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Perspective Article

Hylonome

Vertebrate evolution and the economics of bone and muscle

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This talk begins with the premise that bone and muscle may be viewed as basic commodities in an economy of survival. The currency of this economy is metabolic energy, and its success is measured in genetic preservation. More specifically, I want to consider the relationships between mechanics and biology that have driven vertebrate evolution through their effects on these commodities. We can trace recognition of some of these relationships back to the industrial revolution and beyond. However, it seems to me that there has always been a reluctance to subscribe to the full significance of mechanics in bone biology. In this talk I will argue that when it comes to understanding the musculoskeletal system, biology and mechanics are inseparable because of fundamental physical principles that have, of necessity, influenced vertebrate evolution.

At the heart of the talk is the concept that, while clinicians today strive to increase bone mass, basic physical principles have resulted in evolutionary pressures to reduce the bone mass required to function in a given evolutionary niche. These principles involve four central concepts. First, bone is twice as heavy as other tissues. Second, while the skeleton itself typically constitutes a small percentage of body weight, it can be argued that bone mass is the primary determinant of body mass, which in turn governs metabolic energy requirements. Third, increasing an animal's size results in a disproportionate increase in the stresses in its bones. Finally, the fourth concept may be called the fragility of size: *for a given bone stress*, the risk of fatigue failure increases in proportion to bone volume.

I will argue that these physical factors became significant early in the course of, and heavily influenced, vertebrate evolution, and that they remain of fundamental importance in human bone biology. They represent the reasons why we have a "mechanostat" and why bone remodeling has apparently existed since the first vertebrates of significant size became weight-bearing. They may also explain why the basic mechanical properties of bone have apparently not changed over 350 million years of vertebrate evolution, as has recently been argued[1].

Reference

1. Erickson GM, Catanese J III, Keaveny TM. Evolution of the biomechanical material properties of the femur. Anat Rec 2002; 268:115-124.

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