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Mechanical Properties of Relaxed and Contracted Thigh Muscles using Magnetic Resonance Elastography

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Introduction

The measurement of the *in vivo* mechanical properties of muscles is clinically necessary in order to understand the transformations that occur in muscle with pathologies and treatments. A few techniques (palpation, sonoelastography (Levinson, 1995)) allow measurement of the *in vivo* stiffness of soft tissues but, they are restricted in depth and field of view. Magnetic Resonance Elastography (MRE) is a non-invasive phase contrast MR technique capable of quantifying the *in vivo* mechanical properties and imaging the entire spatial distribution of muscle elasticity (Jenkyn, 2003). The purpose of this study was to measure the mechanical properties of the vastus lateralis (VL), vastus medialis (VM) and sartorius (Sr) muscles in a relaxed and contracted position.

Materials and methods

Fourteen volunteers (4 males and 10 females, mean age 25.2 ± 1.78) participated in this MRE study. The volunteers lay supine in a 1.5T General Electric Signa MRI with the right leg resting in a custom MR compatible leg press, capable of measuring the applied load. Shear waves were applied to the thigh muscles with a mechanical (n=7 VL, n=10 VM, n=9 Sr) or pneumatic driver (n=5 VL, n=4 VM, n=4 Sr). Each driver was positioned on the thigh 1/3 of the distance from the patellar tendon to the greater trochanter. The mechanical driver was composed of a coil of copper wire with a hollow aluminum core driven with an alternative current of variable potential, induced shear waves into the thigh muscles at 120Hz (*f*). The pneumatic driver was composed of a thin silicone tube. A time varying pressure caused the tube around the thigh to expand and contract at 90 Hz (*f*). A custom-made Helmholtz surface coil was placed around the thigh. Axial images were obtained and oblique scan planes passing through the VL, VM and Sr were selected from these images (fig 1).

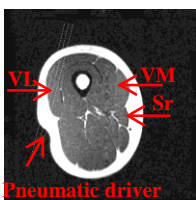


Fig. 1. Axial scout representing the thigh muscles localization in the lateral (VL) and medial (VM, Sr) side.

MRE data were collected with a gradient echo technique. The wavelength (λ) was measured in each of the four offsets and the stiffness was calculated ($\mu = \rho * \lambda^2 * f^2$, where $\rho = 1000 \text{ kg/m}^3$).

Results and discussion

Figure 2 showed shear waves propagating in the vastus medialis (VM) and sartorius (Sr) muscles.

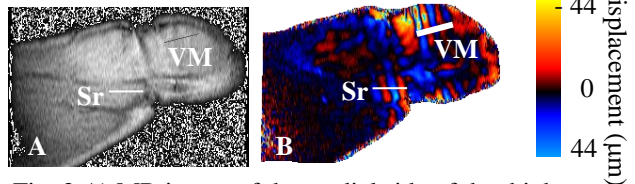


Fig. 2 A) MR image of the medial side of the thigh.

B) Shear waves in the medial side of the thigh

The shear modulus measured at rest (Fig. 2) in the vastus lateralis, vastus medialis and sartorius were $3.73 \pm 0.85 \text{ kPa}$ (VL), $3.91 \pm 1.15 \text{ kPa}$ (VM) and $7.53 \pm 1.66 \text{ kPa}$ (Sr). The stiffness of the sartorius is significantly higher than the vastus stiffness. This may indicate that the propagation of the waves was influenced by the muscle fiber orientation. The fiber orientation is unipennate in the vasti, while it is longitudinal in the sartorius.

During a thigh contraction of 10% MVC, the stiffnesses of the VL and the VM were $6.11 \pm 1.15 \text{ kPa}$ and $4.83 \pm 1.68 \text{ kPa}$, respectively. A faster increase of stiffness ($P < 0.1$) was measured for the VL than for the VM. This may be due to a larger percentage of fast fibers in the VL enabling a faster contraction.

With a level of 20% MVC, the stiffnesses of the VL and the VM were $8.49 \pm 4.02 \text{ kPa}$ and $6.40 \pm 1.79 \text{ kPa}$ ($P < 0.1$), respectively. For both levels of contraction, the stiffness of the sartorius muscle did not exhibit any changes. This may be due to the leg press, which solicits the knee extensors while the sartorius flexes the knee.

Conclusion

We concluded that the MRE technique is able to quantify the stiffness of thigh muscles. Furthermore, the wave length was sensitive to the morphology and fiber composition in each muscle. The MRE technique could be a helpful means to non-invasively improve diagnoses and to understand the effects of pathologies such as Graves Disease which affects proximal muscle strength by changing the composition of the muscle fibers (Brennan, 2001).

References

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