Original article

Cold provocation testing and hand–arm vibration syndrome – an audit of the results of the Department of Trade and Industry scheme for the evaluation of miners

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Background: **Hand–arm vibration syndrome (HAVS) is a major industrial disease that causes considerable morbidity among workers exposed to vibration. Compensation is paid to those affected in civil claims against employers and (in the UK) in claims made under Social Security legislation rules for Prescribed Disease A11. Diagnostic tests have been proposed but most are not objective. The cold provocation test (CPT), which is objective, is often included in the evaluation of HAVS.**
Methods: **A continuous audit was made of the findings recorded at the 18 HAVS test centres in the UK established to evaluate miners. The audit, and its outcome, were monitored by the Medical Reference Panel who advise the Department of Trade and Industry. This audit report constitutes the second analysis of the findings relating to the CPT.**
Results: **The CPT, with measurement of digital rewarming times, is of no value in assessing vibration-induced damage to the hands.**
Conclusion: **In its present format, the CPT should not be used for evaluating the vascular component of HAVS.**

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Introduction

Vibration-induced damage to the hands is a well recognised entity, being first described in 1911 by Loriga and then more fully by Alice Hamilton in 1918[1]. The term spastic anaemia gave way to vibration white finger and, more recently, to hand–arm vibration syndrome (HAVS). The syndrome is characterized by neurological symptoms, principally tingling and numbness, and by vascular symptoms and signs typical of vasospasm. Comparison has been made with Raynaud's phenomenon and HAVS is regarded as a cause of secondary Raynaud's phenomenon. Sufferers probably represent the largest group of workers in the world claiming compensation for any single industrial disease or injury.

Vibration-induced damage to the hands is proportional to the vibration dose received; various standards define harmful exposure, for example BSI 6842 (1987), reissued as DD ENV 25349 in 1993[2], and ISO 5349 (1986)[3]. 'Safe' levels of vibration are described[4], in which the frequency weighted acceleration level does not reach 1·0 m/s^2. When a vibration dose is 2·8 m/s^2 or more for an 8-h working day – the A8 figure – the 'action' level has been exceeded. The 4-h value (A4) equivalent to this A8 figure is 3·9 m/s^2. Medical surveillance should be implemented at these levels. The action level should not be confused with the safe level. Tools used in the mining industry often lie at a high frequency weighted acceleration level. For example, pneumatic picks have levels in the region of 20 m/s^2 and 10 min of exposure will exceed the action level of A8 (2·8 m/s^2). The most harmful vibration frequency range is thought to be 8–1000 Hz.

As with all instances of Raynaud's phenomenon, diagnosis depends on a reliable description of the symptoms given by the sufferer, for there are rarely any signs to be seen at the time of the clinical consultation. The

need for a diagnostic test to confirm the presence of the clinical problem is obvious. The diagnosis of HAVS may result in financial gain and, as an opportunity for abuse of the claiming process exists, the need for a diagnostic test is very relevant in this context. Assessment of the neuropathic component of HAVS is rarely objective. Although neurophysiological assessment is objective, it has not found favour with most clinicians assessing HAVS. HAVS affects small nerve fibres and mechanoreceptors, and neurophysiological testing is best at assessing large rapidly conducting myelinated fibres. It has been suggested that a severe HAVS neuropathy may be assessed by nerve conduction studies[5], but their use is probably best confined to assessing the presence of median nerve damage at the level of the wrist. Other nerve tests are available but, as they require the response of the person being studied, they cannot be regarded as objective.

In the light of the above, attention has concentrated on attempting to ascertain whether the response to cold in the fingers can be measured. If this were possible, objectivity should be achievable. A wide variety of cold challenge 'tests' have been described but, by and large, these 'tests' have proved idiosyncratic to the user and have provided no measurable outcome. Furthermore, none has any standard for comparison. Ice challenge tests and cold-water challenge tests involving visual inspection of the fingers to measure the response are of no value. Their use should have been abandoned long ago[6].

The above notwithstanding, it has generally been thought that the measured response to immersion of the hands in cool water might form the basis of a useful, objective and reproducible test. Such a manoeuvre was evaluated by Griffin and Lindsell[7] and was incorporated into the scheme of evaluation for miners. However, reservations were expressed by the authors who found greater variability of test result in workers with HAVS than in a control group of office workers. They also found that the outcome of testing could be 'positive' one day and 'negative' the next in HAVS sufferers. Despite this, Griffin and Lindsell concluded that the 'repeatability' of the test was acceptable for the routine diagnosis and screening of vibration-induced white finger. They also advised, if the clinical history and the results of testing were not compatible, that the test should be repeated.

The medical assessment process for miners has been described by Lawson and McGeoch[8]. In order to evaluate the usefulness of the test, a regular audit of miners undergoing assessment for HAVS has been maintained by the Medical Reference Panel, a body responsible for advising the Department of Trade and Industry (DTI) in the UK.

Materials and methods

This audit relates to the second cohort of approximately 24 000 miners undergoing assessment at one of 18 HAVS test centres in the UK. A CPT was performed on most of these workers. Miners who had a history of angina or ischaemic heart disease in the 12 months preceding the test and those over the age of 70 years at the time of testing were excluded; this left a group of 19 909 for analysis. The group was assessed by doctors specifically trained for the purpose in one of 18 test centres maintained by the DTI. Histories were taken in which leading questions were avoided; discreet questioning was used to elicit symptoms of blanching or other colour changes in the fingers. A history of digital coldness alone was not accepted as a valid symptom; blanching was required. A blanching score was recorded and, if the history was in keeping with the diagnosis of the vascular component of HAVS, the worker was staged using a modified version of the Stockholm Workshop Scale (*Table 1*).

The temperature of the examination room was maintained at between 20 and 22°C, and was recorded for each claimant. The CPT was carried out by attaching a thermocouple to each of the eight fingers; thumbs were excluded. After a stabilizing period of 2 min, the hands were placed inside plastic gloves and then immersed up to the wrist in water at 15°C for 5 min. Finger skin temperature was measured for 10 min after exiting the bath. All clinical findings and test results were collected in a single database. Normative data for the time to rewarm were taken from Griffin and Lindsell[7] and from Lawson and Nevell[9] (mean + two standard deviations); this was $T + 4$°C at less than 300 s, where T is the preimmersion finger temperature. A scoring system was adopted to define degrees of abnormality (*Table 2*).

Table 1 Modified Stockholm Workshop Scale

Stage	Criteria
0V	No attacks
1V	Attacks affecting only the tips of the distal phalanges of one or more fingers and usually a blanching score of 1–4
2V	Occasional attacks of whiteness affecting the distal and middle phalanges (rarely also the proximal) of one or more fingers and usually a blanching score of 5–16
3V	Frequent attacks of whiteness affecting all of the phalanges of most of the fingers and usually a blanching score of 18 or more
4V	As for 3V with trophic changes

Blanching score relates to extent of blanching: over terminal phalanx 1, middle phalanx 2, proximal phalanx 3. The maximum score per digit is 6. Each hand is scored separately.

Table 2 Scoring system for cold provocation test, *T* is the precooling finger temperature

Time (s) to reach *T* (+ 4°C)	Score
≤ 300	0
> 300, ≤ 600	1
> 600	2

Table 3 Comparison of Stockholm Workshop Scale grading with cold provocation test result (positive response)

Stockholm Workshop Scale stage	Cold provocation test positive response rate (%)	
	Left hand	Right hand
0V	46·8	44·2
1V	47·4	46·2
2V	51·0	50·5
3V	56·1	55·5

Table 4 Clinical severity and cold provocation test score for each hand in 19 909 vibration-exposed workers

	Cold provocation test score				
	0	1–3	4–6	7+	Total
Modified Stockholm Workshop Scale					
Left hand					
0V	2978	811	844	866	5499
1V	1871	531	591	564	3557
2V	3824	1229	1375	1371	7799
3V	1339	486	623	605	3053
4V	1				1
Total	10 013	3057	3433	3406	19 909
Right hand					
0V	2978	762	776	817	5333
1V	1806	523	509	521	3359
2V	3991	1295	1364	1412	8062
3V	1407	510	600	637	3154
4V	1	0	0	0	1
Total	10 183	3090	3249	3387	19 909

Results

An attempt was made to identify the proportion of vibration-exposed miners in the UK who have made a claim for HAVS. A precise figure for the total number of vibration-exposed miners is difficult to obtain and the best proportional estimate that can made is that 55–60 per cent of miners exposed to vibrating tools have claimed compensation for vibration-induced damage to the hands. This estimate is well within the range of analogous values quoted in various work-place epidemiological surveys[10].

The prevalence of vascular symptoms in the 19 909 miners tested was 73·8 per cent. Their mean(s.d.) age was 52·6(11·9) years and the mean(s.d.) number of years of vibration exposure at the time of testing was 20·3(11·9) years. A positive CPT was recorded in 10 692 miners (53·7 per cent) and 9217 (46·3 per cent) had bilateral negative test results.

The clinical stage on the Stockholm Workshop Scale (*Table 1*) was compared with the CPT positive response rate for left and right hands individually; a single subject staged 4V was discounted from the statistical analysis (*Table 3*). The results of the CPT were also scored as in *Table 2*, such that the most abnormal test result was eight points for each hand. The score was then compared with the clinical stage (*Table 4*).

The findings were subjected to receiver operating characteristic analysis. This showed an area under the curve of 0·54 for both the left and the right hand, with 1·0 representing a perfect diagnosis and 0·50 representing a chance finding. Clinical severity correlated only very slightly with test results, showing the CPT to be of no value in the diagnosis of HAVS.

Discussion

When devising a test for a clinical problem a knowledge of the pathological process is desirable. The exact pathophysiology of HAVS is not known. It is well recognized that changes occur in the structure and quantity of small peripheral nerves and nerve endings, and that there is a thickening of the arteriolar media layer; a comprehensive description of the changes is given in Pelmear's book[10]. Does the vasospasm of HAVS occur as a result of the vascular structural changes or is it a function of the neurological damage? Could the vasospasm have another cause? Whatever is responsible for the hypersensitivity to cold, the attacks of vasospasm are usually random in nature.

Given this background, the development of a provocative test of sufficiently high sensitivity and specificity to make it useful in clinical practice was always likely to prove difficult. McGeoch and Gilmour[11] have already shown that there is no association between the CPT and the vascular stage in what was probably the first publication drawing attention to the problems of the CPT in this format. However, this article was not published before the implementation of the miners' assessment programme in the UK.

The present work is the second analysis carried out in British miners; the results of the first analysis were presented in 2001[12]. Even then the data suggested that the CPT was of no practical value and this is confirmed

in the present study. When both studies are considered together, it is clear that almost 40 000 miners have been evaluated without any evidence in favour of the CPT as a useful tool in the assessment of HAVS. This conclusion is similar to that recently reached by the Health and Safety Laboratory[13].

Some authors may disagree with these findings. A small laboratory-based study, involving 21 HAVS sufferers, showed that thermographic evaluation of the response to cold provocation testing provided a useful test with high sensitivity, specificity, and positive and negative predictive values[14]. The test criteria were similar to those of the present study but the measurement of digital rewarming relied on thermography rather than thermocouples. Laboratory-based findings do not always easily translate to the clinical setting.

In a condition as common as HAVS, with its considerable association with financial compensation, there is a need for an objective diagnostic test. However, given the randomness of onset vasospastic attacks, there must be concern that finding objectivity through provocative testing will not prove possible. Nevertheless, work proceeds in this direction, particularly through measurement of the finger systolic arterial pressure response to cooling. From the presently available data, however, the conclusion is clear; the CPT, using the method here described, is of no value in evaluating the presence or severity of HAVS.

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