A NEW METHOD FOR STUDYING THE ANABOLIC EFFECTS OF VIBRATIONAL LOADING OF BONE: CONSTRAINED TIBIAL VIBRATION IN MICE

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INTRODUCTION

Vibrational loading has been shown to initiate the formation of new trabecular bone as well as to prevent bone loss commonly associated with disuse, ovariectomy, or menopause in both animal models and humans. Such methods are potentially useful for the treatment of osteoporosis or age-related bone loss. Studies investigating vibrational loading have typically used whole-body vibration (WBV) as their loading method. However, WBV has limitations in small animal studies because transmissibility of vibration is highly dependent on the posture of the subject. In the current study we propose constrained tibial vibration (CTV) as an experimental method for vibrational loading of mice under controlled conditions, and characterize the vibrational behavior of a mouse leg loaded by CTV.

METHODS

Accelerometers were used to measure the transmissibility of vibration through a mouse lower leg *in vivo* during CTV at frequencies from 20-150 Hz (Fig. 1). First, we examined the frequency response of the mouse tibia to CTV loading at input vibrational magnitudes from 0.1-0.5 g maximum acceleration. Second, we used an elastic finite element model of the tibia/fibula to predict the vibrational response of the tibia during CTV loading. Using this model, we were able to predict the spatial distribution of longitudinal strain, as well as investigate the relationship between the magnitudes of transmissibility and strain. Finally, strain gages were used to validate the relationship between transmissibility and strain predicted by the

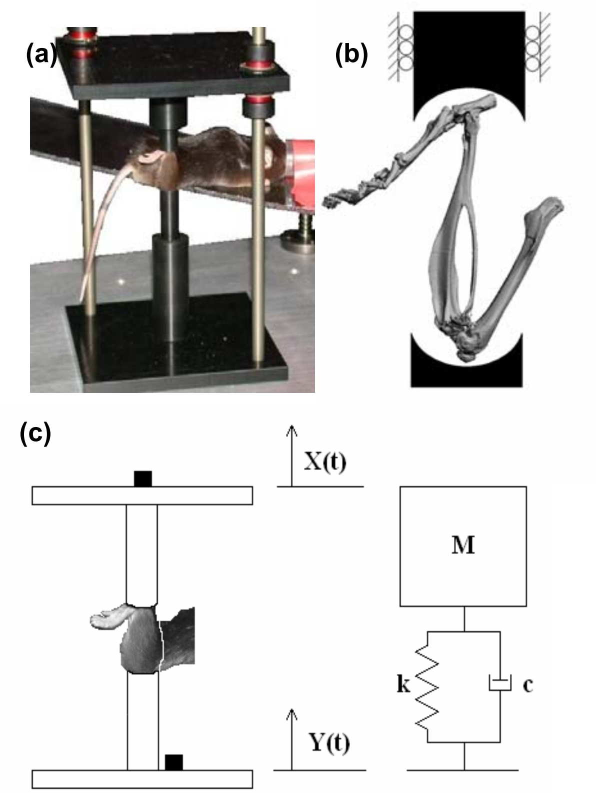

Figure 1: (a) A mouse in the CTV device. (b) MicroCT reconstruction of the orientation of a mouse leg in the CTV device. (c) The CTV device modeled as a one degree-of-freedom vibrational system. M represents the mass of the upper platform (125 g), which is supported by the leg, and is free to slide vertically. Transmissibility is defined as the magnitude of acceleration recorded at the top platform divided by the magnitude of acceleration at the bottom platform.

finite element model, and to determine the absolute magnitude of cortical bone strain experienced during CTV as a function of input frequency.

RESULTS AND DISCUSSION

We found that an *in vivo* mouse leg in the CTV system behaves similarly to a one degree-of-freedom vibrational system. Additionally, it exhibits a nonlinear response to loading magnitude, as increasing the magnitude of vibration from 0.2 g – 0.5 g caused the natural frequency of the system to shift from 75 Hz to 60 Hz. Using the FE model, the locations of maximum strain during CTV were predicted (Fig. 2a), and peak transmissibility was predicted to occur at the same frequency as peak cortical strain (Fig. 2c). Strain gage data confirmed the FE data (Fig. 2d), and showed that the maximum peak-to-peak tibial strain during CTV *in vivo* is approximately 330 με and occurs at 60-70 Hz.

SUMMARY/CONCLUSIONS

This study presents a comprehensive mechanical analysis of constrained tibial vibration (CTV), which we propose as a model for studying the skeletal effects of vibrational loading under highly controlled conditions. We showed a clear dependence of CTV on vibrational frequency and magnitude. These parameters, along with the mass of the top platform of the system, could be altered in future loading studies to control the amount of bone strain experienced during CTV. This loading model will be used in future *in vivo* studies, and may become an important research tool to understanding the mechanisms behind the osteogenic response of bone to vibration.

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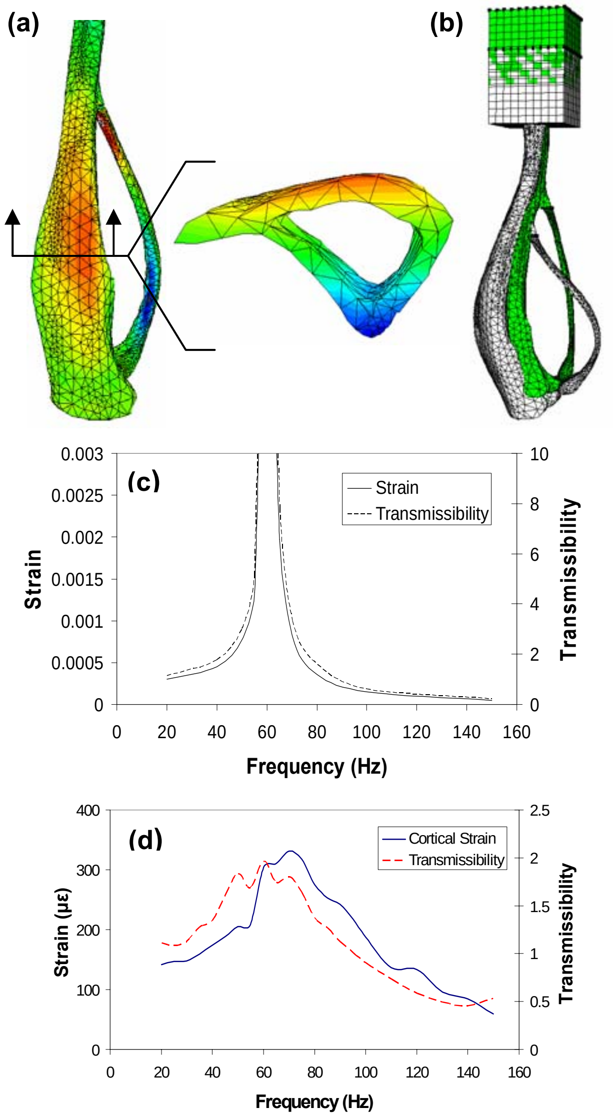

Figure 2: (a) Distribution of longitudinal strain during CTV loading as predicted by the finite element model. The peak tensile strain was located on the anterior-medial surface of the tibia, while the peak compressive strain was located on the interosseous crest of the tibia. (b) Deformational mode of the first natural frequency of the system, showing the deformed (white) and undeformed (green) condition. (c) Plot of the frequency response of transmissibility and longitudinal strain predicted by the finite element model. (d) Experimentally determined frequency responses of transmissibility and cortical strain. Estimated natural frequency was 60-70 Hz for both factors.