A Follow Up Study of Vibration-Induced White Finger in Compensation Claimants

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Abstract

The aim of this follow up clinical study was to investigate the changes in vascular symptoms and the cold response of digital vessels in 73 vibration-exposed workers claiming for VWF compensation. The subjects were followed up over a mean time period of 4.1 (range 1-11) years. They underwent a medical interview, a physical examination and a standardised cold test with measurement of finger systolic blood pressure. During the follow up period, all subjects continued to work with vibratory tools. At the first examination, 29 vibration-exposed workers had a positive history of VWF. There were 14 new cases of VWF during the follow up period ($p<0.05$). On a group basis, a significant increase in the vasoconstrictor response to cold was observed over the follow up time in both the incident cases of VWF and the workers with no symptoms of finger whiteness. Abnormal cold response was not associated with either age or smoking habit. These findings suggest that impairment to digital vasculature can develop over a short time in workers with current exposure to hand-transmitted vibration. That a few extra years of continued work with vibratory tools have caused a significant increase in the occurrence of VWF among currently active workers argues for the implementation of preventive measures as required by the European Directive on mechanical vibration (2002/44/EC).

Introduction

The prognosis of vibration-induced white finger (VWF) is still uncertain. Studies have reported that VWF may improve, persist or worsen in workers with current or previous exposure to hand-transmitted vibration. It has been suggested that cessation or reduction of vibration exposure may be associated with some reversibility of VWF, but the rate of remission of peripheral vascular symptoms over time is not well-known (Bovenzi et al, 1998; Futatsuka et al, 1989; Koskimies et al, 1992; Riddle and Taylor, 1981). On the other hand, there is clinical and epidemiological evidence that continued use of vibrating tools is associated with an unfavourable prognosis for VWF (Bovenzi et al, 1994; Ogasawara and Sakakibara, 1997; Östman et al, 1996). Most of the longitudinal studies of the prognosis of VWF, however, are based on anamnestic findings. Only a few investigators have monitored the natural course of VWF by means of objective clinical tests, in addition to health history (Bovenzi et al, 1998; Ekenvall and Carlson, 1987; Kurozawa et al, 2002; Petersen et al, 1995).

The aim of this follow up study was to investigate the changes in vascular symptoms and the cold response of digital vessels in a group of claimants for VWF compensation.

Materials and Methods

Subjects and medical investigation

From 1988 to 2002, 177 workers claiming for VWF compensation were sent to us by the National Insurance Institute for clinical and laboratory examinations. One hundred and four subjects were compensated, while 73 did not obtain compensation because of a negative medical history for VWF, positive history of VWF but negative cold test results, or incomplete administrative documentation.

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Of these 73 subjects, 10 were construction workers, 11 caulkers, 30 grinders, 9 welders, and 13 mechanics. Table 1 reports the characteristics of the study population at the first examination.

This selected worker group was followed up over a mean time period of 4.1 (range 1-11) years. Following the first examination, 44 subjects underwent a second re-examination, and 29 were re-examined twice. During the follow up period, all subjects continued to work with vibrating tools.

At each follow-up, workers underwent a medical interview, a complete physical examination and a standardised cold test. Subjects were interviewed on their work history, state of health, and consumption of tobacco and alcohol. The anamnestic diagnosis of VWF was based on the following criteria (Olsen et al, 1995): (i) positive history of cold provoked episodes of well demarcated blanching in one or more fingers; (ii) first appearance of finger blanching after the start of occupational exposure to hand-transmitted vibration and no other probable causes of Raynaud's phenomenon; (iii) experience of finger blanching attacks during the last two years. VWF symptoms were staged according to the Stockholm scale (Gemne et al, 1987). An increase or a fall of finger whiteness in at least six phalanges was required to define, respectively, a deterioration or an improvement of the number of phalanges affected with Raynaud's phenomenon over the follow up period.

Cold Test

The cold test was performed with the subject in a supine position after a rest period of 20 – 30 minutes in a laboratory room with an ambient temperature of 21 – 23°C. The cold test consisted of strain-gauge plethysmographic measurement of finger systolic blood pressure (FSBP) during local cooling according to a standardised technique (Nielsen and Lassen, 1977). A double inlet plastic cuff for both air filling and water perfusion was placed on the middle phalanx of the third left finger. In the subjects with subjective symptoms of VWF, the most affected finger was cooled. The test finger was warmed and cooled with water circulating at 30°C and 10°C with a digit cooling system. Two air filled cuffs were applied, one to the proximal phalanx of the test finger (for ischaemia during cooling), and one to the middle phalanx of a reference finger of the same hand (usually the fourth finger). The cold test was performed by pressurising the air cuffs to a suprasystolic level (210 mmHg) and perfusing the water cuff with water, initially at 30°C and then at 10°C. After five minutes of ischaemic cooling, FSBP was measured by a strain gauge in the distal phalanx of the test and reference finger. The results of the cold test was expressed as the change of systolic blood pressure in the test finger at 10°C ($FSBP_{t,10°}$) as a percentage of the pressure at 30°C ($FSBP_{t,30°}$), corrected for the change of pressure in the reference finger during the examination ($FSBP_{ref,30°} - FSBP_{ref,10°}$):

$$(FSBP_{t,10°} \times 100)/(FSBP_{t,30°} - (FSBP_{ref,30°} - FSBP_{ref,10°})) \quad (\%)$$

To avoid nicotine induced vasoconstrictive effects on the digital vessels, tobacco users refrained from smoking for at least two hours before testing.

The cold test at the various surveys was performed by the same method and apparatus (Digitmatic 2000, Medimatic A/S, Copenhagen, Denmark).

In a previous study of the cold response of digital arteries in 455 normal subjects, we found that $FSBP\%_{10°}$ averaged 94.8% (SD 11.8), (Bovenzi, 2002). For medicolegal purposes, in the present study the finding of $FSBP\%_{10°} < 60\%$ (mean − 3 SD in normals) was considered an abnormal response of the digital vessels to cold provocation. The same criterion was applied to define an improvement or a deterioration of the cold response over the follow up period, that is an improvement whether $FSBP\%_{10°}$ changed from a value lower to a value higher than 60%, a deterioration whether $FSBP\%_{10°}$ changed in the opposite direction.

Statistical Methods

Data analysis was performed with the statistical software Stata v. 8.2 (Stata Corporation, 2003) and StatXact v. 4.0.1 (Cytel Software Corporation, 1992). Continuous variables were summarised using means or medians as measures of central tendency and standard deviations (SD), quartiles or range as measures of dispersion. The Kruskal-Wallis one-way analysis of variance was used to compare independent groups. The McNemar test was used to test the equality of response rates in paired dependent data. The χ^2 statistic was applied to independent data tabulated in 2×2 or $2 \times k$ contingency tables. The relation between repeated measures of $FSBP\%_{10°}$ and several individual and exposure variables was assessed by the generalised estimating equations method for longitudinal data in order to account for the within subject correlation (Diggle et al, 1994).

Results

At the first examination, the worker groups were comparable for age, anthropometric characteristics, smoking and drinking habits (Table 1). Daily vibration exposure (hours) was greater in the caulkers (p=0.025) and total duration of usage of vibrating tools (years) was greater in the welder group (p<0.05). Almost all workers reported sensorineural disturbances (tingling and/or numbness) in their fingers and hands. VWF symptoms were more frequent in caulkers, grinders and mechanics when compared with construction workers and welders (p<0.05). Mean latency time for VWF was 7.0 (range 1 – 35) years. There was no association between VWF symptoms and drinking or smoking habits.

At the first examination, 29 vibration-exposed workers had a positive history of VWF. Of these workers, 26 reported unchanged digital vascular complaints, and 3 recovered from white finger during the follow up (Table 2). The three workers who recovered from finger blanching had been classified as VWF stage 1 (n=2) and stage 2 (n=1).

Table 1. Characteristics of the study population at the first examination. Values are given as medians (quartiles) or numbers (%).

	Construction workers (n=10)	Caulkers (n=11)	Grinders (n=30)	Welders (n=9)	Mechanics (n=13)
Age (yr)	53 (46-54)	49 (45-52)	48 (43-52)	50 (44-52)	46 (44-53)
BMI (kg/m^2)	26 (24-30)	27 (24-29)	26 (24-28)	25 (24-26)	27 (24-28)
Smokers	1 (10.0)	6 (54.6)	16 (53.3)	3 (33.3)	5 (38.5)
Drinkers	7 (70.0)	6 (54.6)	20 (66.6)	4 (44.4)	9 (69.2)
Exposure: hr/d	2 (1-3)	4 (3-5)	2.5 (2-5)	2 (1-3)	2 (1-3)**
days/y	100 (80-200)	200 (150-220)	200 (150-220)	150(100-180)	200 (150-220)*
years	20 (4-30)	20 (16-24)	21 (16-29)	34 (30-36)	23 (15-30)*
VWF: Stage 1	1 (10.0)	2 (18.2)	3 (10.0)	0 (0)	2 (15.4)
Stage 2	0 (0)	2 (18.2)	5 (16.7)	0 (0)	4 (30.8)
Stage 3	0 (0)	2 (18.2)	7 (23.3)	1 (11.1)	0 (0)
Stage 1+2+3	1 (10.0)	6 (54.6)	15 (50.0)	1 (11.1)	6 (46.2)†
Sensorineural symptoms	10 (100)	11 (100)	27 (90.0)	9 (100)	13 (100)

BMI: body mass index; Kruskal-Wallis test:*p<0.05, **p=0.025; χ^2 test:†p<0.05

Table 2. Change in vascular disorders from the first to the last examination in the vibration-exposed workers. Values are given as numbers.

	No vasospastic symptoms/signs	Change in vascular disorders		
		Improved	Stationary	Deteriorated
VWF	30	3	26	14*
VWF stage	30	7	20	16*
Number of phalanges with VWF	30	6	16	21*
Abnormal cold response ($FSBP\%_{10°}$ <60%)	45	6	14	8

McNemar test: *p<0.05

Table 3. Logistic regression of vibration-induced white finger (VWF) and finger systolic blood pressure during local cooling to 10°C ($FSBP\%_{10°}$) on individual and exposure variables in the vibration exposed workers (n=73). $FSBP\%_{10°}$ is dichotomised at either 60% of the pressure at 30°C or at zero value (closure of the digital arteries). The generalised estimating equations (GEE) method was used to account for correlation between repeated measures of both dependent and independent variables withing subject during the follow up period. Odds ratios (OR) and robust 95% confidence intervals (95% CI) are shown.

Predictors	VWF	$FSBP\%_{10°}$ < 60%	Zero $FSBP\%_{10°}$
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Age (yr)	0.97 (0.92-1.03)	0.95 (0.89-1.01)	1.04 (0.95-1.12)
Smoking (pack-yr)	1.01 (0.99-1.03)	1.00 (0.97-1.02)	0.97 (0.94-1.01)
Daily vibration exposure (hr)	1.19 (1.01-1.41)	1.06 (0.86-1.30)	0.99 (0.74-1.31)
Follow up time (yr)	1.07 (0.97-1.19)	1.15 (1.01-1.32)	0.98 (0.80-1.20)
VWF (0=no/1=yes)	–	4.24 (1.93-9.31)	6.57 (1.95-22.1)

Table 4. Linear regression of $FSBP\%_{10°}$ on individual and exposure variables in the vibration-exposed workers according to their VWF status during follow up. Estimates of regression coefficients (robust standard errors) by the GEE method are shown.

Predictors	$FSBP\%_{10°}$ during follow up		
	Never VWF (n=30)	Incident cases of VWF (n=14)	Prevalent cases of VWF (n=26)†
Intercept	135 (30.0)	70.9 (32.1)	14.0 (38.5)
Age (yr)	-0.78 (0.59)	0.11 (0.67)	0.41 (0.79)
Smoking (pack-yr)	-0.31 (0.18)	-0.09 (0.22)	0.49 (0.26)
Daily vibration exposure (hr)	-1.92 (1.58)	-2.00 (3.43)	-1.97 (2.55)
Follow up time (yr)	-2.86 (1.01)**	-4.14 (1.82)*	0.04 (1.78)

†Three subjects, who had recovered from VWF, were excluded from analysis
*p=0.02; **p<0.01

There were 14 new cases of white finger during the follow up period ($p<0.05$): eight new cases were classified as VWF stage 1, four as VWF stage 2, and two as VWF stage 3. Among the new VWF cases, 4 were construction workers, 4 welders, 3 grinders, 2 mechanics, and 1 caulker. Significant deterioration in the distribution of VWF stages and the number of phalanges affected with whiteness was observed over the follow up period ($p<0.05$). However, 4 workers showed an amelioration of VWF stage: one subject improved from stage 2 to stage 1, and three men changed from stage 3 to stage 2.

At the end of the follow up, 40 out of 73 workers (54.8%) had a positive history of VWF, 3 subjects had recovered from VWF, and 30 men complained of cold fingers and hands without episodes of finger whiteness. Of the workers affected with digital ischaemic attacks, 14 were in VWF stage 1 (19.2%), 14 in VWF stage 2 (19.2%), and 12 in VWF stage 3 (16.4%).

Cold response of the digital arteries deteriorated in 8 workers (all among the incident cases of VWF), while improvement in the cold test ($FSBP\%_{10°} > 60\%$) was observed in 6 subjects (3 with recovery from VWF, and 3 with amelioration of VWF stage).

Analysis of repeated measures of FSBP during local cooling by the generalised estimating equations (GEE) method for longitudinal data showed that both abnormal cold response of digital arteries ($FSBP\%_{10°} < 60\%$) and closing phenomenon of the digital arteries (zero $FSBP\%_{10°}$) were significantly associated with the presence of VWF (Table 3). Moreover, exaggerated vasoconstrictor response to cold was related to the duration of exposure since the first examination (i.e. follow up time), whereas VWF symptoms were associated with daily exposure time during the follow up.

Marginal linear regression (GEE method) of $FSBP\%_{10°}$ on individual and exposure variables showed that the reduction of $FSBP\%_{10°}$ (i.e. deterioration) was significantly related to the follow up time in both the incident cases of VWF (−4% per year) and the workers with no symptoms of finger whiteness (−3% per year), (Table 4). $FSBP\%_{10°}$ at the first examination and changes in $FSBP\%_{10°}$ during the follow up were not associated with either age or smoking habit.

Discussion

VWF is a peripheral vascular disorder of occupational origin which is compensated in many industrialised countries. In a recent recommendation for a European schedule of occupational diseases (2003/670/EC), the Commission of the European Communities includes "*angioneurotic diseases caused by mechanical vibration*" (Annex I, item 505.02) among health disorders which show a direct link with occupation on the basis of clinical and epidemiological evidence. "*Osteoarticular diseases of the hands and wrists caused by mechanical vibration*" are also included in the new Commission recommendation (Annex I, item 505.01). In Italy, both VWF and bone and joint disorders of the upper limb are included in the official schedule of occupational diseases in industry (item 52) and agriculture (item 27), (DPR No. 336/1994). Moreover, pre-employment and yearly follow up health surveillance is prescribed for workers occupationally exposed to hand-transmitted vibration. At present, vibration-induced upper-limb disorders represent the fifth occupational disease compensated in Italy. To obtain compensation, workers complaining VWF symptoms must undergo a series of clinical and laboratory examinations to assess objectively the presence of vascular disorders and their severity.

The results of this follow up study of VWF in active vibration-exposed workers claiming for compensation are consistent with the findings of other investigations which suggest that continued work with hand-held vibrating tools is significantly associated with an increase in the occurrence of VWF, increased severity of digital vasospastic symptoms, and increased responsiveness of digital arteries to cold. In a cohort study of welders exposed to hand-transmitted vibration, Östman et al (1996) found that among workers with continued vibration exposure, none showed subjective improvement, 56% claimed unchanged problems and 44% reported worse symptoms. In a follow up clinical study of 353 Japanese workers receiving treatment for hand-arm vibration syndrome, it was observed that continued use of vibratory tools was associated with an unfavourable prognosis for VWF (Ogasawara and Sakakibara, 1997). In a follow up study of the course of VWF in 55 Swedish men, patients who continued to work with vibratory tools reported an increase in subjective symptoms which were associated with an increased vasoconstrictor response of the digital arteries to a standardised cold test (Ekenvall and Carlsson, 1987). In a group of active stoneworkers using percussive and rotary tools, a 38% onset of new cases of VWF was observed in a six-year follow up period (Bovenzi et al, 1994). In a follow up clinical investigation of 102 patients with advanced stages of VWF, Petersen et al (1995) reported that continued exposure to hand-transmitted vibration had a negative influence on VWF reversibility.

It is worth noting that most of the aforementioned studies pointed out that cessation or reduction of vibration exposure were associated with either recovery from VWF or improvement of VWF stages. In some studies of forestry workers, the decrease in the incidence of VWF in active chain sawyers was attributed to the use of lighter anti-vibration (AV) chain saws and the introduction of administrative measures curtailing daily saw usage time and improving the organisation of forest work (Futatsuka et al, 1989; Koskimies et al, 1992). It should be noted, however, that new cases of VWF have been reported in active workers who used AV tools of new generation (Bovenzi et al, 1998; Olsen and Nielsen, 1988; Riddle and Taylor, 1982). These findings suggest that health surveillance should be maintained in workers whose work experience is limited to AV tools only. This is also consistent with the provisions established by the new European Directive 2002/44/EC on the protection of workers against risks arising from mechanical vibration (2002).

In this study, an abnormal response of digital arteries to cold provocation was associated with both VWF symptoms and the duration of vibration exposure since the first examination. As expected, digital arterial hyperresponsiveness to cold was significantly related to the follow up time in the incident cases of VWF. However, a significant reduction of $FSBP\%_{10°}$ (i.e. aggravation) was also observed in workers with no positive history of episodes of finger blanching attacks during the follow up period. Similar findings have been reported by other researchers who investigated prospectively the changes in the occurrence of VWF by means of medical interview and cold test (Bovenzi et al, 1998; Olsen et al, 1982; Olsen and Nielsen, 1988). These authors observed a deterioration of FSBP% during cooling in asymptomatic workers who had operated only AV tools. This means that damage to the vasoconstrictor mechanisms in the digital vessels may occur even in subjects exposed to hand-transmitted vibration of low intensity.

The results of this clinical investigation indicate that, when combined with reliable work and health histories, FSBP measurement after finger cooling is an accurate laboratory testing method to detect cold-induced digital vasospasm and to confirm VWF symptoms objectively. Moreover, the cold test may be useful for disclosing increased hyperreactivity in cold-induced vasoconstrictor response in vibration-exposed workers with a negative anamnesis for finger blanching attacks. In this follow up study, some subjects without VWF symptoms exhibited an exaggerated digital arterial response to cold, suggesting that FSBP measurement during local cooling may be useful to uncover preclinical Raynaud's phenomenon.

In this study, there were no significant associations between VWF symptoms and smoking, and between the results of the cold test and smoking both at the first examination and during the follow up. The role of tobacco consumption on the course of VWF is still a controversial matter. The findings of some clinical and epidemiological studies suggest that smokers have a poorer prognosis for VWF (Cherniack et al, 2000; Ekenvall and Carlsson, 1987; Petersen et al, 1995). It has been reported that after cessation or reduction of vibration exposure the rate of VWF recovery was greater and the improvement in the cold response of digital vessels was more evident in non-smokers or ex-smokers than in current smokers. On the contrary, other studies have reported no influence of smoking on either the progression of VWF in current users of vibratory tools or the reversibilty of

VWF in ex-users (Bovenzi et al, 1998; Futatsuka and Sakurai, 1986; Ogasawara and Sakakibara, 1997). Even though the adverse effects of smoking on arterial function are well known, nevertheless its contribution to the onset and development of VWF symptoms, as well as its influence on VWF reversibility, are not yet established.

In conclusion, this clinical investigation showed that 14 new cases of VWF occurred in a selected group of currently active vibration-exposed workers after one to 11 years of observation. Moreover, the cold response of digital arteries deteriorated significantly during the follow up period not only in the incident cases of VWF but also in the vibration-exposed workers with no digital vasospastic symptoms during the follow up. In the incident cases of VWF, finger blanching attacks became visible after 3.4 (SD 1.8) years since the first examination. This finding suggests that impairment to digital vasculature can develop over a short time in workers with current exposure to hand-transmitted vibration from power tools. That a few extra years of continued work with vibratory tools have caused a significant increase in the occurrence of VWF symptoms and signs among currently active men employed in various industrial sectors, is a matter of concern for the occupational health physician. This argues for the adoption and implementation of preventive measures to improve the safety and health of vibration-exposed operators at work as required by the European Directive on mechanical vibration (2002).

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