Follow-Up Study of Vascular and Sensory Functions in Vibration-Exposed Shipyard Workers

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1. INTRODUCTION

Workers exposed to hand-transmitted vibration may complain of vascular and sensory disturbances in their fingers and hands, such as white finger, tingling, and numbness. Clinical and epidemiological studies have reported an association between exposure to hand-transmitted vibration and deterioration of vascular and sensory functions, but no well defined exposure-response relationship could be determined mainly because of the cross-sectional design of these studies (Bovenzi, 1998). The aim of this study was to investigate prospectively vibration induced vascular and sensory dysfunctions in shipyard workers who operated vibratory tools.

2. SUBJECTS AND METHODS

A cohort of 63 vibration-exposed shipyard workers was investigated by means of a medical interview, physical examination and laboratory methods for assessing peripheral vascular and sensory functions. Clinical and laboratory investigations were carried out at the initial survey and over a follow up period of 2 to 4 years, in connection with compulsory occupational health surveillance procedures established by Italian legislation. Thirteen subjects were lost to the follow up because of retirement (n=6) or change of job (n=7). All subjects continued to work with vibratory tools during the follow up. They wore ordinary, non-antivibration gloves. The diagnosis of vibration induced white finger (VWF) was made according to the criteria of the Stockholm Workshop '94, supplemented with administration of colour charts.

Finger systolic blood pressures (FSBP) at 10°C in a test finger as a percentage of FSBP at 30°C in the same finger, corrected for the change in FSBP at 30° and 10°C in a control finger ($FSBP\%_{10°}$), were measured by means of an *HVLab* multichannel strain-gauge plethysmograph according to the procedure recommended by the international standard ISO 14835-2 (2005).

An *HVLab* thermal aesthesiometer and an *HVLab* tactile vibrometer were used to measure hot and cold thresholds and vibrotactile thresholds, respectively. The thermal thresholds were measured before the vibrotactile thresholds. All subjects were tested by a single examiner who used the same apparatus and the same measurement protocol at both the cross-sectional and the follow up surveys. To avoid temporary loss of tactile sensation, on the day of the tests the subjects did not operate vibratory tools prior to the measurements of perception thresholds.

Thermal perception thresholds (TPT in °C) were measured at the palmar surface of the distal phalanx of digit II (innervated by the median nerve) and digit V (innervated by the ulnar nerve) of both hands using the method of limits. The thermograms (six cycles of warm and cold thresholds) were displayed on a computer screen and output to a printer. The software computed the means of the warm and cold thresholds, as well as of the neutral zone (the difference between the warm and cold thresholds), ignoring the first two cycles.

Vibrotactile perception thresholds (VPT) were measured at the fingertips of digit II and digit V of both hands using the up-and-down method of limits according to the recommendations of international standard ISO 13091-1 (2001). VPT were determined at the frequencies of 31.5 and 125 Hz to reflect the response of Meissner's corpuscles and Pacini's corpuscles, respectively. The vibrograms were displayed on a computer screen and output to a printer. The software computed the mean VPT at each frequency by averaging the peaks and troughs of the acceleration time history (six consistent vibration reversals). VPTs were expressed in decibels (dB) relative to a reference r.m.s. acceleration of 10^{-6} $m.s^{-2}$.

Vibration generated by the tools used by the shipyard workers (grinders, wrenches, drills, nut runners, and pistol-grip screwdrivers) was measured according to ISO 5349-1 (2001).

Duration of exposure to hand-transmitted vibration during a typical workday was estimated by a supervisor who used a stopwatch method. Daily vibration exposure was expressed in terms of 8-h energy-equivalent frequency-weighted acceleration ($A(8)$ in $m.s^{-2}$ r.m.s.).

The prevalence and cumulative incidence of vascular and sensory disorders were estimated by conventional epidemiological methods. The relations of vascular and sensory outcomes to measures of vibration exposure were assessed by random-intercept linear regression to account for the within-subject dependency of the observations over time. Data analysis was performed with a transition model to 'capture' the longitudinal part of the relationship between outcomes and predictor variables (Twisk, 2003).

3. RESULTS

At the initial survey, the mean (SD) age of the 50 surveyed workers was 37.5 (10.5) yr; BMI averaged 26.6 (3.8) kg.m^{-2}. Smoking and drinking habits were reported by 56% and 60% of the subjects, respectively. Daily vibration exposure did not differ significantly between the initial survey and the end of the follow up (A(8) about 3.1 ms^{-2}).

Table 1. FSBP%$_{10°}$, hot and cold perception thresholds, and thermal neutral zone (hot threshold – cold threshold) in the vibration exposed workers (n=50) at the initial survey and the end of the follow up. Data are given as means (SD).

Outcome	Digit (r/l)	Initial survey	End of follow-up	P
FSBP%$_{10}$	III r	69.9 (28.9)	64.3 (32.1)	0.025
Hot threshold (°C)	II r	39.4 (3.7)	40.4 (3.6)	0.027
	II l	39.1 (5.0)	39.9 (4.2)	0.18
	V r	40.1 (3.8)	41.2 (3.7)	0.023
	V l	38.7 (3.9)	39.9 (3.3)	0.026
Cold threshold (°C)	II r	25.7 (3.0)	24.9 (3.1)	0.06
	II l	25.3 (3.4)	25.1 (3.1)	0.63
	V r	24.7 (3.3)	23.9 (3.2)	0.10
	V l	25.1 (3.0)	24.2 (3.7)	0.09
Neutral zone (°C)	II r	13.7 (6.3)	15.5 (6.3)	0.029
	II l	13.7 (7.9)	14.8 (6.4)	0.29
	V r	15.4 (6.6)	17.3 (6.5)	0.036
	V l	13.6 (6.4)	15.7 (6.4)	0.030

Table 2. Relation of the changes in FSBP%$_{10°}$ and thermal neutral zone (mean of the right and left digits (D)) to measures of vibration exposure over the follow-up period. The coefficients and robust 95% CI for the change in FSBP%$_{10°}$ or neutral zone per unit of increase in A(8) and follow-up time are estimated by random-intercept linear regression, while adjusting by age, BMI, smoking, drinking, and FSBP%$_{10°}$ or neutral zone measured at one time-point earlier (t – 1).

Outcome	D	Factors	Coeff	95% CI
FSBP%$_{10}$ (%)	III	A(8) (ms^{-2})	-5.0	-9.0 to -1.1*
		Follow-up (yr)	0.3	-9.4 to 9.9
		FSBP%$_{10°(t-1)}$	0.2	-0.2 to 0.5
Neutral zone (°C)	II	A(8) (ms^{-2})	-0.25	-0.81 to 0.30
		Follow-up (yr)	2.97	0.65 to 5.28*
		NZ$_{(t-1)}$ (°C)	0.43	0.18 to 0.67H
	V	A(8) (ms^{-2})	-0.07	-0.64 to 0.49
		Follow-up (yr)	3.06	1.16 to 4.96*
		NZ$_{(t-1)}$ (°C)	0.48	0.24 to 0.71H

*p<0.01; Hp<0.001

At the cross-sectional study, the point prevalence of symptoms was 36% for tingling, 32% for numbness, and 8% for VWF. Over the follow-up period, there were 5 new cases of tingling, 2 new cases of numbness, and 2 new cases of VWF, giving rise to cumulative incidences of 15.6%, 5.9% and 4.3% respectively. In the study population, FSBP%$_{10°}$ and TPT (Table 1), but not VPT (results not shown), deteriorated significantly over the follow-up period. After adjustment for several confounders, data analysis with a random-effects transition model showed that the changes over time in FSBP%$_{10°}$ and TPT were significantly related to either A(8) or the follow-up time. Table 2 reports the relations of the change in FSBP%$_{10°}$ and thermal neutral zone (hot threshold – cold threshold) to measures of vibration exposure. Changes over time in VPT were found to be related to vibration exposure only for digit V at 125 Hz (results not shown).

4. DISCUSSION

This follow up study of shipyard workers showed that exposure to hand-transmitted vibration can deteriorate finger circulation over time. This finding is consistent with those of previous experimental investigations and epidemiological studies with either cross-sectional or longitudinal design (Bovenzi et al., 2000; Bovenzi, 2010). Peripheral sensory dysfunction over time in the digits innervated by the median nerve (index finger) and the ulnar nerve (little finger) was limited to deterioration of thermal thresholds, while no significant differences were observed for vibrotactile perception thresholds. These findings suggest that in the vibration exposed workers of this study sensory nerve damage was at an early stage and occurred primarily in the small-calibre nerve fibres of the fingers which conduct thermal sensation (myelinated Aδ fibres, unmyelinated C fibres), rather than in the large-diameter fibres which are sensitive to tactile, pressure and vibration stimuli (myelinated Aβ fibres), (Nilsson and Lundström, 2001). After adjusting for potential confounders, longitudinal data analysis with a transition model showed that there were significant exposure-response relationships between measures of vibration exposure and impairment to vascular function and thermal acuity.

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