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ORIGINAL ARTICLE

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Can a battery of functional and sensory tests corroborate the sensorineural complaints of subjects working with vibrating tools?

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Abstract ***Objectives:*** The objective of the present paper is to study the relationship between the early sensorineural symptoms, classified according to the Stockholm scale, and the results of the main functional and sensory tests described in the literature, in subjects working with vibrating tools. ***Methods:*** Three groups of male workers were selected from industry: one group (69 subjects) exposed to hand-arm vibration in several workplaces, one group (62) performing heavy and repetitive hand and arm work but without exposure to vibration, and one control group (46) performing light and non-repetitive tasks without vibration. All the workers were interviewed by questionnaire, about their personal characteristics, their health status, their actual and past working conditions and the episodes of tingling at the level of the fingers. From these reported symptoms, the sensorineural stage of the hand-arm vibration was determined using the Stockholm scale. Based on the review of the literature, we selected six functional and sensory tests: maximum voluntary grip force, maximum angles of the wrist, pressure perception threshold test, vibration perception threshold test, distal sensory latency and the Purdue Pegboard test. Each test was performed by the workers in the three groups. ***Results:*** No main differences were observed between the personal characteristics of the three groups. According to the Stockholm scale, the sensorineural symptoms were mainly at stage SN1, with 9% at stage SN2 and none at stage SN3. These symptoms are associated with exposure to vibration, and had a prevalence of 40% in group 1, versus 20% in the two other groups. Furthermore, 25% of the workers exposed to vibration complained of symptoms at least once a week, compared with only 2% in the other groups. The multivariate logistic regression analysis showed an association between the existence of symptoms and a decrease in the maximum flexion angle of the wrist and an increase in the pressure perception threshold. This association, however, was too low to determine limit values with a sensitivity and specificity sufficiently high to make a reliable diagnosis. ***Conclusions:*** The sensorineural symptoms at stage N1 on the Stockholm scale, experienced occasionally by some 40% of the users of vibrating tools, could not be corroborated by the functional and sensory tests.

Key words Sensorineural symptoms · Functional and sensory tests · Hand-arm vibration · Vibrating tools

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Introduction

The first studies of hand-arm vibration were concerned mainly with osteo-articular and vascular effects. During these studies, however, the occurrence of other disorders became explicit: decrease of the maximum grip force (Färkkilä et al. 1980, 1986); tingling (Juntunen et al. 1983); and decrease in tactile sensitivity (Lidström et al. 1982).

These last three sensorineural disorders are linked to changes in the sensory receptors and the peripheral nerves and appear to develop in two phases (Brammer and Pyykkö 1987): initially through a temporary decrease in excitability of the sensory receptors (Lundström 1986) and short term disorders; and later, through irreversible damage of the peripheral nerves and the receptors with permanent disorders.

A scale was proposed for the severity of these disorders. Initially (Taylor and Pelmear 1975), they were considered jointly with the vascular problems. In 1987, the scale relative to vascular problems was revised (Gemne et al. 1987) and a separate scale was set up for the sensorineural disorders (Brammer et al. 1987). This scale included four stages: stage SN0, exposed to vibration but no symptoms; stage SN1, intermittent numbness with or without tingling; stage SN2, intermittent or persistent numbness and reduced sensory perception; and stage SN3, intermittent or persistent numbness, reduced tactile discrimination and/or manipulative dexterity.

The classification rested on symptoms and sensations felt by the workers. The authors (Brammer et al. 1987) postulated however, that stage SN2 could be confirmed by some sensory tests (light touch, pain, temperature and vibration perception threshold). The corroboration of stage SN3 would need additional tests: aesthesiometry, manual dexterity and measurement of nerve conduction velocity (Pelmear et al. 1992).

In the case of peripheral neurological disorders, in particular due to nerve compression, the first symptoms are tingling and numbness. As the problems get worse, the results of some tests become "abnormal": first the vibration perception threshold (VPT) and then the pressure perception threshold (PPT), well before modification of the aesthesiometric threshold and of the maximum voluntary grip force (MVF) (Gelberman et al. 1983, Szabo et al. 1984).

The use of a single test may be relevant to compare groups of workers but not on an individual basis (Wenemark et al. 1996), and a battery of several tests is needed to establish a complete and reliable diagnosis. Among others, Harada (1987) has shown that a sensitivity of 85% and a specificity of 95% can be obtained by combining four different tests. This sensitivity and specificity of a given test can also be increased by the performance of this test after provocation, for example, after cold water immersion (Harada 1987) or after compression of the median nerve (Szabo et al. 1984).

The objective of the present paper is to study the relationship between the early sensorineural symptoms, classified according to the Stockholm scale and the results of the main functional and sensory tests described in the literature. As exposure to biomechanical constraints can lead to neurological symptoms (carpal tunnel syndrome for example), workers exposed to hand-arm vibration are compared with two groups of workers not exposed: workers exposed to heavy and repetitive work and workers performing light work (control group).

Methodology

The first group (G1) included 69 workers exposed to vibration in six industrial sectors:

1 Car assembly plant: 23 persons
2 Quarries: 17 persons
3 Construction: 4 persons
4 Wood industry: 9 persons
5 Steel industry: 9 persons
6 Metal industry: 7 persons

These sectors were selected in order to get a rather large range of vibrating tools: drillers, grinders, polishers, pneumatic hammers, and so on. All the workers using these tools participated in the study in the companies that accepted this research.

The second group (G2) included 62 subjects performing heavy and repetitive hand and arm work, without vibration. These workers were packing coils and metal sheets in the steel industry.

The third group (G3), the control group, included 46 people performing light and non-repetitive tasks, without vibration, in the warehouse of the same steel factory.

All workers were fully informed about the protocol, the objectives of the research and the confidentiality of the results. They were free to participate in the study and to withdraw at any time for any reason. All the subjects who accepted were included in the study. The 177 workers underwent an interview, a clinical examination orientated towards the upper limbs, and several functional and sensory tests. The interviews were conducted by a physiotherapist. A checklist including a total of 160 items was used to collect information concerning:

1 Personal characteristics: age, weight, height, plant and workplace seniority, smoking habits, alcohol consumption, hobbies and sports, in general, and involving the upper limbs.
2 Health status: chronic diseases other than upper limb disorders, accidents, medication.
3 Actual and past working conditions: perception of the physical workload, lifting efforts performed with the hands and wrists, movement repetition, exposure to some risk factors such as solvents or the cold, and the use of vibrating tools. The workers of G1 were invited to describe the different vibrating tools they used on a regular basis (grinders, drillers, and so on.) and to estimate the frequency or duration of use for each.
4 Episodes of tingling at the level of the fingers. The workers had to describe the frequency of occurrence, the circumstances in which tingling appeared, the fingers involved, as well as the existence of dexterity problems or muscle weaknesses.

According to the nature of the item, the data were recorded in terms of intensity (light, medium and heavy) or frequency (never, sometimes, often and always). The sensorineural stage of the hand-arm vibration syndrome was determined from these reported symptoms for each hand using the Stockholm scale described above (Brammer et al. 1987).

Six functional and sensory tests were selected on the basis of the review of the literature, based on the criteria that they:

- be described as a potential tool for the early detection of sensorineural disorders and mainly vibration syndrome
- be usable in industry and by occupational physicians
- take little time to perform in order to fit the time constraints imposed by industry

Before each test series, the skin temperature of the hand was measured with an infrared thermometer (Digitron 805/H). The tests were performed only if the skin temperature was above 30 °C, otherwise, the hand was warmed for a few minutes in a glove until it satisfied this criterion.

1 The maximum voluntary grip force

The MVF was recorded by a JAMAR PC5031J1 dynamometer. The subject, sitting comfortably with the arm bent at 90° and resting on a support, was invited to grip the dynamometer progressively and to exercise a maximum grip force for 3 s. The recorded value was the maximum force held during this time.

2 The maximum angles of the wrists

The maximum wrist angles were measured by means of goniometers (Penny & Giles, type M110, Blackwood Ltd, UK), in the two planes of movement: in radial-ulnar deviation and in flexion-extension, while the subject was sitting with the arm in pronation on the table. The precision of the measurements was to 1°.

3 The pressure perception threshold test

The PPT test was performed using the monofilaments of Semmes-Weinstein according to the procedure described by Bell-Krotoski (1990). The recorded value was the pressure force (log. force, ref. 0.1 mg) of the filament, felt three consecutive times.

4 The vibration perception threshold test

The VPT test was recorded at 63, 125 and 250 Hz, using a mini-shaker B&K 4810, mounted on a balance and equipped with a rod, so that the contact surface was 5 mm^2 and the force on the pulp of the test finger (the third and the fifth fingers) was kept constant at 0.2 N. The signal was generated by a modified audiometer (Madsen Micromate 304) with increments of 5 dB, and an ordinary amplifier. The system had a dynamic range from 50 to 160 dB (ref. 10^{-6} m s^{-2}) (0.3 mm s^{-2} to 100 m s^{-2}). The testing procedure was the one used in manual audiometry: increasing the level progressively until the subject reacted, and then decreasing and increasing the level again in order to exceed three times the threshold. The value recorded was the threshold detected three times consecutively.

5 The distal sensory latency

The distal sensory latency (DSL) was recorded for the median nerve between the wrist and the second finger, and for the ulnar nerve between the wrist and the fifth finger, by means of a Nervepace S200 (Neurotron Medical) (Durnil et al. 1993).

6 The manual dexterity

The Purdue Pegboard test (PPB) was chosen to test the manual dexterity (Tiffin and Asher 1948, Banister and Smith 1972). The subject had to place the maximum number of pegs in the holes of the board in 30 s.

The results for the 3 groups were compared by means of Chi^2 tests for the discrete variables (complaints and some personal data). For the continuous variables (personal data and results of the functional and sensory tests), a one-way analysis of variance was performed, followed by a Scheffe multiple range test. The relationship between the probability of complaints and the results of the functional and sensory tests was then studied by a multiple logistic regression, taking into account the personal confounding factors.

Results

Characteristics of the population

Table 1 gives the mean and standard deviation of age, weight, height and seniority for the three groups of workers, as well as the statistical significance of the differences between the group exposed to vibration and the two other groups. The three groups can be considered to be comparable, although the workers exposed to vibration have a slightly greater weight, and the control group has a slightly lower workplace seniority.

Of the subjects, 74% estimated their health to be "good" or "excellent"; 17% suffered from a "chronic disease" (diabetes, thyroid problems, hypertension, rheumatoid arthritis, gout, and so on.); 56% had had an accident concerning the upper limbs. Compared with G1, the prevalence of chronic diseases was significantly greater in G2 and lower in G3. As far as their personal habits were concerned, globally, 47% of the workers were smokers, 67% drank alcohol (from a little to a lot) and 45% practised one or another sport (4.5% a sport involving the upper limbs) more than once a week. A total of 60% of the workers had heavy extra-occupational activities or hobbies and 20% used vibrating tools during these activities. The workers exposed to vibration consumed alcohol and used vibrating tools during their hobbies more significantly than did the others.

Prevalence of the different sensorineural stages

Table 2 describes the percentage of workers at the different stages of the Stockholm scale for the sensorineural disorders. The prevalence of stage SN1, (intermittent numbness with or without tingling), is significantly greater for the group G1 exposed to vibration. When both stages SN1 and SN2 are grouped together, the prevalence for the non-exposed groups is of the same order of magnitude (17%) and significantly lower than for the exposed subjects (40%).

Functional and sensory tests

Table 3 gives the mean and standard deviation of the results of each test, for the three groups of workers. Except for the maximum voluntary force for which the data are given separately, the values did not differ between the right and left hands. Therefore, the data are presented for both hands and not per person.

Table 1 Mean and standard deviation of the characteristics of the three groups of workers and statistical significance between the group exposed to vibration and the two other groups (one-way analysis of variance) (*NS* not significant)

n	G1	G2		G3	
	Vibration 69	Heavy work 62		Control group 46	
Age (years)	35.6 (7.2)	35.1 (6.9)	NS	35.6 (6.3)	NS
Weight (kg)	81.3 (12.4)	75.4 (12.4)	***	74.9 (11.9)	***
Height (cm)	174.6 (6.7)	173.7 (7.8)	NS	172.9 (5.9)	NS
Workplace seniority (years)	7.0 (6.1)	7.2 (6.2)	NS	4.9 (4.7)	*
Plant seniority (years)	12.9 (8.4)	13.4 (7.0)	NS	14.4 (6.6)	NS
Smoking (%)	47.8	53.2	NS	37.0	NS
Sport (%)	44.9	37.1	NS	54.3	NS
Alcohol (%)	82.6	53.2	***	63.1	*

* $P < 0.05$; *** $P < 0.001$

Table 2 Prevalence (in %) of sensorineural symptoms of the hands and the wrists, and statistical significance of the differences with respect to group 1 (*NS* not significant)

Sensory stage	Side	G1 Vibration (n = 69)	G2 Heavy work (n = 62)	Test G1 vs G2	G3 Control group (n = 46)	Test G1 vs G3
SN1	Right	24.6	11.3	*	8.7	*
	Left	27.5	12.9	*	4.3	**
	Either	31.9	16.1	*	8.7	**
SN2	Right	8.7	0.0	*	4.3	NS
	Left	1.4	1.6	NS	4.3	NS
	Either	8.7	1.6	NS	4.3	NS
Total (SN1 and SN2)	Right	33.3	11.3	**	13.0	*
	Left	28.9	14.5	*	8.7	**
	Either	40.6	17.7	**	15.2	**

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

For some tests, differences between groups were statistically significant due to the high number of hands or persons and the small standard deviations. However, these differences do not exceed on average, 3.5° for the maximum angles, 0.3 for the PPT and 3 dB for the VPT (with the exception of the VPT at 63 Hz on the fifth finger). It can be concluded therefore, that on average, the differences between the three groups are not important and not systematic. The number of observations (354) being very important, the correlation coefficient between the results of two different tests is statistically significant at the 5% level as soon as greater than 0.1.

As we were interested in determining whether two tests gave the same information and explained the same variance, we considered, somewhat arbitrarily, only the pairs of tests that correlated with a regression coefficient greater than 0.5. This was the case only for the VPT and the PPT on the third and fifth fingers (correlation coefficient between 0.6 and 0.8). It can therefore be concluded that the results of the different tests (angles, force, PPT, PVT, and so on.) are not highly correlated and that, therefore, they appear to be complementary to characterise the functional and sensory capacities of the workers.

Association between sensorineural symptoms (Stockholm scale) and the results of the functional and sensory tests

As shown in Table 2, none of the workers presented symptoms at stage SN3 of the Stockholm scale and very

Table 3 Mean and standard deviation for each functional and sensory test for all hands, per group, and statistical significance of the differences between groups (one-way analysis of variance) (*NS* not significant)

	G1 Vibration	G2 Heavy work	Test G1 vs G2	G3 Control group	Test G1 vs G3
Maximum angles					
Ulnar deviation (°)	32.1 (6.0)	34.2 (5.2)	**	35.7 (5.0)	***
Radial deviation (°)	17.4 (4.4)	15.6 (4.9)	**	16.8 (5.4)	NS
Extension (°)	72.5 (9.1)	71.0 (8.8)	NS	71.9 (8.3)	NS
Flexion (°)	57.2 (8.3)	57.1 (7.1)	NS	59.9 (8.5)	**
Maximum voluntary grip force (kg)					
Right	52.9 (9.8)	51.3 (10.6)	NS	52.5 (8.6)	NS
Left	51.4 (8.0)	49.8 (9.9)	NS	48.4 (8.5)	NS
Pressure perception threshold					
Third finger	3.5 (0.3)	3.3 (0.3)	***	3.2 (0.3)	***
Fifth finger	3.5 (0.3)	3.3 (0.4)	***	3.2 (0.3)	***
Vibration perception threshold					
Third finger 63 Hz (dB)	110.6 (6.5)	111.5 (6.3)	NS	111.7 (6.6)	NS
Third finger 125 Hz (dB)	100.4 (7.3)	101.0 (7.1)	NS	100.9 (7.1)	NS
Third finger 250 Hz (dB)	105.7 (8.3)	103.1 (8.5)	*	102.6 (8.3)	**
Fifth finger 63 Hz (dB)	118.8 (5.7)	113.0 (6.1)	NS	112.9 (5.7)	NS
Fifth finger 125 Hz (dB)	101.7 (6.3)	102.5 (7.1)	NS	101.9 (6.0)	NS
Fifth finger 250 Hz (dB)	104.1 (8.2)	101.7 (8.2)	*	100.8 (7.1)	**
Distal sensory latency					
Second finger (ms)	2.8 (0.3)	2.7 (0.4)	**	2.8 (0.6)	NS
Fifth finger (ms)	2.7 (0.3)	2.5 (0.4)	**	2.6 (0.3)	*
The manual dexterity					
Purdue Pegboard test (no. of pegs)	14.4 (1.7)	13.6 (1.8)	*	14.4 (1.4)	NS

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

few reached stage SN2. The results of the tests were not statistically different between subjects at stage SN1 and stage SN2. Therefore, the comparison can be based on 354 wrists (177 workers), between the wrists with ($n = 69$) and without ($n = 285$) symptoms at stage SN1 or SN2.

Table 4 gives the mean and standard deviation of the results of the tests for the two groups. The subjects with symptoms in at least one wrist are on average, older (37.5 ± 6.4 vs 34.9 ± 6.9 years). When this age effect is taken into account, only the angles in maximum flexion and the PPT are significantly different between the two groups.

A multiple logistic regression analysis was performed, with the existence or not of sensorineural symptoms (stages SN1 or SN2) as the dependent variable, the individual characteristics, the group number (1 vs 2, 1 vs 3, 1 vs 2 and 3) as confounding variables and the results of the functional and sensory tests as independent variables. In the first step, the tests were considered individually. In the final model, they were introduced simultaneously (Table 5).

The significant individual characteristics were health status (bad), smoking habits, the wrist efforts and the use of vibrating tools at previous workplaces. The probability of sensorineural symptoms (stages SN1 and SN2) were significantly higher (prevalence odds ratio (POR) = 4.5, $P < 0.001$) for the subjects belonging to group 1. When in addition to the previous factors, the results of the tests are introduced one by one, the same

Table 4 Mean (M) and standard deviation (SD) of the results of the functional and sensory tests for the wrists with symptoms (stages SN1 or SN2) and no symptoms (stage SN0)

	No symptoms M (SD) $n = 285$	With symptoms M (SD) $n = 69$
Maximum angles		
Ulnar deviation (°)	33.9 (5.6)	33.3 (6.0)
Radial deviation (°)	16.8 (5.0)	16.0 (4.5)
Extension (°)	71.7 (8.9)	72.5 (8.2)
Flexion (°)	58.8 (7.9)	54.2 (7.6)
Maximum voluntary grip force (kg)	51.4 (9.2)	50.1 (10.0)
Pressure perception threshold		
Third finger	3.31 (0.36)	3.52 (0.29)
Fifth finger	3.30 (0.36)	3.55 (0.32)
Vibration perception threshold		
Third finger 63 Hz (dB)	110.9 (6.2)	112.6 (7.3)
Third finger 125 Hz (dB)	100.3 (6.9)	102.5 (8.0)
Third finger 250 Hz (dB)	103.5 (8.2)	105.9 (9.0)
Fifth finger 63 Hz (dB)	112.4 (5.6)	112.8 (7.0)
Fifth finger 125 Hz (dB)	101.8 (6.2)	103.0 (7.8)
Fifth finger 250 Hz (dB)	102.0 (7.8)	104.1 (8.9)
Distal sensory latency		
Second finger (ms)	2.74 (0.44)	2.89 (0.37)
Fifth finger (ms)	2.62 (0.31)	2.57 (0.29)
Manual dexterity: Purdue Pegboard test (no. of pegs)	14.3 (1.6)	13.6 (1.8)

Table 5 Results of the multiple logistic regression analysis on the sensorineural symptoms as a function of the personal characteristics, and the results of the functional and sensory tests (prevalence odds ratios (POR), 95% confidence interval (CI) and statistical significance) (*PPT* pressure perception threshold)

	POR	95% CI	Significance
Questionnaire			
Health status (bad)	3.26	1.75–6.25	***
Smoking habits (yes vs no)	0.54	0.30–0.97	*
Wrist efforts at previous working situations	3.42	1.77–6.63	***
Vibrating tools at previous working situations	0.23	0.10–0.52	***
Groups			
Group 1 vs Groups 2 and 3	4.50	2.39–8.48	***
Tests taken separately			
Maximum flexion (°)	1.34[a]	1.11–1.63	**
PPT third finger	1.22[b]	0.99–1.49	*
PPT fifth finger	1.32[b]	1.08–1.62	**
Tests taken simultaneously			
Group 1 vs groups 2 and 3	3.20	1.56–6.55	**
Maximum flexion (°)	1.31[a]	1.07–1.61	**
PPT fifth finger	1.29[b]	1.03–1.63	*

* $P < 0.05$; **$P < 0.01$; ***$P < 0.001$
[a] POR maximum flexion: decrease of 5°
[b] POR PPT: increase of 0.2

Table 6 Results of the multiple logistic regression analysis on the sensorineural symptoms of workers exposed to vibration (group 1), as a function of the personal characteristics, and the results of the functional and sensory tests (prevalence odds ratios (POR), 95% confidence interval (CI) and statistical significance) (*NS* not significant)

	POR	95% CI	Significance
Questionnaire			
Health status (bad)	3.87	1.34–11.15	*
Vibrating tools at previous workplaces	0.17	0.06–0.48	***
Tiring previous workplaces	3.89	1.50–10.07	**
Tests taken separately			
Maximum radial deviation (°)	1.67[a]	1.01–2.78	*
Maximum flexion (°)	1.41[b]	1.03–1.92	*
Tests taken simultaneously			
Age	NS	NS	NS
Maximum radial deviation (°)	1.71[a]	1.02–2.85	*
Maximum flexion (°)	1.44[b]	1.04–1.98	*

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$
[a] POR maximum radial deviation: decrease of 5°
[b] POR maximum flexion: decrease of 5°

group effects remain and the results are significant only for three tests mentioned previously, maximum angle in flexion and PPT. When considered simultaneously, the group effects remain, but only the maximum angle in flexion and the PPT at the fifth finger show a significant association: a decrease in the maximum flexion angle by 5° leads to a POR of 1.31.

In principle, the use of the Stockholm scale is restricted to subjects exposed professionally to vibration. The above regressions were therefore repeated for only the 69 workers of group 1 (138 wrists) (Table 6). The main result is still the association with the maximum angle in flexion: a decrease by 5° leading to a POR of 1.44.

Discussion

The present study confirms the association between sensorineural symptoms and the exposure to vibration, association reported by different authors (Maeda and Griffin 1993, Nishiyama et al. 1994, Maeda et al. 1996). This association is very strong: the prevalence is about 40%, while, for the two groups not exposed to vibration, it is about twice as low (15 to 20%). The prevalence of 40% does not appear to be exceptionally high, many authors having reported values between 10 and 80% (Pyykkö 1986, Pelmear et al. 1992, Gemne et al. 1993).

According to the Stockholm scale, the symptoms are mainly at stage SN1 (low severity), with 9% of the cases at stage SN2 and none at stage SN3. McGeoch et al. (1994) reported much more severe symptoms (25% at stage SN2 and 9% at stage SN3); the population however, was much older and had had, on average, 25 years of exposure to vibration.

These sensorineural symptoms are mainly associated with the exposure to vibration. The main difference between the groups, resides actually, in the frequency of occurrence of these symptoms: 25% of the subjects of G1 complained of symptoms at least once a week, compared with only 2% in the two other groups. However, the prevalence was rather high (20%) for the subjects not exposed to vibration and it is surprising that few studies not dealing with vibration have considered these effects (except as far as the carpal tunnel syndrome is concerned). The Nordic questionnaire (Kuorinka et al. 1987), traditionally used to record musculoskeletal complaints, could be explicitly extended to include these sensorineural disorders.

The functional and sensory tests gave very different results for the three groups. The correlation between the results of the different tests was rather low ($R < 0.5$) suggesting that they are complementary, as was expected when we chose the tests. For the same test, the values recorded on different fingers and at different frequencies were, however, very highly correlated (R from 0.6 to 0.8). It is only in the case of a carpal tunnel syndrome that a disequilibrium between fingers can appear between the median and the ulnar nerves. Few cases of carpal tunnel syndrome were observed, and therefore the global correlation remained very high. The results were similar to those reported by Malchaire (1995) from a worker population ($n = 201$) not exposed to vibration.

The multivariate logistic correlation analysis showed an association between the existence of symptoms, a decrease in the maximum flexion angle of the wrist and an increase in the PPT (third and fifth fingers). This association however, was too low to make it possible to determine the limit values with a sensitivity and specificity sufficiently high to make a reliable diagnosis. This leads to the conclusion that the information given by these tests cannot be considered in relation with the sensorineural symptoms at stages SN1 and SN2 of the Stockholm scale.

In order to determine if the results of these tests, individually or collectively, make it possible to confirm the existence of sensorineural symptoms, we felt it might be that the tests should be performed when the subjects present those symptoms. This was not the case, since the symptoms occurred during the past 12 months and the situation may have improved by the time of the test. This is particularly true for very severe symptoms that would have justified a sick leave. Therefore, it cannot be concluded that these tests do not make it possible to diagnose sensorineural symptoms. At the most, the tests do not show any residual sign for subjects having presented symptoms during the past year but who continued or returned to work.

In conclusion, the stage SN1 symptoms on the Stockholm scale, experienced occasionally by some 40% of the users of vibrating tools, cannot be corroborated by the functional and sensory tests. The literature suggests that the PPT and VPT increase as a function of the severity of the neurological pathology. It can be therefore suggested that the symptoms observed at stages SN1 and SN2 are the first symptoms of the sensorineural disorders and precede any significant modification of the sensory functions. This contradicts the observation by Lawson and Nevell (1997): the number of cases reported by these authors was, however, very low.

Our study does not permit a conclusion to be drawn concerning the association between the tests and the symptoms at stages SN2 and SN3. However, in industrial environments, one is interested in the prevention of early symptoms at stage SN1. Therefore, there does not appear to be any test that occupational physicians could use to corroborate these symptoms.

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