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Response to “Clinical Evaluation of Bone Strength and Fracture Risk”

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We read with great interest the recent review by de Bakker et al. that summarized the state of several existing and emerging technologies for estimating bone strength and fracture risk *in vivo* [1]. We commend the authors for a well-written review of DXA-based bone mineral density (BMD), imaging-based structural measurements, and finite element analysis-based techniques, as well as alternate methods including quantitative ultrasound (QUS), bone biopsy, reference point indentation (RPI), and statistical shape and modeling. Much of their review focused on how well the measurements of these technologies predicted experimental measurements of bone strength by *ex vivo* quasistatic mechanical testing (QMT) and on how well they tracked changes in mechanical properties of bone. The authors noted that the association of DXA measures of trabecular bone score and areal and volumetric BMD, QUS measures of speed of sound and broadband attenuation, and RPI-derived measure of indentation increase with bone strength was moderate at best (R^2 values in the 0.20 to 0.67 range).

The authors did not include mechanical response tissue analysis (MRTA) in their review. MRTA is a dynamic mechanical bending test that uses a vibration analysis technique to make immediate, direct, functional measurements of the mechanical properties (mass, stiffness and damping) of long bones in humans *in vivo*. The basic technique was invented 30 years ago at Stanford University [2] and developed with support from NASA, but its commercialization was blocked by the rapid adoption of DXA in the 1990s. The 20-year history of legacy MRTA devices used in experimental and clinical research has been described elsewhere [3]. Especially intriguing to us was its ability to detect large (~25%) changes in bone stiffness in response to short periods (20 weeks) of resistance exercise [4]; [5] and to selective experimental degradation of collagen by potassium hydroxide (KOH) [6]. The latter *ex vivo* finding was confirmed by QMT and went undetected by DXA and QUS.

Several years ago, we noted a declining confidence in DXA due to its poor performance in predicting fractures in prospective studies [7–9]: most patients diagnosed with osteoporosis

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do not fracture and most fractures occur in patients who do not have osteoporosis. We also noted an increasing clinical interest in cortical bone, because after age 60 most bone lost is cortical and most fractures occur at sites with large amounts of cortical bone [10]. Because MRTA is specifically sensitive to cortical bone mechanics, we decided to investigate whether MRTA might be further developed.

Since then, our proprietary improvements to the legacy MRTA technology have enabled us to achieve unmatched accuracy in QMT-validated measurements of the bending stiffness ($R^2 = 0.999$) of 39 artificial human ulna bones [11], and most recently in QMT-validated measurements of the bending stiffness and estimates of the bending strength (both $R^2 = 0.99$) of ulna bones within 35 cadaveric human arms from donors ranging widely in age (17–99 yrs) and BMI (13–40 kg/m²). To distinguish our improved technique from the legacy MRTA technology, we refer to it as Cortical Bone Mechanics Technology (CBMT). Further research will determine whether such CBMT measurements are clinically useful.

Again, we commend de Bakker and colleagues for their recent review, and appreciate this opportunity to supplement it.

References

1. de Bakker CM, et al. Clinical Evaluation of Bone Strength and Fracture Risk. *Curr Osteoporos Rep*. 2017; 15(1):32–42. [PubMed: 28185216]
2. Steele CR, et al. Noninvasive determination of ulnar stiffness from mechanical response--in vivo comparison of stiffness and bone mineral content in humans. *Journal of Biomechanical Engineering*. 1988; 110(2):87–96. [PubMed: 3379938]
3. Miller LE, et al. Rationale, design and clinical performance of the mechanical response tissue analyser: a non-invasive technology for measurement of long bone bending stiffness. *Journal of Medical Engineering and Technology*. 2013; 37(2):144–9. [PubMed: 23360197]
4. Miller LE, et al. Isokinetic resistance training increases tibial bending stiffness in young women. *Calcified Tissue International*. 2009; 84(6):446–52. [PubMed: 19407920]
5. Miller LE, et al. Isokinetic training increases ulnar bending stiffness and bone mineral in young women. *Bone*. 2007; 41(4):685–9. [PubMed: 17693150]
6. Wynnckjy C, et al. A new tool to assess the mechanical properties of bone due to collagen degradation. *Bone*. 2009; 44(5):840–8. [PubMed: 19150659]
7. Stone KL, et al. BMD at multiple sites and risk of fracture of multiple types: long-term results from the Study of Osteoporotic Fractures. *J Bone Miner Res*. 2003; 18(11):1947–54. [PubMed: 14606506]
8. Siris ES, et al. Identification and fracture outcomes of undiagnosed low bone mineral density in postmenopausal women: results from the National Osteoporosis Risk Assessment. *JAMA*. 2001; 286(22):2815–22. [PubMed: 11735756]
9. Wainwright SA, et al. Hip fracture in women without osteoporosis. *Journal of Clinical Endocrinology and Metabolism*. 2005; 90(5):2787–93. [PubMed: 15728213]
10. Seeman E. Growth and Age-Related Abnormalities in Cortical Structure and Fracture Risk. *Endocrinology and Metabolism*. 2015; 30(4):419–428. [PubMed: 26394727]
11. Arnold PA, et al. Accuracy and reproducibility of bending stiffness measurements by mechanical response tissue analysis in artificial human ulnas. *Journal of Biomechanics*. 2014; 47(14):3580–3. [PubMed: 25261885]