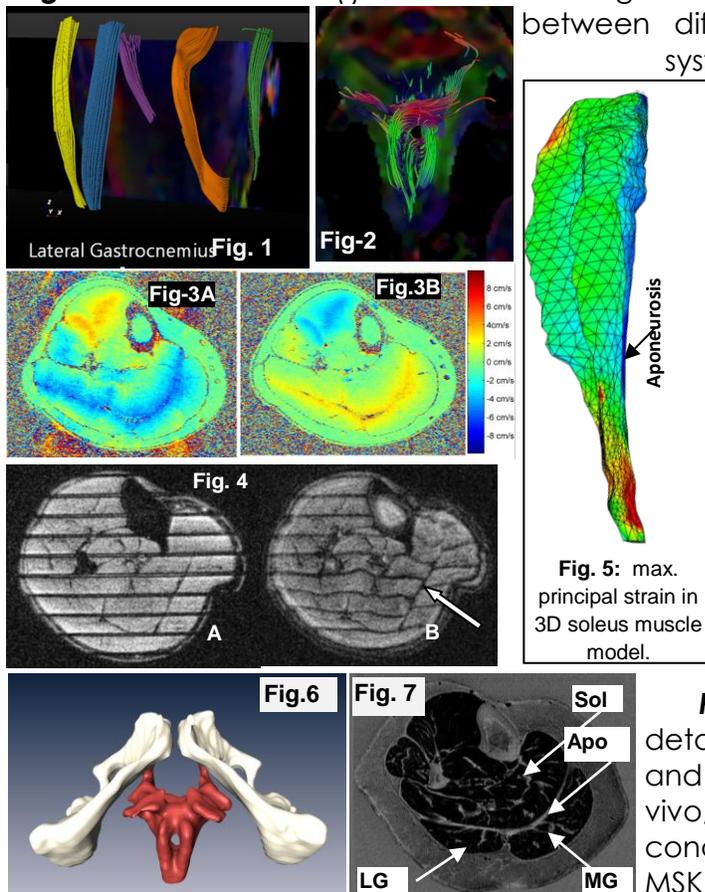


Specialty Area: Imaging Muscle Structure & Function
Title: Imaging Muscle Fiber Structure & Function
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Highlights:

- **Diffusion Tensor Imaging**, DTI based **fiber tracking (Fig. 1, 2)**, **UTE imaging (Fig.7)**, **High resolution imaging** of human muscles in-vivo and **subsequent 3D volume rendering (Fig. 6)** can define precisely the inner architecture in terms of muscle fibers, pennation angles, adipose and connective tissue, while,
- **Velocity-encoded imaging** using either phase-contrast (VE-PC, Fig. 3) or spin-tag (Fig. 4) can elucidate dynamic interactions between muscle groups and tendon/aponeuroses.
- The combination of output from these structural and functional studies can then be input into **modeling studies (Fig. 5)** to much better predict force output.
- This has far ranging clinical potential **for tailored management of patients with musculoskeletal disease** such as chronic muscle disuse, muscular dystrophy and spasticity.
- Applications to **lower leg, female puborectal & anal-sphincter muscles** presented.

Target Audience: (i) Clinicians seeking to understand the complex interactions between different muscle groups of the MSK system towards mitigating force reduction during various pathologies, (ii) the MR physicist devising newer methods to visualize both statics and dynamics of the MSK system in-vivo in humans and (iii) the bio-engineer seeking more accurate and realistic inputs to his modeling studies to better predict human performance.



system towards mitigating force reduction during various pathologies, (ii) the MR physicist devising newer methods to visualize both statics and dynamics of the MSK system in-vivo in humans and (iii) the bio-engineer seeking more accurate and realistic inputs to his modeling studies to better predict human performance.

Outcome/Objective: To provide not only the clinician but also the imaging physicist and the bio-engineer, sophisticated MR imaging methods to elucidate both the detailed architectural design and dynamics of the human MSK system.

Purpose: Lack of detailed knowledge of the architecture and dynamics of individual muscles in vivo, particularly under diseased conditions, lead to failure of models of the MSK system to correctly predict force

production. The MR imaging methods listed above were used to obtain such structural and functional information which were then used as inputs for modeling studies.

Methods: (i) High resolution morphologic imaging, with sufficient contrast and resolution to allow semi-automated segmentation and volume rendering of

adjacent muscle compartments in both (a) lower leg in normal and atrophied state and (b) puborectal region (Fig.6). (ii) Diffusion tensor imaging at both 3T and 1.5T, of muscles in both these regions. For the lower leg, in both relaxed and plantarflexed state. (iii) DTI based fiber tracking in lower leg (Fig.1, fibers in lateral gastrocs), and in anal sphincter region (Fig.2). (iv) Gated cine dynamic imaging using VE-PC (Fig. 3A-plantarflexion, 3B-dorsiflexion) and spin-tag (Fig. 4. A-relaxed, B-note tag distortions in plantarflexion) of the lower leg, using a computer-controlled foot pedal device, with optical pressure sensor, to image passive, concentric and eccentric contractions, (v) Spin-tag imaging of the anal sphincter and adjacent muscles, using a catheter mounted pressure transducer inserted rectally, which sensed the period squeeze pressure of the subject. (vi) Analysis methods included determination of strains within muscles, aponeuroses, elastic constants of tendon, volumes and other relevant parameters.

Results: (i) Decrease in muscle force disproportionately higher than muscle atrophy. (ii) Inhomogenous strain along aponeurosis length, along fiber and muscle length. (iii) Can be explained to large extent by Finite Element Modeling (Fig.5, modeling of principal strain in Soleus). (iv) In the puborectal region, fiber tracking reveals the "purse-string" nature of external anal sphincter, perineal body and pubic rami muscles. (v) Dynamic imaging of the anal sphincter muscle supports the "purse-string" morphology of these muscles.

Discussions and Conclusions: Such comprehensive characterization of the multi-component musculoskeletal (MSK) architecture and function of the lower leg, in normal, diseased and at various stages of recuperation, using a highly integrated array of imaging techniques will help to gain better insight into the design features of muscle-tendon complex, a better understanding of chronic muscle adaptations such as disuse atrophy and better prediction of outcomes of therapeutic interventions. Similarly for the external anal sphincter muscle, such combination of imaging approaches strongly bolster our hypothesis of a "purse-string" configuration rather than a "donut", with significant implications for effects of lateral episiotomy on the EAS function and surgical reconstruction of the EAS to treat anal incontinence.