Bone Biomechanics and Glucocorticoid Effects

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Bjoern Buehring, MD
Assistant professor, Department of Medicine, Division of Geriatrics and Gerontology, University of Wisconsin-Madison
bbeuehring@medicine.wisc.edu
Bone is a Multi-Composite Material

- Bone consists of:
  - Cells (osteoblasts, osteoclasts and osteocytes)
  - Extra-cellular matrix
    - Organic (Collagen)
    - Mineral (Carbonated Hydroxyapatite, $\text{Ca}_{10}(\text{PO}_4)_{6}(\text{OH})_2$)

- The strength / quality of bone depends on all components
  - The pathophysiology of metabolic bone diseases can affect one or more components
Whole Bone Strength Components

- Strength of the tissue
  - Protein (primarily type 1 collagen)
  - Cross-linking
  - Mineralization
- Size of the bone
  - Cross-sectional area for compression
  - Moment of inertia for bending and torsion
- Architecture of the trabeculae
  - Orientation
  - Connectivity
Summary

- DXA BMD is a good predictor of osteoporotic fractures but has limitations because it cannot measure bone architecture and geometry.
- Parameters include trabecular connectivity, length, thickness, and cortical area, porosity, and thickness.
- These parameters determine fracture risk independent of BMD.
According to Wolff’s law and Frost’s Utah Paradigm bone adapts to loads/forces. These forces are sensed by osteocytes which locally control bone modeling and remodeling. GIO causes fractures at higher BMD compared to post-menopausal osteoporosis due to changes in trabecular and cortical micro-architecture. These changes occur faster and are more pronounced because of the broad negative effects of GC on bone biology and physiology.
Better methods to determine fracture risk in GIO are necessary and need to include assessment of bone architecture and geometry.

One such method currently being investigated is the trabecular bone score which can be done at the same time of lumbar spine DXA.

TBS improves fracture risk prediction independent of DXA BMD.
References of Interest

- Relationship of BMD and fragility fracture in GIO

- Overview of bone biomechanics
  - Friedman, J Clin Rheumatol. 2006 Apr;12(2):70-7

- Frost’s Mechanostat Theory / Utah Paradigm

- Theories on bone mechanosensors

- Advanced imaging techniques
  - Kalpakcioglu, Bone, 2011, 48:1221–1231
  - Griffith, Ann NY Acad Sci, 2010, 1192:45–56

- Trabecular bone score
  - Silva, JBMR, 2014, epub