Evidence Review Paper

HSE Workplace Health Expert Committee (WHEC)

HAND-ARM VIBRATION SYNDROME (HAVS) – REVIEW OF EVIDENCE ON PROGNOSIS

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WHEC Report

WHEC
Workplace Health Expert Comittee

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HAND-ARM VIBRATION SYNDROME (HAVS) – REVIEW OF EVIDENCE ON PROGNOSIS

This report, its contents, including any opinions and/or conclusions expressed, are those of the committee members alone and do not necessarily reflect HSE policy.

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Foreword

The development of policy in HSE needs to be informed by the best available contemporary scientific evidence. In 2015, HSE formed the Workplace Health Expert Committee (WHEC) to provide independent expert advice to them on:

- New and emerging workplace health issues
- New and emerging evidence relating to existing workplace health issues
- The quality and relevance of the evidence base on workplace health issues

Questions about workplace health issues come to WHEC from many sources, which include HSE, trade unions, employers, interested individuals and members of WHEC. WHEC's responses to these questions are published online as reports to HSE, as position papers following investigation, or as a briefer response where the current evidence is insufficient to warrant further investigation. In cases where the evidence-base is limited WHEC will maintain a watching brief and undertake further investigation if new and sufficient evidence emerges.

In its formal considerations, WHEC aims to provide answers to the questions asked based on the available evidence. This will generally include review of the relevant scientific literature, identifying the sources of evidence relied on in coming to its conclusions, and the quality and limitations of these sources of evidence.

The purpose of WHEC reports is to analyse the relevant evidence to provide HSE with an informed opinion on which to base policy. Where there are gaps in the evidence, which mean that this is not possible, WHEC will identify these and, if appropriate, recommend how the gaps might be filled.

Executive Summary

Hand transmitted vibration (HTV) can give rise to pathological effects on the peripheral vascular system, peripheral nervous system, muscles and other tissues of the hand and arm. The symptoms are collectively known as Hand-Arm Vibration Syndrome (HAVS) which is conventionally classified according to the Stockholm staging system that grades vascular and sensorineural symptoms separately. The mechanism by which HTV causes the blanching attacks of vascular HAVS remains unclear but it is thought to be multifactorial involving both local and central factors while the neurosensory element probably results from the loss of nerve-ending receptors and nerve fibres in the distal upper extremities. A 2015 systematic literature review of the exposure-response relationship between HTV and HAVS concluded that the evidence concerning reversibility of the syndrome was sparse and complicated by a diagnostic and staging regimen which is based largely on symptoms and therefore subject to numerous sources of bias. Nevertheless, the authors suggested that the vascular component may improve while the neurosensory element was likely to be permanent.

Subsequent research addressing the prognosis for HAVS has been very limited and is somewhat contradictory. However, it appears to reinforce the view that both vascular symptoms and vascular function may improve over time with cessation of exposure to HTV. Improvement of vascular symptoms is more likely in younger workers and those with shorter exposure time. Clinical observation suggests that vascular symptoms may plateau even with continuing exposure to HTV. Conversely, sensorineural symptoms are unlikely to improve, even with cessation of exposure, and may deteriorate. Sensorineural function appears unlikely to improve or resolve over time with continuing exposure to HTV. Further research is indicated, particularly in relation to objective testing of the vascular component of HAVS and the persistence of sensorineural symptoms with and without continuing HTV exposure.

Introduction

The Workplace Health Expert Committee (WHEC) has been asked by the Health and Safety Executive (HSE) to advise on Hand-Arm Vibration Syndrome (HAVS). The request has been framed as two linked questions:

1. Please can WHEC comment upon the permanency or otherwise of the vascular and neurological changes occurring as part of Hand-Arm Vibration Syndrome?
2. Does WHEC's opinion on the above alter when considering differing severities of the vascular or neurological changes?

Background

Chronic exposure to hand transmitted vibration (HTV) can give rise to pathological effects on the peripheral vascular system, peripheral nervous system, muscles and other tissues of the hand and arm. The symptoms are collectively known as HAVS and the vascular component may be referred to as Vibration White Finger (VWF). The effects can be disabling with an impact on touch sensitivity, manual dexterity and grip strength as well as pain in the fingers. Exposure can occur in a number of industries and is generally associated with the prolonged use of hand-held power tools, hand guided equipment or by holding materials being worked by hand fed machines. It was estimated in 2000 that more than 4.8 million workers in Great Britain were exposed to HTV in a one-week period and that at least 1.2 million of those were likely to exceed a suggested action level marginally higher than that now in place across Europe[1]. Data from The Health Occupational Research Network (THOR) scheme indicate that reporting of HAVS in the UK was rising in the late 1990s, peaked just after 2000, fell in the succeeding decade but has now risen again to a similar level as at the start of this century[2]. Reports of HAVS made under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) continue to run at some 700 – 900 cases per year indicating that the condition remains a significant occupational health issue.

The mechanism by which HTV causes the blanching attacks of vascular HAVS remains unclear but it is thought to be multifactorial involving both local and central factors[3].

The mechanism causing the neurosensory element of HAVS is probably based on the ultimate loss of nerve-ending receptors and nerve fibres in the distal upper extremities through repeated insult, ultimately overwhelming repair mechanisms[4]. It appears that, like exposure to other physical agents, HTV can cause a temporary threshold shift in both thermal and vibrotactile perception[5] and that permanent damage can ensue with continued exposure. Histopathology in biopsies from humans exposed to vibration and animal models has shown significant damage to the vascular, peripheral neurological and muscle systems[6, 7].

The Control of Vibration at Work Regulations 2005 impose a daily Exposure Action Value of 2.5 m/s² (A8) and a daily Exposure Limit Value of 5 m/s² (A8). However, the measurement of vibration emissions is difficult and values obtained in laboratory environments may vary considerably when the same equipment is used in the real world. Health surveillance therefore remains an important control measure for workers potentially at risk.

Health surveillance is recommended to follow a tiered approach[8] with a baseline assessment (Tier 1) followed by an annual screening questionnaire (Tier 2). Symptomatic workers should be assessed by a suitably qualified health professional (Tier 3) and referred to an appropriately qualified doctor for a diagnosis (Tier 4). Standardised testing (Tier 5) may be used in Tiers 3 and 4 to supplement clinical assessment. HAVS is conventionally classified according to the staging system developed more than 30 years ago at the Stockholm Workshop[9]. The system (set out in Table 1) grades vascular and sensorineural symptoms separately and the scores are shown together for each hand (e.g. (R) 2SN 2V, (L) 1SN 2V).

Table 1 Stockholm Workshop scale

Vascular component		
Stage	*Grade*	*Description*
0_v		No attacks
1_v	Mild	Occasional attacks affecting only the tips of one or more fingers
2_v	Moderate	Occasional attacks affecting distal and middle (rarely also proximal)phalanges of one or more fingers
3_v	Savere	Frequent attacks afecting all phalanges of most fingers
4_v	Very severe	As in stage 3, with trophic changes in the fingertips
Sensorineural component		
Stage		*Description*
0_{SN}		Vibration-exposed but no symptoms
1_{SN}		Intermittet numbness with or without tingling
2_{SN}		Intermitted or persistent numbness, reduced sensory perception
3_{SN}		Intermitted or persistent numbness, reduced tactile discrimination and/or manipulative dexterity
Note: The staging is made separetly for each hand. The grade of disorder is indicated by stage and number of affected fingers on both hands, e.g. stage/hand/number of digits.		

A grading classification is helpful, not so much because of its relevance for therapeutic interventions which are very limited in nature, but because it assists in monitoring the progression of the condition and in the occupational management of sufferers. Significant symptomatology and associated functional loss are an indication for exclusion from further exposure to HTV, which may well limit earnings capacity and even threaten livelihoods. Such decisions are made clinically on a case by case basis but staging is a useful guide. In practice, most significant employment restrictions are applied to people at Stage 2 and in the UK that has been sub-divided into "early" and "late" to further assist in management[10].

Current State of Knowledge

A systematic literature review on the nature of the exposure-response relationship between HTV and the elements of HAVS was carried out in 2015 by the Health & Safety Laboratory (HSL) for HSE[11]. Although not part of the main research question for the study, some evidence was gathered about the reversibility of the condition. The authors concluded that:

There is not a great deal of evidence on the reversibility of vascular HAVS, or any relationship to the levels of continuing exposure, apart from complete cessation of vibration exposure. The evidence would seem to suggest that vascular HAVS may show some reversibility, but over a time frame of years and to a greater degree in the less severe cases. The evidence for reversibility of neurosensory HAVS is sparse. However, based on an understanding of the neurological pathology and the very limited evidence available, it seems unlikely that neurosensory HAVS shows reversibility.

The authors went on to comment that matters were complicated by a diagnostic and staging regimen which is based largely on symptoms. It is recognised, both with vascular HAVS and primary Raynaud's disease (a very similar non-occupational condition), that sufferers modify their lifestyles to compensate for their symptoms. They may well therefore perceive and report that their symptoms have ameliorated over time. Such lifestyle modifications are not effective for sensorineural HAVS but the prevalence of non-specific, symptoms of tingling and numbness in the hands and fingers of workers has been reported as being around 15-20% in the general working population.

The consensus view remains that there is no widely available method for objective testing of vascular HAVS which is sufficiently valid and repeatable for clinical practice[12]. However, in a tightly controlled laboratory environment Finger Systolic Blood Pressure (FSBP) has been shown to have sensitivity and specificity in excess of 90%[13]. The HSL report referenced a study by Bovenzi using FSBP[14] that found a significant improvement of the digital vasoconstrictor response to cold after cessation of exposure to HTV – on a group basis that improvement averaged about 3% per year. They comment that the objective testing of sensorineural loss is less contentious but there is dearth of evidence that has specifically studied changes in these tests in HAVS sufferers after reduction or cessation of exposure.

Relevant evidence published since the HSL study appears limited. In late 2015, after publication of the HSL review, Sauni and colleagues[15] reported a follow up study of HAVS patients diagnosed by the Finnish Institute of Occupational Health between 1990 and 2008. The aim was to assess the association of the vascular and sensorineural symptoms of HAVS with patients' employment status after diagnosis, as well as self-assessed quality of life, general health, current work ability, and self-evaluation of future work ability. 241 patients were sent a postal questionnaire and

149 (62%) responded. The mean age of the respondents was 59.3 years and the average time lag between diagnosis and questionnaire completion was 8.5 years.

The study found that about one-third of the patients reported improvement in vascular and sensorineural symptoms. The patients who no longer had VWF attacks or whose VWF symptoms had improved after diagnosis were younger than those whose symptoms had either stabilized or deteriorated. However, age was not associated with the persistence or deterioration of sensorineural symptoms. The persistence or deterioration of vasospastic symptoms was associated with longer exposure time to HTV. No similar association with exposure time was found for sensorineural symptoms but the cumulative exposure index tended to be higher in the group with stabilized or deteriorated sensorineural symptoms. Although not commented on in the paper, the tabulated data shows that those who remained in the same job were significantly more likely to report persistent or worsened finger numbness/tingling; persistent or worsened VWF was also commoner among those in the same job though not to a level of statistical significance. The differences between the symptoms of smokers, ex-smokers and non-smokers were not statistically significant though the authors note that other research is conflicting on this point.

The authors state that their results suggest that not only vascular symptoms but also tingling and numbness may be at least partly reversible, although they may be more persistent than vasospastic symptoms. They also note that their assumption, that workplace-based interventions would result in fewer symptoms and disabilities, was not borne out by the results and that discontinuation of the exposing job did not seem to improve symptoms. They opine that this may be due to the fact that changes were performed only when the symptoms were severe and improvement could no longer be achieved. They comment that the size of their study, the standardised initial diagnostic methodology and the provenance of their questionnaire design are strengths. They also acknowledge weaknesses in the inability to repeat clinical examinations, including objective testing, and the various biases consequential upon using a survey design.

A systematic review and meta-analysis of HTV and the risk of vascular and neurological diseases was published by Nilsson in 2017[16]. It is helpful in confirming that workers who are exposed to HTV have an increased risk of vascular and neurological diseases compared to non-vibration-exposed groups and that the risk increase is approximately 4–5 fold. It also calculates that at equal exposures, neurosensory injury occurs with a 3-time factor shorter latency than Raynaud's phenomenon. However, the paper sheds no light on prognosis.

In 2018 the results were published of a Delphi study intended to develop consensus criteria for the diagnosis and staging of HAVS as an update to the Stockholm Workshop Scale (SWS)[17]. The consensus view of the seven international experts was that clinical staging should be simplified. Objective testing for the vascular element was again found to be problematical and recommendations were made for using methods with the best evidence base for assessing sensory perception and manual dexterity. The issue of permanence was not addressed.

Aarhus and colleagues published two linked studies in 2018 and 2019 reporting a 22 year follow up of the vascular[18] and sensorineural[19] components of HAVS. The investigators reviewed a cohort of workers from a construction company first assessed for HAVS in 1994; the company shut down in 1999. Of the original cohort of 110 people, 61 could be traced in 2017 and were invited to participate in the study – 40 subjects agreed, of whom 27 had been diagnosed with HAVS in 1994. 35 of these workers reported exposure to HTV during the follow up period; there was no information regarding vibration levels during that time but most subjects had used sanders. The SWS and the same objective tests were used in both the initial and the follow-up assessments. Vascular testing used cold challenge photo-plethysmography (PPG), employing the same equipment as in 1994, while sensorineural testing was conducted using a battery of standardised manual dexterity, hand strength and vibrometry instruments. Information was also gathered about cardiovascular disease, smoking habits and alcohol consumption. Serum cotinine, caffeine, carbohydrate deficient transferrin (CDT), glycosylated haemoglobin (HbA1c) and folate was measured on the day of the examination in 2017.

Of the 27 workers diagnosed with HAVS in 1994, 16 workers reported white finger attacks – by 2017 seven of these had no vascular symptoms. In subjects diagnosed with HAVS at baseline, vibration exposure during follow-up was associated with deterioration in the white finger symptom score (SWS) whereas smoking and age were

associated with deterioration in the objectively measured vascular component (PPG). Among those with sensorineural symptoms, no overall statistically significant change was observed in hand numbness (SWS), shoulder/arm pain (pain scale) or finger pain from 1994 to 2017. However, vibration exposure during the study period did predict increased pain at follow up. Manual dexterity declined in agreement with published reference values when allowing for aging but objective tests for smoking, alcohol consumption, glucose metabolism and folate deficiency (all established risk factors of polyneuropathy) showed no influence. Descriptive data showed that isolated hand numbness without white finger attacks was more common in 1994 than in 2017, consistent with previous reports that neurosensory injury occurs with a shorter latency than Raynaud's phenomenon.

Most recently the Industrial Injuries Advisory Council (IIAC) published a position paper in July 2019 on the assessment of the vascular component of HAVS[12]. The review was driven by issues relating to the assessment of HAVS for benefit purposes and focussed on developments in objective testing of vascular function and problems associated with the interpretation of history and time course for symptoms. The paper nevertheless offers another review of evidence which may be relevant in answering HSE's questions.

The IIAC paper observed that a major challenge in the diagnosis of the vascular component of HAVS is the episodic nature of signs and symptoms and the difficulty of reproducing them for clinical verification. Diagnosis therefore relies essentially on the patient's recollection and description of symptoms. Recent studies of the efficacy of various objective tests were reviewed and it was concluded that none of the available methods should be required for diagnosis in this context. Of perhaps more relevance was the consideration given to the variability of symptoms over time. The method chosen was to consult international experts in the field for their views. Several experts commented that the majority of cases plateaued at stage 1V or 2V (SWS) despite ongoing vibration exposure. Similarly, the relationship between years of exposure and stage progression was considered not to be a simple linear one and that case progression is often dependent upon a number of factors. Finally, it was noted that vascular symptoms can develop for the first time after cessation of exposure to HTV and that this may relate to the timing of the first cold challenge after damage has occurred (i.e. the following winter).

Discussion

HAVS is a clinical diagnosis based principally on symptomatology. Signs are only rarely observed and objective testing is problematical, especially for the vascular component. The dividing line between a physiological response to HTV and a pathological condition is not well defined in the SWS although some efforts have been made to address this in the proposed revised system. Consequently, any diagnosis of HAVS is subject to numerous sources of bias and that this is most likely to be material when the condition is graded as being at an early stage. It is therefore probable that some people assessed as HAVS cases will not have established pathology and therefore at reassessment will not be classed as having the condition.

The diagnostic criteria and methods of objective testing for sensorineural damage are less contentious than for the vascular element. Diagnostic accuracy and reproducibility of staging are therefore likely to be higher.

The sensorineural component of HAVS generally appears earlier than the vascular component but against a significant background prevalence of tingling and numbness in the working population. The association between HTV and disease is best known by workers and the general public in the context of VWF, so it seems likely that late presentation will be commoner for sensorineural symptoms and that pathology will therefore be more established at the time of first assessment.

The HSL statement that "*based on an understanding of the neurological pathology and the very limited evidence available, it seems unlikely that neurosensory HAVS shows reversibility*" appears to remain largely valid in the light of the limited subsequent evidence. Sauni et al did find an improvement in sensorineural symptoms among about one third of the study group and concluded that tingling and numbness may be at least partly reversible. Those who described improvement had mainly retired or moved to another job and therefore (presumably) ceased exposure to HTV. These findings are however based solely on questionnaire follow up and are therefore subject to the potential bias discussed earlier. Conversely, Aarhus et al in a smaller but more controlled study found no significant change in hand numbness or pain among those who had sensorineural symptoms 22 years earlier; critically, most of this cohort had ongoing exposure to HTV.

The vascular component of HAVS appears later for an equivalent exposure to HTV but there is currently no form of objective testing considered suitable outside of a laboratory environment. Diagnostic accuracy and reproducibility of staging are therefore likely to be lower but, perhaps because of that, there has been more research which throws light on the prognosis of the condition.

The HSL conclusion was that "*The evidence would seem to suggest that vascular HAVS may show some reversibility, but over a time frame of years and to a greater degree in the less severe cases.*" Sauni et al again found that in about one third of their cohort vascular symptoms had either resolved or improved. That group was younger than those whose symptoms had either stabilized or deteriorated with a shorter exposure time to HTV. Aarhus et al, contrary to their findings in relation to the sensorineural component, found that 7 of the 16 people with vascular symptoms in 1990 had no vascular symptoms in 2017. This appears to reinforce the view that the vascular component is partially reversible over time and that there is an association with lower levels of HTV.

"Permanency" implies not only the absence of reversibility but also the lack of progression over time. The HSL review references Bovenzi's study using FSBP which found a significant improvement of the digital vasoconstrictor response to cold after cessation of exposure to HTV. This contrasts with the findings of Sauni et al who note that discontinuation of the exposing job did not seem to improve symptoms though there was worsening in those who remained. Aarhus et al also noted that HTV exposure during follow-up was associated with a deterioration in vascular SWS score though not in objective testing; deterioration in the vascular component with continuing HTV exposure is reported by a number of studies reviewed by HSL. The HSL study refers to just one study, by Bovenzi[20], in which several new cases of tingling and numbness occurred in a follow up of 1-3 years during which there was continuing exposure. However, Aarhus found no such deterioration in hand numbness, despite most of the cohort continuing to be exposed to HTV, though continuing exposure did predict increased pain at follow up. The expert views commissioned by IIAC were clear in stating that the majority of cases of which they had clinical experience plateaued at an early stage for the vascular component despite continuing HTV exposure. The IIAC review only concerned the vascular element so their views on the plateauing or otherwise of the sensorineural component remain unrecorded.

The HSL review in 2015 determined that the evidence base for the reversibility or otherwise of HAVS was very limited but that, nevertheless, some conclusions could be drawn. There have been only a small number of papers of relevance published since that time and they largely reinforce earlier findings but the evidence base remains weaker than one would like. Further research is indicated, particularly in relation to objective testing of the vascular component and the persistence of sensorineural symptoms with and without continuing HTV exposure.

Conclusions

This review of the evidence suggests that:

- There is consistent evidence that a cessation of exposure to HTV can be associated over time with an improvement of **vascular symptoms** in up to one third of workers and, less often, complete resolution may occur
- There is consistent evidence that improvement in **vascular symptoms** with exposure cessation is more likely in younger workers and those with a shorter exposure time to HTV
- There is limited evidence that a cessation of exposure to HTV can be associated over time with a gradual improvement in objective testing of **vascular function**
- There is limited evidence that with continuing exposure to HTV **vascular symptoms** may plateau or (rarely) improve but they may also deteriorate in some cases
- There is limited evidence that **sensorineural symptoms** may improve or resolve over time with cessation of exposure, but more often they do not
- There is limited evidence that **sensorineural symptoms** tend to persist and may deteriorate with continuing exposure to HTV
- There is consistent evidence that objective testing of **sensorineural function** is unlikely to improve or resolve over time with continuing exposure
- There is consistent evidence that improvement or resolution of any form of HAVS is more likely where the condition has been graded as less severe

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What is WHEC?

The Workplace Health Expert Committee (WHEC) provides independent expert opinion to HSE by identifying and assessing new and emerging issues in workplace health. Working under an independent Chair, WHEC gives HSE access to independent, authoritative, impartial and timely expertise on workplace health.

https://webcommunities.hse.gov.uk/connect.ti/WHEC/view?objectId=235408&exp=c1

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