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EFFICACY OF VIBRATION, ELECTRIC CURRENT AND THERMAL PERCEPTION TESTS IN DIAGNOSIS OF HAND-ARM VIBRATION SYNDROME

EWA ZAMYSŁOWSKA-SZMYTKE

Department of Physical Hazards
The Nofer Institute of Occupational Medicine
Łódź, Poland

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Abstract. Vibration perception test is usually proposed as a useful tool for quantitave assessment of neurological disturbances induced by hand-arm vibration syndrome (HAVS). The increased mean vibration perception threshold (VPT) is an early manifestation of this syndrome. However, we have identified a group of exposed subjects with normal VPT who showed electric current and/or thermal sensitivity impairment. The use of three tests instead of a single vibration test increased by 27% the number of persons with detected quantitative skin sensory disorders. The intensity of quantitative disorders of vibration and electric current sensitivity was closely related to the duration of vibration exposure. The thermal perception was diminished in subjects working for a longer period of time, but there was no relationship between intensity of disorders and the duration of exposure. In an early stage of hand-arm vibration syndrome (prevention of HAVS) the use of three tests helps to identify a larger numer of workers at risk who should undergo thorough diagnostic examinations. In our study the proportion of identified workers increased from 27% (32 subjects with vibration sensory impairment) to 45% (53 persons with disorders detected in one, two or even three tests).

INTRODUCTION

Hand-arm vibration syndrome (HAVS) is a combination of non-specific pathophysiological symptoms and disorders induced by chronic occupational exposure to vibration among workers who use hand vibrating tools. The syndrome is manifested by disorders of the peripheral circulatory system, functional and structural changes in sensory and motor nerves and receptors (*angioneuropathia vibratoria*), and disorders of the musculoskeletal system (*osteoarthropathia vibratoria*). In the sensorineural form of vibration syndrome such symptoms as numbness and tingling of the fingers, paraesthesia and diminished touch sense are observed.

Address reprint request to Dr E. Zamysłowska-Szmytke, Department of Physical Hazards, The Nofer Institute of Occupational Medicine, P.O. Box 199, 90-950 Łódź, Poland.

Examination of vibration sensitivity is recommended as a diagnostic, quantitative method for assessing the activity of peripheral nerves and their endings in the skin (10). The vibration perception threshold (VPT) measurements are very useful in the prevention of HAVS as the occurrence of the sensory disorders is most frequently an indication for more thorough diagnostic examinations, but they are less important in the occupational disease certification.

Vibration is a specific stimulus which activates only mechanoreceptors. Chronic exposure to vibration is responsible for the damage of various structures of the central and peripheral nervous systems. In order to assess the damage different specific (thermal) and non-specific (electric current) stimuli, activating many nervous structures, can be used.

The main objectives of this study were to evaluate the efficacy of vibration, electric current and thermal perception tests in the diagnosis of sensorineural disorders induced by hand-arm vibration; to find out whether the use of these three tests, instead of one single vibration perception test used to date, produces better diagnostic results; and to evaluate their applicability to the prevention of hand-arm vibration syndrome.

MATERIALS AND METHODS

The study covered 250 men, including 171 workers occupationally exposed to hand-arm vibration and 79 persons non-exposed to vibration. The characteristics (age and employment duration) of the subjects are summarised in Table 1. Among 171 exposed persons, there were 113 chain saw operators and 58 persons performing different jobs (grinders, cleaners, pneumatic drill operators). None of these persons had suffered from illnesses with clinical symptoms similar to disorders induced by HAVS.

Table 1. Characteristics of the study groups

The age ranges	Non exposed	Chain saw operators		The other jobs	
	Number of subjects	Number of subjects	The mean years of exposure	Number of subjects	The mean years of exposure
below 30	47	13	5.2±3.2	3	2.4±3.2
31–40	22	48	8.3±3.8	11	3.3±3.9
41–60	10	52	17.1±6.2	44	20.1±8.6
Total	**79**	**113**	**12.9±7.1**	**58**	**18.0±8.7**

Following medical investigations and other diagnostic tests the group of 171 workers was divided into two subgroups: one group was composed of 119 healthy workers and those with early signs of HAVS who continued their work, and the other consisted of 52 persons with more severe disorders (early and advanced lesions) periodically or permanently removed from work because of ill health.

A multifunctional device 'Telmest' was used to measure vibration perception thresholds, electric current and temperature of the following parameters of stimuli:

– Vibration of 63, 125, 250, 400, 500 and 640 Hz within the range of velocity amplitude, 60–dB re $5*10^{-8}$ m/s;

– Direct and alternative electric current of 50, 100, 400 and 1 000 Hz increased by 33 μA/s within the range of 0–2 mA;

– Heat was measured by using blocks of brass maintaning constant temperature of 35, 40, 45, 50 and 55°C with the accuracy $\pm$0.1°.

The study protocol and normative values of vibration perception test were adopted according to recommendations (10). The methology of electric current and temperature measurements were based on the pilot study described previously (12). The normative values of the current perception thresholds were adopted on the basis of our own studies carried out in the group of non-exposed persons.

The skin sensitivity was evaluated according to the following criteria:

– The vibration perception threshold (VPT) was diminished when the mean value remained above 85 dB*;

– The current perception threshold (CPT) was diminished when the mean values of perception threshold exceeded normal values for four frequencies in both hands or for five frequencies in one hand and at least three frequencies in the other hand**;

– The thermal perception threshold (TPT) was diminished when the subject examined perceived no identifiable thermal sensation following contact with the first heat applicator (1°C) or other applicators (2–5°C).

The actual temperature of the fingertips checked before the examination should not fall below 27°C.

Statistical analysis

The significance of the difference between two means was assessed by Student's t-test. The relationship between continuous variables was determined on the basis of correlation coefficient, and between non-continuous TPT variables using the chi-square test. P value < 0.05 was considered to reflect statistical significance between variables. Statisical analyses were performed with Statistics for Windows and Excel 5.0.

RESULTS

The relationship between age and employment duration and diminished sensory threshold values, revealed in the present study, was assessed. The effect of the age was evaluated in non-exposed persons, analysing at the same time the differences between sensory thresholds in the age groups under 30 years, 30–35 years, 35–40 years and above 40 years.

The VPT assessment revealed statistically significant differences between mean perception thresholds in all age groups. In the age group under 30 years the threshold value did not grow with age ($r = 0.08$; $p < 0.05$). The CPT assessment indicated significant differences between mean perception thresholds only in two age groups, under 30 and 31–35 years. In none age group the difference between mean TPTs was observed.

The relationship between sensory threshold values and employment duration was assessed in 113 chain saw operators. Considering the effect of age, the results

* According to recommentaions (10).

** Based on our own studies.

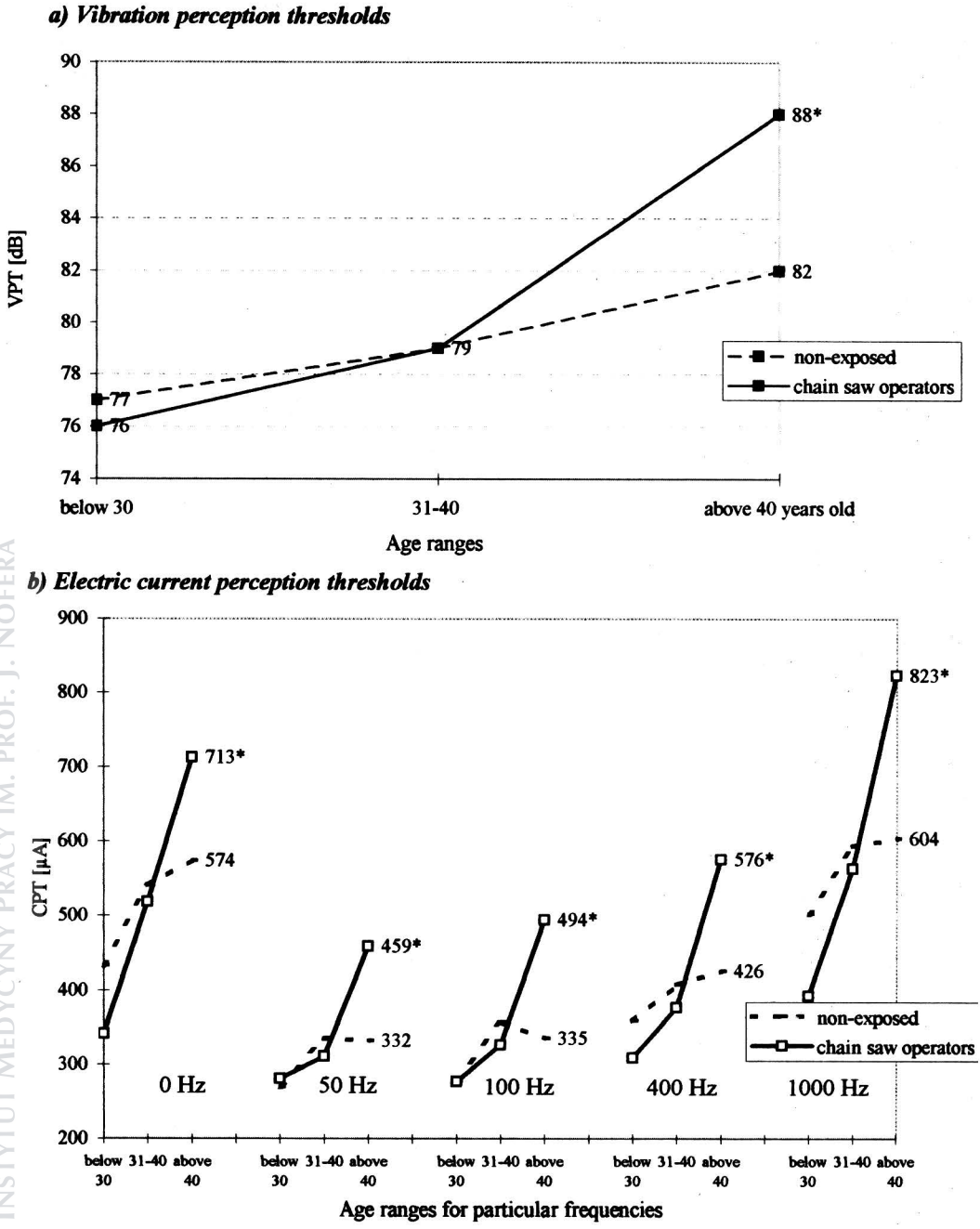

Fig. 1. Vibration and electric current threshold values in chain saw operators compared to non-exposed group.

obtained in the analysis of sensory threshold values were assessed in comparison to controls in the three age groups, under 30 years, 31 – 40 years, and above 40 years. Fig. 1 shows significantly higher mean VPTs and CPTs in the whole range of frequencies in the group of chain saw operators aged above 40 years than in the control group. It is likely that the relationship between higher VPTs and CPTs and occupational exposure to vibration does really exist.

The impairment of thermal perception was found in 33 chain saw operators of this number, 13 workers did not perceive a 40°C heat applicator (2°), 15 workers a 45°C applicator (2°), and 5 workers a 50 or 55°C applicator (4° and 5° together). Statistically significant increase in TPT values associated with longer employment duration was revealed only in the group of workers with impaired perception when compared to persons with normal perception ($t = 5.1$; $p < 0.05$). In groups of workers with growing intensity of disorders (2, 3, 4 and 5°) no relationship between the occurrence of these disorders and occupational exposure was found. Taking into account that none of the controls showed any impairment of thermal perception, the relationship between the disorders observed in the group of chain saw operators and vibration exposure is likely to occur.

In the group of 171 workers exposed, regardless of the job performed, the number of persons with diminished perception detected in one of the tests applied was compared with the number of persons with diminished perception detected in individual tests, particularly in the assessment of vibration perception.

Diminished skin sensitivity indicated by any test (or by two or three tests jointly) was found in 96 persons (100%), but impaired vibration perception in 70 persons (73%) only. Due to application of new diagnostic tests it was possible to identify a larger number (by 26%) of persons at risk who should undergo more thorough diagnostic examinations (Fig. 2).

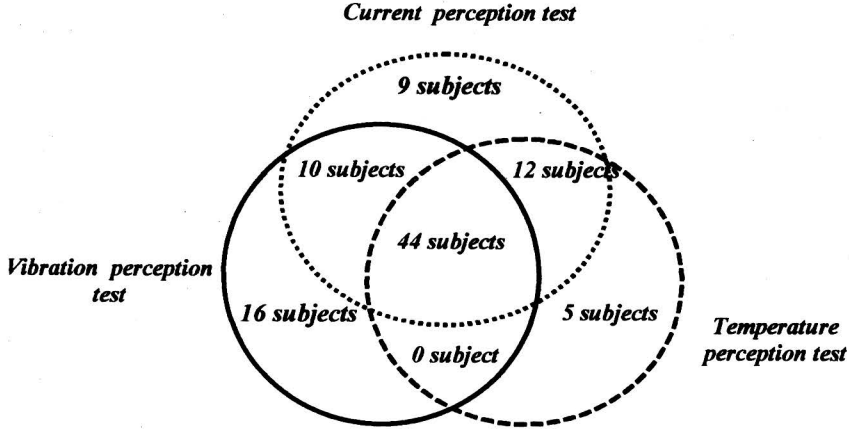

Fig. 2. The number of subjects (n = 96) with sense impairment revealed in particular test.

The skin sensitivity impairment detected by all the three tests was found in 44 persons, however, the impairment was not very severe since 50% of workers in this group were allowed to continue their work under exposure.

The efficacy of these tests in early diagnosis can be evaluated by comparing the incidence of diminished sensitivity to individual stimuli in the group of persons exposed but still allowed to continue their work.

Table 2. Exposed subjects (119) who in spite of sense disturbances were allowed to work under exposure (an early stage of HAVS). Every test was assessed independently

The years of exposure	Number of subjects with increased VPT	Number of subjects with increased CPT	Number of subjects with increased TPT	Number of subjects with sense impairment revealed in any test*
0–10	6	11	6	14
11–20	14	19	20	23
above 20	12	14	13	16
Total	**32**	**44**	**39**	**53**

*i.e. number of subjects with vibration perception impairment independently of the other test results. The same for electric current or temperature perception impairment.

The characteristics of these subjects are summarised in Table 2. It shows that of 119 workers allowed to continue their work under exposure, 53 persons (45%) showed sensitivity disorders at least in one quantitative assessment. If the diagnosis had been based only on vibration perception test then this number would have been lower by 27% (32 persons).

Comparing the results obtained in individual tests, the electric current perception test helped to identify the largest number of persons with diminished sensitivity, but the use of all the three tests produced the best results.

DISCUSSION

Disorders of vibration perception indicate early symptoms of post-vibration changes, therefore detection of these disorders is so important in the prevention of hand-arm vibration syndrome. Vibration is a specific stimulus, which activates major mechanoreceptors, however, chronic exposure to vibration leads to the impairment of different receptors of sensitivity. In general practice, objective assessment of sensitivity is not used in diagnosis. Although, the relationship between the results of vibration sensitivity test and clinical symptoms, and the assessment of nerve conduction velocity in the hands and fingers (4,14) is observed, the tests are more useful in the occupational disease certification than in screeening. Simple and non-invasive tests are most useful in the prevention, therefore, an attempt has been made to introduce a set of tests facilitating a more thorough assessment of the nervous system.

The establishment of vibration perception thresholds is the only method recommended to date in the quantitative diagnosis of disorders of the skin sensitivity. The method is easy to perform in ambulatory conditions. It has been well documented that it indicates strong relationship between the results obtained and the size of vibration exposure (3). The measurements and their evaluation were described previously (6,10).

The quantitative assessment of the thermal sensitivity is not widely used in HAVS diagnosis (10), mainly due to the lack of standardised equipment and

methodology. It is well known that impairment of thermal sensitivity is an early sign of post-vibration disorder (11) In the present study we tried to find out whether the method adopted (in terms of the equipment available) can be used in the assessment of vibration-induced sensory impairments. The fact that this method revealed the presence of sensitivity disorders only in persons exposed, and that they were not related with age enhances its value.

The lack of association with age may result from marked differences between the temperature of plates. The adopted difference of 5°C was necessary because of great thermal inertia of thermoreceptors (9), and a small contact area of the fingertips. The justness of parameters was verified in the discussion on changes in temperature, necessary to perceive its difference. It was agreed that a 5° change per one second should be adopted since a 2° change per one second is too slow for a thermal stimulus. The results discussed by Gerr (5) confirm that thermal perception thresholds are significatly higher in persons with neurological disorders induced by exposure to vibration, however, the relationship between these disorders and the size of exposure was not observed.

The assessment of the current perception threshold is another method for testing sensitivity, however, until recently its value had been neglected because of existing relationship between perception thresholds and the skin impedance (2). Only the application of a feedback control circuits in 'Telmest' made it possible to maintain constant current intensity independent from the skin impedance (8,15), although, a standardised method for the measurment of perception thresholds and evaluation of results has not as yet been developed (7,8,15). Pelmear (13) recommended to assess electric current sensitivity when defining the intensity and location of neuropathy in HAVS despite nonspecificity of current stimulus (13). In our study CPTs were significantly higher in persons exposed than in controls what confirmed the usefulness of electric current test in the diagnosis of post-vibration impairment of the skin sensitivity.

The usefulness of the tests in question in early diagnosis was assessed in the group of persons with minor symptoms of sensitivity impairment. These persons were allowed to work under exposure but they were subjected to frequent periodical examinations and obliged to observe the dynamics of pathological changes. Frequently, the sensory disorders are the only sign of the onset of hand-arm vibration syndrome. Thus, the more examinations, the larger number of persons at risk identified. The examinations helped to remove from exposure persons hypersensitive to mechanical vibration who after an adoped interval between examinations might show much more severe clinical symptoms.

CONCLUSIONS

1. Exposure to vibration impairs vibration, electric current and thermal perception. The incidence of quantitative disorders of vibration and electric perception and their intensity depends significantly on the duration of vibration exposure.

2. The use of the three tests instead of one single vibration test increased by 27% the number of identified persons with quantitative sensitivity disorders.

3. In an early stage of hand-arm vibration syndrome the use of three tests increased the number of persons who should be subjected to thourough diagnostic

examinations from 27% (32 subjects with vibration sense impairment) to 45% (53 persons with disturbances detected in one, two or even three quantative tests of sensitivity).

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