THE EFFECTS OF VIBRATION ON PSYCHOPHYSICAL GRIP AND PUSH FORCE-RECALL ACCURACY

TW McDowell[1], SF Wiker[2], RG Dong[1], DE Welcome[1]
[1]National Institute for Occupational Safety and Health, Morgantown, West Virginia, U.S.A.
[2]West Virginia University, Morgantown, West Virginia, U.S.A.

Introduction

Workers using vibrating hand tools have the potential for developing health problems associated with repeated forceful actions and exposures to hand-transmitted vibration. Hand-arm vibration syndrome (HAVS) and other hand-arm system disorders have been associated with such exposures.[1-2] To better assess health risks, comprehensive evaluations of these exposures must include quantitative assessments of hand-tool coupling forces; unfortunately, no standardized method for quantifying hand forces exists. Handle instrumentation may be ill-suited for some field environments. Psychophysical force-recall techniques may provide alternatives to handle instrumentation. A thorough understanding of the effects of vibration and other factors on force-recall accuracy and reliability is important before such methods are applied in risk assessments.

Methods

In this study, the effects of vibration and other factors on the accuracy of psychophysical force-recall were explored in two experiments. Twelve male subjects participated in the first experiment. The second experiment employed 20 participants (10 female, 10 male). In each experiment, participants applied specific grip and push forces to an instrumented handle mounted on a shaker system. Participants were exposed to sinusoidal vibration at frequencies that ranged from 0 Hz to 250 Hz. Three levels of applied force (low: grip = 15 N/push = 25 N, medium: grip = 30 N/push = 50 N, and high: grip = 45 N/push = 75 N) and two levels of vibration magnitude (low: ANSI 4-8-hr limit and high: ANSI <0.5-hr limit)[3] were examined. During the vibration exposure period, participants were provided with visual feedback while they attempted to "memorize" the applied grip and push forces. At the conclusion of the vibration exposure/force memorization period and a controlled rest period, the participants tried to duplicate the grip and push forces on a non-vibrating handle without the aid of visual feedback. The effects of different vibration frequencies, vibration magnitudes, and grip and push force levels were tested in a random order from trial to trial.

Results

Participants tended to overestimate grip and push forces. Depending on exposure conditions, error means ranged from 2 N to 10 N. The ANOVA revealed that force-recall errors for exposures between 31.5 Hz and 63 Hz were significantly higher than those at other vibration frequencies ($p < 0.05$). The frequency effect is depicted in Figure 1. Error means were greater when participants were exposed to the higher vibration magnitude (mean = 9.1 N, 95% CI = 8.2-10.1 N) when compared with the lower vibration magnitude (mean = 4.9 N, 95% CI = 3.9-5.8 N) ($p < 0.05$). The effect of vibration magnitude is shown in Figure 2. The average error for

females (4.9 N, 95% CI = 4.0-5.8 N) was significantly less than that for males (8.3 N, 95% CI = 7.4-9.2 N) ($p < 0.05$). The effects of force level were mixed.

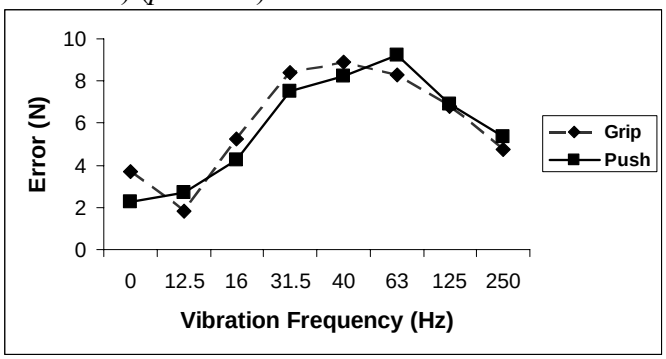

Figure 1. Grip and push force-recall error means plotted vibration frequency across all conditions of the two experiments.

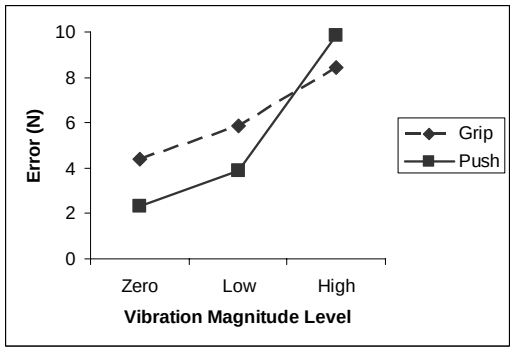

Figure 2. Force-recall error as a function of against vibration magnitude (Low = ANSI 4-8 -hr limit, High = ANSI <0.5-hr limit)[3] and exertion type.

Discussion

Overall, recalled force errors were relatively small over the range of operationally-relevant hand-handle coupling forces and vibration exposure conditions. Vibration exposure significantly affected grip and push force-recall accuracy. This result is consistent with previous research.[4-5] The vibration effect was particularly pronounced with vibration exposures between 31.5 Hz and 63 Hz. This frequency range coincides with that of hand-arm system resonance.[6-7] The effect of vibration was greater at higher levels of vibration magnitude. This force-recall technique shows promise as an alternative to expensive and fragile force-sensing instrumentation. For example, to account for anticipated force-recall errors due to vibration effects, weighting functions can be developed to yield accurate force estimates. Once refined, this psychophysical force-measuring technique can be incorporated into various risk assessments of hand-transmitted vibration.

References

1. Griffin, M.J. and Bovenzi, M. (2001). The diagnosis of disorders caused by hand-transmitted vibration: Southampton workshop 2000. Int Arch Occup Environ Health. 75, 1-5.
2. NIOSH. (1997). *Musculoskeletal disorders and workplace factors: A critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back, NIOSH publication 97-141*. U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health, Cincinnati, OH.
3. ANSI. (2002). *ANSI S3.34, 2002: Guide for the measurement and evaluation of human exposure to vibration transmitted to the hand.* American National Standards Institute (ANSI), New York.
4. Nowak, D.A., Rosenkranz, K., Hermsdorfer, J. and Rothwell, J. (2004). Memory for fingertip forces: Passive hand muscle vibration interferes with predictive grip force scaling. Exp Brain Res. 156, 444-450.
5. Cafarelli, E. and Kostka, C.E. (1981). Effect of vibration on static force sensation in man. Exp Neurol. 74, 331-340.
6. Kihlberg, S. (1995). Biodynamic response of the hand-arm system to vibration from an impact hammer and a grinder. Int J Ind Ergo. 16, 1-8.
7. Dong, R.G., Schopper, A.W., McDowell, T.W., Welcome, D.E., Wu, J.Z., Smutz, W.P., Warren, C. and Rakheja, S. (2004). Vibration energy absorption (VEA) in human fingers-hand-arm system. Med Eng Phys. 26, 483-492.

Proceedings of the

First American Conference on Human Vibration

June 5-7, 2006

Waterfront Place Hotel
Morgantown, West Virginia, U.S.A.

Ren Dong, Ph.D.
Kristine Krajnak, Ph.D.
Oliver Wirth, Ph.D.
John Wu, Ph.D.

Engineering and Control Technology Branch
Health Effects Laboratory Division
Morgantown, West Virginia, U.S.A.

Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

Disclaimer

Mention of any company or product does not constitute endorsement by NIOSH. In addition, citations to Web sites external to NIOSH do not constitute NIOSH endorsement of the sponsoring organizations or their programs or products. Furthermore, NIOSH is not responsible for the content of these Web sites. The findings and conclusions in this report have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

ORDERING INFORMATION

To receive documents or other information about occupational safety and health topics, contact NIOSH at

NIOSH – Publications Dissemination
4676 Columbia Parkway
Cincinnati, OH 45226-1998

Telephone: 1-800-35-NIOSH (1-800-356-4674)
Fax: 513-533-8573
E-mail: pubstaft@cdc.gov

Or visit the NIOSH Web site at www.cdc.gov/niosh

DHHS (NIOSH) Publication No. 2006-140
June, 2006