

A consideration of doseresponse relationships for vibration-induced white finger

Appendix H2C to Final Report May 2001

EC Biomed II concerted action BMH4-CT98-3291

Griffin MJ <sup>(1)</sup>, Bovenzi M <sup>(2)</sup>, Nelson CM <sup>(3)</sup>

 <sup>1.</sup> Human Factors Research Unit, Institute of Sound and Vibration Research, University of Southampton, Southampton SO17 1BJ, England, e-mail: mjg@isvr.soton.ac.uk
<sup>2.</sup> Department of Public Health Sciences, Clinical Unit of Occupational Medicine, University of Trieste, Centro Tumori, Via della Pieta' 19, 1-34129 Trieste, Italy, e-mail: bovenzi@univ.trieste.it

<sup>3.</sup> Health and Safety Executive, DST E4, 316 Magdalen House, Stanley Precinct, Bootle, Merseyside L20 3QZL, England, e-mail: chris.nelson@hse.gsi.gov.uk

# Introduction

Occupational exposure to hand-transmitted vibration is associated with various disorders, collectively known as the 'hand-arm vibration syndrome'. The syndrome includes vascular, neurological and musculoskeletal disorders that may become manifest individually or collectively. The conditions causing each of these disorders are not known. However, for the best known vascular disorder, vibration-induced white finger (VWF), several studies have reported the vibration conditions associated with an observed incidence, or prevalence, of the condition.

This study investigated the relationships between finger blanching and characteristics of exposures to hand-transmitted vibration, specifically the vibration magnitude and lifetime exposure duration. The effects of vibration frequency were investigated by comparing dose-response models constructed with and without the frequency weighting recommended in current standards.

## Methods

Three previously published studies of VWF have been reanalysed: a study of dockyard workers (Nelson and Griffin, 1989, 1993), a study of quarry/stone workers (Bovenzi, 1994), and a study of forestry workers (Bovenzi *et al.*, 1995). In each of these studies, medical history, employment history, extent, severity and development of vibration-induced white finger, and exposure to vibration were obtained from individual workers during interviews using a structured questionnaire. The three sets of data provided a group of 1557 male subjects in seven occupational subgroups: stone grinders, stone carvers, quarry drillers, dockyard caulkers, dockyard boilermakers, dockyard painters and forest workers.

Subjects were asked to identify the vibrating tools used during their working life. Tool operating time was obtained in hours per day, days per year and total number of years, separately for each period of use of each tool type. The estimated total (i.e. lifetime) operating duration in hours was thus obtained for each subject, for each tool. The total vibration exposure duration for each subject was obtained by the addition of the operating durations for the different tools.

Vibration was measured on representative samples of the tools. Vibration magnitudes were expressed as root-mean-square acceleration, frequency-weighted in accordance with ISO 5349 (1986). Unweighted acceleration magnitudes were also obtained over the same nominal frequency range (6.3 - 1250 Hz).

From the vibration magnitudes and exposure durations, various alternative vibration 'doses' were calculated for each subject:

$$dose = \sum_{i} [a_i^m t_i]$$

where  $a_i$  and  $t_i$  are the acceleration magnitude and the exposure duration, respectively, for tool *i*, and m = 0, 1, 2 or 4.

## Results

For all seven measures of dose, an increase in dose was associated with a significant increase in the occurrence of vibration-induced white finger (Figure 1). However, the strength of the relationship between alternative measures of dose and the occurrence of vibration-induced white finger varied between dose measures. Generally, dose measures with high powers of acceleration (i.e. m > 1) faired less well than measures in which the acceleration,  $a_{wi}$  or  $a_{uwi}$ , and lifetime exposure duration, t, were given equal weight. Indeed, dose determined solely by the duration of exposure (without consideration of the vibration magnitude) tended to give better predictions than measures with values of m greater than unity.

Logistic regression suggested that all measures of dose provided better predictions when the dose was calculated from the unweighted acceleration than from the frequency-weighted acceleration.

#### Discussion

Current methods for evaluating exposures to hand-transmitted vibration are based on standards that assume a squared relationship between vibration magnitude and exposure duration during the working day (i.e. m = 2) and a linear relationship between vibration magnitude and years of exposure (i.e m = 1). The data shown here are restricted to the total exposure duration and do not discriminate between exposures accumulated over the day and those accumulated over years. With exposure duration evaluated in this way, it seems that a linear relationship between vibration magnitude and exposure duration is appropriate for predicting the occurrence of vibration-induced white finger.

The predictions were dependent on the frequency weighting, with poorer predictions when the currently recommended frequency weighting was employed. This suggests that more weight should be given in the standards to vibration at some intermediate or high frequencies.



## Vibration dose

Figure 1 Relation between vibration-induced white finger (VWF) and alternative measures of vibration dose in the vibration exposed workers (n=1557). The prevalence of VWF in each quintile of vibration dose is shown. ( $a_{wi}$  = frequency-weighted acceleration;  $a_{uwi}$  = unweighted acceleration;  $t_i$  = exposure duration)

## Conclusions

The findings suggest that improvements are possible to both the frequency weighting and the time-dependency in current standards used to predict the development of vibration-induced white finger.

## Acknowledgements

Research supported by the European Commission under the BIOMED2 concerted action BMH4-CT98-3251 (Vibration Injury Network).

## References

Bovenzi,M., Italian Study Group on Physical Hazards in the Stone Industry (1994) Hand-arm vibration syndrome and dose-response relation for vibration induced white finger among quarry drillers and stonecarvers. Occupational and Environmental Medicine, 51, 603-611.

Bovenzi,M., Franzinelli,A., Mancini,R., Cannavà,M.G., Maiorano,M., Ceccarelli,F. (1995) Dose-response relation for vascular disorders induced by vibration in the fingers of forestry workers. Occupational and Environmental Medicine, 52, 722-730.

International Organization for Standardization (1986) Mechanical vibration - Guidelines for the measurement and the assessment of human exposure to hand-transmitted vibration. International Standard ISO 5349.

Nelson, C.M., Griffin, M.J. (1989) Vibration-induced white finger in dockyard employees. Institute of Sound and Vibration Research, Technical Report 170, University of Southampton.

Nelson, C.M., Griffin, M.J. (1993) Comparison of predictive models for vibrationinduced white finger. Proceedings of the 6th International Conference on Hand-arm Vibration, Bonn, (1992), Published: HVBG, D-53754 Sankt Augustin, ISBN: 3-88383-331-2, 875-883.