Anti-vibration gloves and the forearm efforts during tools operations

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ABSTRACT

The objective of this paper is to analyze the forearm muscular contraction levels associated to the use of anti-vibration gloves, by comparing the contraction levels with gloves and without gloves. Two different vibration tools were used in a simulated work environment: (1) A compact Duty Multi-Cutter Bosch and (2) and a Percussion Drill with a drill bit Ø20 mm. Standard operations were performed by each subject in the following materials: (1) Performing cross-sectional cuts in 80x40 mm pine section and (2) performing 20 mm diameter holes in a concrete slab 2 x 2 m, 70 mm thick. The forearm contraction level were measured by surface electromyography in four different muscles: *Flexor Digitorum Superficialis* (FDS), *Flexor Carpi Ulnaris* (FCU), *Extensor Carpi Radialis Longus* (ECRL) e *Extensor Carpi Ulnaris* (ECU). For the flexor muscles (FDS, FCU), an increase tendency in muscular contraction was observed when the operations are performed without gloves (2-5% MVE increase in the FDS and 3-9% MVE increase in the FCU). For the extensor muscles ECU a decrease tendency in muscular contraction was observed when the operations are performed without gloves (1-10% MVE decrease). Any tendency was found in the ECRL muscle. ECU was the muscle with the highest contraction level for 79% and 71% of the operators, during the operations respectively with the multi-cutter (P50= 27-30%MVE) and with the percussion drill (P50=46-55%MVE). As a final conclusion from this study, anti-vibration gloves may increase the forearm fatigue in the posterior region of the forearm (ECU muscle) during operations with the mentioned tools.

Key-Words: EMG, anti-vibration gloves, muscular contraction, forearm
JEL codes: J28

Cabeças, José Miquel; Milho, Rute J. (2009): Anti-vibration gloves and the forearm efforts during tools operations, *Enterprise and Work Innovation Studies*, 5, IET, pp. 59 - 67.

Introduction

Injuries or disorders caused by hand-transmitted vibration

Prolonged occupational exposure to hand-transmitted vibration has been associated with many forms of upper extremity health disorders in the upper extremities. *Hand-arm vibration (HAV)* is caused by vibration transmitted into the hand and arms through the palm and fingers. Workers exposed regularly to excessive hand-arm-transmitted vibration may be suffer in the long term with vascular disorders (Raynaud´s syndrome), neurological disorders, carpal-tunnel syndrome and musculoskeletal disorders of the hand and arm (hand-transmitted-arm vibration are recognized occupational diseases in several European countries) [1].

The percentage of workers exposed to hand-tools vibration varies between 4.6% and 10.9% among countries like Germany, Spain, France and Finland [2]. Most exposure (WBV and HAV) is found in construction (63 % of workers), manufacturing and mining (44 %), agriculture and fishing (38 %). With respect to construction, the greatest concern is posed by the use of vibrating hand-held tools [2]. Cases of Raynaud's syndrome ranks fifth on the list of the most common European occupational diseases recognized in 2001 [3].

An incidence rate of 2.0/100,000 workers was recognized in 2003, particularly incident in Mining and quarrying activities [4]. The presence of carpal tunnel syndrome (CTS) in 125 forestry workers with exposure to vibration was examined clinically by electromyography. In 25 forestry workers CTS was diagnosed [20]. Vibration is a known risk factor for CTS. Tanaka et al. in a study on data from the National Health Interview Survey analyzed the relationship between occupational and non-occupational factors and CTS and found that repetition and vibration remain important risk factors for work related CTS [21][22].

The vibration isolation performance of gloves

Several types of anti-vibration gloves have been developed and used as a preventive measure to help minimize the occupational hazards posed by hand-transmitted vibration. To be effective at attenuating vibration gloves shall succeed the test required by EN ISO 10819:1996_Mechanical vibration and shock -- Hand-arm vibration -- Method for the measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand [5]. This standard provides a means for checking whether gloves comply with the Personal Protective Equipment EC Directive 89/686. To be marketed as an anti-vibration glove in Europe, with the "CE" mark, a glove must achieve the vibration attenuation criteria set out in the standard [6].

According to Griffin [8] the ISO 10819 does not provide a convenient or sufficient means of evaluating the vibration isolation performance of gloves. The standard can classify a glove as an anti-vibration glove when it provides no useful attenuation of vibration on the handle of a tool, whereas a glove which does provide useful attenuation of vibration on a specific tool can fail the tests. A study by Dong et al

[12] revealed that there is a strong linear correlation between the isolation effectiveness of a typical anti-vibration glove and the biodynamic characteristics of the human hand–arm system in a broad frequency range (40–200 Hz) [12][13][14][15][16]. The push and grip forces produced during operation of equipment are major factors that affect the vibration levels that reach the hand.

Any increase in these forces will also have an increasing effect on the vibration intensity that will reach the hand [7]. The variations in the grip and feed forces also influence the fundamental frequency, resonant transmissibility and high-frequency vibration isolation property of the glove [8].

The biomechanical effects of gloves

The glove condition and type of handgrip contraction have an effect on physiological fatigue and subjective perception of fatigue. A study by Fleming et al. [23] indicate an increase in fatigue responses for the gloved condition versus the no glove condition and an increase in fatigue responses for isometric versus eccentric muscle action of handgrip. The results show that the use of gloves on handgrip fatigue decreases the amount of hold time and therefore accelerates fatigue. Gloves can have disadvantages and can reduce manual dexterity and sensory input, and can change dimensions of the hand that may interfere with a person' s grasping ability. Na explanation for the increase in fatigue with glove use may be that a certain amount of energy goes into manipulating the glove [24].

The most popular method to assess the biomechanical effects of gloves is to measure the maximal grip strength with a handgrip dynamometer. Wearing gloves generally leads to a 5–30% decrease in grip strength depending on the type of glove [24][25]. To do a given task, wearing stiff gloves (very-stiff and moderately stiff gloves) requires more forearm muscle activation (15% on average) than without gloves. However, the results concerning a moderately-stiff glove involved a statistically significant increase in muscle activation (relative to barehand) only for the wrist extensors.

A similar increase in EMG occurred from the barehand to the moderately stiff glove condition for FCR; however, this increase was not statistically significant [26]. Kovacs, K. et al [27] stated that there can be as much as a 23,7% drop in the grip strength when wearing gloves and a lack of a significant effect of glove type on the forearm EMG activity. The authors suggested less elastic glove types cause a greater decrease in peak grip force than thinner, more elastic glove types. Thus, the ''thinnest,'' elastic gloves—surgical glove and barehanded—allow for the most force output, followed by the thin, elastic gloves: jersey, oversized jersey, and oversized surgical [27].

Larivière et al. [28] showed that the normalized RMS amplitude of EMG muscle activation can increase by 16–21% (depending on the muscle) from the bare hand to the stiffest glove condition. Such increases in muscle activation are far from negligible in terms of risk to develop musculoskeletal disorders during repetitive exertions, as stated by the authors.

As stated, gloves may reduce the level of force that may be exerted on an object. Therefore, an elevated internal force must be attained to reach the force output required for the task. This increased internal force may raise the risk for both acute and cumulative injuries. Gloves may alter the recruitment and force of the forearm muscles, which may lead to cumulative trauma. The increased force creates an increase in the biomechanical stress on the tendons, another contributing factor to cumulative damage [27].

The objective of the paper

The objective of this paper is to analyze the forearm muscular contraction level associated to the use of anti-vibration gloves. Two different vibration tools were used in a simulated work environment. The tools were operated with different anti-vibration gloves and without anti-vibration gloves. Standard operations were performed by each subject, associated to each tool, performed without anti-vibration glove and with three different types of gloves. The forearm EMG muscular contractions were measured during operations.

2. Materials and Methods

The Equipments

Two different hand tools were used in the research. The tools and the operations/materials performed were the following ones:

- Compact Duty Multi-Cutter Bosch GOP 10.8V-LI Cordless Pro Multi Tool, equipped with Bosch Plungecut Wood Sawblade AIZ 28 EB (28mm Width / 50mm Depth), 1 kg weight without accessories, thumbwheel for orbit frequency preselection set to maximum speed (20.000 RPM), vibration total values (triax vector sum) determined according to EN 60745: a_h=13.1 m/s^2, uncertainty K=1.5 m/s^2.

- Percussion Drill Bosch GBH2-24DSR, 4 kg Weight (without accessories), hammer drilling operating mode, equipped with a SDS Plus Masonry Drill Bit, 20x150x200 mm. Typical weighted acceleration measured values determined according to EN 50144-1(1998): 11 m/s^2.

Operations were performed by the tools in the following materials:

- Multi-Cutter: This tool performed cross-sectional cuts in 80x40 mm pine section, 1 m high.

- Percussion Drill: This tool performed 20 mm diameter holes in a concrete slab 2 x 2 m, 70 mm thick.

Three types of anti-vibration gloves were used by the subjects in the research:

- Leather full: drivers style vibration reducing glove full-finger, leather full Abrasion resistance and flexibility; meets ANSI S3.40:2002 / EN ISO

10819:1996 anti-vibration glove standards; CE marked; patented molded Gelfom pad in palm and fingers.

- Neoprene/leather/elastic cuff: drivers style vibration reducing glove full-finger, neoprene/leather/elastic cuff

  Shock, Impact and Vibration protection from a patented Polymer; meets ANSI S3.40:2002 / EN ISO 10819:1996 anti-vibration glove standards; CE marked; pigskin leather palm and fingers; neoprene knuckle pad; closure with woven elastic cuff.

- Half finger: vibration reducing glove liner, half-finger
  Ideal when only occasional vibration protection is required; patented Gelfom pad in palm, fingers and over thumb crotch; spandex back to give low profile and breathability for comfort under work gloves.

The subjects

Fourteen volunteer engineering students participated in the study (Table 1).

Table 1 - Mean (SD) and range of age, anthropometrics, and muscular strength for the subjects (n=14)

Demographic data	Mean (SD)	Range
Male subjects (n)	14	-----
Age (years)	23.0 (2.3)	16-27
Height (cm)	180.0 (5.0)	170-186
Weight (kg)	75.3 (7.1)	65-90
Handgrip strength – Right hand (kg)	40.4 (7.6)	30.0-51.3

Electromyography

Surface EMG was recorded using disposable bipolar electrodes with a sensor area of 13.2 mm^2, with a skin contact size of 40.8 x 34, placed with a 34 mm center-to-center distance (Ag/AgCl sensor, Ambu Blue Sensor M, Ambu A/S, Ballerup, Denmark). Data was measured in the right forearm, in the *M.Flexor Digitorum Superficialis* (FDS), *M. Flexor Carpi Ulnaris* (FCU), *M. extensor carpi ulnaris* (ECU) and *M. extensor carpi radialis longus* (ECRL).

The maximum isometric tests were performed with the participants seated in a chair with adjustable height, the forearm resting at wrist and olecranon level in two soft expanded polystyrene (EPS) plates supported on a table, with a 90º flexed elbow and the hand palmar surface down, extended according to forearm direction. The subjects were instructed to maintain the hand horizontal, face down, extended and aligned with the forearm direction. Four protocols of tests were executed:

(1) each participant was encouraged to exert a maximum palmar wrist

flexion against a Manual Muscle Tester (MMT),

(2) each participant was than encouraged to exert a maximum dorsal wrist extension simultaneously with maximum radial wrist deviation against the MMT

(3), each participant was encouraged to exert a maximum dorsal wrist extension simultaneously with maximum ulnar wrist deviation against the MMT, and finally

(4) each participant was encouraged to exert a maximum hand grip exertion against a Jamar Hydraulic Hand Dynamometer.

The hand tools operations and EMG measurements

The hand tools operations were performed at a simulated work environment. The 80x40 mm, 1 m high pine bar was vertically fixed and horizontal 80 mm cuts were performed with the Multi-Cutter with the operators standing, at elbow level. The concrete slab 2 x 2 m, 70 mm thick was supported horizontally at knee level. The 20 mm holes were performed by the Percussion Drill at the periphery of the concrete slab. The following protocol was executed by each subject (n=14):

(1) to execute a 20 mm hole with the Drill in the concrete slab during ~40 s, without gloves, and with each one of the three selected gloves (Leather full, Neoprene /leather /elastic cuff and Half finger glove), and

(2) to perform horizontal cuts in the pine bar, without gloves, and with each one of the tree selected gloves. EMG data was recorded in the four muscles during each one of the 8 operations performed by each subject. The mean operation time (n=56 operations) with the Multi-Cutter was 40 s and 37 s (n=56 operations) with the Percussion Drill.

3. Results and Discussion

The EMG signal was normalized to the maximum contraction level in each muscle (MVE), in order to evaluate the muscular contraction levels during tools operations, according to the following equation: $\%MVE = (EMG_{RMS,\mu V} / MVE_{RMS,\mu V}) \times 100$. The following protocols were selected to normalize EMG signal in each muscle:

- *M.Flexor Digitorum Superficialis* (FDS): $MVE_{RMS,\mu V}$ was measured during maximum hand grip exertion against the Jamar Hydraulic Hand Dynamometer
- *M. Flexor Carpi Ulnaris* (FCU): $MVE_{RMS,\mu V}$ was measured during maximum palmar wrist flexion against a Manual Muscle Tester (MMT)

- *M. extensor carpi ulnaris* (ECU): $MVE_{RMS,\mu V}$ was measured during hand dorsal extension simultaneously with ulnar deviation

- *M. extensor carpi radialis longus* (ECRL): $MVE_{RMS,\mu V}$ was measured during hand dorsal extension simultaneously with radial deviation

For the flexor muscles (FDS, FCU), an increase tendency in muscular contraction was observed when the operations are performed without gloves (2-5% MVE increase in the FDS and 3-9% MVE increase in the FCU). The range of values P25-P75 for the muscles FDS and FCU is higher when operating without gloves.

For the extensor muscles ECU a decrease tendency in muscular contraction was observed when the operations are performed without gloves (1-10% MVE decrease). The range of values P25-P75 is lower when operating without gloves. Any tendency was found in the ECRL muscle.

ECU was the muscle with the highest contraction level for 79% and 71% of the operators, during the operations respectively with the Multi-Cutter and with the Percussion Drill. The P50 contraction levels ranged respectively between ~27-30%MVE and ~46-55%MVE. Non significant differences were found in the contraction levels between the flexor muscles.

FCU was the muscle with the highest contraction level for 14% and 21% of the operators and FDS for 7% of the operators. ECRL was the muscle with the lowest contraction level for all the operators and all the tools.

As a final conclusion from this study, taking into consideration that ECU was the muscle with the highest contraction level, and that anti-vibration gloves increased the contraction level in this muscle, the use of anti-vibration gloves may increase the risk of fatigue in the posterior region of the forearm (ECU muscle). The extensor muscles must be the target muscle group to biomechanical assessment of forearm fatigue during tool operations with anti-vibration gloves.

These results are in line with authors like Larivière et al. [26]. Most of the forearm problems related to the use of anti-vibration gloves are found in the extensor muscles side; these muscles must operate to keep (stabilize) the wrist in neutral position during tools use.

The control measures related to vibration tools must focused on the selection of adequate tools and on the working time, rather than in the protection of operators with anti-vibration gloves.

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