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MODELLING SUSCEPTIBILITY VIBRATION-INDUCED INJURY

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ABSTRACT

The aim of this paper is to outline some of the factors which could influence the quantification of individual susceptibility to vibration-induced white finger and neurological disorders caused by hand-transmitted vibration, and to outline the basis of a predictive model based on the principle of differential damage susceptibility .

1. INTRODUCTION

Acute exposure to hand-transmitted vibration can, in the course of time, induce the development of vibration-induced white finger (VWF) and vibration-induced neurological disorders (VND) in human subjects. Vibration white finger (VWF) is a peripheral vascular disease where ischemia in the digits or hands is triggered by cold, its main symptom being the intermittent blanching of the fingers, although more recently Taylor (1989) and Okada (1990) have both confirmed that the pathogenic effects of VWF can be accounted for by both central and periferal mechanisms. Vibration-induced neurological disorder (VND) is a peripheral neurological disease the first symptoms of which are numbness and tingling in the fingers and hands. As the disease progresses pain and nightly paraesthesia can also occur, and impairment of tactile sensitivity, muscle wasting, decreased nerve conduction velocity and weakness of hand grip have also been reported.

2. SUSCEPTIBILITY TO DAMAGE

Taylor and Brammer (1982) discussed several factors that were known or believed to influence the adverse effects upon individuals of occupational exposure to vibration from hand held tools. These included biological susceptibility to vibration, vasoconstrictive agents affecting the peripheral circulation (e.g. smoking, drugs), predisposing disease or prior injury to the fingers or hands, hand size and weight and epidemiological factors (e.g. age). Griffin (1988) also reported that the such responses of the body to vibration are neither repeatable nor consistent, and that both intra and inter-individual differences can be expected. Available data suggest that there is not enough evidence to assume that age is an important factor, and in respect of gender the number of recent studies using female subjects is severely limited so that although there is a suspicion that females are more at risk, no definitive conclusions can be reached. Smoking is an important factor considering the vasoconstrictive effect of nicotine, but the findings are unequivocal so that further investigation is necessary. When discussing aspects of susceptibility related to vascular function blood viscosity, vessel diameter and the pattern of reaction to low temperatures (measured by finger systolic blood pressure and rewarming times after local cooling) seem to be the most important factors. Blood viscosity and vessel diameter were found respectively to increase or decrease in subjects with VWF. Whilst peripheral resistance seems to provide useful information about susceptibility to VWF, no study appears to have specifically focused on identifying individual susceptibility to VWF.

3. POSSIBLE MEASURES OF SUSCEPTIBILITY

Most of the procedures available for the measurement of such dysfunctions have the disadvantage that the results tend to be analysed and reported on a group basis, and are therefore limited in their application to the detection of individual susceptibilty. The most promising test for use in the diagnosis of VWF seems to be strain-gauge plethysmography since it has demonstrated sensitivity, specificity (Olsen and Nielsen, 1979; Bovenzi,1988c and 1993) and repeatablity of results (Carnicelli et al, 1992), although it is clear that further normative data is still needed. The cold provocation test with the measurement of rewarming times is also a widely used procedure although its value as a reliable and repeatable objective diagnostic measure is more questionable. Several procedures have been used for the evaluation of peripheral neurological disorders induced by hand-transmitted vibration although vibrotactile threshold measurement and aesthesiometry seem to have most merit for use on an individual basis.

4. MODELLING INDIVIDUAL SUSCEPTIBILITY

The basis of a possible model which could be used in the evaluation of susceptibility to noise induced hearing loss (NIHL), the principles of which could be applied to VWF, has been proposed by Lawton and Robinson (1985, 1986, 1987). The first factor is based on well established facts

about hearing and depends on the large dispersion in thresholds levels among the normal population (about ± 20dBHL). Whilst some of this less acute dispersion may be explained by the presence of sub-clinical hearing losses, due for example to exposure in childhood to adverse environmental influences like noise and ototoxic substances, there is nevertheless, considerable inherent biological variability present. The second and perhaps principal factor is that in general hearing does not improve with age and exposure to noise. However, not withstanding adverse exposure to these factors some individuals nevertheless retain good hearing threshold levels after many years of exposure to noise; these are the noise survivors. Therefore, it could perhaps be assumed that a noise survivor was the possessor of better-than-average hearing threshold levels in his youth.

From this model it can be postulated that noise survivors would present the same auditory patterns as younger people who possess better-than-average results in cochlear function tests. This has been demonstrated to some extent by Lawton and Robinson in the above mentioned studies, and indicates that a normal young adult who has a better-than-average scores in specific susceptibility tests (i.e hearing threshold level at 4 kHz, temporal integration and frequency selectivity) is possibly more resistant to NIHL.

The principle of differential damage susceptibility has so far only been exclusively applied to noise-induced hearing loss. However, there is no reason why it could not be extrapolated to the investigation of susceptibility to VWF and VND due to exposure to hand-transmitted vibration. In order to assess this possibility some aspects of vascular and neurological function must be investigated in both normal healthy subjects of different ages and in VWF survivors. If the principle could be applied to vibration it would be expected that healthy individuals not exposed to vibration with more sensitive results in the vascular and neurological tests, would behave in a similar fashion to the vibration survivors. Using this hypothesis it could perhaps be expected that a test battery for the prediction of susceptibility to VWF and VND could be formulated.

5. PILOT STUDY FINDINGS

As there is no specific test or battery of tests available to investigate susceptibility to vibration-induced white finger and neurological disorders, some procedures commonly used in the diagnosis of these diseases were selected based on theoretical inferences that could convey relevant information on susceptibility. The repeatability of these vascular (finger systolic blood pressure and finger rewarming measurements) and neurological (aesthesiometry and vibrotactile thresholds) tests was investigated in two different experiments. Finger systolic blood pressure ($FSBP\%_{15}$) and vibrotactile thresholds were the procedures which showed less variability of results when applied on different occasions.

The hypothesis that the differential damage susceptibility model could be applied to finger systolic blood pressure after cooling and vibrotactile threshold measurements was tested. It was found that $FSBP\%_{15}$ fits to the model with VWF survivors presenting similar $FSPB\%_{15}$ values to those of the young controls who were significantly higher than older controls. Therefore, using the model of differential damage susceptibility, better than average values of $FSBP\%_{15}$ could be used as an indicator of resistance to vibration-induced white finger in young unexposed subjects.

Vibrotactile thresholds at 125 Hz also fitted to the model of differential damage susceptibility, suggesting that this test could also be an indicator of susceptibility to vibration-induced neurological disorders in young unexposed subjects.

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