Mechano-adaptation of bone: Are all strains equal?

Jörn Rittweger[1,2]

[1]Institute of Aerospace Medicine, German Aerospace Center (DLR), 51147 Cologne, Germany

[2]Department of Pediatrics and Adolescent Medicine, University of Cologne, Cologne, Germany

Bone research has been re-directed in the 1990s by three revolutions: firstly the recognition that bones respond to changes in their mechanical environment in a dose-dependent way; secondly by the idea that these changes in bone size can be understood as self-adaptation to variant forces by a servo-control mechanism (mechanostat theory); and thirdly by the proposition that muscles 'enslave' bone's mechan-adaptation. It has been an inherent assumption in most of these bone studies that bone deformations mostly result from bending and compression, and little to no attention was paid to torsional loading. Notably, axial strains dominate in axial loading, whilst torsional loading is associated with relatively large shear strains.

To better understand the mechanical interplay between regional muscle contractions and bone deformations, my team performed the MUST-study: bone pins were inserted into the human tibia, and non-collinear retro-reflective marker clusters were affixed to these pins in order to assess translational and rotational tibia deformations. Results from that study revealed that torsion is a prevailing deformation type within the human tibia, and that tibia torsion is causally linked to calf muscle contractions. Simultaneously, a series of *in-silico* experiments in our lab with a mechanostat model were undertaken. They revealed that torsion (i) is the most effective mode of bone deformation, and (ii) that it can explain the so-called flexure neutralization of miss-aligned fractures, which is inexplicable on grounds of compression and bending alone. Moreover, recent data also suggest that torsion, rather than impact may the bone-effective agent in the side-differences encountered in tennis players and baseball pitchers.

Thus, I am currently following the idea of torsion as an effective deformation mode to elicit bone-anabolic responses. This is in contradiction to the main stream in bone research, which still regards impact loading as the most efficient way. Understanding and settling this question will be important in order to provide optimized exercise prescriptions that will maximize the benefits for bone, and minimize adverse events, such as joint sprains, cartilage damage, and tendon problems.

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