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Viscoelasticity-based MR elastography of skeletal muscle

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Abstract

An *in vivo* multifrequency magnetic resonance elastography (MRE) protocol was developed for studying the viscoelastic properties of human skeletal muscle in different states of contraction. Low-frequency shear vibrations in the range of 25–62.5 Hz were synchronously induced into the femoral muscles of seven volunteers and measured in a cross-sectional view by encoding the fast-transverse shear wave component parallel to the muscle fibers. The so-called springpot model was used for deriving two viscoelastic constants, μ and α, from the dispersion functions of the complex shear modulus in relaxed and in loaded muscle. Representing the shear elasticity parallel to the muscle fibers, μ increased in all volunteers upon contraction from 2.68 $\pm$ 0.23 kPa to 3.87 $\pm$ 0.50 kPa. Also α varied with load, indicating a change in the geometry of the mechanical network of muscle from relaxation ($\alpha = 0.253 \pm 0.009$) to contraction ($\alpha = 0.270 \pm 0.009$). These results provide a reference for a future assessment of muscular dysfunction using rheological parameters.

Introduction

Tissue mechanics is increasingly recognized as a novel source of contrast in medical imaging. This development has been driven by the well-known sensitivity of macroscopic mechanical parameters to micro-structural properties of biological tissues. Current techniques of elastography are based on medical ultrasound or magnetic resonance imaging combined with static tissue deformation, transient shear waves, or continuous time-harmonic wave stimulation. Magnetic resonance elastography (MRE) (Muthupillai *et al* 1995, Plewes *et al* 1995) is particularly suited for measuring the shear modulus in living muscle tissue: (i) MRE is based on shear waves capable of mechanically stimulating tissue deep inside the body; and (ii) MRE allows the observation of full-strain wave fields with equal sensitivity

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