International Journal of Industrial Ergonomics

International Journal of Industrial Ergonomics 23 (1999) 629–632

Short communication
Effects of hand vibration on reflex behaviors and pain perception – A pilot study

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Received 11 September 1997; received in revised form 21 January 1998; accepted 21 January 1998

Abstract

This research investigated the effects of hand vibration on the protective reflex responses and perception of the stimulus intensity. Electrical pulses were applied to the wrist to elicit the reflex responses. Changes of the reflex response were measured using the surface electromyographic activities from the hand flexor muscles, and were analyzed as a function of vibration frequency and initial level of grip force. Psychophysical experiment was also performed to assess the effects of hand vibration on perception of the electrical stimulus. The reflex responses were stronger during vibration, and were more visible at lower vibration frequencies and higher muscle contraction level. During vibration, a poor correlation was found between the reflex responses and stimulus perception.

Relevance to industry

Results suggesting to adopt low level of grip exertion (light-weighted tool) and high vibration frequency to minimize the vibration-induced change of the protective reflex behaviors are useful to tool manufacturers and related workers.

Keywords: Hand-tool vibration; Withdrawal reflex; EMG; Sensorimotor control; Perception

1. Introduction

Among the various neurophysiological mechanisms involved in sensorimotor activities, the withdrawal reflex is a protective mechanism. This reflex is a response to a noxious stimulus applied to the skin, which elicits a movement causing a withdrawal from the offending stimulus. Hagbarth and Finer (1963) observed two components in the withdrawal reflex responses elicited in the lower limbs: an early component appearing on average 60 to 80 ms after the stimulus onset, and a late component with a latency between 120 and 200 ms.

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0169-8141/99/$ – see front matter
PII: S0169-8141(98)00035-3

Many studies have been carried out on the withdrawal reflex itself but little is known about the ways in which this reflex is integrated into the total adaptive defense behavior of human operators under vibratory environments similar to those encountered in real industrial situations. The objectives of this study are to quantify the changes in protective reflex behaviors elicited in the hand flexor muscles as a function of vibration frequency and grip force level.

2. Methods

2.1. Subjects

Ten male subjects participated in the study (average age 29 yr). The subjects gave informed consent and were paid for their participation.

2.2. Experimental apparatus

The subject was seated comfortably in a chair. The right hand held the vertical handle equipped with a strain gage dynamometer. The handle was attached to an electromagnetic vibrator (Vibration Test Systems 100).

Reflex responses from the finger flexor (flexor digitorum superficialis) and wrist flexor (flexor carpi radialis) muscles were elicited by electrical stimulation of the anterior branch of the radial nerve. The stimuli were delivered randomly at intervals of 10–30 s.

Electromyographic activity (EMG) from the finger flexor muscle and the wrist flexor muscle was recorded using the surface electrodes embedded in a preamplifier. A ground electrode was attached on the radial styloid of the wrist.

2.3. Procedure

2.3.1. Experiment I: reflex responses

Before the experiment, the level of the maximum voluntary contraction (MVC) of the grip force was determined. The subject then was trained to maintain 10% of his MVC by looking at a force monitor display.

Vibration was applied to the hand along the forearm axis (Z-axis). The vibration displacement magnitude was fixed at 0.2 mm peak-to-peak. Three vibration frequencies (90, 150, and 200 Hz) and two levels of muscle contraction (resting and 10% MVC) were used in the experiment and were randomly presented.

The reflex responses were evaluated before and during vibration exposure. Comparisons between controls and treatments were made for each subject.

2.3.2. Experiment II: pain perception

The lowest and highest intensities of the electrical stimulus, corresponding to the tactile threshold and pain tolerance, respectively, were presented to the subject. They were assigned values corresponding to the lower and the upper limit, respectively, on a 10 cm visual analog scale (VAS). The intensity used to obtain the reflex response in Experiment I was presented to the subject as a reference and remained constant throughout the experiment, which the subjects were not aware of.

Each subject was asked to rate the intensity perceived before and during hand vibration by placing a mark on the VAS. The same vibration frequencies and the two levels of muscle contraction were again employed in this experiment. Distances from the tactile threshold to the rated intensities on the VAS were measured and analyzed.

3. Results

3.1. Reflex behaviors

Fig. 1 illustrates the effects of hand vibration (90 Hz) on the reflex behaviors measured from the

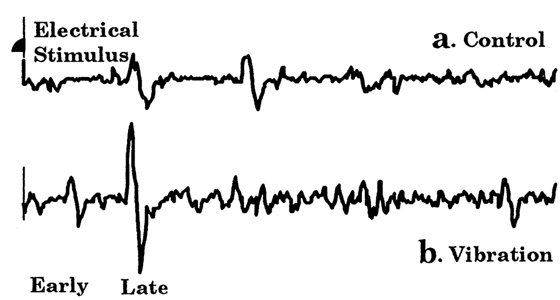

Fig. 1. Reflex responses without vibration (a) and with vibration (b).

rectified raw EMG signals from the finger flexor muscle (resting). The reflex responses were stronger with vibration than without vibration.

Repeated measures analysis of variance (ANOVA) treating each subject as a block was performed to determine the effects of vibration frequency and muscle contraction level on the magnitude, latency, and number of occurrence of the early and late components of the reflex responses.

3.1.1. Magnitude of the reflex responses

EMG integrals significantly increased with vibration ($p < 0.05$) for the muscles tested. Vibration frequency had a significant influence on the increase of the early component for the finger flexor muscle; Tukey comparisons revealed that the increase at 90 Hz was significantly higher than at 200 Hz ($p = 0.018$), but there was no significant difference between 90 and 150 Hz ($p = 0.425$), and between 150 and 200 Hz ($p = 0.283$). Grip force level was a significant factor for both components for the muscles tested. Higher level of muscle contraction induced a stronger reflex responses ($p < 0.05$).

3.1.2. Latency

On average, the latency of both components significantly decreased with vibration by 2.5 and 4.3 ms ($p < 0.05$), respectively. The ANOVA indicated that neither vibration frequency ($p > 0.207$) nor initial muscle contraction level ($p > 0.511$) had a significant influence on latency reduction for the muscles of interest.

3.1.3. Reflex behavior occurrence

The reflex responses were observed more frequently during vibration exposure. This increase varied from 23 to 86%; however, it was only significant ($p < 0.04$) for the 10% MVC contraction. The frequency of vibration did not have significant influence on the increase of the occurrences ($p > 0.2$).

3.2. Pain perception

At rest, seven subjects perceived a decrease in the stimulus intensity during vibration, whereas the remaining three subjects perceived an increase. At 10% MVC, however, only two subjects perceived a decrease and four subjects perceived an increase. This latter group includes the three subjects who reported an increase at rest. The remaining four subjects showed mixed responses. ANOVA showed that neither the vibration frequency ($p = 0.516$) nor the muscle contraction ($p = 0.177$) significantly influence changes in perception of the stimulus intensity.

4. Discussion

4.1. Motor activity

Vibration activates a large number of cutaneous and muscle proprioceptive afferents. These latter increase α-motoneurons depolarization principally via a polysynaptic pathway (Hultborn and Wigström, 1980). Thus the accessibility of α-motoneurons by cutaneous channel increases and contributes to the increase of the cutaneous reflex components.

Vibration frequency had significant effects on the EMG magnitude of the early component of the finger flexor muscle. The early component is the expression of a tactile response mediated by the $A_{\alpha\beta}$-fibers with low threshold, while the late component is associated with a nociceptive response mediated by high threshold $A_{\delta}C$-afferents. Hence, the early component is more sensitive to the vibration frequency than the late component.

The differential modulation between the two flexor muscles could be explained by the functional differences of the muscles. In addition, because of the posture and task required in the experiment, the level of activity was higher for the finger flexor muscle than for the wrist flexor, which influenced motoneuron accessibility differently.

The withdrawal reflex responses increased with voluntary muscle contraction. This may result from several factors. First, higher level of voluntary muscle contraction influenced the depolarization and accessibility of the motoneurons (Burke et al., 1976). Second, muscle contraction increases vibration transmissibility (Pyykko et al., 1976). Third, habituation of the reflex responses is likely to be reduced by a steady voluntary muscle contraction (Desmedt and Godaux, 1976).

4.2. Inconsistency between motor activity and perception

Dissociation between the neurological responses and perception was observed when vibration was applied. This dissociation was obvious even when a background voluntary muscle contraction was exerted, which confirms an interaction of supraspinal origin. In addition, the threshold at which nociceptors begin to fire does not usually coincide with the threshold of pain perception (Zimmerman, 1984), resulting in different modulations of the reflex responses and perception.

To conclude, it is suggested that low level of grip exertion (or light-weighted tool) and high vibration frequency could minimize the vibration-induced alteration of the protective reflex behaviors. This is in agreement with the results of a previous study concerning vibration-induced motor effects (Park and Martin, 1993). In addition, a poor correlation was found between the motor responses and perception during vibration exposure. This dissociation suggests that subjective evaluation of critical external stimulation may not always be correct.

Acknowledgements

This study was supported by a grant from the National Institute for Occupational Safety and Health (RO1 - OH02967-02).

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