ANISOTROPIC ELASTICITY & VISCOSITY DEDUCED FROM SUPERSONIC SHEAR IMAGING IN MUSCLE

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INTRODUCTION

Although the role of viscoelasticity in muscle mechanics is well recognized, methods for measurement *in situ* are limited. Recent advances in elastography have made possible the imaging of viscoelastic moduli within individual muscles [1, 2]. We have investigated a new approach, supersonic shear imaging (SSI), which combines high frame-rate (5kHz) ultrasound with acoustic radiation force induction of shear plane waves transients [3]. The elastic moduli can then be deduced from the propagation of these waves, and the viscous moduli from their attenuation.

METHODS

We applied SSI elastography in a single subject. With the subject seated comfortably, ultrasound image sequences were obtained from the right (dominant) biceps during sustained contractions. With the elbow held at 90°, various loads were applied by having the subject hold known weights. In addition, data were collected with the forearm supported (unweighted,) and unloaded (limb weight only). Image sequences were obtained and tissue displacements calculated using frame-to-frame cross-correlation.

RESULTS AND DISCUSSION

Displacement image sequences (e.g. Figure 1) were used to reconstruct speed of sound maps (Figure 2) in both the transverse and axial (longitudinal fiber orientation) directions. Average shear elastic moduli were obtained from these (Table 1) Propagation could not be observed in the transverse direction for loads greater than 0.8 kg. It is evident that the axial elastic moduli are significantly greater than their transverse counterparts, and that both increase with load.

Although we currently lack a direct means of calculating viscosity, it is evident from the observed attenuation of the induced waves that transverse viscosity is significantly greater than axial viscosity and that transverse viscosity increases dramatically with load to the point that propagation is suppressed entirely at greater loads. Whereas the significance of these results is not clear, we anticipate that knowledge of anisotropic and dynamic viscosity could have a significant impact on the field of Biomechanics.

Figure 1: Composite image showing a 3 frame sequence of displacement data. Frame 1 is shown in red, frame 2 in green and frame 3 in blue.

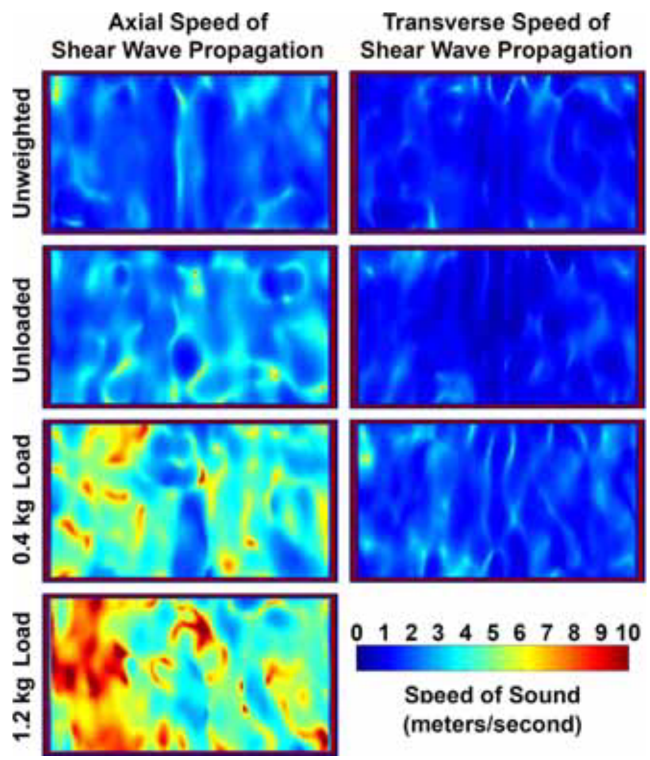

Figure 2: Speed of sound images in a for axial and transverse propagation at 4 applied loads. Propagation in the transverse direction did not occur above the 0.8 kg.

REFERENCES

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Table 1: Axial and transverse shear elastic modulus values (kPa) in the biceps brachii as a function of the applied load

	Unweighted	Unloaded	0.4 kg	0.8 kg	1.2 kg	1.6 kg	2.0 kg
Axial	4.0	7.3	47.2	50.8	59.7	82.5	94.6
Transverse	1.2	1.3	1.8	4.1	—	—	—