

Keynote presentation

## Advances in image-based biomechanics of the human ankle

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### Introduction

Medical Imaging techniques including CT, MRI, Micro-CT and micro-MRI have matured over the last years into affordable, practical and accessible observational tools to the Biomechanics community. These tools provide unique opportunities to expand the knowledge of the biomechanics of the human foot and ankle. The purpose of this presentation is to demonstrate the potential of these imaging techniques through three specific applications from our current research.

### Image-based models

The morphology of the bones, articular surfaces and ligaments and the passive mechanical characteristics of the ankle complex were reported to vary greatly among individuals. The later were often presumed to be associated with variations in experimental conditions. MRI-based models of various individuals were used to test the hypothesis that the variations observed in the passive mechanical properties of the ankle complex are strongly influenced by morphological variations. Confirmation of this hypothesis suggests that individualized subject-specific treatment procedures for ankle complex disorders are potentially superior to a one-size-fits-all approach. It suggests that, in the future, MRI-based subject-specific models of the hindfoot could be used as individualized surgical planning tools for improvement of clinical outcome.

### Characterization of passive structural properties

The passive structural properties of the hindfoot are assessed from measurements of the displacements produced at the hindfoot in response to applied loads. Cur-

rent in vivo and in vitro techniques have shortcomings that limit their scientific and clinical usefulness. In vitro conditions fail to account for phenomena such as tissue remodeling or partial damage effects. The in vivo approach, based on external observations has been shown to be inaccurate due to soft tissue and skin interference and the inaccessibility of the talus to external markers. The MRI-based technique referred to as "3D stress MRI" and abbreviated as 3D sMRI, solves many of the problems associated with present in vivo and in vitro techniques. 3D sMRI does not require exposure to harmful radiation, it is non-invasive, and internal bone kinematics can be derived without soft tissue interference. The technique can also provide direct visualization of the level of integrity of the underlying structures. The 3D sMRI technique may be used in the future to expand fundamental knowledge of the biomechanics of the hindfoot in vivo and for developing sensitive and reliable clinical diagnostic and evaluation procedures for a variety of ankle pathologies such as chronic ankle instability. However, as with any new technology, considerable further development is needed to take sMRI from its current state to a stage where it can be routinely used in the clinic.

### Skeletal development in clubfoot treatment

Congenital clubfoot is a common foot deformity often treated using serial manipulations and casting such as the Ponseti Technique. It provides a unique natural occurring experiment to observe the mechanisms of tissue adaptation under external loads. These mechanisms of adaptations including cartilage and bone adaptation as well as osteogenesis can be observed through multiple MRI observations of the treated clubfoot. Using this observa-

tional tool some unique observations on cartilage adaptation and osteogenesis were made.

### Conclusion

Image-based biomechanics, although still in its infancy, has the potential to evolve into a major field that can deepen and expand biomechanical knowledge lead to improved clinical management of hindfoot disorders.

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