EFFECTS OF REPEATED VIBRATION EXPOSURES IN MUSCLE TISSUE

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Introduction

Workers exposed to vibrating hand tools are at risk of developing symptoms such as cold-induced vasospasms, loss of tactile sensitivity, and loss of grip strength in the fingers and hands. These symptoms are known collectively as vibration white finger (VWF) or hand-arm vibration syndrome (HAVS). Symptoms of VWF or HAVS are in part due to repeated and prolonged peripheral vasoconstriction[1, 2]. The reduction in blood flow that occurs with vasoconstriction can result in oxygen deprivation (hypoxia) in soft tissues, such as nerves and muscle, and lead to functional and structural changes in these tissues. The present study examined muscle tissue to determine if vibration-induced changes in transcript levels and protein concentrations result in enhanced vasoconstriction and hypoxia. Manual dexterity was also assessed intermittently to determine if vibration-induced changes in cellular factors are accompanied by performance deficits.

Methods

An animal model was developed to study the biological and functional changes that occur in response to repeated segmental vibration exposures. In this model, the right paw of intact rats was exposed to a platform vibrated at a frequency 250 Hz and amplitude of 49 m/s^2 to simulate the vibration characteristics of hand-held grinders. Three groups of 8 rats each were studied: a vibration-exposed group, an exposure-control group, and a cage-control group. Exposure sessions, with or without vibration, were conducted 4 hr/day, 5 days/week for 5 weeks.

Manual dexterity was assessed intermittently during the 5-week exposure period with the Montoya stair-case test[3], which quantifies the rat's ability to reach for, grasp, and retrieve small food pellets placed below the rat on different levels or steps. Following the 5-week exposure period, the flexor muscles of the right forelimb were collected for analysis of gene expression, protein concentrations, and immunohistochemistry.

Results

Vibration-exposure resulted in an approximate 2-fold increase in the expression of α2C and α1D receptor transcripts in flexor muscles (Figure 1). These receptors mediate norepinephrine-induced vasoconstriction in smaller arteries. Vibration-exposure also resulted in an approximate 2-fold increase in hypoxia-induced factor-1α (HIF-1α), a transcription factor that is expressed in response to tissue hypoxia. Western analyses demonstrated that restraint caused a decrease in α1-receptor protein concentrations in the flexor, but vibration-exposure prevented the restraint-induced reduction (Figure 2). Immunohistochemistry performed on flexor muscles (not shown) demonstrated that α1 receptors are primarily located in arteries; maintained levels of these receptors could contribute to prolonged vasoconstriction following repeated vibration exposure. The staircase test showed some performance improvement, or a training effect, in manual dexterity for the control groups but not the vibration-exposed group (Figure 3).

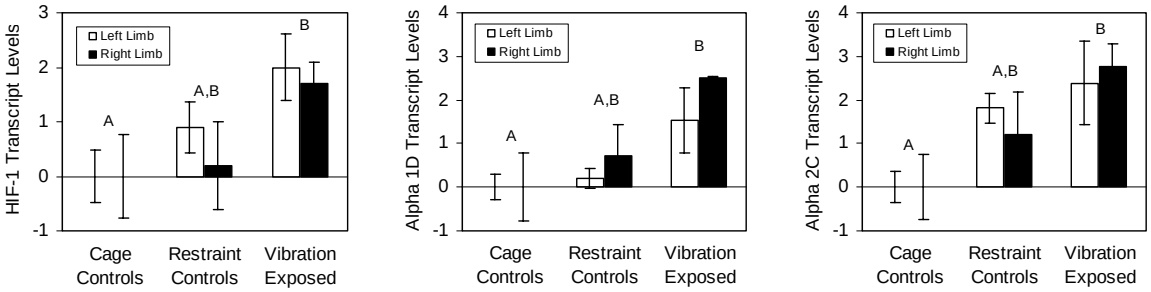

Figure 1. Relative gene transcript levels, expressed as mean fold change (±SE) in critical threshold from cage controls, for α2c, α1a/d, and HIF-1α in the left and right (exposed) limbs. Right limb is not significantly different from left; with right and left combined, A is significantly different from B.

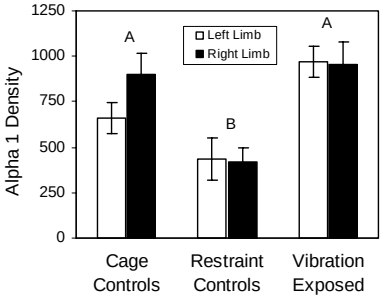

Figure 2. Mean relative optical density (±SE) of α1 proteins in the right flexor muscles as determined by western blot analysis.

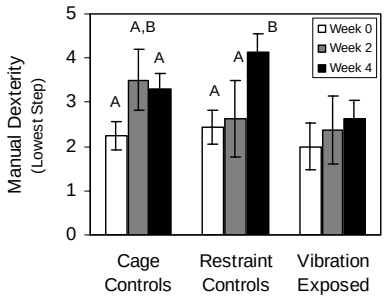

Figure 3. Staircase test of manual dexterity in the right limb (mean±SE; higher = better dexterity).

Discussion

Results are consistent with the notion that vibration causes increased vasoconstriction in the vasculature, and subsequent damage or loss of function may be associated with hypoxia. Similar changes in transcript levels in both right and left limbs in the vibration-exposed group are consistent with reports of vibration-induced sympathetic vasoconstriction responses in contralateral (nonexposed) limbs[4]. Results also support the hypothesis that vibration-induced disturbances in motor control, manual dexterity, or loss of strength might be linked to hypoxia. A better understanding of these mechanisms can lead to the identification of early indicators of injury and improved methods for diagnosis and treatment of VWF or HAVS.

References

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