VPA-BASED WEIGHTING CURVE: PRELIMINARY ASSESSMENT OF GENDER DIFFERENCE

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1. INTRODUCTION

The UNI EN ISO 5349-1:2004 weighting curve (WC) is the standard risk assessment of HAV.[1] This made use of subjective sensation data reported by Miwa on vibration perception in 1967 performed on ten subjects.[2] Risk assessment is generally done following the cited standard, even if the foundation of the weighting curves has been criticized by some authors.[3] This means, from a pragmatic point of view, that any revision of this standard should preserve the weighting curve, eventually modifying it in order to cope with various vibratory conditions. Recently, an alternative method to compute WC has been proposed,[4,5] which is based on Vibration Absorbed Power (VPA) measurements. These authors found a resonance frequency for the hand-arm system around 31.5 Hz through VPA and MI (Mechanical Impedance) measurements. In the present work, where the range 10-60 Hz was explored, two frequencies immediately before and after that peak, i.e. 30 Hz and 33 Hz, were examined. The aim of this study is to derive weighting factors from VPA measurements and establish the possibility of a gender difference.

2. METHODS

36 young subjects were enrolled, equally divided by genders (18 men: age 26.4±2.5 years, weight 75.4± 10.5 kg, height 178.1±6.2 cm); 18 women: age 25.6±4.4 years, weight 58.9±7.3 kg, height 167.3±8.2 cm). Nine pure sinusoidal vibration signals (10, 20, 30, 31.5, 33, 40, 50 and 60) were generated by a vibration exciter (RMS SW 1508, Germany). Subjects were positioned as described in UNI EN ISO 10819. The grip force was set to 50 N.

The exerted force was constantly shown to the subject. An adapter with a load cell (FGP Sensor & Instruments, FGPXFL212R, France) and an accelerometer (PCB, SEN026, U.S.A.) were fixed to the palm of the hand. Acceleration and force signals were recorded by a real time 32 channel analyzer (OROS, OR38, France) at a sampling rate of 2,500 samples per second.

VPA evaluation is the product of force and velocity. Force was measured directly by means of palm mounted load cell, the velocity was estimated by numeric integration of the palm acceleration along the z-axis. For comparison purpose, MI was derived from VPA measurements through the following equation:[5]

$$P(\omega_i) = \mathrm{Re}[Z(\omega_i)] \cdot \left(\frac{A(\omega_i)}{\omega_i} \right)^2 \quad (1)$$

VPA frequency weighting evaluation has been done following the scientific, [4] and technical literature:[1]

$$\mathrm{W}_{VPA}(\omega_i) = 0.958 \frac{\sqrt{P(\omega_i)}}{A(\omega_i)} \Big/ W_{VPA\_Max} = 0.958 \frac{\sqrt{P(\omega_i)}}{V(\omega_i) \cdot \omega_i} \Big/ W_{VPA\_Max} \quad \mathbf{(2)}$$

where $P(\omega_i)$, $A(\omega_i)$ and $V(\omega_i)$ are frequency mean power absorption, acceleration and velocity, respectively, while W_{VPA_Max} is the W_{VPA} maximum attained in the investigated frequency range and assumed as the reference value.

3. RESULTS

VPA data are reported in Figure 1. Absorbed-power based frequency weighting curves WVPA and MI curves were computed for both genders and compared with UNI EU ISO 5349-1:2001 and the literature (Figures 2 & 3).[6]

Referring to the male and female VPA data (Figure 1 a and b, respectively), we may observe that up to 20 Hz the relative behaviours are almost the same, and within the intrinsic statistical variation. Within the range 30 to 33 Hz, the male notch response is more pronounced than that of the females. At both outer frequencies, the male curve is higher and drastically drops at 31.5 Hz. This local minimum is also evident for females, though less pronounced than for the other gender. Above the range 30 to 33 Hz, and up to 60 Hz, the curves for both genders are close one to the other with the male curve beneath the female one.

Concerning gender differences (Figure 2), the female's WVPA curve is almost similar to that of male subjects up to 20 Hz. From 20 Hz up to 60Hz, the male curve is, with no-statistical significance, under the relative female curve. Within the more deeply investigated frequency range, we found for both genders two analogous peaks at 31.5 Hz, with approximately the same maximum absolute value. Clearly, the relative weight of these peaks is higher for male subjects then for females, though the curves are within each other's error margins. Both curves are below the ISO curve.

Concerning MI curves (Figure 3), a small gender difference is evident, with the resonance peak for females at a lower frequency (31.5Hz) than for males (33 Hz). By comparison with the literature,[6] the published resonance behaviour is less evident and more damped than in the present data.

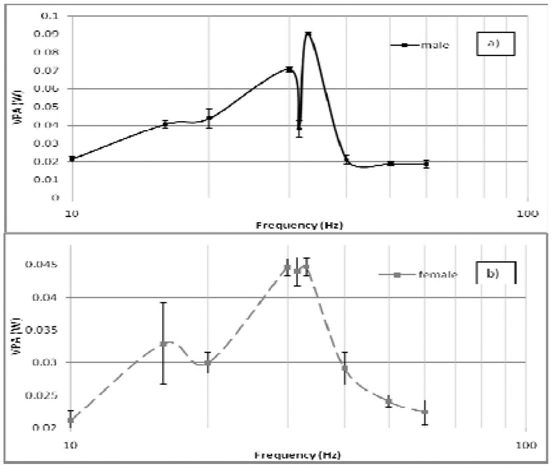

Figure 1. Male (a) and female (b) VPA curves. Data are mean values for each gender group ± standard error. Note that the vertical scales are different.

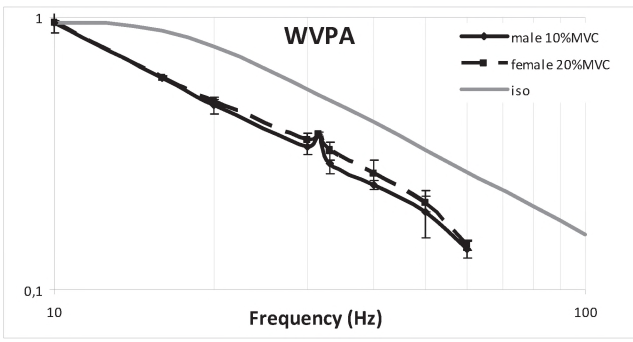

Figure 2. Weighting curves WVPA derived from the VPA curves for both genders. In this case, the ISO curve is taken as a reference curve. Data are mean values evaluated on each gender group ± standard error

4. DISCUSSION AND CONCLUSIONS

By comparing MI curves with those of Dong et al [6] (see Figure 3), we may notice that their profiles are almost similar for all frequencies but from 30 to 33 Hz where the presence of a peak at 31.5 (female) or 33 Hz (male) is evidence of resonance behaviour. The explanation for this discrepancy is twofold: firstly, the resonance behaviour is enhanced in our study by increasing the sampling rate within the 30 to 33 Hz frequency range; secondly, our experimental set-up allowed a direct assessment of palm acceleration and force, instead of those at the handle, which, in turn, gave more accurate measurements. Moreover, we can exclude any influence of the adapter dynamics on the sharp resonance in our results, since a previous accurate transducer calibration procedure guaranteed an absolutely flat frequency response in the range 5 to 100 Hz.

A possible physiological explanation comes from the observation of the Meissner corpuscles behaviour, which have a maximal sensitivity just at that frequency.

By comparing male versus female VPA curves, we may observe that the females curve is below that of the males. Presumably this is due to the higher effort for female subjects to exert the same 50 N grip force. This, in turn, causes different muscle stiffness and consequently a different absorbed power.

Concerning the weighting WVPA curves depicted in Figure 2, we may notice that the normalization procedure adopted in equation (2) decreases the relative curve dynamic, rendering both female and male curves closer to each other. The sharp peak observed at 31.5 Hz in the VPA curves is also evident in the WVPA curves but much smaller. Anyway, the most important conclusion about the WVPA curves is that they are both clearly below the ISO standard curve. This conclusion addresses the most important aim of the present research, which is to prevent vibration injures in the work environment for both genders.

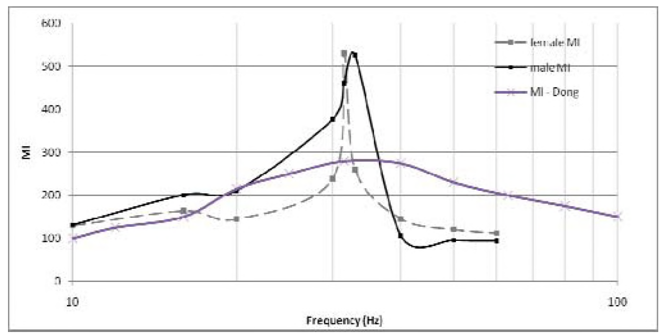

Figure 3. MI curves derived from the VPA curve for both genders. In this case, the curve from Dong et al. is taken as a reference curve.[6]

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