A Study of Tissue Vibration Transmissibility Using a Scanning Laser Vibrometer

W. Paul Smutz, Ren G. Dong, and Aaron W. Schopper
National Institute for Occupational Safety and Health, Morgantown, WV, USA

INTRODUCTION

Prolonged exposure to vibration has been associated with the development of hand-arm vibration syndrome (HAVS). While vibration is known to have adverse physiological effects on the tissues of the human hand, it is still unclear how these physiological effects are influenced by factors such as tissue thickness or vibration intensity, frequency, and duration. Understanding the response of the hand to vibration may be helpful in determining the mechanisms behind the development of HAVS. Dynamic response of the hand and arm to vibration has been studied by several investigators (Abrams and Suggs, 1966, Burstrom, 1990). However, these studies have concentrated on the overall impedance of the hand/arm system or have looked only at the vibration transmitted along the bones or on the surface of the hand or arm. The vibration transmissibility through individual tissues such as skin, fat, muscle, blood vessels, and nerves has not been investigated because of the difficulty in making these measurements in vivo. Computer models of the hand have been proposed as a solution to this problem. By using finite element modeling techniques, each tissue can be modeled separately and the vibration transmissibility at different tissue depths can be calculated. However, for these models to be truly useful, validation is necessary. As a first approximation to validate these models, transmissibility in skeletal muscle and fat was measured as a function of the tissue depth using a scanning Doppler laser vibrometer.

METHODS

The test system consisted of an electro-mechanical shaker, a power amplifier, an open loop controller, a scanning Doppler laser vibrometer, and a data acquisition and analysis system. The heart of the system was the scanning Doppler laser vibrometer (Polytech PSV 300). The vibrometer measures the Doppler shift of laser light that is reflected off of a vibrating object and determines the velocity of the object. The velocity of the vibrating object is then differentiated to obtain acceleration. The laser vibrometer has several advantages over accelerometers. First, because it is a non-contact device, no mass is added to the tissue which may alter the local properties of the mechanical system and thus affect the measured data. Second, because the vibrometer can scan several points quickly, a detailed pattern of the vibration can be obtained.

For this study bovine tissue was used because it was easier to obtain and safer to use than human cadaveric tissue. Samples of skeletal muscle and fat from a beef steak were cut into sections 25 mm square and of various thicknesses. Using cyanoacrylate, the samples were glued to an aluminum plate that was attached to the shaker. Care was taken to keep the samples moist. Tests were performed at room temperature. A sine wave that was repeatedly swept linearly from 1 to 1600 Hz over a 10 second period was input into the shaker. The laser vibrometer was then used to measure the acceleration of 9 points on the surface of the sample and 2 points on the aluminum plate. The test was performed on each sample for acceleration amplitudes of 2, 4 and 8 g's (peak). Tissue transmissibility was calculated by dividing the acceleration at each point on the surface of the sample by the acceleration of the aluminum plate.

RESULTS AND DISCUSSION

Test results showed a marked difference in vibration transmissibility for muscle and fat. For skeletal muscle, a fundamental resonance was found between 50 and 200 Hz (Figure 1-3). Muscle thickness was found to influence vibration transmissibility as well as the frequency of the fundamental resonance. Fat was found to have a transmissibility close to unity for thicknesses of less than 6 mm and for frequencies between 1 and 1000 Hz.

The results from this study for the skeletal muscle are consistent with those of previous studies which report that resonant peaks for the hand and arm are in the frequency range of 80 to 200 Hz and that vibrations above 500 Hz are damped out quickly in the hand (Potts et al., 1983). This study showed that the laser vibrometer was capable of measuring the acceleration of soft tissues exposed to vibration. The muscle reflected sufficient light back to the laser vibrometer so that accurate measurements could consistently be made.

Future studies using the laser vibrometer will include measuring the vibration transmissibility of the soft tissues of the hand using cadaveric specimens. These values will then be compared to those predicted by finite element models of the finger that have been developed in our laboratory.

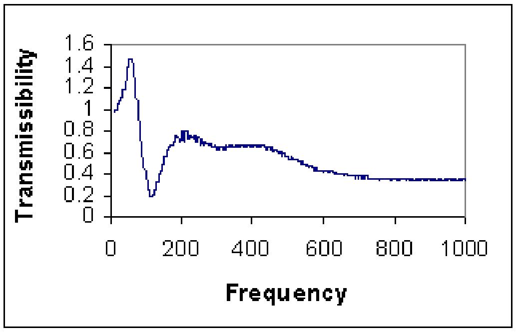

Figure 1. Muscle 8 g's 18.0 mm thick

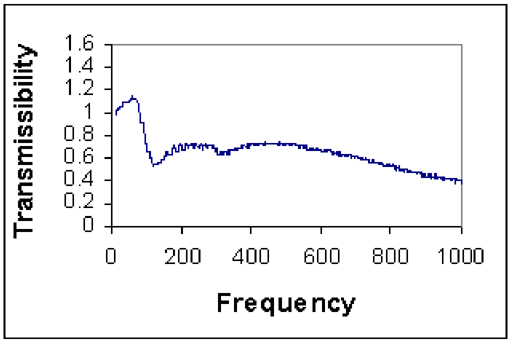

Figure 2. Muscle 8 g's 12.3 mm thick

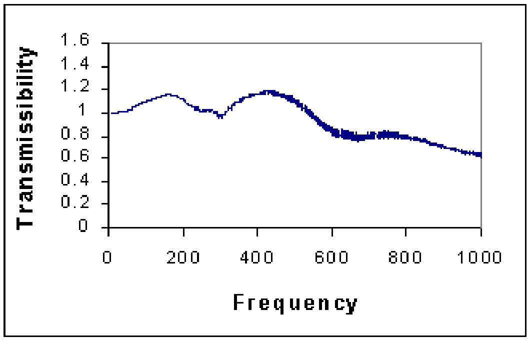

Figure 3. Muscle 8 g's 4.6 mm thick

REFERENCES

Abrams, C.F. and Suggs, C.W. (1966) *Transactions of ASAE*, 423-425

Burstrom, L. (1990) *In Arch Occup Environ Health*, 62(6):431-439

Potts, R.O. et al. (1983) *J Biomech*, 16(6):365-372