MRI Assessment of Passive Muscular Mechanics in vivo Using Intensity Based Nonrigid B-spline Registration: Effects of Epimuscular Myofascial Force Transmission

A. Yaman[1], M. Ledesma-Carbayo[2], G. Baan[3], P. Huijing[3], C. Yucesoy[1], and C. Ozturk[1]

[1]Institute of Biomedical Engineering, Bogazici University, Istanbul, Turkey, [2]Departamento de Ingeniería Electrónica, Universidad Politécnica de Madrid, Madrid, Spain, [3]Research Instituut. Move, Faculteit Bewegingswetenschappen, Vrije Universiteit, Amsterdam, Netherlands

Introduction: In addition to myotendinous pathways, important pathways for transmission of muscle force are comprised by connective tissue structures providing mechanical linkage between muscles and neighboring muscular and nonmuscular tissues [e.g., 1]. Experimentally and using finite element modeling, such *epimuscular myofascial force transmission* (EMFT) [2] has been shown to affect muscular mechanics substantially in the rat, leading to proximo-distal force differences and major sarcomere length heterogeneity [3]. The purpose of this work is showing effects of EMFT using MRI in human in vivo by calculating strain fields via intensity based nonrigid B-spline semilocal registration.

Methods: The ankle angle of a subject (male, 30 years old, height=175 cm and weight=70 kg) was fixed (at 90°). The effect of changing his knee angle (from 160° to 130°) on local deformation within the lower leg was assessed: Deformation of muscles not crossing the knee (e.g. Soleus muscle) remaining isometric due to an unchanged ankle angle are considered as an indicator of the effects of EMFT.

For the two knee angles studied, 3-D image sets were collected by 3T Siemens Trio scanner using Turbo Flash sequence (Feet first prone, 320x320x144 matrix size, 0.8x0.8x0.8 mm voxel size, 2000 ms TR, 3.94 ms TE, no fat suppression, 12 degree flip angle, 130 Hz per px bandwidth). Intensity based nonrigid B-spline semilocal registration is used to obtain displacement fields for a knee angle=160° as the reference state and a knee angle=130° as the deformed state [4]. A Green-Lagrange strain tensor was calculated for each voxel from displacement fields. Principle strain values were calculated and visualized as superquadric glyphs, size and direction of which are related to magnitude and direction of strain. The color scheme represents orthotropy index of the strain glyphs i.e., the ratio of linear anisotropy to total anisotropy [5].

Results: The method developed allows quantification of strains within both muscular and nonmuscular tissues. Fig 1 shows that despite remaining isometric during the experiment, Soleus muscle is strained considerably (maximal local lengthening and shortening equals 36% and 50% respectively). Note that, the strain field obtained should be rotated to the local muscle fiber direction in order to show possible changes in sarcomere length distributions; a more direct means of confirming effects of EMFT on muscular mechanics, in vivo.

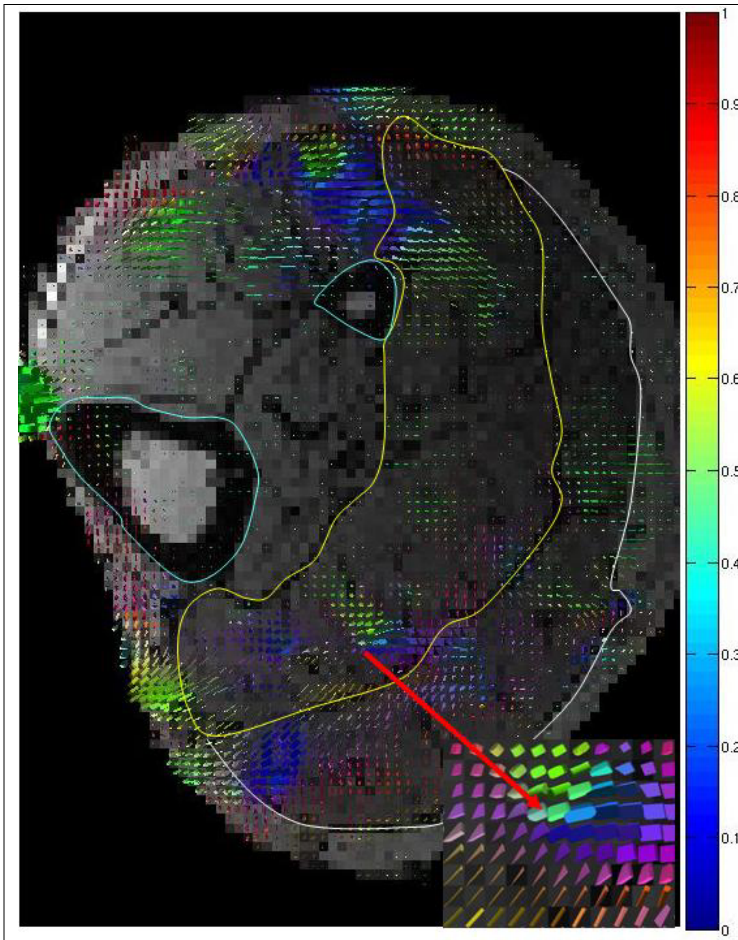

Figure 1: Strain field of an axial slice of the lower leg. The yellow line delimits isometric Soleus muscle and the white line delimits Gastrocnemius muscle. The lower blue line indicates the Tibia and upper the Fibula. Colors of the glyphs represent orthotropy index: Red glyphs exhibit high planar anisotropy and blue ones exhibit high linear anisotropy. The red line indicates the location of a magnified image of the glyphs in a selected region (inset).

References: [1] Huijing & Baan (2001). Acta Physiol. Scand. 173: 1-15. [2] Yucesoy et al., J. Biomedical Eng. 2005 Vol. 127, pp. 819-828. [3] Yucesoy et al., J. Biomechanics. 2003 36, pp. 1797-1811. [4] Ledesma-Carbayo et al., IEEE Trans Med Imaging 2005; 24:1113–1126. [5] Ennis et al., Magn Reson Med 2005; 53: 169–176.