Repetitive Impacts From Manual Hammering: Physiologic Effects On The Hand-Arm System

D.R. Peterson and M.G. Cherniack
Biodynamics Laboratory, University of Connecticut School of Medicine, Farmington, CT 06030-6210

1. INTRODUCTION

Repetitive impact from both percussive and power tools is frequently encountered in industry. It is widely recognized that dose effect models derived from oscillatory motion may significantly underestimate impact related effects. Research on translating laboratory measurements from individual impact hand tools into human health effects is underdeveloped (SUGGS, 1982; ISO/CD 15694, 2000). Results derived from detailed dynamic measurements (i.e., forces and angles measured at high sampling rates at at point of impact rather than accumulated and averaged for the entire work cycle) have yielded measurable quantities. These are in concept that were both closely related to potential human health risks and are significantly differentiable between a sample of representative commercial hammers (PETERSON and CHERNIACK, 2001). Table 1 summarizes the observed differences of each biomechanical factor obtained from preliminary data investigations on these types of observations. Vibration analyses from these experiments showed that while the importance of vibration measured at the wrist has high importancebeen recognized because of transmission to important arm structures, but it did not differ substantially between the hammers tested. Vibration at the hammer handle was widely different between tools, but its importance is obviated by the absence of differential transmission to the hand and arm (PETERSON and CHERNIACK, 2001). On the other hand, the highest levels of energy transfer were mapped at the fingertips. This may have important health consequences because of the proximity of important neurological and neurovascular organelles.

The accelerations of the bony structures of the hand at point of impact are more likely to correspond with actual exposures than measurements that are accumulated and averaged for the entire work cycle. An even more critical consideration may be a preferential distribution of effect in the hand, particularly at the fingertip with its density of neuro-afferents and neurovascular structures. The purpose of this study was the determination of the distribution of transmitted vibration (vibration mapping) over the entire hand during a manual hammering task. Vibration mapping provides a more physiologic representation of how energy is transmitted to the hand during the tool usage than is possible from temporal and spatial cumulative models.

2. METHODS

Vibration mapping was determined from individual trials on subjects performing a standardized hammering task. A set of four uni-axial accelerometers were placed perpendicular to the longitudinal axis of, and bisected the lengths of the distal, middle, and proximal phalanges, and the metacarpal of a particular finger. The set of accelerometers were limited to one finger only for each experimental run. (Note that the thumb only required the use of three accelerometers.) In these experiments, we have used conventional commercial hammers - a specific anti-vibration model, as well as all-steel, graphite, fiberglas, and wood models - to provide single impact force mapping.

3. RESULTS

Vibration mapping on the right hand was determined by averaging the observed peak accelerations for each accelerometer. Results show that peak acceleration values of 27.0 to 34.0 m/s^2 were observed on the distal phalanges while values from 20 to 26.9 m/s^2 were observed on the middle phalanges. Peak acceleration values from 16 to 19.9 m/s^2 were observed on the metacarpal and proximal phalanges from digits 1, 4 and 5, and values from 12 to 15.9 m/s^2 were observed on the proximal phalanges from digits 2 and 3.

As was expected, vibrations were observed to be higher in the distal phalanges when compared the metacarpals. The peak acceleration values on the metacarpals were observed to be greater than the proximal phalanxes. This contrast may be due to variations in grip forces during the use of the hammer, or if the subject did not operate the tool consistently. It is necessary to study more subjects in order to prove that the values of these accelerations are consistently distributed.

4. DISCUSSION AND CONCLUSIONS

The observed values are potentially influenced by several factors. The subject is free to grip the tool at various locations about the hammer handle. Changes in these grip locations, as well as the strength of the grip, can affect vibration transmission. Missing the nail and hitting the wood board can also affect vibration transmission. Also, each accelerometer needs to be secured in the right position above the phalanx. Poorly mounted accelerometers can promote sensor and sensor wire movement and introduce erroneous artifacts within the measurements, especially at the time of hammer and nail contact.

The distribution of the transmitted vibration over the hand was greatest for the distal phalanges of the hand. The metacarpals showed a greater or equal value of vibration than the proximal phalanges, which is possibly a factor of grip.

Further investigation of vibration mapping should include measures of grip force to accompany the measures of vibration in order to understand better the distribution of vibration transmission during a hammering task. Current and intended investigations of the effects of impact on mechanoreceptors and receptor mediated blood flow in the fingertips are warranted, given the high levels of energy transfer to the glabrous pad of the fingertip.

5. REFERENCES

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Table 1: Biomechanical factors and observed differences within the measured data among tested hammers.

Biomechanical Factors (Measured Quantities)	Location of Measurement	Observed Differences
Vibration (RMS Acceleration)	Hammer Shank Just Prior to Handle (Tool)	Substantial
	Between the Syloids of the Radius and Ulna (Wrist)	No
	Ratio (Wrist/Tool)	No
Muscle Activity (%MVC sEMG)	Extensor Carpi Ulnaris	Moderate
	Flexor Carpi Ulnaris	Moderate – No
	Number of Muscle Contractions	No
Exherted Grip Force (RMS Pounds Force)	Distal Phalanges of Digits 2-5, Thenar, and Hyperthenar	Very Substantial
Range of Motion (Degrees)	Ulnar Deviation	Moderate – No
	Radial Deviation	Moderate – No
	Overall Range	Moderate – No
Strike Force	Estimated Hammer Strike	Substantial