Estimating Skeletal Muscle Forces in vivo: A Shear Wave Elastography Approach

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INTRODUCTION:
Modelling and simulation of skeletal muscles are essential to understand neuromuscular diseases better and to improve treatment strategies. However model validation with direct muscle force measurements at the respective tendons intraoperatively (e.g. 1) is not straightforward and not feasible for many scenarios in particular for healthy muscles.

Ultrasound shear wave elastography (SWE) was shown to represent in vivo active (2) and passive (3) muscle mechanics.

We hypothesized that changes in mechanical properties of the Biceps Brachii muscle (BB) can be detected with SWE both in passive state and during isometric ramp contractions. We investigated whether SWE can reveal individual muscle mechanics in relation to joint function.

MATERIALS AND METHODS:

- SWE, surface electromyography (sEMG) of the BB, and isometric elbow torque measurements at different elbow angles (here: α=60°).
- An exemplary SWE image during isometric submaximal contraction is shown.
- 14 healthy volunteers (7 females, 28.07 ± 5.06 years)
- Measurements at rest, during maximum voluntary contractions (MVC), and isometric ramp contractions (up to 25%, 50%, 75% of MVC torque) were performed.
- BB length was measured using B-mode ultrasound (US) imaging

RESULTS:
- BB muscle length increased with increasing elbow angle from flexion to extension (p<0.001)
- Passive shear elastic modulus increased with increasing elbow angle from flexion to extension (p<0.001)
- During sub-maximal isometric contractions, both elbow angle and activity level affected shear elastic modulus significantly (p<0.001, Fig. 2)

DISCUSSION:
We hypothesized that changes in mechanical properties of the Biceps Brachii muscle (BB) can be detected with SWE both in passive state and during isometric ramp contractions. We investigated whether SWE can reveal individual muscle mechanics in relation to joint function.

Conclusions:
1. Passive shear elastic modulus of the BB increased with increasing muscle length
2. Active shear elastic modulus of the BB increased with increasing elbow torque at shorter muscle lengths
3. SWE revealed muscle length dependent active muscle mechanical properties

Ongoing work: Understand the contribution of individual muscles to the resulting joint torque and relate direct muscle force measurements with muscle’s shear elastic modulus.

References: