Occupational Medicine 2016;**66:**285–291
Advance Access publication 24 March 2016 doi:10.1093/occmed/kqw013

The relationship between clinical and standardized tests for hand–arm vibration syndrome

C. J. M. Poole[1], H. Mason[2] and A.-H. Harding[3]

[1]Centre for Workplace Health, Health and Safety Laboratory, Harpur Hill, Buxton, Derbyshire SK17 9JN, UK, [2]Chemical and Biological Risk Unit, Health and Safety Laboratory, Harpur Hill, Buxton, Derbyshire SK17 9JN, UK, [3]Mathematical Science Unit, Health and Safety Laboratory, Harpur Hill, Buxton, Derbyshire SK17 9JN, UK.

Correspondence to: C. J. M. Poole, Centre for Workplace Health, Health and Safety Laboratory, Harpur Hill, Buxton, Derbyshire SK17 9JN, UK. Tel: +44 01298 218452; e-mail: jon.poole@hsl.gsi.gov.uk

Background	Standardized laboratory tests are undertaken to assist the diagnosis and staging of hand–arm vibration syndrome (HAVS), but the strength of the relationship between the tests and clinical stages of HAVS is unknown.
Aims	To assess the relationship between the results of thermal aesthesiometry (TA), vibrotactile (VT) thresholds and cold provocation (CP) tests with the modified Stockholm scales for HAVS and to determine whether the relationship is affected by finger skin temperature.
Methods	Consecutive records of workers referred to a Tier 5 HAVS assessment centre from 2006 to 2015 were identified. The diagnosis and staging of cases was undertaken from the clinical information contained in the records. Cases with alternative or mixed diagnoses were excluded and staging performed according to the modified Stockholm scale without knowledge of the results of the standardized laboratory tests.
Results	A total of 279 cases of HAVS were analysed. Although there was a significant trend for sensorineural (SN) and vascular scores to increase with clinical stage ($P < 0.01$), there was no significant difference in scores between 2SN early and 2SN late or between 2SN late and 3SN. There was moderate correlation between the TA and VT scores and the clinical SN stages ($r = 0.6$). This correlation did not change when subjects were divided into those with a finger skin temperature <30 and >30°C. CP scores distributed bimodally and correlated poorly with clinical staging ($r = 0.2$).
Conclusions	Standardized SN tests distinguish between the lower Stockholm stages, but not above 2SN early. This has implications for health surveillance and UK policy.
Key words	Finger skin temperature; hand–arm vibration syndrome; HAVS; standardized tests; Stockholm scales.

Introduction

Hand–arm vibration syndrome (HAVS) is a disease caused by exposure to excessive amounts of hand-transmitted vibration. Both the magnitude of the vibration and the duration of exposure are important for causation, with a lifetime dose–response relationship [1]. Symptoms include tingling, numbness, pain, cold sensations, loss of dexterity, weakness of grip and blanching of the fingers, but its diagnosis may be difficult as it may not be distinguishable from other causes of Raynaud's phenomenon. HAVS is divided into vascular (V) and sensorineural (SN) components and its staging is determined by a combination of clinical symptoms, examination findings and standardized laboratory tests [2].

The standardized tests are psychophysical and designed to detect sensory peripheral neuropathy and vascular malfunction in the fingers. They include the measurement of thermal and vibration perception in the fingertips and cold provocation (CP) with thermography, plethysmography or systolic blood pressure measurements of the fingers. The tests were developed and standardized at the Institute of Sound and Vibration Research at the University of Southampton specifically to assist with the diagnosis and staging of workers with suspected HAVS [3].

Normal data (from a population of white- and blue-collar workers) for thermal and vibration perception thresholds and thermography after CP testing have shown increasing age, smoking and room temperature

to be confounding factors [4]. Results from thermal and vibration perception thresholds have been used to devise a scoring system and to separate Stockholm SN Stage 2 into early and late [5]. This scoring system has been used to assess >100 000 miners and ex-miners seeking compensation for HAVS from the UK's Department of Trade and Industry [6].

These tests, however, are limited by being available in only a few specialized centres and by low sensitivity and specificity for diagnosing vascular HAVS [7–9]. For this reason, the CP test is no longer used in some centres, although the SN tests are still being used in conjunction with clinical tests to detect receptor or small sensory nerve fibre dysfunction [10–12].

In the UK, the Health and Safety Executive (HSE) advises that workers exposed to >2.5 m/s^2 A (8) of hand-transmitted vibration should undergo tiered health surveillance. Those found to have HAVS at Stage 2 (late) or higher should be declared unfit to work with vibrating tools [13], so accurate diagnosis and staging is important if workers are not to lose their jobs unnecessarily or to be left to progress to more severe forms of the disease. High-level (Tier 5) HAVS testing with clinical examination by an occupational physician and standardized testing has been undertaken in the Health and Safety Laboratory (HSL) for many years.

The aim of this research was to evaluate the relationship between the clinical modified Stockholm stages of HAVS and the standardized laboratory test results and to see if the initial finger skin temperature has any effect on the relationship.

Methods

Workers referred to HSL for Tier 5 health surveillance have their clinical history ascertained to include an estimate of exposure to hand-transmitted vibration on the basis of previous and current tool usage, a medication review, a physical examination and standardized clinical testing. The latter includes sensory testing with five Weinstein Enhanced Sensory Tests (WEST) hand monofilaments with an inability to detect a minimum of 2 g force (purple) on the pulp of a digit taken as being abnormal, Adson's and Allen's vascular tests, Tinel's and Phalen's provocative tests for carpal tunnel syndrome, three maximum grip strengths measured with a Jamar dynamometer and dexterity tests using a Purdue pegboard.

The clinical diagnosis and Stockholm staging [13] were made by C.J.M.P. from the documented clinical information in stored medical records from 2006 (when monofilaments were introduced for sensory testing) to 2015, independently and blind of the results of standardized laboratory tests. The V stage was determined according to the extent and frequency of declared blanching. SN staging was based on symptom duration, evidence of sensory perception and dexterity loss. Cases that were not HAVS or cases with symptoms and signs of carpal tunnel syndrome, ulnar neuropathy or thoracic outlet syndrome were excluded from analysis. Cases of Raynaud's phenomenon judged not to be due to vibration, such as Raynaud's disease, were also excluded. Subjects with symptoms that were of uncertain credibility, such as blanching lasting for >2 h or no symptoms despite many years of high vibration exposure, were also excluded.

Thermal and vibrotactile (VT) perception tests were carried out by one of three trained technicians in a designated laboratory at an ambient temperature of 22°C (±2°C) and a noise level <50 dB(A). Subjects were allowed to habituate in indoor clothing for 30 min and until their finger skin temperature measured by a thermocouple was above 22°C. Workers were asked to avoid exposure to vibration on the day of testing and to avoid smoking for 1 h, coffee for 4 h and alcohol for 12 h prior to testing.

Thermal perception thresholds were measured for hot and cold by the Marstock method of limits with a rate of change of 1°C/s and a reference temperature of 32.5°C [3]. The stimulus was applied to the palmar surface of the centre of the pulp of the distal phalanx of the index and then the little fingers with a digit force of 2 N. A minimum of six cycles with a delay of 3 s between reversals were made with the first two hot and the first two cold cycles ignored for calculation. The mean hot threshold, the mean cold threshold and the difference between the hot and the cold thresholds, also known as the thermal neutral zone (TN), were calculated in degrees Celsius. A score was then calculated on the basis of the size of the difference between the thresholds and by combining the scores for the index and little fingers of each hand as recommended by Lawson and McGeoch [5]. The testing was done with the subject seated and whilst applying the pulp of a finger to an electrically heated smooth surfaced plate.

VT perception thresholds were measured for 31.5 and 125 Hz sinusoidal vibrations by the up-and-down method of limits (Bekesy method) with a final rate of change of vibration magnitude of 3 dB/s and measurement duration of 45 s [3]. The stimulus was applied to the palmar surface of the centre of the pulp of the distal phalanx of the index and then the little fingers with a digit force of 2 N whilst the subject was seated. The vibration magnitude was increased from zero until the subject perceived the stimulus and responded, and then decreased until the subject no longer perceived the vibration and responded, when the stimulus magnitude rose again. The threshold was calculated from the mean of the average peak and the average trough after ignoring the first peak and trough and expressed in m/s^2 rms. A score was then calculated for each frequency and finger tested using the method of Lawson and McGeoch [5].

When CP testing was undertaken in the laboratory, each hand was tested in turn and kept dry during immersion to the wrist into water at 15°C for 5 min. The hands were then removed from the tank and allowed to rewarm for 10 min. The rewarming curve from the beginning of the settling period to the end of the test was recorded for each finger using thermocouples. A score was given for each finger according to the time taken to rise by 4°C. The combined score for all the fingers of each hand was recorded.

Data entered onto an Excel spreadsheet included age, length of exposure to vibration in years, V and SN staging of each hand by C.J.M.P. Skin temperature, TN, VT and CP scores for each hand were entered by H.M.

Summary statistics of the data were produced. A non-parametric test for trend was used to analyse TN, VT and CP scores, age and length of exposure across the clinical SN and V stages. The Wilcoxon rank-sum test was used to compare the scores between each of the SN and V stages. Bootstrapped *t*-tests were used to compare skin temperatures. Correlation between the scores and staging was estimated by Spearman's rank correlation coefficient. Logistic regression was used to compare the odds ratio of HAVS associated with skin temperature <30 and ≥30°C. The trend in CP scores across categories of V staging was examined using bootstrapped linear regression. The association between age and length of exposure with SN and V staging was examined using bootstrapped ordered logistic regression. Statistical analysis was undertaken using Stata v13.1 (StataCorp 2013, Stata Statistical Software: Release 13; StataCorp LP, College Station, TX).

Ethical consent was obtained from HSE Ethics Research Committee (Ethcom/reg/01/12).

Results

The records of 279 cases of HAVS with a mean age of 45.5 (range 20–64) and a mean length of vibration exposure of 21.6 years (range 2–44 years) were analysed. All subjects were male. Six records were excluded due to uncertain credibility of the declared symptoms. There was a significant increase in the Stockholm SN stages by age and length of exposure ($P < 0.01$), but for the V stages, only length of exposure for the right hand and not age was significant ($P < 0.01$). There was high correlation between the right and left hands for SN and V scores (0.9 and 0.8 respectively), moderate correlation between age and length of exposure (0.6), but low correlation between SN and V stages (0.35).

The clinical SN and V stages, TN, VT and CP scores by hand are shown in Table 1. Fewer CP scores are shown because CP testing was stopped in this laboratory in 2012. The median scores increased significantly by clinical stage for the TN, VT and CP tests. For the SN tests, scores for Stage 0 were significantly different from Stage 1, which were significantly different from Stage 2 early,

Table 1. Descriptive statistics of the TN, VT and CP scores by clinical stage

	0SN	1SN	2SNE	2SNL	3SN	Test for trend[a]
SN stage						
Left hand						
Count	86	121	35	24	13	–
TN[b]	0 (0, 8)	2 (0, 8)	6 (0, 8)	6 (0, 8)	6 (0, 8)	<0.001
VT[b]	0 (0, 8)	1 (0, 8)	7 (0, 8)	7 (0, 8)	8 (1, 8)	<0.001
Combined[b,c]	0 (0, 16)	4 (0, 16)	12 (0, 16)	12.5 (0, 16)	13 (1, 16)	<0.001
Right hand						
Count	86	117	39	23	14	–
TN	0 (0, 8)	2 (0, 8)	8 (0, 8)	6 (0, 8)	8 (0, 8)	<0.001
VT	0 (0, 8)	1 (0, 8)	6 (0, 8)	6 (0, 8)	8 (0, 8)	<0.001
Combined[c]	0 (0, 16)	5 (0, 16)	11 (0, 16)	12 (2, 16)	15.5 (0, 16)	<0.001
	0V	1V	2VE	2VL	3V	Test for trend[a]
V stage						
Left hand						
Count	76	12	26	36	19	–
CP[b]	2 (0, 8)	7 (0, 8)	7 (0, 8)	7 (0, 8)	7 (0, 8)	<0.01
Right hand						
Count	78	18	20	35	18	–
CP[b]	2 (0, 8)	6 (0, 8)	5 (0, 8)	6 (0, 8)	7.5 (0, 8)	<0.001

SNE, sensorineural early; SNL, sensorineural late; VE, vascular, early; VL, vascular, late.
[a]Non-parametric test for trend across ordered categories.
[b]Data are medians with range in parentheses.
[c]Combined score = TN + VT.

but the scores for Stage 2 early were not significantly different from those for Stage 2 late and neither were the scores for Stage 2 late significantly different from Stage 3. The scores in Stage 1 were significantly different from Stage 2 if the early and late scores were combined, but the combined scores of Stage 2 were not significantly different from those of Stage 3 (Table 2).

The distribution of SN scores (TN and VT) by stage for the right and left hands are shown in Figures 1 and 2.

Table 2. Comparisons of TN and VT scores between SN stages

Comparison	TN score		VT score	
	Left hand	Right hand	Left hand	Right hand
0SN versus 1SN	<0.001	<0.001	<0.001	<0.001
1SN versus 2SNE	<0.001	<0.001	<0.001	<0.001
2SNE versus 2SNL	0.692	0.913	0.728	0.829
2SNL versus 3SN	0.920	0.407	0.462	0.098
1SN versus 2SNE + 2SNL	<0.001	<0.001	<0.001	<0.001
2SNE + 2SNL versus 3SN	0.764	0.373	0.332	0.065

Data are *P* values for the Wilcoxon rank-sum testing the difference in scores between the stages. SNE, sensorineural early; SNL, sensorineural late.

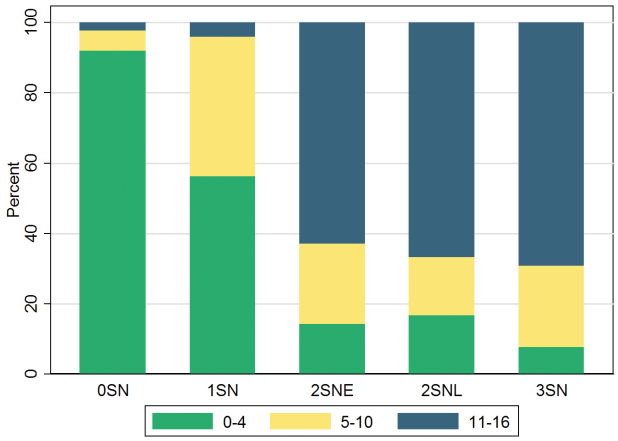

Figure 1. Left hand TN + VT scores by SN stage.

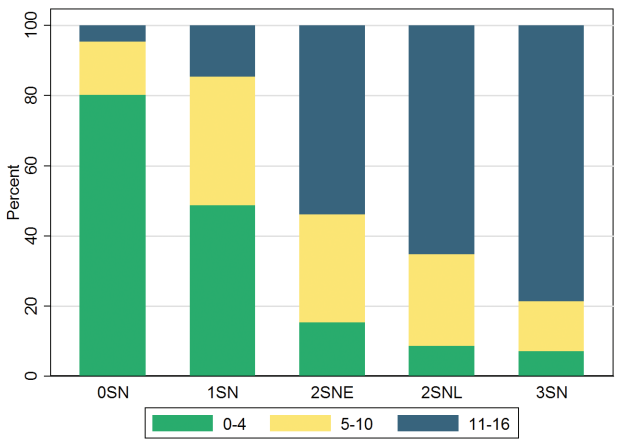

Figure 2. Right hand TN + VT scores by SN stage.

The distribution was similar when the TN and VT scores were disaggregated (not shown). The vascular CP scores divided into bimodal groups of high and low scorers (Table 3), suggesting that some people had an exaggerated vascular response to cold and others did not.

There was a moderate strength of correlation between the clinical SN stages and the TN, VT and TN/VT scores combined, but low correlation between the clinical V stage and the CP score (Table 4). Combining both the TN and VT scores increased the strength of the correlation by ~20%. There was no significant difference in the strength of the correlations when the subjects were divided into those with a finger skin temperature <30°C (n = 104 right and 110 left hands) and ≥30°C (n = 174 right and 168 left hands).

Those with vascular HAVS had a mean finger skin temperature of 29.5°C (28.8, 30.2) for right and 29.6°C (28.9, 30.3) for left hands and those without HAVS had a mean finger skin temperature of 31.2 (30.6, 31.8) right and 30.6 (29.9, 31.3) left hands ($P < 0.001$ right and $P < 0.05$ left hands). Six subjects had a finger skin temperature of <22°C. The finger skin temperature of those with SN HAVS was no different from those without SN HAVS. Those with a finger skin temperature <30°C had a higher CP score than those >30°C ($P < 0.001$). There was a significant trend for finger skin temperature to decrease as the V stage increased ($P < 0.001$ right and $P < 0.05$ left hands).

Table 3. CP scores by V stage and by hand

CP scores	V stage					
	0V	1V	2VE	2VL	3V	Total
Left hand CP scores						
0	**29**	**5**	**5**	**9**	**4**	52
1	4	0	0	1	0	5
2	6	0	0	2	0	8
3	6	0	1	2	0	9
4	7	0	1	0	1	9
5	1	0	3	1	1	6
6	1	1	0	1	3	6
7	2	0	4	4	2	12
8	**20**	**6**	**12**	**16**	**8**	62
Total	76	12	26	36	19	169
Right hand CP scores						
0	**34**	**7**	**4**	**7**	2	54
1	4	0	0	2	0	6
2	6	0	0	1	0	7
3	3	0	2	6	1	12
4	7	0	2	0	3	12
5	2	0	3	1	1	7
6	0	3	1	1	1	6
7	2	1	1	1	1	6
8	**20**	**7**	**7**	**16**	**9**	59
Total	78	18	20	35	18	169

Bold indicates bimodal distribution of scores. VE, vascular, early; VL, vascular, late.

Table 4. Correlations between clinical stage and TN, VT and CP scores

	TN score	VT score	Combined score[a]
SN stage			
Left hand (n = 279)	0.595 (0.514, 0.666)	0.561 (0.475, 0.636)	0.657 (0.585, 0.719)
Right hand (n = 279)	0.519 (0.427, 0.600)	0.517 (0.425, 0.598)	0.610 (0.530, 0.679)
	CP score		
V stage			
Left hand (n = 169)	0.231 (0.083, 0.369)		
Right hand (n = 169)	0.282 (0.137, 0.416)		

Data are correlation coefficients with 95% confidence intervals in parentheses.
[a]Combined score = TN + VT.

Discussion

This study found a moderate degree of correlation between the scores from standardized laboratory tests of SN function in the fingers and the clinical SN stages of HAVS. The strength of correlation was similar for thermal aesthesiometry and VT threshold testing but increased by ~20% when both scores were combined. Dividing the cases into those with cold or warm finger skin temperatures had no effect on the strength of the association. The strength of the correlation between the thermography scores with CP testing and the clinical V stages was low, indicating that this test should be abandoned for the diagnosis and staging of HAVS. Subjects also broadly divided into two populations—those with normal CP scores and those with markedly abnormal scores, with little gradation in between, providing more evidence of its unreliability as a test for vascular HAVS.

TN, VT and CP scores showed a significant increasing trend with the modified [5] Stockholm stages with significant differences in SN scores between Stages 0, 1 and 2, but no significant difference in scores between Stage 2SN early and 2SN late or between Stage 2SN late and 3. The proportion of high SN scores can be seen in the stacked bar charts, to increase markedly after Stage 1 and to be similarly distributed in Stages 2 and 3. The inability of the SN tests to accurately identify when a worker has reached Stage 2 late has implications for the UK's Guidance on the Control of Vibration at Work Regulations 2005 and the management of workers with HAVS who are currently advised to stop working with hand-transmitted vibration when they reach Stage 2SN late [13], that is when they have lost sensory perception in their fingers but before any impairment in dexterity.

The strength of this study is that it is based on a large number of workers exposed to hand-transmitted vibration who were undergoing health surveillance which led to them being referred for Tier 5 HAVS assessment. The laboratory assessments were done in a standardized way and the results of those tests were entered into a spreadsheet, blind to the results of the clinical staging. Another strength is that the diagnosis of cases for inclusion in the analysis was done by one physician with extensive experience in HAVS and any cases with co-existing symptoms suggestive of an alternative or additional diagnosis, such as carpal tunnel syndrome, were excluded from the analysis.

A potential weakness of the research is that the clinical staging relied on reported and documented subjective symptoms by the workers, including the frequency of finger blanching and the duration of SN symptoms. To reduce subjectivity from sensory perception testing, subjects were not included in the study until monofilament testing was introduced in the laboratory, although since then different doctors have undertaken the clinical assessment which may have introduced some inter-observer bias in the sensory perception testing which was relied on by C.J.M.P. Setting the inability to perceive the 2 g force monofilament as the upper limit of normal sensory perception for older, heavy manual workers is in keeping with others [14] although a lower threshold in the range of 0.2–2 g force has been recommended [15].

Our finding of colder fingers in those with vascular HAVS is in keeping with a previous observation of finger coldness being associated with Raynaud's phenomenon [16]. The trend for finger skin temperature to fall with increasing stage of vascular HAVS is in keeping with this. We expected a cold finger skin temperature to have an adverse effect on the strength of the correlation with the clinical SN stage, but this was not the case. SN perception in normal subjects who had their fingers artificially cooled has been shown not to be adversely affected until finger skin temperature falls <20°C [17], although the VT perception threshold at 125 Hz has been shown to rise below 28°C [18].

The SN and V scoring system adopted by the HSE in their Guidance on the Control of Vibration at Work Regulations 2005 is based on the work of three groups: Lindsell and Griffin, who measured temperature and vibration thresholds in the fingers of normal subjects and found them to be non-normally distributed [4]; McGeoch *et al.*, who developed a scoring system to distinguish SN Stages 0 and 1 from Stages 2 and 3 [19] and Lawson and Nevell, who identified from a small number of cases the three best predictors for staging SN cases

and their discriminatory power [20], which were subsequently refined by Lawson and McGeoch to two predictors (TN and VT) for the assessment of a large number of litigants [5]. However, these authors give no detail about the power of their systems to distinguish normal from abnormal, or to stage cases, other than to say 'the scoring system was adopted from previous studies and available normative data from the existing laboratories in the UK'.

In Lawson and McGeoch's modification of the Stockholm Workshop scale, SN Stage 2 is subdivided into early and late according to the combined SN scores, or by the reported duration of the SN symptoms, with late being defined as when symptoms last more than 2 h, but are not constant. Our research would suggest that the former method of subdivision by combining SN scores may be unreliable. The latter method of symptom duration assumes that increasing degrees of sensory neuropathy are associated with longer lasting neurological symptoms, when in fact the converse may be true, thereby leading to misclassification of Stage 2. Whether the neuropathy in HAVS is temporary (i.e. a neuropraxia,), long lasting (i.e. an axonotmesis) or permanent (i.e. a neurotmesis) is unknown and warrants research.

In the light of industry's ability to control vibration exposure better, it is reasonable to argue that greater disablement of workers could be avoided by stopping exposure to vibration at an earlier stage of HAVS, such as when sensation starts to be lost in the fingers. If recommendations about workability are to be based on objective evidence, then our research would indicate that exposure to hand-transmitted vibration should cease when there are signs of early sensory peripheral neuropathy that is, at Stage 2 early. Such a change would have implications for HSE policy and for workers.

Key points

- There was a moderate level of correlation between the scores from thermal aesthesiometry and vibrotactile threshold testing and the clinical stages of sensorineural hand–arm vibration syndrome.
- The standardized sensorineural tests were unable to distinguish between the more severe clinical stages of hand–arm vibration syndrome.
- Consideration should be given to stopping exposure to hand-transmitted vibration when sensory perception is lost (2 sensorineural early), rather than just before hand dexterity is impaired (2 sensorineural late).

Funding

This work was funded by the Health and Safety Executive.

Conflicts of interest

None declared.

References

1. Jang JY, Kim S, Park SK, Roh J, Lee TY, Youn JT. Quantitative exposure assessment for shipyard workers exposed to hand-transmitted vibration from a variety of vibration tools. *AIHA J (Fairfax, Va)* 2002;**63:**305–310.
2. Lawson IJ, Burke F, McGeoch KL, Nilsson T, Proud G. Hand-arm vibration syndrome. In: Baxter PJ, Aw T-C, Cockcroft A, Durrington P, Harrington JM, eds. *Hunter's Diseases of Occupations*. 10th edn. London: Hodder & Stoughton, 2010;489–512.
3. Lindsell CJ, Griffin MJ. *Standardised Diagnostic Methods for Assessing Components of the Hand–Arm Vibration Syndrome. Contract Research Report 197. Institute of Sound and Vibration Research, University of Southampton*. Sudbury, UK: HSE, 1998.
4. Lindsell CJ, Griffin MJ. Normative data for vascular and neurological tests of the hand–arm vibration syndrome. *Int Arch Occup Environ Health* 2002;**75:**43–54.
5. Lawson IJ, McGeoch KL. A medical assessment process for a large volume of medico-legal compensation claims for hand–arm vibration syndrome. *Occup Med (Lond)* 2003;**53:**302–308.
6. McGeoch KL, Lawson IJ, Burke F, Proud G, Miles J. Use of sensorineural tests in a large volume of medico-legal compensation claims for HAVS. *Occup Med (Lond)* 2004;**54:**528–534.
7. Mason HJ, Poole K, Saxton J. A critique of a UK standardized test of finger rewarming after cold provocation in the diagnosis and staging of hand–arm vibration syndrome. *Occup Med (Lond)* 2003;**53:**325–330.
8. Poole K, Elms J, Mason HJ. The diagnostic value of finger systolic blood pressure and cold-provocation testing for the vascular component of hand–arm vibration syndrome in health surveillance. *Occup Med (Lond)* 2004;**54:**520–527.
9. Thompson A, House R, Manno M. The sensitivity and specificity of thermometry and plethysmography in the assessment of hand–arm vibration syndrome. *Occup Med (Lond)* 2008;**58:**181–186.
10. Nilsson T, Burström L, Hagberg M, Lundström R. Thermal perception thresholds among young adults exposed to hand-transmitted vibration. *Int Arch Occup Environ Health* 2008;**81:**519–533.
11. Rolke R, Rolke S, Vogt T *et al.* Hand–arm vibration syndrome: clinical characteristics, conventional electrophysiology and quantitative sensory testing. *Clin Neurophysiol* 2013;**124:**1680–1688.
12. Gerhardsson L, Burstrom L, Hagberg M, Lundstrom R, Nilsson T. Quantitative neurosensory findings, symptoms and signs in young vibration exposed workers. *J Occup Med & Tox* 2013;**8:**8.
13. *Hand–Arm Vibration—The Control of Vibration at Work Regulations 2005*. Sudbury, UK: HSE Books, 2005.
14. Birke JA, Brandsma JW, Schreuders TA, Piefer A. Sensory testing with monofilaments in Hansen's disease and normal control subjects. *Int J Lepr Other Mycobact Dis* 2000;**68:**291–298.

15. Poole K, Mason H. *The Value of the WEST Monofilaments in Detecting Neurosensory Deficit Caused by Hand–Arm Vibration Exposure: RR712*. Sudbury, UK: HSE Books, 2009.
16. Ishitake T, Ando H. Significance of finger coldness in hand–arm vibration syndrome. *Environ Health Prev Med* 2005;**10:**371–375.
17. Hayward RA, Griffin MJ. Measures of vibrotactile sensitivity in persons exposed to hand–arm vibration. *Scand J Work Environ Health* 1986;**12:**423–427.
18. Harazin B, Harazin-Lechowska A. Effect of changes in finger skin temperature on vibrotactile perception threshold. *Int J Occup Med Environ Health* 2007;**20:**223–227.
19. McGeoch KL, Gilmour WH, Taylor W. Sensorineural objective tests in the assessment of hand–arm vibration syndrome. *Occup Environ Med* 1994;**51:**57–61.
20. Lawson IJ, Nevell DA. Review of objective tests for the hand–arm vibration syndrome. *Occup Med (Lond)* 1997;**47:**15–20.

doi:10.1093/occmed/kqv209

It's not all hot air

I have now been playing the bagpipes for almost 60 years. I first became interested in the medical aspects of piping at medical school and later had the opportunity to research the physiological aspects at the RAF Institute of Aviation Medicine.

There is an old joke that pipers march up and down because it is harder to hit a moving target. Whilst that may, or may not, be true, there is a physiological benefit to marching in this way. The combination of hyperventilation and increased intrathoracic pressure can lead to fainting, particularly in young and inexperienced pipers. Keeping on the move facilitates return of blood to the heart by exercising the muscle pump. However, there are other occupational hazards to playing the Highland bagpipes.

Pipers can develop noise-induced hearing loss—although my wife complains that I have a listening deficit, not a hearing deficit. Many years ago, I took my pipes into an anechoic chamber to measure just how noisy they were. The noise at the left ear was 112 dBA (others have measured even higher levels) which is presumably why the HSE recommends hearing protection for pipers in pipe bands. There is a school of thought that those pipers in a band who are near to the drummers, who can be even louder, are more at risk than those in the front rank.

There has been a case of a young piper suffering a pneumothorax when playing, caused by the bursting of a bulla. Other pipers, particularly those who have been immunologically compromised, have been infected by the hide bag. Such bags are traditionally seasoned or kept supple and airtight by syrup or sugar solutions or commercially available seasonings. These are ideal culture media for such 'bag bugs' as cryptococcus or aspergillus, particularly if the piper is a 'wet blower'. Many pipers have moved to Goretex bags which removes the requirement for seasoning and reduces the risk.

One further risk is one not experienced by the author but known to Shakespeare. Shylock says in Act IV of *The Merchant of Venice*, 'And men there are... when the bagpipe sings i' th' nose cannot contain their urine'.

Mike Gibson
e-mail: mikegibson47@btinternet.com