Towards in vivo Passive and Active Muscle Force Estimation using Shear Wave Elastography

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1. Introduction

Modelling and simulation of skeletal muscles are essential to better understand musculo-skeletal diseases and improve treatment strategies. However model validation with direct muscle force measurements at the respective tendons intra-operatively [e.g. 1] is not straight-forward and not feasible for many scenarios in particular for healthy muscles.

Surface electromyography (sEMG) has been widely used for muscle characterization, but it lacks the representation of the passive state of muscles. Previously, muscle stiffness deduced from shear wave elastography (SWE) was shown to represent muscle mechanics [e.g. 2].

Aiming to investigate the use of a SWE approach in understanding active and passive force production of skeletal muscles, the present study hypothesized that changes in mechanical properties of the BB can be detected both in passive state and during isometric ramp contractions. We investigated whether SWE can reveal individual muscle mechanics in relation to joint function which would help improve existing muscle models.

2. Materials and Methods

SWE, sEMG of BB, and isometric elbow torque measurements were performed on 14 healthy volunteers (7 females, 28.07 ± 5.06 years) after they gave written consent to participate. A passive trial, maximum voluntary contractions (MVC) and isometric ramp contractions (up to 25%, 50%, 75% of MVC torque) were performed for five elbow angles (60°, 90°, 120°, 150°, and 180°). BB muscle length was determined with ultrasound imaging.

3. Results

Muscle length of BB increased with increasing elbow angle ($p<0.001$). At passive state, elastic modulus of BB deduced from SWE significantly increased with increasing elbow angle ($p<0.01$) but no significant differences were observed for sEMG root-mean squared amplitude (RMS) ($p<0.05$). During sub-maximal isometric contraction, both elbow angle and activity level revealed significant effects on shear elastic modulus ($p<0.001$, see Fig. 1) but only activity level affected sEMG RMS amplitude ($p<0.01$).

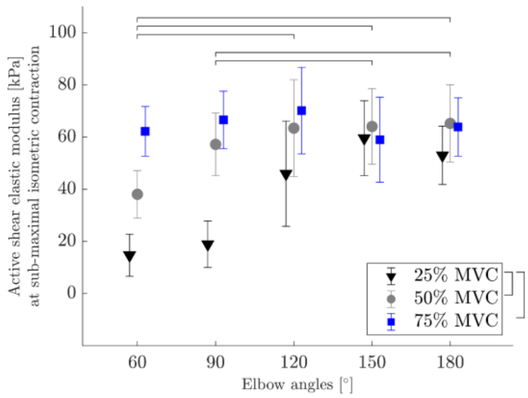

Figure 1: Average active shear elastic modulus at 25%, 50%, and 75% isometric contractions for different elbow angles (90°-180°).

4. Discussion and Conclusions

Our hypothesis posed was supported as SWE but not sEMG was able to characterize passive mechanical muscle properties. During active state, SWE reflected different activity levels tested while indicating muscle length dependent characteristics.

We conclude that SWE providing more realistic results can be developed as an index of muscle force. If validated with experiments [e.g. 1], SWE findings can be used to improve muscle models and simulate the effects of e.g. exercise, neuromuscular conditions, or treatments.

5. References

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