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Mechanical vibration - Guide to the health effects of vibration on the human body

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Mechanische Schwingungen - Leitfaden über die Wirkung von Schwingungen auf die Gesundheit des Menschen

Vibrations mécaniques - Guide concernant les effets des vibrations sur la santé du corps humain

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Foreword

This CEN report has been drawn up by Technical Committee CEN/TC 231 "Mechanical vibration and shock", working group 5 "Vibration effects".

Annexes A and B are informative.

Introduction

This CEN report provides a short overview of the current knowledge of the possible effects of vibration on the human body. It is an informative document which presents general background information for the user of the different European Standards on vibration.

Mechanical vibration arises from a wide variety of processes and operations performed in industry, forestry and agriculture, and public utilities. Vibration caused by vehicles, powered processes, hand-held and hand-guided tools, or workpieces can greatly influence the human body. Exposure to harmful vibration can induce several complaints and health disorders, mainly at the upper limbs and the lower back. A comprehensive knowledge of the unwanted effects of vibration on the body is essential to implement appropriate administrative, technical and medical preventive measures.

1 Scope

The aim of this CEN report is to provide information on the possible adverse health effects caused by exposure to vibration at work. The report addresses manufacturers as well as employers and employees using vibrating machinery in order to improve their understanding of the possible health problems arising from occupational exposure to vibration.

This CEN report is limited to the effects on health and does not cover the potential effects of vibration on comfort, human performance or vibration perception. Most of the information on whole-body vibration in this CEN report is based upon data available from research on human response to vibration of seated persons. There are only few data on the effects of vibration on persons in standing, reclining or recumbent positions. The information on both hand-transmitted vibration and whole-body vibration is based upon data from laboratory research on acute effects as well as upon data from epidemiologic studies.

Additional information may be obtained from the scientific literature (see annex A).

2 Normative references

This CEN report incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this CEN report only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

CR 1030-1 Hand-arm vibration – Guidelines for vibration hazards reduction – Part 1: Engineering methods by design of machinery

CR 1030-2 Hand-arm vibration – Guidelines for vibration hazards reduction – Part 2: Management measures at the workplace

prEN 1299 Vibration isolation of machines – Information for the application of source isolation

ENV 25349 Mechanical vibration – Guidelines for the measurement and the assessment of human exposure to hand-transmitted vibration (ISO 5349:1986)

EN 30326-1 Mechanical vibration – Laboratory method for evaluating vehicle seat vibration – Part 1: Basic requirements (ISO 10326-1:1992)

prEN ISO 10819 Mechanical vibration and shock – Hand-arm vibration – Method for the measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand (ISO/DIS 10819:1995)

3 Hand-transmitted vibration

3.1 General

Powered processes and tools which expose operators' hands to vibration are widespread in several industrial activities. Occupational exposure to hand-transmitted vibration can arise from rotating and percussive hand-held power tools used in the manufacturing industry, quarrying, mining and construction, forestry and agriculture, and public utilities. Exposure to hand-transmitted vibration can also occur from vibrating workpieces held in the hands of the operator, and from hand-held vibrating controls such as motorcycle bars or vehicle steering wheels.

Excessive exposure to hand-transmitted vibration may include disturbances in finger blood flow, and in neurological and locomotor functions of the hand and arm. It has been estimated that 1,7 to 3,6 % of the workers in the European countries and the U.S.A. are exposed to potentially harmful hand-transmitted vibration.

The term *hand-arm vibration (HAV) syndrome* is commonly used to refer to the complex of peripheral vascular, neurological and musculoskeletal disorders associated with exposure to hand-transmitted vibration. Workers exposed to hand-transmitted vibration may be affected with neurological and/or vascular disorders separately or simultaneously. Vascular disorders and bone and joints abnormalities caused by hand-transmitted vibration are compensated occupational diseases in several countries. These disorders are also included in an European schedule of recognized occupational diseases.

3.2 Vascular disorders

Workers exposed to hand-transmitted vibration may complain of episodes of pale or white finger usually triggered by cold exposure. This disorder, due to temporary abolition of blood circulation to the fingers, is called Raynaud's phenomenon (after Maurice Raynaud, a French physician who first described it in 1862). 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 vosoconstrictor reflex caused by prolonged exposure to harmful vibration, while others tend to emphasize the role of vibration-induced local changes in the digital vessels.

Various synonyms have been used to describe vibration-induced vascular disorders: dead or white finger, Raynaud's phenomenon of occupational origin, traumatic vasospastic disease, and, more recently, vibration-induced white finger (VWF). VWF is a prescribed disease in many countries.

Initially attacks of blanching involve the tips at one or more fingers, but, with continued exposure to vibration, the blanching can extend to the base of the fingers. Sometimes, an attack of blanching is followed by cyanosis, i. e. a bluish discoloration of the affected fingers due to increased extraction of oxygen from the sluggish digital circulation. In the recovery phase, commonly accelerated by warmth or local massage, redness, eventually associated with pain, may appear in the affected fingers as a result of a reactive increase of blood flow in the cutaneous vessels. The blanching attacks are more common in winter than in summer and last from a few minutes to more than one hour. The duration varies with the intensity of the triggering stimuli, the attack is usually ending when the entire body is warmed.

If vibration exposure continues, the blanching attacks become more frequent and may occur all year around. In the rare advanced cases, repeated and severe finger blanching attacks can lead to trophic changes (ulceration or gangrene) in the skin of the fingertips. During the attack the affected workers can experience a complete loss of touch sensation and manipulative dexterity, which can interfere with work activity increasing the risk for acute injuries due to accidents. In occupational medicine various staging systems for the classification of VWF have been developed. A grading scale proposed at the Stockholm Workshop 86 is reported in table 1.

Several laboratory tests are used to diagnose white finger objectively. Most of these tests are based on cold provocation and the measurement of finger skin temperature or digital blood flow and pressure before, during and after cooling of the fingers and hands.

Epidemiologic studies have demonstrated that the prevalence of VWF varies widely, from 0 to 100 %. It appears that the probability and severity of white finger symptoms is influenced by several factors such as the characteristics of vibration exposure (frequency, magnitude, direction, impulsiveness, duration), the type of tool and work process, the environmental conditions (temperature, air flow, humidity, noise), some biodynamic and ergonomic factors (grip force, push force, arm position), and various individual characteristics (susceptibility, diseases and agents, e. g. smoking and certain medicines, affecting the peripheral circulation). Thus, there is a complex relationship between vibration exposure and the development of white finger symptoms. Epidemiologic studies suggest that the occurence of VWF increases with increasing duration of vibration exposure. There is some evidence that the cumulative exposure before the appearance of finger blanching is approximately inversely proportional to the magnitude of the vibration exposure (i. e. if the vibration magnitudes are doubled, a halving of the years of exposure is required to produce the same effect).

Since the late 1970s a decrease in the incidence 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 (e. g. cold, and physical stress). Recovery from VWF has also been reported among retired forestry workers. Similar findings are not yet available for tools of other type.

Table 1: The Stockholm Workshop scale for staging cold-induced Raynaud's phenomenon in the hand-arm vibration syndrome

Stage	Grade	Symptoms
0	–	No attacks
1	Mild	Occasional attacks affecting only the tips of one or more fingers
2	Moderate	Occasional attacks affecting distal and middle (rarely also proximal) phalanges of one o more fingers
3	Severe	Frequent attacks affecting all phalanges of most fingers
4	Very severe	As in stage 3, with trophic skin changes in the fingertips

3.3 Neurological disorders

Workers exposed to hand-transmitted vibration may experience tingling and numbness in their fingers and hands. If vibration exposure continues, these symptoms tend to worsen and can interfere with work capacity and life activities. Vibration-exposed workers may exhibit a reduction in the normal sense of touch and temperature as well as an impairment of manual dexterity at the clinical examination. As an effect of hand-transmitted vibration, also a reduction of the vibration sensitivity of the skin of the fingertips may be found. Epidemiologic surveys of vibration-exposed workers show that the prevalence of peripheral neurological disorders varies from a few percent to more than 80 %, and that sensory loss affects users of a wide range of tool type. It seems that sensorineural disturbances may develop independently of other vibration-induced disorders, probably reflecting different pathological mechanisms.

A classification for the neurological component of the HAV syndrome was proposed at the Stockholm Workshop 86, consisting of three stages according to the symptoms complained and the results of clinical neurological examination and psychophysical testing methods such as tactile discrimination, vibrotactile perception, and precision manipulation (see table 2).

Vibration-exposed workers may sometimes show signs and symptoms of entrapment neuropathies, such as carpal tunnel syndrome (CTS), a disorder due to compression of the median nerve as it passes through an anatomical tunnel in the wrist. CTS seems to be a common disorder in some occupational groups using vibrating tools such as rock-drillers, platers and forestry workers. It is believed that ergonomic stressors acting on the hand and wrist (repetitive movements, forceful gripping, awkward postures), in combination with vibration can cause CTS in workers handling vibrating tools.

Table 2: Sensorineural stages of the hand-arm vibration syndrome according to the Stockholm Workshop scale

Stage	Signs and symptoms
0SN	Exposed to vibration but no symptoms
1SN	Intermittent numbness, with or without tingling
2SN	Intermittent or persistent numbness, reduced sensory perception
3SN	Intermittent or persistent numbness, reduced tactile discrimination and/or manipulative dexterity

3.4 Musculoskeletal disorders

3.4.1 Skeletal

Vibration-induced bone and joint disorders are a controversial matter. Early radiological investigations 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 manual workers not exposed to vibration. Excess occurrence of wrist and elbow osteoarthrosis as well as ossifications at the sites of tendon insertion, mostly at the elbow, have been found in miners, road construction workers and metal-working operators exposed to shock and low-frequency vibration (< 50 Hz) of high magnitude from pneumatic percussive tools. An excess prevalence of Kienböck's disease (lunate malacia) and pseudoarthrosis of the scaphoid bone in the wrist has also been reported by a few investigators.

There is little evidence of 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 operation. Heavy physical effort, forceful gripping and various biomechanical factors may account for the higher occurrence of skeletal injuries found in workers operating percussive tools. Local pain, swelling, and joint stiffness and deformities may be associated with radiological findings of bone and joint degeneration. In some countries (e. g. France, Germany, Italy), bone and joint disorders occurring in workers using hand-held vibrating tools are considered to be an occupational disease and the affected workers are compensated.

3.4.2 Muscular

Workers with prolonged exposure to vibration may complain of muscular weakness, pain in the hands and arms, and diminished muscle force. 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 (i. e. inflammation of tendons and their sheaths) 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 hand-transmitted vibration is not conclusive.

3.5 Other disorders

Some studies indicate that in workers affected with VWF, hearing loss is greater than that expected on the basis of ageing and noise exposure from vibrating tools. It has been suggested that VWF subjects may have an additional risk of hearing impairment due to vibration-induced vasoconstriction of the blood vessels supplying the inner ear.

In addition to peripheral disorders, other adverse health effects involving the endocrine and central nervous system of vibration-exposed workers have been reported by Russian and Japanese investigators. The clinical picture, called "vibration disease", includes signs and symptoms related to dysfunction of the higher centres of the brain (e. g. persistent fatigue, headache, irritability, sleep disturbances, impotence, electroencephalographic abnormalities These findings should be interpreted with caution and further carefully designed epidemiologic and clinical research work is needed to confirm the hypothesis of an association between disorders of the central nervous system and exposure to hand-transmitted vibration.

3.6 Prevention

The prevention of injuries or disorders caused by hand-transmitted vibration requires the implementation of administrative, technical and medical procedures. Guidelines on preventive procedures are included in CR 1030-1, CR 1030-2 and ENV 25349. Prevention includes technical measures aimed at elimination or reduction of hand-transmitted vibration at the source, appropriate information and advice to employers and employees, instruction to adopt safe and correct work practices, and medical preventive guidance.

No adequate personal protective equipment against hand-transmitted vibration is presently available. 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 prEN ISO 10819. Heating systems for hand grips of motor chain saws have been proved to be a very effective prevention measure in forestry work. Since continuous exposure to vibration is believed to increase vibration hazard, work schedules should be arranged to include rest periods. A 10 min rest break for each hour of continuous vibration exposure as well as the use of warm rest rooms or cabins have been suggested as preventive measures.

The aims of *health surveillance* are to inform the worker on the potential risk associated with vibration exposure, to assess health status and to diagnose vibration-induced disorders at an early stage. Pre-employment medical screening and periodic clinical examinations at regular intervals should be performed on vibration-exposed workers. At the first screening examination the subject's personal, work and medical history should be carefully recorded. Particular attention should be paid to any condition which may be aggravated by exposure to vibration (e. g. constitutional tendency to white-finger disease, some forms of secondary Raynaud's phenomenon, past injuries to 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. A complete neurological, vascular and osteoarticular physical examination should be performed by a qualified physician. The worker should be advised to wear adequate clothing to keep the entire body warm, and to avoid or minimize the smoking of tobacco.

The pre-employment examination shall be followed by periodic health re-assessment with a regular interval (e. g. every 1 or 2 years). At subsequent screening examination, any illness occurred since the last examination and any symptom related to vibration exposure should be recorded. The findings of the physical examination should be also reported. Specific diagnostic tests (assessment of digital circulation after local cooling, neurophysiological investigations) should be decided by the physician on the basis of the worker's symptoms and the results of clinical examination. The diagnostic tests should be selected and performed by specialists. Observation of finger blanching is an important diagnostic marker. Vibration-exposed workers should be instructed to report and demonstrate finger blanching when it first occurs or if there