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Presentation Abstract

Session: 21-5-Biomechanical meet molecular cues: impact on tissue formation, regeneration and adaptation

Presentation: Load Complexity Categories: An Important Consideration in Bone Adaptation Studies

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Abstract: There is sufficient evidence to support creating a ‘rule’ that should be followed in most studies of cortical (compact) bone adaptation. This ‘rule’ is to conceive a study, and report its results, in the context of the “load-complexity category” of the bone or region of bone being investigated. Another issue that could significantly confound interpretations if unrecognized is the “multi-domain load hypothesis”, which is derived from the “load-complexity category hypothesis”. Dozens of studies have quantified in vivo strain milieus of bones during controlled and uncontrolled activities. These studies provide details of usual/daily (habitual) load history of many bones in terms of spatial-temporal variations of strain characteristics including: magnitude, mode, rate, energy density, and gradient. In most bone regions that have been studied, there is a neutral axis, or ‘zone’, where longitudinal strains are low and shear strains are increased. Although the position of the NA moves through the loading/unloading cycle, it usually falls between regions that experience different strain modes: prevalent/predominant tension on one side of the NA and prevalent/predominant compression on the other side. However, the NA can exhibit broad changes in its location during some habitual load environments, producing a less discernible “tension” and “compression” regions. An extreme case would be a bone region habitually loaded in torsion with superimposed bending (hence, a broadly shifting/rotating NA). Consequently, some bones have a load history that seems relatively less predictable. However, it is usually not that predictability diminishes rather it is the habitual load complexity that changes. Over the past 20 years my research team has focused on identifying structural or material characteristics of various bones that strongly correlate with strain histories/distributions of bending vs. torsion. We sought to determine if habitual load complexity across this natural range can be retrospectively indentified and prospectively predicted. The most sensitive and specific characteristic that we have found is the distribution of predominant collagen fiber orientation (CFO) of a bone’s cross-section. We have also found that some investigators have been puzzled when they did not find correlations between structural/material characteristics in bone and what they believe is a rather simple load history (often bending). Some of these studies have even quantified regional variations in predominant CFO. Reasons for failing to find “expected” relationships are often two-fold: (1) a priori expectations of how and why the bone cortex adapts did not consider the influence of increased load complexity in general or in some individuals, and (2) failure to recognize that load-complexity strongly influences the expression of bone tissue-level adaptation. For example, there are studies where “expected” CFO patterns were not found because torsion-related tissue adaptations likely overwhelmed bending-related adaptations. In this perspective, I make these assertions: (1) there are at least four reasonably separable “load-complexity categories”, and (2) adaptations of bones or bone regions that fall in different “categories” could be less comparable than would be typically/conventionally anticipated. In addition to providing evidence that supports these assertions, my presentation will also provide evidence that supports the possibilities that different load-complexity categories: (1) can be present in different locations (e.g., proximal vs. distal) of the shaft of the same bone (i.e., the “multi-domain hypothesis”), and (2) can change during the natural growth-related usage of some bones.