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The Measurement of Grip and Push Forces Applied to Vibrating Tools Using a Psychophysical Force-Recall Technique

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Operators of powered, vibratory hand tools are at risk of developing health problems associated with repeated forceful actions and exposure to intense hand-transmitted vibration. Carpal tunnel syndrome (CTS), hand/wrist tendonitis, hand-arm vibration syndrome (HAVS), and other hand-arm system disorders have been associated with forceful hand actions in combination with awkward postures and repetitive motions. To better assess health risks, comprehensive risk evaluations of these tasks must include quantitative assessments of hand-tool coupling forces; however, no standardized method for quantifying hand forces exists. Studies have shown that humans have an awareness of the sensations associated with the application of static and dynamic forces to stationary and mobile objects. Humans are also able to reproduce postures, movements, and forces by relying on the memory of those sensations. Hence, psychophysical force-recall techniques may be viable alternatives to handle instrumentation. An understanding of the effects of vibration and other factors upon force-recall accuracy and reliability must first be explored before such methods are applied in risk assessments.

In this study, the effects of vibration and other factors on the accuracy of a psychophysical force-recall technique 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 (grip=30±15 N; push=50±25 N) and two levels of vibration magnitude 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 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. To evaluate test-retest reliability, the test was repeated on a later day with each participant.

Abstracts

Overall, recalled force errors were relatively small over the range of operationally-relevant hand-handle coupling forces and vibration exposure conditions. 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 were statistically-significant at vibration exposures between 31.5 Hz and 63 Hz ($p < 0.05$). Error means were greater when participants were exposed to the higher vibration magnitude (mean=9.14 N, 95% CI=8.19-10.08 N) when compared with the lower vibration magnitude (mean=4.88 N, 95% CI=3.93-5.82 N) ($p < 0.05$). The average error for females (4.90 N, 95% CI=4.01-5.79 N) was significantly less than that for males (8.30 N, 95% CI=7.41-9.19 N) ($p < 0.05$). The effect of force level remains unclear. Pearson product-moment correlation results indicated strong test-retest reliability as correlations for all but one participant were found to be significant ($0.45 < r < 0.95$, $p < 0.01$) for recalled grip and push forces.

This force-recall technique shows promise as an alternative to expensive and fragile force-sensing instrumentation. To account for anticipated force-recall errors due to vibration effects, weighting functions can be developed. Once refined, this psychophysical force-measuring technique can be incorporated into various risk assessments used in the construction, manufacturing, mining, and other industry sectors.

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