

B. J. Martin, D. Adamo

Center for Ergonomics, Department of Industrial and Operations Engineering
The University of Michigan, 1205 Beal Avenue, Ann Arbor, MI 48109-2117, U.S.A.

1. INTRODUCTION

Musculoskeletal disorders resulting from vibration exposure have been documented since Ramazzini indicated a relationship between vibration and health. Nevertheless, the complexity of the reactions of the musculoskeletal system is not clearly understood. This complexity stems not only from biomechanical events and physiological effects but also from the interference of vibration with the functioning of sensorimotor system. Such interference has been shown to alter central and peripheral sensory feedbacks involved in the control of muscle contraction, posture, movement, movement coordination and fatigue. These perturbations have contributed significantly to the understanding of proprioception, exteroception and their respective role in motor control. However, little attempt has been made to link the response of neurophysiological mechanisms and health outcomes. This review presents an overview of the sensory and motor responses associated with human vibration and points to the likely contribution of vibration-induced alteration of sensory motor functions to disorders.

2. KINESTHETIC ILLUSION

The early work of Goodwin et al. (1972) and following studies have demonstrated that tendon vibration applied to a static limb induces kinesthetic illusions of movement whose characteristics in term of direction, magnitude and velocity are a function of the muscles vibrated and vibration frequency. The illusion of movement is in the direction compatible with the elongation of the vibrated muscle (Goodwin et al. 1972) and the magnitude and velocity of the perceived joint rotation increase with vibration frequency (Sittig et al. 1985). Furthermore, when vibration is applied simultaneously to antagonist muscles, the direction of the illusory movement is a function of the unbalance between the respective frequencies (Gilhodes et al. 1986).

3. MOVEMENT CONTROL AND COORDINATION

Tendon vibration applied to the moving limb increases the aiming error. Undershooting occurs when vibration is applied to the antagonist muscle, while vibration of the agonist muscle does not affect target attainment (Capaday and Cooke, 1983). These results obtained in shortening and lengthening contractions (Inglis et al. 1991) indicate that sensory information from the lengthening muscle is important for perception and control of limb position and movement. Furthermore, movement sequences such as a combination of elbow rotation and hand opening can be disrupted

by tendon vibration (Cordo et al. 1995). This alteration of motor coordination was found to be dependent on the vibration frequency and the timing of vibration application (before, at, or after the initiation of the movement).

4. POSTURAL RESPONSES

Various alterations of postural control are associated with vibration of the foot sole (Kavounoudias et al. 1999), legs (Martin et al. 1980), hand (Roll et al. 1986; Martin et al. 1992), neck (Wierzbicka et al. 1998) and extra-ocular muscles (Roll and Roll 1988). These alterations demonstrate that sensory information from all body areas contribute to balance and body orientation in space, which indicates that human vibration exposure profoundly modifies motor behavior in a broad manner.

5. EYE-HAND-HEAD COORDINATION

Aiming errors can be induced by neck (Biguer et al. 1988), or hand vibration (Martin et al. 1997). The latter also contribute to an alteration of eye movements. These errors are associated with an alteration of visual perception and proprioceptive information. They also confirm the contribution of hand proprioception to eye-hand coordination.

6. POST VIBRATION RESPONSES

Motor unit activity and thus increase in muscle tension remain for tenth of seconds after short duration vibration exposure (Ribot-Ciscar et al. 1996). These post effects have mainly a central origin involving a change in the processing of proprioceptive information. Some further evidence of a central effect is illustrated by long lasting modification of postural sway following neck vibration (Wierzbicka et al. 1998).

7. REFLEXES

Monosynaptic proprioceptive reflexes, involved in the adjustment of muscle tension are inhibited by tendon or segmental vibration while tonic responses, the so called tonic vibration reflex and antagonist vibration enhancement develop in the agonist or antagonist muscles with associated kinesthetic illusions, respectively (Calvin-Figuere et al. 1999). Increase in muscle tension is also induced by whole hand vibration.

8. FORCE CONTROL, FATIGUE COMPENSATION OR ENHANCEMENT

It is well known that force exertion increases under hand

vibration exposure, even when visual feedback is provided. In addition, the decrease in voluntary exertion resulting from fatigue can be compensated by short term vibration or exacerbated by long term vibration (Bongiovanni and Hagbarth, 1990, Adamo et al. 2001)

9. MECHANISMS

These effects are proprioceptive and exteroceptive consequences of the vibration-induced changes in the firing rate of muscle spindles, as evidenced by microneurographic recordings (Burke et al. 1976; Roll and Vedel, 1982). Changes in the sensory messages and their significance modify the gain of the sensorimotor loops at central and peripheral levels, which result in a) changes in motor commands and the general pattern of muscle activity, b) an increase in muscle load, and c) a forced drive of some motor units. These mechanisms contribute to an increased muscle tension and exacerbated fatigue. Hence, they are most likely to lead directly and indirectly to tissue disorders.

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