floor or to the knees.
The patient shall return to erect position and a short rest before the next test.

Extension: during spinal extension, the examiner should ensure that the patient’s hips and knees remain locked. Particular attention should be paid to movement in the lumbar area, and this should be distinguished from hip extension. The patient is asked about the reproduction of typical back pain. Pain increased by (repetitive) extension suggests degenerative changes involving posterior elements of the spine, lumbar spinal stenosis, or both. The range of motion is not measured. The patient shall return to the erect position and a short rest before the next test.

Lateral flexion: the patient is asked to flex to the side and indicate any pain or discomfort. Normal subjects should be able to reach the fibular heads with their fingertip. The examiner should compare the range of motion to the left and to the right.

Muscle weakness: the power of plantar flexion is tested by having the patient perform 10 toe raises standing on both feet and then 10 more standing on each foot separately. Repeated activity causes fatigue of the calf muscles and reveals minimum differences in the strength of muscles innervated by the S1 nerve root. The strength of the dorsiflexors, innervated by the L4 and L5 nerve roots, is tested by having the patient walk on his/her heels.

Quadriceps is tested by having the patient squat holding on to the examiner's hand for balance.

The hip abductor muscles are tested in the Trendelenburg's test, in which the patient is asked to stand on one leg and then the other, while the examiner sits behind the patients with his hands on the patient's iliac crests. Any drop of the pelvis on the side opposite the stance leg constitutes a positive sign of weakness of the abductors on the stance leg indicating that the L5 nerve root is affected.

Patient sitting on the examination table

Peripheral neurologic examination: the knee and *Achilles reflexes* are tested with the patient sitting on the examining table with legs hanging free. A distinct strike with the reflex hammer on the tested tendon will produce an unvoluntary extension jerk of the lower leg and the foot respectively. Alternatively, for testing the Achilles reflex the patient can be kneeling on a chair holding on to the back of the chair with both hands.

With the patient sitting or lying on the examination table the strength of the *extensor hallucis longis* is tested by applying a resistance against extension of the both halluces. Weakness indicates that the L5 nerve root is affected.

Quadriceps can be tested with the patient sitting on the examination table and asked to extend his/her lower leg from the knee. The examiner puts a resistance against the extension and compares the strength with the unaffected leg. Weakness indicates that L3 and L4 nerve roots are affected.

Hip flexion is tested with the patient sitting on the examination table and asked to lift his/her leg up from the table. The examiner puts one hand just above patella and applies resistance by pressing down on the thigh. Weakness indicates that L1 and L2 nerve roots are affected.

Patient lying supine

Straight leg raising test is the classic test of sciatic nerve irritation. The examiner stands to one side of the patient, places one hand on the patient's knee to extend the knee and the other hand under the patient's heel and then lifts the leg while keeping the knee straight. A positive result produces typical pain radiating down the back of the thigh below the knee and to the foot while the leg is elevated 60 degrees or less at the hip. However, S1 and occasionally, L5 irritation can stop at the buttocks or posterior thigh. Symptoms produced at elevations greater than 60 degrees may represent irritation of the nerve root, but frequently reflect referred mechanical back pain or hamstring tightness. The examiner should also perform the crossed straight leg raising test by lifting the well leg. If this causes pain on the affected side this demonstrates an extreme irritability of the affected nerve root. Crossover pain describes a situation when pain is produced in the normally asymptomatic leg when the affected leg is lifted. Crossover pain indicates central disc herniation.

Sensitivity is tested by light strokes, using the index and middle fingers, bilaterally on the medial, anterior and lateral sides of the lower leg, the dorsal, lateral, and medial surface of the foot.

Back muscle endurance test may be indicated when back pain has been present for a long period of time (months). The patient is lying prone on the examination table. A chair is placed at the top end of the table. The patient's legs and pelvis are supported by the table. The upper trunk is outside the top end of the table and the patient supports himself by his hands on the chair. The legs are either strapped or held down by the examiner when the patient is asked to extend his upper body and put his hands behind his back. Normal or good endurance is the ability to hold the position for 4 minutes at which time the test is interrupted.

Waddell’s tests consist of five nonorganic physical signs to identify those patients who have a significant psychological or socioeconomic basis for their pain:

1. *Nonorganic tenderness* may include either broad, superficial tenderness to light touch in the lumbar region and/or widespread deep tenderness in a nonanatomic distribution.
2. *Simulation tests* suggest to the patient that a specific examination is being performed though, in fact, it is not. For example, low back pain produced with either axial loading of the skull or passive rotation of the shoulders and pelvis in the plane through the hips suggests involvement of nonorganic factors in the pain response.
3. *Distraction tests* attempt to reproduce positive physical findings while the patient’s attention is distracted. A positive supine straight-leg raising response may be suspect if the patient can flex his/her hip to 90º with the knee extended in the sitting position.
4. *Regional disturbances* are sensory and motor abnormalities that involve multiple regions and are unexplained on a neuroanatomic basis. “Give way” weakness and sensory loss in a “stocking”, rather than dermatomal, distribution probably have a nonorganic component.
5. *Overreaction* during examination is statistically the most important nonorganic physical sign. Disproportionate verbalisation, inappropriate facial expression, tremor, collapsing, and sweating are all manifestations of this Waddell sign.

Appendix E

List of medical conditions that may increase the risk of disorders of the spine or other organs and structures in workers exposed to whole-body vibration.

Disorders of the spine

1. Distinct premature (not related to age) degenerative changes in the spine
2. Disorders of the intervertebral disc (with or without radicular syndromes)
3. Active inflammatory conditions of the spine
4. Manifest acquired or congenital deformation of the spine
5. Increased stiffness of the spine (e.g. following surgical treatment)
6. Earlier spinal injuries with fractures of vertebrae
7. Recurrent episodes of chronic back pain

Other conditions

1. Severe neck-shoulder disorders
2. Chronic gastritis and/or gastric or duodenal ulcers
3. Vestibular disorders
4. Pregnancy

Appendix F

Ethical issues recommended by the International Commission on Occupational Health (ICOH):

- The objectives and the details of the health surveillance must be clearly defined and the workers must be informed about them. The validity of such surveillance must be assessed and it must be carried out with the informed consent of the workers by an occupational health professional approved by the competent authority. The potentially positive and negative consequences of participation in screening and health surveillance programmes should be discussed with the workers concerned.
- The results of examinations, carried out within the framework of health surveillance must be explained to the worker concerned. The determination of fitness for a given job should be based on the assessment of the health of the worker and on a good knowledge of the job demands and of the worksite. The workers must be informed of the opportunity to challenge the conclusions concerning their fitness for their work that they feel contrary to their interest. A procedure of appeal must be established in this respect.
- The results of the examinations prescribed by national laws or regulations must only be conveyed to management in terms of fitness for the envisaged work or of limitations necessary from a medical point of view in the assignment of tasks or in the exposure to occupational hazards. General information on work fitness or in relation to health or the potential or probable health effects of work hazards, may be provided with the informed consent of the worker concerned.

Conditions of execution of the functions of occupational health professionals

- Occupational health professionals must keep good records with the appropriate degree of confidentiality for the purpose of identifying occupational health problems in the enterprise. Such records include data relating to the surveillance of the working environment, personal data such as the employment history and health-related data such as the history of occupational exposure, results of personal monitoring of exposure to occupational hazards and fitness certificates. Workers must be given access to their own records.