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Hand-Arm Vibration Syndrome

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This medical discussion paper will be useful to those seeking general information about the medical issue involved. It is intended to provide a broad and general overview of a medical topic that is frequently considered in Tribunal appeals.

Each medical discussion paper is written by a recognized expert in the field, who has been recommended by the Tribunal's medical counsellors. Each author is asked to present a balanced view of the current medical knowledge on the topic. Discussion papers are not peer reviewed. They are written to be understood by lay individuals.

Discussion papers do not necessarily represent the views of the Tribunal. A vice-chair or panel may consider and rely on the medical information provided in the discussion paper, but the Tribunal is not bound by an opinion expressed in a discussion paper in any particular case. Every Tribunal decision must be based on the facts of the particular appeal. Tribunal adjudicators recognize that it is always open to the parties to an appeal to rely on or to distinguish a medical discussion paper, and to challenge it with alternative evidence: see *Kamara v. Ontario (Workplace Safety and Insurance Appeals Tribunal)* [2009] O.J. No. 2080 (Ont Div Court).

Introduction

Hand-Arm Vibration Syndrome (HAVS) is a common problem due to exposure to hand-arm vibration from the use of hand-held rotating or percussive power tools or hand contact with vibrating work surfaces. It is comprised of vascular, neurological and musculoskeletal abnormalities.

The vascular component of HAVS has received the most clinical and research attention since it was first reported by Loriga in Italy in 1911. The condition is a form of secondary Raynaud's phenomenon manifested by cold-induced finger blanching and is often referred to as vibration white finger (VWF). The extent of the problem was brought to public attention in the U.S. by Hamilton in 1918 in her report of the high prevalence of Raynaud's phenomenon in the limestone quarry workers of Bedford, Indiana. Subsequently there was increased recognition that hand-arm vibration was also associated with neurological and musculoskeletal abnormalities and the term Hand-Arm Vibration Syndrome was developed to capture the three types of abnormalities associated with hand-arm vibration exposure. An international conference on hand-arm vibration in Stockholm lead to the development of classifications for the vascular and neurological components of HAVS in the 1980's which are referred to as the Stockholm workshop scales.[1,2] These classifications were based only on history and physical examination and it was mentioned at the time they were created that objective tests needed to be used to measure the various components of HAVS. This is especially the case for compensation purposes. A Stockholm classification was not developed for the musculoskeletal component of HAVS.

HAVS Related to Workplace Vibration Exposure

The contact of the hand with a vibrating tool or surface can result in exposure to vibration over a broad frequency range. Vibration is a vector quantity and therefore its measurement involves a description of both direction and intensity (usually in acceleration units). Vibration acceleration is measured in three orthogonal axes using a triaxial accelerometer that is usually mounted on the tool handle. The measurements are made in each axis using root mean squared (r.m.s) acceleration values at each measured frequency and the values are summed using frequency weighting to attempt to account for differences in the response of the hand-arm system to different frequencies. The values from the three axes can be combined and, in conjunction with the daily exposure duration in hours, used to calculate an A(8) in meters/sec^2 (an eight hour energy equivalent vibration total value). According to the European Directive 2002/44/EC[3] the daily exposure limit value is an A(8) of 5 meters/sec^2 and the daily exposure action value, which requires employers to implement measures to protect workers from hand-arm vibration is 2.5 meters/sec^2.

Therefore values below 2.5 meters/sec2 could be assumed to not be associated with risk of HAVS. However there is controversy about the current frequency weighting. The weighting is based on comfort when exposed to HAV and provides greater weight to lower frequencies (< 32.5 Hz). However the resonant frequency of the fingers of the human hand is in the range of 150 to 300 Hz and incident vibration at frequencies above 100 Hz is completely absorbed by the fingers and hands and is not transmitted to the rest of the upper extremity4,5. Therefore the higher frequencies that appear to be associated with the vascular and sensorineural effects of HAV are not given appropriate weight in the current method of measurement. In contrast low frequency vibration can be transmitted to the arm and shoulders[6,7] and may be associated with musculoskeletal abnormalities at these sites. Therefore the current frequency weighting may be more appropriate for the musculoskeletal component of HAVS. Consequently the association between vibration exposure levels and health effects should be interpreted with caution.

The risk of developing HAVS depends on the intensity (in acceleration units), frequency and duration of vibration exposure. The prevalence of HAVS in workers regularly exposed to vibration has been reported to vary from 6% to 100% with an average of 50%[8]. The reported latencies between exposure and development of HAVS range from 6 weeks to 14 years9 and latency can be quite short with HAVS developing in less than two years if the exposure levels are high. Miyashita et al10 reported that, in forestry workers, symptoms of HAVS did not typically appear until after 2000 hours of exposure but symptoms were present in more than 50% of workers after 8000 hours of exposure.

Pathophysiology and Histopathology of HAVS

The mechanisms by which vibration leads to tissue damage and the vascular, sensorineural and musculoskeletal outcomes of HAVS are incompletely understood although, as summarized by Stoyneva et al[11], considerable research has been done in this area. Absorption of vibration may be associated with tissue shear and bending stresses that may increase the risk of tissue damage through increases in oxidative stress and inflammation. Finger biopsies of patients with HAVS[12] have shown thickening of the smooth muscle of digital arteries due to muscle cell hypertrophy. As well vascular endothelial cell damage leads to release of the potent vasoconstrictor endothelin – 1 and an imbalance between endothelin – 1 and calcitonin-gene-related peptide (CGRP), a powerful vasodilator. Vibration damage may also be associated with changes in sensitivity to vasodilating and vasoconstricting factors. Finger biopsies have also shown demyelinaton of nerve fibres, axonal degeneration and nerve fibre loss12. The loss of digital cutaneous perivascular nerve fibres which secrete the potent vasodilator calcitonin gene-related peptide (CGRP) also leads to an increased tendency to vasoconstriction, showing an inter-relationship between the pathophysiology of vascular and sensorineural effects. Necking et al[13] have reported that biopsies of the abductor pollicis longus muscle of patients with HAVS have shown evidence of direct damage to muscle fibres which correlate with the duration of vibration exposure as well as evidence of muscle damage which is likely secondary to nerve injury.

Clinical Outcomes Associated with the Use of Vibrating Tools

These outcomes are summarized in Table 1. They include effects possibly due to hand-arm vibration and/or ergonomic stressors or work practices associated with the use of vibrating tools.

1. Vascular

Raynaud's phenomenon is the outcome most clearly associated with vibration exposure and there is strong evidence of a causal association between exposure to hand-arm vibration and the development of Raynaud's phenomenon[14]. The Raynaud's phenomenon is manifested by the development of cold-induced blanching of the fingers. The blanching may also sometimes be triggered by acute exposure to vibration at work. The blanching begins in the tips of one or more exposed fingers and, as the condition worsens, the blanching may extend down the entire finger and all fingers and thumbs may be affected. Cold exposure may also be associated with cyanosis due to reduced local supply of oxygenated hemoglobin and, during rewarming, there may be reactive hyperemia due to vasodilatation. During blanching there is usually numbness and tingling due to digital nerve ischemia. In very severe cases there may be trophic changes in the fingers due to decreased blood supply and the trophic areas may become gangrenous resulting in loss of digits.

Raynaud's phenomenon may also develop in the feet in workers exposed to hand-arm vibration[15]. Workers who develop vascular abnormalities in the feet usually complain of increased cold intolerance of the feet but they seldom have an opportunity to look at their feet when cold-exposed and hence seldom report cold-induced blanching of the toes. The risk of Raynaud's phenomenon in the feet appears to be increased in workers who first develop Raynaud's phenomenon in the hands due to vibration[15].

Workers using vibrating tools may also develop thrombi in the arteries in the hands[16]. This mainly affects the ulnar artery at the wrist which lies just below the hypothenar eminence but it may also involve the radial artery or the digital arteries. The development of hand thrombi may also occur from other types of hand injury. Hypothenar hammer syndrome refers to the development of ulnar artery thrombosis due to use of the hypothenar eminence as a hammer for forceful striking. The corresponding condition affecting the radial artery is called thenar hammer syndrome. The evidence for these thrombotic lesions being due to vibration is mainly from case reports and, based on the number of reports, it appears to come to clinical attention infrequently. However Kaji et al[17] reported that, in 330 workers exposed to vibration (293 with HAVS) who all had had arteriography of the hand vasculature, 24 (7.2%) were found to have the vascular abnormalities of hypothenar hammer syndrome. Possibly in the majority of workers with arteriographic evidence of this abnormality, the condition develops slowly which allows sufficient time for development of collateral circulation. The small percentage of workers in whom the condition develops rapidly with resultant compromise of digital circulation and potential loss of the affected digit are perhaps more likely to come to clinical attention and become the subjects of case reports. It is at present unclear if these reported cases are due to work practices (forceful striking with the hand) or some aspect of the vibration such as the dominant frequency or impulsivity of the vibration.

2. Neurological

Hand-arm vibration can result in the development of damage to the sensory nerve fibres in the fingers producing a digital sensory neuropathy. This may affect all of the exposed fingers. The sensory abnormalities in the fingers are probably also due to impairment in skin mechanoreceptors including Meissner's corpuscles, Pacinian corpuscles, Merkel cell neurite complexes and Ruffini endings. These abnormalties result in numbness and tingling in the fingers which is present even when not exposed to the cold. Cold exposure may lead to digital vasospasm and transient reduction in blood supply to peripheral nerves with resultant transient numbness and tingling but these transient abnormalities do not constitute evidence of the sensorineural component of HAVS. The Stockholm Sensorineural classification[2] is based on digital polyneuropathy and it does not include carpal tunnel syndrome. However carpal tunnel syndrome due to median nerve compression at the wrist is common in workers with HAVS. For example Lander et al[18] in a group of 162 patients assessed for HAVS at the Occupational Health Clinic, St Michael's Hospital, Toronto reported that 33% of subjects had CTS and 11% had ulnar neuropathy of the right upper extremity. CTS and digital polyneuropathy due to HAVS present with similar symptoms, therefore creating a diagnostic challenge[19].

3. Musculoskeletal

Decreased grip strength was reported over 30 years ago by Farkkila[20] in workers with high exposure to hand-arm vibration and this was confirmed in subsequent studies21,22 although not all studies have shown consistent findings. Necking et al,13 using biopsies of the abductor pollicis longus in 20 patients with HAVS and four controls, found that vibration exposure is associated with evidence of direct damage to muscle such as muscle necrosis, fibrosis and structural disorganization. Other pathological findings described by Necking et al suggested nerve injury with secondary muscle denervation / re-innervation. Therefore the decreased grip strength may be related to a combination of direct muscle injury and nerve injury due to vibration.

Liss and Stock[23] investigated the association between Dupuytren's contracture and hand-arm vibration. Dupuytren's contracture is an abnormality of the palmer fascia that results in thickening and band formation of the palmer surface with secondary finger contractures. In a literature review they found only three published studies of good quality addressing this topic. All three reported statistically significant odds ratios ranging from 2.1 (95% CI: 1.1-3.9) to 2.6 (95% CI: 1.2-5.5) for this association and two of the studies presented some evidence of a dose-response relationship. They concluded that there was good support for an association between vibration exposure and Dupuytren's contracture. However this association is still not considered to be definitely causal in nature and may be related to other factors such as manual work.

A number of other musculoskeletal outcomes have been associated with hand-arm vibration including bone cysts and osteoporosis in the hands and wrists, osteoarthritis of the wrist, elbow and shoulder, epicondylitis and non-specific muscle and joint pain and stiffness. Hagberg24 carried out a comprehensive review of these musculoskeletal outcomes and concluded that the evidence that vibration per se is a risk factor was weak although there was strong evidence that work with vibrating tools was associated with these musculoskeletal disorders. Ergonomic factors and/or work practices were potential confounders of an effect due to hand-arm vibration for all of these musculoskeletal outcomes.

HAVS Case Definition

A clear case definition is lacking for HAVS. The main outcomes that are clearly associated with vibration exposure are secondary Raynaud's phenomenon and digital polyneuropathy. These may occur either singly or in combination. As well HAVS is usually described as having a musculoskeletal component but it is not clear exactly what musculoskeletal abnormalities are definitely part of HAVS. Also the measurement of the components of HAVS and the specification of measurements in a case definition present challenges.

Measurement of HAVS

1. Vascular Component

The diagnosis of Rayaud's pheonomenon requires a history of cold-induced finger blanching which sounds quite straightforward. However workers may sometimes have difficulty describing the presence and distribution of finger blanching. They sometimes remark that they seldom look at their hands when cold-exposed and hence can not provide a good medical history about this key outcome. Therefore objective tests are useful, especially in a compensation context.

Various tests have been used to attempt to measure the cold-induced abnormalities associated with HAVS. The main tests have involved measuring (a) blood flow to the fingers or digital blood pressure and the change in blood flow or digital blood pressure due to the induction of digital vasospasm from a cold stimulus (usually cold water immersion) or (b) the recovery in finger temperature (as an index of recovery of digital vasospasm) after cold water immersion. The main tests that measure induction of vasospasm utilize plethysmography (strain gauge or photocell) or laser Doppler techniques. The tests that measure recovery of finger temperature include thermometry (using finger thermocouples) or thermography (using an IR camera). There is currently no standardized test and there is variation in test technique reported in the literature including the temperature and duration of cold water immersion and the timing of measurements following cold stimulation. Regardless of the test method utilized, the test should be properly developed with measurements in HAVS patients and controls and the establishment of a clear cut point for a positive result to operationalize the test with the best combination of sensitivity and specificity for the intended use of the test. Tests used for screening require high sensitivity whereas tests used for diagnosis require high specificity.

2. Neurological Component

The definitive test for measurement of peripheral nerve abnormalities is a nerve conduction test. This test allows measurement of nerve conduction velocity, latency and amplitude in large myelinated nerve fibres. The nerve conduction test is especially useful for measurement or neuropathy proximal to the hand such as median or ulnar neuropathy at the wrist. However conventional electrode placement only allows measurement in the proximal parts of the fingers and does not permit measurement of the distal parts of the fingers that are initially affected by hand-arm vibration. Segmental or fractionated nerve conduction may be carried out with electrode placement in the distal parts of the finger allowing improved measurement of digital neuropathy25,26. However this is technically challenging and it is not done in most nerve conduction laboratories. We were not able to produce reliable results when we attempted to use this technique in the electromyography laboratory of St. Michael’s Hospital. An alternative is to use quantitative sensory tests (QST) such as current perception threshold (CPT) or a combination of vibration perception threshold (VPT) and temperature perception threshold (TPT) in conjunction with conventional nerve conduction studies. The CPT or combination of VPT and TPT allows measurement of all of the important nerve fibres in the fingers which may be damaged by vibration. For example CPT measurements are usually carried out in the index finger (median nerve innervation) and baby finger (ulnar nerve innervation) at three frequencies – 2000 Hz, 250 Hz, and 5 Hz which correspond to large myelinated (Abeta), small myelinated (Adelta) and unmyelinated (C) fibres respectively.

When QST are combined with conventional nerve conduction tests the QST have been found to be better predictors than the nerve conduction tests of the Stockholm sensorineural scale stages. This has been shown in studies examining CPT by House et al27 and VPT by Stromberg et al28. Therefore the quantitative sensory tests appear to be more sensitive tests than conventional nerve conduction tests for the measurement of the sensorineural abnormalities in the distal fingers associated with HAVS. Similarly when segmental nerve conduction is done, the nerve conduction findings in the distal portions of the fingers are better predictors of the Stockholm sensorineural scale stages than are the findings across the wrists[26]. Hence the QST and the segmental nerve conduction in the distal segments of the fingers appear to be measuring a similar phenomenon.

However QST are less objective than the nerve conduction tests and therefore should be used, if possible, in conjunction with nerve conduction tests, especially if the assessment is occurring in a compensation setting.

Hence it is recommended that the measurement of the neurological abnormalities in workers being assessed for HAVS should consist of:

(a) conventional nerve conduction test and CPT, or

(b) conventional nerve conduction test and VPT and TPT, or

(c) segmental nerve conduction test, if reliable measurement can be demonstrated

3. Musculoskeletal Component

A thorough clinical examination of the upper extremities is the best method to determine the presence of musculoskeletal problems that might be associated with hand-arm vibration exposure and/or ergonomic factors. The effect of vibration on grip strength can be measured using a grip dynamometer. Usually three measurements are done in each hand and the average is obtained during the clinical assessment. The strength of the intrinsic muscles of the hand can also be measured with a pinch meter using a method similar to measurement of grip strength. Other tests such as X-rays of the hands and wrists to demonstrate bone cysts or other boney abnormalities, CT scan, MRI or bone density measurement could be done depending on the clinical context but are usually not part of routine assessment for HAVS.

Clinical Assessment of a Worker to Diagnose HAVS

The assessment protocol has not been standardized and there is some variation in the assessment components in different centres. A recommended assessment might include the components described in Table 2.

The occupational history is essential and should include documentation of the type of work in which vibration exposure occurred, the vibrating tools used, the duration of exposure to vibrating tools (hours per day, days per year). Any associated field measurements of vibration would be helpful. The medical history is also essential to enquire about symptoms of finger blanching, numbness and tingling in the fingers and musculoskeletal symptoms as well as a history of other medical problems that might be associated with conditions similar to HAVS. The physical examination should focus on the vascular, neurological and musculoskeletal systems and is also an essential component to diagnosis. The blood tests should include tests to identify other causes of Raynaud’s phenomenon such as collagen vascular disease and common causes of neuropathy like diabetes mellitus and musculoskeletal co-mordibity such as rheumatoid arthritis.

Objective assessment of the components of HAVS is usually needed for compensation purposes and it is in this area where differences are likely to be present in different centres. The Doppler assessment is used to determine the presence of other lesions in the larger blood vessels in the upper and lower extremities. The digital plethysmography measures induction of vasospasm and the thermometry or thermography measures recovery of finger temperature after cold-induced vasoconstriction. Singly or in combination these tests provide an assessment of the vascular component of HAVS. The conventional nerve conduction study mainly measures neurological co-morbidity such as median or ulnar neuropathy at the wrist although occasionally digital sensory neuropathy is found. For example Lander et al[18] described one case of digital sensory neuropathy being found in 162 workers assessed for HAVS with conventional nerve conduction tests. The QST can be used to determine the presence of digital sensory neuropathy but should be evaluated in conjunction with nerve conduction studies, if possible. The grip strength tests measures the reduction in grip strength associated with vibration exposure but it must be interpreted in conjunction with the results of the overall assessment because it can be affected by musculoskeletal co-morbidity (such as epicondylitis) and/or neurological co-morbidity (such as carpal tunnel syndrome with motor nerve involvement). The Purdue pegboard is a test of fine motor hand function which helps to assess overall impairment in hand function and suitability for alternative work such as keyboarding.

Prognosis of HAVS

If vibration exposure continues, the various components of HAVS would be expected to worsen in severity. If exposure ends, there may be some improvement in the vascular component of HAVS, especially in milder cases. Vascular symptoms and plethysmography response to cold have been reported to be more severe in smokers than in non-smokers and smoking may delay improvement in plethysmography response to cold challenge after exposure to vibration ends[29].

Management of HAVS

The management of workers with existing HAVS is mainly directed towards control of symptoms. Workers with HAVS should avoid cold exposure as much as possible and wear thermal protective clothing when exposed to cold ambient conditions. Medication (calcium channel blockers) may be used for control of cold-induced vasospastic symptoms although results are mixed and many workers are initially reluctant to take medication. Smoking should be avoided. Workers should wear ISO approved anti-vibration gloves if possible even though AV gloves are, in general, more effective at higher frequencies and definitive evidence of the usefulness of such gloves in a work setting is lacking. Tools should be gripped with the minimum grip force consistent with safe operation of the tools and regular work breaks should be provided to workers when exposed to vibration (approximately 10 minutes every hour). Procurement of new anti-vibration, ergonomically designed tools would have the best primary preventive effect.

Controversial Issues Related to HAVS

1. HAVS of the Feet Related to Vibration Exposure

Acute vibration exposure to one hand is associated with a decrease in blood flow in not only the exposed hand but also the other hand[30] and the toes[31]. This is thought to be due mainly to generalized stimulation of the sympathetic nervous system. The concentration of noradrenaline, which is secreted by sympathetic nerve endings, has been shown to be higher in the plasma of workers with the vascular component of HAVS than in controls following cold stimulation[32] and workers with HAVS have greater urinary excretion of noradrenaline in comparison to controls[33]. Other mechanisms may also be involved such as the systemic release of endothelin - 1 from vascular endothelial cells damaged by vibration34. There is epidemiologic evidence that HAVS is also associated with chronic vascular abnormalities in the feet and a systematic literature review by Schweigert16 concluded that cold-induced vasospasm in the feet may also be present in workers with the vascular component of HAVS in their hands. In my experience in assessing workers with HAVS, cold provocation digital plethysmography abnormalities are often found not only in the hands, but also the feet.

2. HAVS complicated by CTS

CTS frequently occurs in workers using vibrating tools. This is presumed to be mainly due to the ergonomic stressors associated with tool use, in particular repeated forceful flexion and extension of the wrists. However there is also evidence that vibration exposure may be associated with carpal tunnel syndrome. In a recent systematic literature review Palmer et al[35] found that there was reasonable evidence that regular and prolonged use of hand-held vibratory tools increased the risk of CTS by more than two fold. Interestingly CTS due to hand-arm vibration exposure is compensated in the U.K.

Palmer et al[35] also concluded that there was substantial evidence for similar or even higher risks of CTS from prolonged and highly repetitious flexion and extension of the wrist, especially when allied with a forceful grip.

The presence of carpal tunnel syndrome complicates the diagnosis of the sensorineural component of HAVS (digital polyneuropathy). Both may present with symptoms of numbness and tingling in the fingers. In HAVS the numbness and tingling usually involves the distal digital segments of both the median and ulnar nerves and it is not uncommon to have all of the fingers affected. In CTS the symptoms are usually restricted to the median nerve although sometimes patients report symptoms in all of the fingers. Increased symptoms of numbness and tingling while trying to sleep are typical of CTS due to postural effects influencing median nerve compression at the wrist and are usually not present in digital polyneuropathy. CTS can be both sensory and motor with thenar muscle wasting due to motor neuropathy whereas digital neuropathy is sensory only. HAVS may be associated with musculoskeletal effects but thenar atrophy is usually absent.

Nerve conduction studies with conventional electrode placement are useful for the diagnosis of CTS and other neuropathies proximal to the hand such as ulnar neuropathy at the wrist or elbow. However such nerve conduction studies are not sensitive measures of digital sensory neuropathy as discussed previously. Quantitative sensory tests may be used to diagnose digital neuropathy but it should be borne in mind when interpreting the tests that the QST measurements may also be affected by median and ulnar neuropathy proximal to the hand36. Therefore the QST's should be interpreted in conjunction with nerve conduction studies.

Previous research has indicated an increased risk of Raynaud's phenomenon in individuals with CTS37,38. This is presumably secondary to compression of autonomic nerve fibres in the carpal tunnel38. In general this effect of CTS is not well appreciated by clinicians. The first occurrence of Raynaud's phenomenon shortly after the development of CTS would suggest that the Raynaud's phenomenon might be secondary to the CTS.

3. HAVS with Pre-existing Raynaud's Phenomenon

The underlying pathophysiology of the vascular component of HAVS and pre-existing Raynaud's phenomenon (either primary or secondary) is likely different but there is no test which can be used to determine definitively the cause of the finger blanching. A family history of Raynaud's phenomenon and the presence of Raynaud's phenomenon prior to vibration exposure likely indicate the presence of primary Raynaud's phenomenon. However workers often begin to work with vibrating tools in their late teens and early 20's before the symptoms of primary Raynaud's phenomenon become manifest. Therefore it may be difficult to differentiate the vascular component of HAVS from primary Raynaud's phenomenon, especially if the symptoms begin within a few years of starting work.

The occurrence of the other components of HAVS - the polyneuropathy and musculoskeletal symptoms – in a worker with a history of vibration exposure support a diagnosis of HAVS. Blood tests such as RF and ANA can be used to screen for collagen vascular disease which is a common cause of secondary Raynaud's phenomenon. The occupational history is also important to identify a history of other problems that may be associated with secondary Raynaud's phenomenon such as significant hand trauma and frostbite.

4. Raynaud's Phenomenon Resulting from Exposure to Cold Temperatures

Attacks of Raynaud's phenomenon are precipitated by exposure to cold ambient conditions in individuals with Raynaud's phenomenon (primary or secondary, including HAVS). Frostbite is an established cause of secondary Raynaud's phenomenon. However exposure to cold in the absence of frostbite does not appear to cause Raynaud's phenomenon, it merely precipitates the symptoms.

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Tables

Table 1.
Health Effects Associated with Use of Vibrating Tools

Vascular

- Raynaud's phenomenon
  - Hands **
  - Feet
- Thrombi in hands

Neurological

- Digital neuropathy (fingers) **
- Proximal neuropathies (wrist) – CTS, Ulnar neuropathy

Musculoskeletal

- Decreased grip strength
- Dupuytren's contracture
- Bone cysts
- Osteoporosis of hand / wrist bones
- Osteoarthritis – wrist, elbow, shoulder
- Upper extremity muscle / joint pain

** Definitely recognized to be due to hand-arm vibration exposure

Table 2
Recommented Assessment Protocol for HAVS

1. Occupational History
2. Medical History
3. Physical Examination
4. Additional tests
   (a) Blood tests to rule out other similar conditions
   (b) Tests of Vascular Function
      - Doppler examination of the upper and lower extremities
      - Thermometry after cold water immersion
      - Cold provocation digital plethysmography
   (c) Tests of Neurological Function
      - Nerve conduction studies
      - CPT or a combination of VPT and TPT
   (d) Musculoskeletal Tests
      - Grip strength
      - Pinch strength
   (e) Test of Fine Motor Hand Function
      - Purdue pegboard