IS THE MAST CELL A KEY PLAYER IN VIBRATION DISEASE?

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Introduction

Hand arm vibration syndrome (HAVS) involves pathological changes in multiple tissues. Lowering injury requires understanding the primary cellular targets of vibration exposure. Impact vibration generates immediate mast cell degranulation and causes skin hypersensitivity to noxious heat[1]. Mast cells secrete histamine which increases sensory nerve excitability[2]. In this study, we developed methods to cut whole cross sections of the rat tail for global analysis of mast cells. Mast cells are numerous and widely distributed throughout the skin and the connective tissues that support arteries, veins, nerves, skeletal muscles and tendons in the tail. Similar distribution patterns of mast cells occur in human hands and feet[3]. Vibration magnitude and frequency influence the course of HAVS. In the present study, we compared the acute effects of sinusoidal and impact shock wave vibration on mast cell degranulation.

Methods

Sprague Dawley male rats (275 g) were assigned 4 per group to the nontreated Control, Sinusoidal vibration, and Impact vibration groups. Rats were restrained in tube cages during 12 min of vibration. For sinusoidal vibration, the tail was taped to an aluminum platform accelerated 100 m/s² by a B&K 4809 motor at 33 Hz. The impact hammer was supplied with 20 psi air. The vibration platform was loaded by 40 N to trigger cycling at 33 Hz[1, 4]. The unweighted acceleration was ~100 m/s² with peak accelerations ≥20,000 m/s² [4]. The tail was taped to the vibration platform. After vibration, the rats were euthanized and 4 mm cross sections were cut from the mid tail region. All procedures were approved by the Institutional Animal Care and Use Committee of the Medical College of Wisconsin. After formaldehyde fixing the slices, the bone was decalcified before freezing for cryostat sectioning (60 µm). Mast cells were stained with fluorescent-tagged avidin that binds histamine in the secretory granules[5]. Degranulation was quantified morphometrically to generate the area% secreted granules in the peripheral tissues. The group means of area% secreted granules (secreted granule area ÷ mast cell area x 100) were compared by 1-way ANOVA with post hoc analysis Newman-Keuls Multiple Comparison Test.

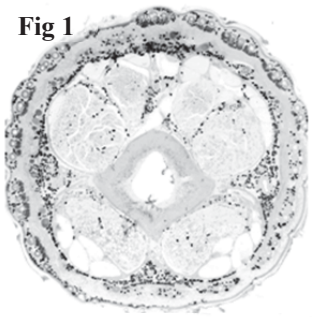
Fig 1

Results

Mast cells were associated with hair follicles, blood vessels and nerve fibers in the skin and clustered between the skin, tendons and skeletal muscles (Fig 1). Mast cell secretion created pepper-like secretory granules (Fig 2). The average amounts of secretion (area%) were 2.2±0.1 for control, 3.0±0.3 for sinusoidal and 3.7±0.2 for impact vibration. Mast cell secretion in the impact group was significantly ($p<0.01$) increased 65.7% over control. Sinusoidal vibration secretion was 32.9% greater ($p<0.05$) than control. The impact vibration secretion was 24.7% higher ($p<0.05$) than sinusoidal.

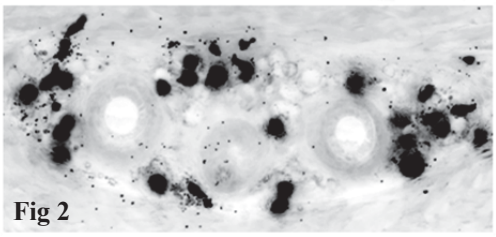
Fig 2

Discussion

This study reveals that mast cells are primary responders to vibration. Degranulation increased significantly after sinusoidal and impact vibration. The dominant vibration energy of sinusoidal is 33 Hz low frequency, whereas the impact vibration consists of 33 Hz low frequency (duty cycle) plus kHz high frequency shock wave energy. In absolute terms, sinusoidal increases secretion by 0.8 area% above control, and impact hammer increases secretion by 0.7 area% above sinusoidal and 1.5 area% above control. This indicates that the low frequency and the high frequency components of the impact hammer each generate ~50% of the increase over control. Thus, it is unwise to dismiss the high frequency component of impact vibration by ISO 5349 frequency weighting.

Mast cell granules contain many bioactive molecules, including histamine, proteinases, growth factors and cytokines, that could influence the response to vibration[6]. Mast cells are best known for their pro-inflammatory actions[7]. Mast cell participation is essential in all phases of skin wound healing[8]. Tissue exposure to high vibration energy can be considered tissue wounding. The rat tail absorbs vibration energy over the wide range of frequencies[4]. Vibration stress and strain are likely to open cell membranes to influx of calcium that activates mast cell secretion. Physical disruption of nerve membranes induces the release of neuropeptides, such as substance P that activate mast cell secretion. Sinusoidal and impact vibration disrupt nerve fibers[1, 9, 10]. Thus, vibration energy is postulated to cause mast cell secretion by direct membrane damage and indirectly by nerve damage and neuropeptide release.

Histamine promotes edema by increasing vascular leakage and stimulates hyperalgesia[1, 2]. The proteinases degrade the extracellular matrix, and along with cytokines, stimulate cell migration and turnover. VEGF, promotes blood vessel growth. Tryptase degrades endothelin-1, a potent vasoconstrictive peptide and reduces vasoconstriction. Vibration white finger may be worsened by reduced tryptase activity. Future studies will examine mast cells after multiple days of vibration to determine whether their numbers are reduced. Improved understanding of the responses of mast cells to vibration may lead to new targets for HAVS intervention.

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