HIGH-FRQUENCY LOADING WITH REST INSERTION COUNTERBALANCES HIGH-FAT-SUCROSE DIET EFFECTS ON BONE PROPERTIES

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INTRODUCTION

Changes in disease etiology in the past century highlight the need to examine environmental factors that influence the epidemic of chronic disease in modern society. For bone, fracture associated with osteoporosis can lead to severe morbidity or mortality and is increasing faster than demographic changes in the population. Bones meet competing demands both structurally and metabolically with an ability to adapt functionally to their environment. High-fat-sucrose (HFS) diets can adversely affect bone by limiting calcium availability and retention [1]. Conversely, applying mechanical stimuli, appropriate in magnitude, frequency, and rate can be osteogenic. As the response of bone to mechanical stimuli quickly saturates, the implementation of rest periods between loading cycles may circumvent the adaptive response saturation. The potential, counterbalancing effects of combining diet and rest-inserted high-frequency loading in a growing-bone model have yet to be examined. We hypothesized that mice exposed to a high-frequency, rest-inserted mechanical loading stimulus would accrue skeletal benefits, whereas the consumption of a HFS diet would adversely affect skeletal structural integrity. We anticipated that despite the osteogenic potential of loading stimuli, the calcium-limiting effects of a HFS diet would result in a net decrease in bone structural properties, when considered in combination.

METHODS

The current study assessed morphological, structural, and material changes in a growing murine model consuming one of two experimental diets: low-fat, complex carbohydrate (LFCC) or HFS; and exposed to one of two loading conditions: high-frequency rest-inserted loading, or a non-loaded control. At 9 wk of age, C57BL/6 mice were randomly assigned to either LFCC or HFS diets. At 15 wk of age, mice within each dietary cohort were further sub-divided into loaded or control groupings. Mice designated to high-frequency, rest-inserted loading were exposed to non-invasive exogenous cantilever bending of the right tibia with a signal magnitude of 850 $\mu\varepsilon$, applied at 30 Hz, for 1-s pulses, followed by a 10-s rest period for a total of 100 s daily, 5 d/wk, for 3 wk. One wk was given to allow for new bone consolidation. Upon sacrifice, tibiae were dissected; morphological and mechanical properties were assessed and compared within and between dietary cohorts.

RESULTS AND DISCUSSION

After the 10 wk protocol, HFS mice were significantly heavier (32%) and had greater body fat (15%) than LFCC groups ($p < 0.001$). LFCC loaded mice had significantly elevated structural properties, including greater flexural rigidity (24%) and maximal load (11%) than LFCC controls ($p < 0.05$). LFCC loaded mice also had thicker tibial cortices. Loaded HFS mice responded to mechanical loading by increasing geometrical indices of adaptation. For example, HFS loaded mice had 9% greater mid-shaft cross-sectional area and 4% greater cortical thickness than HFS controls ($p < 0.01$). Moreover, energy to failure in loaded HFS mice was greater than controls. After adjusting for the substantial differences in body mass, loaded LFCC mice had significantly superior structural and geometrical properties versus HFS loaded mice ($p < 0.01$). Tibial material properties were not affected by diet and loading regime.

Elements of our results were consistent with earlier studies investigating 10-s of rest-insertion within mechanical loading regimes using a murine model. Robling et al. reported increases in structural properties, as well as in cortical area (~6%) in mice exposed to rest-inserted loading [2]. The current results also substantiated findings by LaMothe and Zernicke, who reported large increases in periosteal mineralizing surface, mineral apposition rate, and bone formation rate in mice exposed to high-frequency, rest-inserted loading [3].

For the first time, these results revealed that high frequency loading with a rest insertion can counterbalance the otherwise skeletally deleterious effects of an HFS diet on bone. The differential skeletal adaptation observed in response to rest-inserted loading between dietary cohorts, however, remains to be elucidated. Potentially, the hormonal environment created by inducing obesity in the HFS cohort could account the varied manifestations of adaptation [4].

CONCLUSIONS

For the large and growing number and children and adolescents deemed overweight or obese, the results of this study suggest insights into the complex interrelations between dietary factors and mechanical loading on bone, with emphasis on counteracting poor dietary choices with exercise or loading regimes designed to enhance proper skeletal development and growth in the attainment of peak bone mass, and the prevention of skeletal disease throughout life.

REFERENCES

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