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MECHANICAL ENERGY ABSORPTION IN HUMAN FINGERS EXPOSED TO HAND-TRANSMITTED VIBRATION

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ABSTRACT

Vibration white finger (VWF), typically characterized by finger blanching along with tingling and numbness in the hand and fingers, has been associated with extensive exposure to hand-transmitted vibration. Vibration exposure is usually quantified by measuring acceleration on vibrating tools [1]. Vibration energy absorption (VEA) in the fingers may be a significant etiologic factor for VWF and may provide a better quantification of vibration than the tool acceleration spectrum. As the first step to test this hypothesis, a method for measuring the VEA in the fingers was proposed and evaluated in the present study. Six subjects were employed in the evaluation experiment. Constant-velocity (14 mm/s rms) sinusoid accelerations at 10 different frequencies in the range of 16-1000 Hz were used. The characteristics of the VEA measured on the fingers were also compared to those of the VEA measured on the palm of the hand. The results revealed that the finger VEA in the low frequency range (≤25 Hz) was less than that measured on the palm, but finger and palm VEA measurements were comparable at higher frequencies (≥160 Hz). Secondly, the VEA measured on the fingers at frequencies higher than 160 Hz was independent of palm-handle coupling conditions.

MATERIALS AND METHODS

Vibration energy per unit time, or power, flowing into the fingers-hand-arm system from a vibratory tool handle can be calculated from

$$E(t) = \mathbf{F}(t) \bullet \mathbf{V}(t) \quad (1)$$

where **F** and **V** are the interaction vibration force and velocity at the interface, respectively, as shown in Fig. 1.

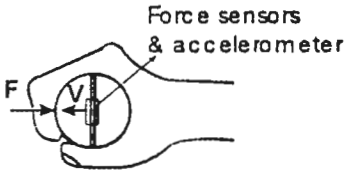


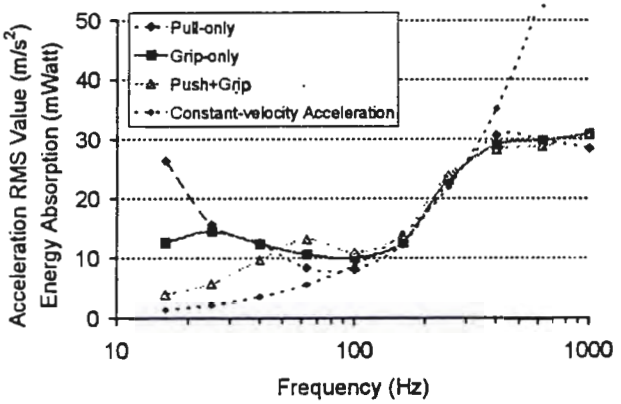
FIGURE 1. Hand-handle coupling and measurements of vibration force and acceleration

A special instrumented handle was designed and constructed to simulate a vibratory tool handle. It was attached to a shaker to deliver vibration to the fingers-hand-arm system. Two piezoelectric force sensors (Kistler 9212) were installed in the handle to measure the force. An accelerometer (PCB 339B24) was also installed in the handle to measure the acceleration. The measured acceleration was integrated to obtain the velocity for the energy calculation. For a comparison with the VEA on the fingers, the energy flowing into the palm-hand-arm system was also measured by rotating the handle

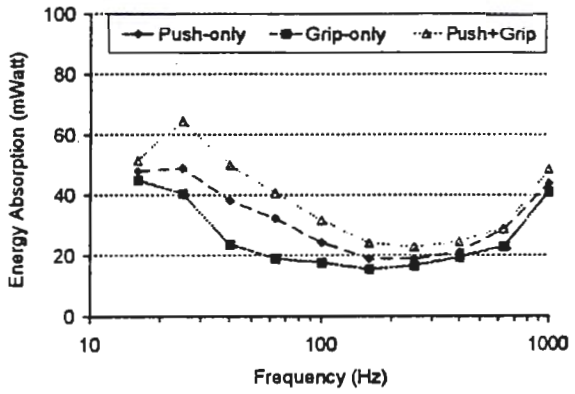
180^0 from its finger VEA measurement position (Fig. 1). The experiment was carried out on six healthy male subjects with the following hand-handle coupling actions: Grip-only (50 N), Grip (50 N)+Push (50 N), Pull-only (50 N), and Push-only (50 N). The Push-only trials were completed with the handle in the palm VEA measuring orientation while the Pull-only trials were run in the finger VEA measurement position. A constant velocity (14 mm/s) sinusoid vibration at 10 different frequencies (16, 25, 40, 63, 100, 160, 250, 400, 630 and 1000 Hz) corresponding to 10 accelerations (1.4, 2.2, 3.5, 5.6, 8.8, 14.1, 21.9, 35.1, 55.0, 87.6 m/s^2 rms) were used in the experiment.

RESULTS AND DISCUSSIONS

Fig. 2 depicts the mean values of the VEA measured on the fingers for the three combinations of finger-related hand couplings, together with the constant-velocity accelerations. The VEA measured on the palm is shown in Fig. 3. As it can be seen, the VEA measured on the fingers in the low frequency range ($\leq$ 25 Hz) is less than that on the palm. However, they are at a comparable level in the high frequency range ($\geq$ 160 Hz). These data suggest that low-frequency vibration may not affect the fingers as much as other parts of hand-arm system such as the wrist, elbow, and shoulder joints. Previously reported epidemiological studies as reviewed by Griffin [2] indicated that VWF was not closely correlated to low frequency vibration. Therefore, it may not be appropriate to use the total VEA (finger VEA + palm VEA) as an assessment factor for VWF, especially in the low frequency range. This may be a fundamental deficiency of the total energy approach that was exclusively used in many previous VEA studies [3-4] regarding VWF. As can also be seen in Fig. 2, the VEA measured on the fingers at frequencies higher than 160 Hz was independent of the palm-handle coupling conditions, which suggests that the energy in this frequency range is mostly consumed locally in the fingers. At frequencies less than 100 Hz, however, the VEA measured on the fingers depends on the finger-handle coupling conditions. The finger VEA increases approximately proportionally with the acceleration in the frequency range of 100-400 Hz but remains more or less constant as the acceleration and frequency are further increased proportionally.



FINGER 2. VEA measured on the fingers



FINGER 3. VEA measured on the palm

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