HAND-TRANSMITTED VIBRATION - A PRIMER FOR FUTURE STUDY

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INTRODUCTION

The problem of hand-transmitted vibration from the use of various hand tools is receiving increasing attention from central government agencies, the medical profession and researchers in different countries. The main emphasis of this work has been centred around Raynaud's Phenomenon (Vibration-Induced White Finger: VWF) although other types of injury have been associated with vibrating hand tools,

viz a) Bone and joint disorders (e.g. bone cysts)
b) Neurological disorders (e.g. nerve conduction velocity)
c) Muscle disorders (e.g. atrophy)
d) Other general whole body symptoms
e) Disorders to the circulatory system, of which VWF is one.

The clinician often has a difficult task in identifying whether occupational exposure to vibration of the hand-arm system has been the sole cause or contributor to any one of these manifestations and an in-depth study of the patients' history has to be undertaken in order to establish the reason for the symptoms exhibited, in a similar vain to occupational noise investigations.

More details of these other disorders and the problems associated with determining the root cause are given in Taylor's paper (1) and a report by Griffin (2).

RAYNAUD'S PHENOMENON

This is the term given to the vascular disorder which results in finger blanching, numbness etc. of which there are many causes, including the use of powered hand tools (see Figure 1). The attacks of blanching are often sporadic in nature and are preceded by slight tingling and numbness of the finger tips which often pass unnoticed and are not attributed to the effects of vibration exposure. Blanching initially commences at the tips and may extend to effect the whole finger with continued vibration exposure. The attacks typically last for less than one hour and terminate in hyperaemia and associated pain. It has been found that, during an attack, sensitivity to pain, temperature and touch may be reduced. Continuing and prolonged exposure can result in more fingers becoming affected and they may take on a permanently blue-black cyanotic appearance or even become gangrenous, in extreme cases. The degree to which a person can suffer from this syndrome is related to the duration of exposure during a normal working day, the amplitude and frequency of the dose received, and the manner by which the tool is held.

HAND-TRANSMITTED VIBRATION

OCCUPATIONAL ACTIVITIES ASSOCIATED WITH CAUSING RAYNAUD'S PHENOMENON

Raynaud's Phenomenon caused by some classes of occupational activity is a prescribed disease within the terms of the Social Security (Industrial Injuries) (Prescribed Diseases) Regulations 1980 (as amended) for which Social Security benefit can be paid. The types of occupations which would warrant payment are, however, clearly defined and generally relate to industries using percussive tools and chain saws. However, there are many different types of industrial tools which could give rise to vibration to the hand-arm system such that monitoring and control is necessary. One such activity was the subject of a study by the author; the measurement of hand-transmitted vibration from a beef-splitting saw used in animal slaughtering industry (3). The results indicated that, using the assessment method in ISO 5349:1986 (4), an operative could be exposed to a high risk of exhibiting symptoms associated with Raynaud's Phenomenon within a normal working life. The type of environment prevalent in a slaughterhouse (i.e. cold and damp) has been found to precipitate attacks of the syndrome.

Several surveys are being undertaken in order to establish the numbers of people exposed to vibration transmitted from the use of hand tools and the types of tools involved. It is hoped that the information obtained may lead to more intensive monitoring and research which will assist in compiling a data base which can be used to quantify the problem and to identify those activities which present most risk to the workforce.

MEASUREMENT OF HAND-TRANSMITTED VIBRATION

Although the measurement of vibration transmitted to the hand by traditional methods is fraught with problems, it has been even more difficult to derive a dose-response relationship owing to the paucity of data available. The current British and International Standards include an assessment of the possible effects of exposure over a variable time period but state that this is for guidance purposes only owing to the small number of subjects on which the guidelines are based. The main problem associated with the measurement of the vibration received by the operative of a hand tool is to ensure that the same operational conditions exist during the monitoring period as when work is being carried out normally. Several factors may contribute towards not recording the dose normally received:

- if using a hand-held adaptor for providing a mounting point for the accelerometer, normal grip pressure should still be exerted and the adaptor should not affect the transfer function between the tool and the fingers or hand.
- the operatives' attitude to the monitoring may affect the manner in which the tool is normally gripped or held or the way in which the normal operation is carried out.
- spurious results due to overload of the monitoring system (e.g. movement of hand position on the tool), d.c. shift in accelerometers or excessive movement of the accelerometer connecting cable resulting in the tribo-electric effect.
- monitoring in an environment hostile to the use of precision equipment (e.g. very humid conditions) requiring great care to be taken over protection of connections etc.

A number of these problems can be overcome by measuring the vibration produced by the tool using tool-mounted transducers or by adopting more sophisticated techniques, such as lasers, rather than quantifying the dose received at the hand.

Resume of Relevant British and International Standards

Both the British Standards Institution and the International Organisation for Standardisation have taken some time in producing documents for measuring and assessing hand-transmitted vibration. The British Standards Institute produced a draft for development in 1975, (BS DD:43), (5), and it has taken over 12 years for the full standard to appear (BS 6842:1987), (6). One of the reasons for the delay in producing the Standard in final form may be attributed to the deliberations of the International Organisation for Standardisation which produced its current Standard in 1986 (ISO 5349:1986),(4) after producing two draft forms in 1979 (7) and 1984 (8).

The original draft ISO documents differed from the BS Draft for Development in that measurements were to be undertaken in $\frac{1}{3}$ octave bands, rather than 1/1 octaves, over a narrower frequency range, initially, although ISO 53949.2 did reduce the discrepancy by increasing the suggested frequency range over which measurements should be taken. The major difference between the draft documents produced by these organisations, though, was that the ISO sought to derive a dose-response relationship as guidance as to the possible effect of long-term exposure to vibration whereas DD 43 suggested maximum frequency-related exposure levels which should not be exceeded during an 8-hour day.

ISO 5349:1984 and BS 6842:1987 both stipulate the use of a similar monitoring methodology and give guidance on the evaluation of exposure in terms of a dose-response relationship. Where they differ is that the International Standard equates everything to a 4-hour exposure period during a normal working day, whereas BS 6842 works towards an 8-hour exposure period in order to provide uniformity with other occupational exposure standards i.e. noise and occupational exposure limits. Furthermore, ISO 5349 presents data for the exposure time required, in years, before the onset of symptoms attributable to Raynaud's Phenomenon in 10 to 50% of the exposed population for frequency-weighted acceleration levels of 2 to 50 ms^{-2}, whereas the British Standard presents the magnitudes of frequency-weighted acceleration required to show symptoms in 10% of the exposed population depending upon daily and life-time exposures. The criterion suggested by ISO 5349 is based upon results derived from approximately 40 studies whereas BS 6842 merely points to some evidence suggesting that about 10% of persons exposed to a frequency-weighted vibration magnitude of the order of 4 ms^{-2} from a tool used regularly for 4 hours per day may exhibit symptoms of blanching after about 8 years. If the magnitude is other than 4 ms^{-2}, provision is made for calculating the number of years required to produce symptoms in 10% of the population or, alternatively, the daily exposure time for exhibition after about 8 years. The difference in approach is illustrated by reference to Figure 2 which reproduces the dose-response tables given in both Standards.

BS 6842:1987 gives reasonably precise details of the methodology to be employed during monitoring and provides design criteria for the direct measurement of frequency-weighted acceleration using a frequency weighting network, although measurements made in $\frac{1}{3}$ and 1/1 octave bands can be converted to weighted measurements using an appropriate correction factor.

THE WAY FORWARD

It can be said that the problem of occupational exposure to noise has largely been quantified, assessed and steps taken to protect employees from possible hearing damage although debates will undoubtably continue over the adequacy of the standards being proposed. The number of people using vibrating hand tools needs to be quantified and more dose-response data obtained so that definitive recommended exposure limits can be derived. This work will require the co-operation of workers and management to ensure that as much information is gathered as possible and manufacturers of equipment must be made aware of the need to incorporate appropriate damping mechanisms in the design of tools presenting the greatest risk. A lot of work needs to be done in this field as well as in the risk of whole-body exposure to vibration. As more information is gained about the incidence of Raynaud's Phenomenon and more research is carried out into more effective measurement techniques, the problems associated with assessment will be more clearly understood which should enable proper protection to be given to the exposed population as well as financial support to a wider class of sufferers of the injury.

REFERENCES

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(4) ISO 5349:1986: Mechanical Vibration - Guidelines for the Measurement and the Assessment of Human Exposure to Hand-Transmitted Vibration, British Standards Institution, Milton Keynes.

(5) BS DD:43 (1975): Guide to the Evaluation of Exposure of the Human Hand-Arm System to Vibration, British Standards Institution, Milton Keynes.

(6) BS 6842:1987: Measurement and Evaluation of Human Exposure to Vibration Transmitted to the Hand, British Standards Institution, Milton Keynes.

(7) ISO DIS 5349 (1979): Principles for the Measurement and Evaluation of Human Exposure to Vibration Transmitted to the Hand, British Standards Institution, Milton Keynes.

(8) ISO DIS 5349.2 (1984): Guidelines for the Measurement and the Assessment of Human Exposure to Hand-Transmitted Vibration, British Standards Institution Milton Keynes.

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Figure 1

Causes of Raynaud's Phenomenon (after Taylor and Pelmear, 1975 (9)

A) Primary Raynaud's Disease

a) Raynaud's disease
b) constitutional white finger

B) Secondary Raynaud's Disease

i) connective tissue disease:

a) scheleroderma
b) systemic lupus erythematosus
c) dermatomysitis
d) rheumatoid arthritis
e) polyarteritis nodosa
f) mixed connective tissue disease

ii) trauma:

- direct to extremities:

a) following injury, fracture or operation
b) of occupational origin (vibration)
c) frostbite and immersion syndrome

- to proximal vessels by compression:

a) thoracic outlet syndrome
b) costoclavicular and hyperabduction

iii) occlusive vascular disease:

a) thromboangiitis obliterans
b) arteriosclerosis
c) embolism
d) thrombosis

iv) dysglobulinaemia:

a) cold haemagglutination syndrome

v) intoxication:

a) acro-osteolysis
b) ergot
c) nicotine

Figure 2

Dose-Response Relationships Given in ISO 5349:1986 and BS 6842:1987

Table 4 — Exposure time in years for different percentiles of a population for various weighted accelerations

Weighted acceleration $(a_{h,w})_{eq(4)}$ $m \cdot s^{-2}$	Percentile of population, C				
	10	20	30	40	50
	Exposure time, years				
2	15	23	>25	>25	>25
5	6	9	11	12	14
10	3	4	5	6	7
20	1	2	2	3	3
50	<1	<1	<1	1	1

a) ISO 5349:1986

Table 5. Frequency weighted vibration acceleration magnitudes ($m \cdot s^{-2}$ r.m.s.) which may be expected to produce finger blanching in 10 % of persons exposed

Daily exposure	Life-time exposure					
	6 months	1 year	2 years	4 years	8 years	16 years
8 h	44.8	22.4	11.2	5.6	2.8	1.4
4 h	64.0	32.0	16.0	8.0	4.0	2.0
2 h	89.6	44.8	22.4	11.2	5.6	2.8
1 h	128.0	64.0	32.0	16.0	8.0	4.0
30 min	179.2	89.6	44.8	22.4	11.2	5.6
15 min	256.0	128.0	64.0	32.0	16.0	8.0

NOTE 1. With short duration exposures the magnitudes are high and vascular disorders may not be the first adverse symptom to develop.

NOTE 2. The numbers in the table are calculated and the figures behind the decimal points do not imply an accuracy which can be obtained in actual measurements.

NOTE 3. Within the 10 % of exposed persons who develop finger blanching, there may be a variation in the severity of symptoms.

b) BS 6842:1987