Massimo Bovenzi · Fabio Giannini · Simone Rossi

Vibration-induced multifocal neuropathy in forestry workers: electrophysiological findings in relation to vibration exposure and finger circulation

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Abstract Objectives: To investigate neural conduction in the upper limbs of symptomatic forestry workers with and without exposure to hand-transmitted vibration. A further aim was to assess the possible relationships between vibration exposure, nerve conduction and finger circulation in the forestry workers who used chain saws.

Methods: A detailed neurophysiological investigation was performed on the upper extremities of 20 chain saw workers, 20 forestry operators with heavy manual work but without vibration exposure, and 20 healthy male controls. All subjects were screened to exclude polyneuropathy. Measurements of sensory and motor nerve conduction (velocity and amplitude) were obtained bilaterally from the median, ulnar and radial nerves. To assess peripheral vascular function, the forestry workers underwent a cold test with plethysmographic measurement of finger systolic blood pressure (FSBP). In the chain saw operators, vibration exposure was evaluated according to the International Standard ISO 5349. Indices of daily vibration exposure and lifetime cumulative vibration dose were estimated for each chain saw operator.

Results: Sensory nerve conduction in several segments of the median and radial nerves was significantly reduced in the chain saw operators compared with that in the workers doing heavy manual work and the controls. The neurophysiological pattern more frequently observed in the chain saw operators was a multifocal nerve conduction impairment to several neural segments with predominant involvement of sensory rather than motor fibres. Sensory nerve conduction velocities in the hands of the chain saw operators were inversely related to both daily and lifetime cumulative vibration exposures. In the vibration-exposed forestry workers, neither were sensori-motor complaints associated with vascular symptoms (finger whiteness) nor were electrophysiological data related to cold-induced changes in FSBP.

Conclusions: Exposure to hand-transmitted vibration, in addition to ergonomic stress factors, can contribute to peripheral nerve disorders occurring in forestry workers who operate chain saws. The findings of this study suggest the existence of an exposure-effect relationship for vibration-induced neuropathy. Different underlying mechanisms are likely to be involved in the pathogenesis of the neurological and vascular components of the hand-arm vibration syndrome.

Key words Carpal tunnel syndrome · Finger systolic blood pressure · Hand-transmitted vibration · Heavy manual work · Neural conduction · Neuropathy

Introduction

Workers who operate hand-held vibrating power tools may experience tingling, numbness, and pain in their fingers and hands. If vibration exposure continues, loss of tactile function, reduction of manual dexterity and muscular weakness may develop. This collection of sensori-motor symptoms and signs represents the neurological component of the hand-arm vibration syndrome, which also includes vascular disturbances (vibration-induced white finger) and musculoskeletal disorders in the upper limbs [4]. Clinical and epidemiological studies have suggested that neurological disturbances may develop independently of other vibration-induced disorders, probably reflecting different pathogenic mechanisms [15].

The electrophysiological and clinical criteria for the classification of vibration-induced neuropathy are still uncertain. A great occurrence of entrapment
neuropathies, e.g. carpal tunnel syndrome (CTS), has been reported in some occupational groups (rock-drillers, platers, forestry workers), in which vibration exposure is combined with ergonomic stress factors such as excessive muscular force, repetitive wrist movements, and awkward postures [1, 9, 11, 19, 23, 24, 26, 35]. In these workers, symptoms and signs of CTS may be present either alone or in association with pathological changes in the most distal branches of the median nerve [6, 7, 27]. Involvement of the ulnar nerve at various sites along the hands and forearms has also been found in various studies [6, 20, 23]. On measuring fractionated nerve conduction within the hand, some authors have in contrast suggested that digital nerve impairment predominantly occurs in vibration-exposed patients [29].

In the present study, a detailed neurophysiological investigation was performed on the upper limbs of a group of chain saw operators sampled from a cohort of forestry workers [5]. The aim was to assess the possible relationship between occupational exposure to hand-transmitted vibration and electrophysiological evidence of peripheral neural impairment. To evaluate the relative importance of vibration exposure and ergonomic stress factors in the development of peripheral nerve injuries, we compared the neurographic findings in the vibration-exposed workers with those obtained from a group of forestry workers performing heavy manual work and never exposed to hand-transmitted vibration. Both forestry worker groups were compared with a group of healthy male personnel engaged in sedentary work activities. A further purpose was to assess whether neurological disturbances and electrophysiological abnormalities were associated with symptoms and signs of vascular disorders in the fingers of the vibration-exposed forestry workers.

In order to avoid the effects of any underlying polyneuropathy, we excluded from the study a matched pair of forestry workers if either or both of them were found to be affected with any of the following conditions: (a) hyperglycemia (fasting blood glucose > 110 mg/100 ml); (b) higher than normal serum levels of γ-glutamyl transpeptidase and/or increased aminotransferase activities; or (c) slowing of neural conduction of the sural and/or ulnar nerve. After the application of these selection criteria, the final study groups consisted of 20 chain saw operators and 20 manual forestry workers.

Twenty healthy men were age-matched with the forestry workers to form the control group. They were members of the medical and technical staff of a university hospital and performed sedentary work activities with no evident risk factors for cumulative trauma disorders in the upper limbs. They had no symptoms suggesting peripheral vascular or neurological disorders.

Vascular investigation

The anamnestic diagnosis of vibration-induced white finger (VWF) in the chain saw operators was based on a positive history of blanching attacks involving one or more fingers and occurring after the start of exposure to vibration produced by chain saws. The severity of VWF was staged according to the Stockholm scale [16]. The manual forestry workers were also questioned on the occurrence of symptoms of finger whiteness.

The forestry workers underwent a cold test procedure consisting of measurement of finger systolic blood pressure (FSBP) during localized cooling [5]. A double inlet plastic cuff for both air filling and water perfusion was placed around the middle phalanx of the third left finger of the subjects without symptoms of finger whiteness. In the subjects with a positive anamnestic for white finger, the most affected finger was cooled. The test finger was thermostated with water circulating at 30 °C and 10 °C with a digit cooling system (Medimatic A/S, Copenhagen, Denmark). Two air-filled cuffs were applied on the proximal phalanx of the test finger (for ischemia during cooling) and on the middle phalanx of a reference finger (usually the fourth finger). We performed the cold test by pressurizing the air cuffs at a suprasystolic level (210 mmHg) and perfusing the water cuff initially at 30 °C and then at 10 °C. After 5 min of ischemic cooling, we measured the FSBP on the test and reference fingers by a strain-gauge plethysmographic technique. The change of systolic blood pressure in the test finger at 10 °C (FSBP_{10°C}) as a percentage of the baseline at 30 °C (FSBP_{30°C}) corrected for the change of pressure in the reference finger during the cold test (FSBP_{ref,30°C} – FSBP_{ref,10°C}), was calculated according the following formula:

$$\text{FSBP}_{9\%} = \frac{(\text{FSBP}_{10°C} \cdot 100)}{\text{FSBP}_{30°C} - (\text{FSBP}_{ref,30°C} - \text{FSBP}_{ref,10°C})} \%$$

To avoid nicotine-induced vasooconstrictive effects on the digital arteries, tobacco users were recommended to refrain from smoking for at least 2 h before being tested.

Neurophysiological investigation

Neurophysiological recordings were carried out with a Medelec Mistro MS25 electromyograph at a constant skin temperature of 32–33 °C. Details of the electrophysiological techniques have been reported in a previous paper [12].

Briefly, the sensory nerve conduction velocity (SNCV) of the left sural nerve was measured antidromically in the segment middle calf-external malleolus. The motor nerve conduction velocity (MNCV) of the right peroneal nerve was measured in the segment capitulum fibulae-ankle, by recording the compound motor action potential (CMAP) from the extensor digitorum brevis muscle.

Orthodromic SNCVs and mixed NCVs were determined in all digit-wrist and palm-wrist segments of both hands. Digital stimulation of the thumb (M1), index (M2), middle (M3) and ring (M4) fingers for the median nerve, the ring (U4) and little (US) fingers for

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**Material and methods**

Subjects and clinical investigation

The source population for this study was a cohort of 92 chain saw workers who were followed for a 5-year period to investigate the occurrence of vibration-induced vascular disorders [5]. Thirty chain saw operators were randomly sampled from the members of the cohort (n = 68) who complained of sensory (numbness, tingling, nocturnal paresthesias, with or without pain) and/or motor (reduction of manual dexterity, distal weakness) disturbances in at least one hand. They were individually matched, with respect to age (± 5 years) and declared drinking habit (daily alcohol consumption in grams), to 30 forestry workers engaged in heavy manual activities at the same workplace. The latter group had never been exposed to hand-transmitted vibration from chain saws and complained of symptoms of nerve dysfunction in at least one hand.

Each forestry worker underwent a medical interview, a complete physical examination with special consideration for the neurological and vascular systems, and laboratory investigations. These latter included a cold provocation test with measurement of finger systolic blood pressure, an electrophysiological investigation in the upper and lower limbs, and biochemical tests. No subject had suffered from fractures or other important trauma requiring immobilization of the upper limbs. None reported either exposures to neurotoxic agents in the past or regular use of medicines.