

**Brief Report**

## Evaluation of Protective Gloves and Working Techniques for Reducing Hand-arm Vibration Exposure in the Workplace

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**Abstract: Evaluation of Protective Gloves and Working Techniques for Reducing Hand-arm Vibration Exposure in the Workplace: Matija MILOSEVIC, et al. Electrical and Computer Engineering Department, Ryerson University, Canada—Objectives:** Operation of handheld power tools results in exposure to hand-arm vibrations, which over time lead to numerous health complications. The objective of this study was to evaluate protective equipment and working techniques for the reduction of vibration exposure. **Methods:** Vibration transmissions were recorded during different work techniques: with one- and two-handed grip, while wearing protective gloves (standard, air and anti-vibration gloves) and while holding a foam-covered tool handle. The effect was examined by analyzing the reduction of transmitted vibrations at the wrist. The vibration transmission was recorded with a portable device using a triaxial accelerometer. **Results:** The results suggest large and significant reductions of vibration with appropriate safety equipment. Reductions of 85.6% were achieved when anti-vibration gloves were used. **Conclusions:** Our results indicated that transmitted vibrations were affected by several factors and could be measured and significantly reduced. (J Occup Health 2012; 54: 250–253)

**Key words:** Accelerometer, Anti-vibration gloves, Hand-arm vibrations, Handheld power tools

Numerous recent<sup>1</sup> and older studies<sup>2</sup> show a serious risk and significant consequences for workers from acute vibration exposure when using handheld power-tools. Bernard<sup>2</sup> defined hand-arm vibration (HAV) as the transfer of vibration from a tool to a worker's hand and arm. He also provided evidence of the positive association between the exposure to HAV and the hand-arm vibration syndrome (HAVS). HAV

has been recognized as a significant hazard for the health and safety of workers<sup>2-4</sup>. The negative effects of vibrations are related to vascular (vibration-induced white finger), neurological, osteoarticular and musculoskeletal disorders of the hands and arms<sup>5,6</sup>.

According to a recent study<sup>7</sup> it is estimated that every day in the United States, 8–10 million employees are exposed to whole body or hand-arm vibrations at work. In the United Kingdom, approximately one million employees are exposed to vibrations at work during a seven-day period. The majority of workers exposed to vibrations are in the construction industry (e.g., carpenters, joiners, building contractors) and metal working occupations (e.g., fitters, motor mechanics). However, an investigation<sup>8</sup> found that among Swedish car mechanics, a quarter initially reported cold-induced white finger and persistent numbness. Subsequent clinical examinations have shown that 15% of them suffered from vibration-induced white finger. In Canada, according to the National Occupational Classification, more than 40 occupational groups are exposed to vibrations at work<sup>9</sup>. A study of the prevalence of HAVS in a metal mine found that among workers who had a medical examination, 50% were diagnosed with HAVS, while a quarter were diagnosed with having multiple symptoms or difficulties<sup>10</sup> (Hill *et al.*, 2001). A large number of miners in the United Kingdom exposed to vibrations resulted in more than 100,000 insurance claims related to hand-arm vibration syndrome<sup>11</sup>.

Exposures to vibrations at work are governed by ISO standards and government regulations, which differ between countries and occupations. Limits for the duration and intensity of exposure to vibrations at work provide a solution, but it is often not adequate. It has been shown that ISO standards underestimate the risk of vibration-induced white finger<sup>8</sup>. There are difficulties in the implementation of the rules and established guidelines for HAV monitoring<sup>12</sup>. This is

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related to the lack of appropriate devices for vibration monitoring in work settings.

The development of mobile and reliable devices for vibration detection would significantly aid prevention and foster risk management. In our previous studies, we demonstrated usefulness of a device for measuring the level of vibration resulting from handheld power tools<sup>13)</sup>. The results indicated that the developed device could be used for studies about health and safety at work, evaluation of protective equipment and recording worker exposure to vibrations in a natural working environment.

### Objectives

The objective of this study was to evaluate vibration transmission from a handheld power tool with different work techniques, one- vs. two-handed grip, use of a cushioned handle and use of protective gloves (standard, air and anti-vibration gloves), for the purpose of identifying ways to reduce exposure to HAV.

### Methods

#### Subject

One subject was subjected to nine repeated measurements on different days. The subject was right handed and had previous experience using handheld power tools. The experimental protocol was approved by the institutional ethics review board.

#### Vibrations

Contact with a vibrating object results in transmission of vibration to that body segment which is in contact. Therefore, an acceleration measure was used to examine the transmission of vibration intensities from a handheld power tool to the wrist.

#### Experimental protocol

Vibrations were applied via operation of a tool that produces fixed vibrations (constant amplitude, frequency and exposure to vibration) using an off-center rotational motor (Fig. 1). The tool contains two cylindrical handles with a diameter of 1 cm and

produces a 57 Hz fixed vibration intensity. The vibration intensity is in the range of the intensity produced by standard handheld power tools. The resultant vibration transmission to the operator's wrist was recorded during operation with protective equipment and with one- and two-hand operation. Acceleration values for each test condition were recorded during a one-minute period. Push and grip forces were not recorded. There were in total 10 conditions, separated by at least one minute, presented in random order in each recording session:

- i) Protective equipment: protective equipment used to reduce vibrations included:
  - *No protection*: The tool did not contain any protection against vibrations. This condition was used as a baseline for comparison.
  - *Protective grip*: The tool handles were cushioned with foam.
  - *Standard gloves*: A set of standard protective leather gloves were used.
  - *Air gloves*: A set of gloves with air isolation were used (AIR650, Impacto Protective Products Inc., Belleville, ON, Canada).
  - *Anti-vibration gloves*: A set of anti-vibration gloves were used (BG650, Impacto Protective Products Inc., Belleville, ON, Canada).
- ii) Work techniques: The tool was operated during use of protective equipment with one hand holding the tool handle or two hands handling both tool handles (Fig. 1). The proper techniques were demonstrated by the investigator, and the subject was given the opportunity to try the techniques before data collection. For one-handed operation, the vertical handle was held comfortably with one hand as close as possible to the motor mechanism. For two-handed operation, both the vertical and horizontal handles were held as close as possible to the motor mechanism. All conditions were performed in a standing posture, with the tool held at a comfortable working height.

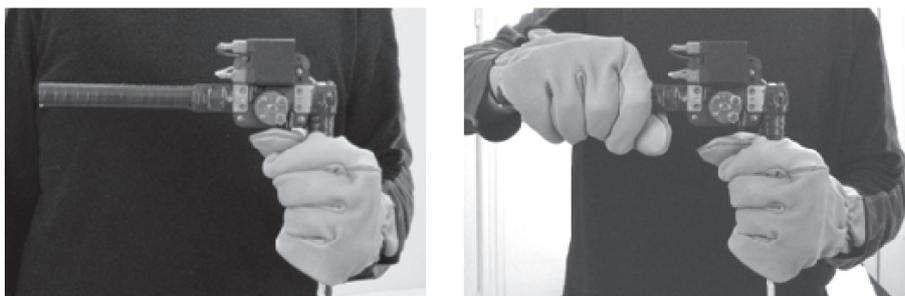


Fig. 1. Handheld power tool operation for a) one hand and b) two hands.

### Safety

The total exposure to vibrations was 10 min, and data collection included mandatory breaks between each recording. All data recordings were done with the supervision of the investigators and were properly timed. The exposure to any long-term injury was minimal, as risks of vibration induced injury are measured by exposure over years<sup>14</sup>.

### Data acquisition

The transmission of vibration intensities was measured using a triaxial accelerometer with a  $\pm 2.0$  g range (KXM52-1050, Kionix, Inc., Ithaca, NY, USA), which was securely attached to the participant's wrist. The wrist location was selected to avoid interference with tool operation. This sensor was shown to be effective for recording hand-arm vibrations<sup>13</sup>. Signals were sampled at 500 Hz and digitized using a 12-bit resolution data acquisition system (NI USB-6008, National Instruments, Austin, TX, USA). Data acquisition and storage were performed using the LabVIEW 8.6 software (National Instruments, Austin, TX, USA). The frequency of vibrations was assessed using a digital laser tachometer (Starmeter Instruments, Shenzhen, China).

### Data processing

Accelerometer data were analyzed in Matlab 7 (The MathWorks, Inc., Natick, MA, USA) using a custom-made application. The data were filtered with a high-pass filter to remove any artifacts due to the rotation of the sensor. The accelerations were then combined into a vector magnitude unit (VMU) of acceleration  $A_{VMU}$  as in Equation 1<sup>15</sup>. The acceleration VMU unit represents the total magnitude of experienced vibration intensities by combining accelerations measured in the mediolateral ( $a_x$ ), vertical ( $a_y$ ) and anterior-posterior ( $a_z$ ) planes.

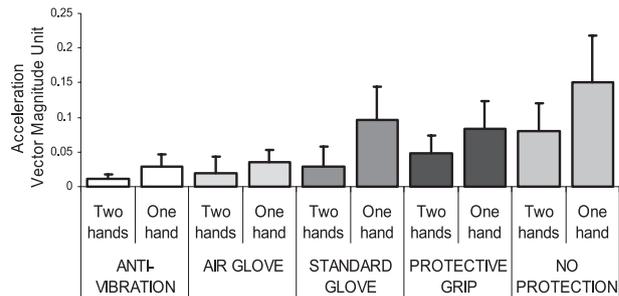
$$A_{VMU} = \sqrt{a_x^2 + a_y^2 + a_z^2} \quad (1)$$

The VMU is a non-calibrated unit of acceleration. The acceleration VMU intensities were normalized by comparing them to the condition when no protective equipment (No Pn) was used. This allowed relative comparison of reduction of vibration transmission to the wrist. The unit was expressed as the percentage of vector magnitude unit acceleration  $A_{VMU}\%$  (Equation 2).

$$A_{VMU}\% = \frac{A_{VMU}}{A_{VMU-NoPn}} \quad (2)$$

### Statistical analysis

Statistical analysis was performed using repeated measures ANOVA to compare the mean accelerations



**Fig. 2.** Mean and standard deviation for acceleration VMU for all conditions. The values were obtained from one subject on 9 different testing days.

transmitted to the wrist for one hand and two hands. The analysis was performed using the SPSS v.17.0 software (SPSS Inc., Chicago, IL, USA).

### Results

The results showed large reductions in levels of vibration transmission to the wrist through appropriate use of protective equipment and work techniques. Descriptive statistics in Fig. 2 show mean and standard deviation bars for the  $A_{VMU}$  during operation of protective equipment for one hand and two hand operation. A smaller mean vibration transmission was observed when two hands were used to operate the tool instead of one hand for all conditions.

The results of the ANOVA test showed a significant difference in the transmitted vibrations for different protective equipment both for one-handed use ( $F=27351.766$ ,  $p<0.0001$ ) and two-handed use ( $F=18236.585$ ,  $p<0.0001$ ). For one-handed use, the anti-vibration glove reduced transmitted vibrations by 80.6% versus those when no protective equipment was used. Similarly, reductions of 76.1, 36.3 and 44.6% were found for the air glove, standard glove and protective grip, respectively. With two-handed operation, vibrations were reduced by 85.6% for anti-vibration gloves, 76.7% for air gloves, 64.5% for standard gloves and 40.0% for protective grip relative to when no protection was used.

### Discussion

In order to enable compliance with established guidelines, it would be helpful to provide a portable monitoring device in the workplace to provide continuous feedback about exposures to vibration. Considering frequent exposures of workers to HAV and the negative impact that vibrations have on human health, vibrations should be monitored and prevented in everyday occupational settings. Our analysis suggests that there was a significant reduction of hand-arm vibrations experienced by the operator with the use of protective gloves. Transmitted vibra-

tion intensities were shown to vary considerably and were affected by protective equipment. Reduction of vibrations by over 80% was achieved by using anti-vibration gloves.

Work methods can vary from day-to-day or task-to-task in the workplace setting. Vibration exposure standards attempt to provide guidelines for safe exposure to vibrations but are difficult to implement<sup>8, 12)</sup> given that there is no feedback to workers. The use of protective equipment to reduce exposure should be explained to workers and enforced.

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