Mechanics of Biceps Brachii Muscle in Relation to Elbow Function Using Shear Wave Elastography

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Background and Aim:

Mechanical characterization of skeletal muscles in vivo is a key for better understanding movement and performance alterations due to exercise, aging, or neuromuscular diseases. Since non-invasive force measurements are hardly feasible in vivo, surface electromyography (sEMG) has been widely used for muscle force estimation. However additional to many other limitations, sEMG lacks information on resting muscle. Previously, the elastic modulus of muscles attained using shear wave elastography (SWE) was shown to represent muscle mechanics in both passive [1] and active [2] states. Though, relating muscle stiffness to its length and in vivo position is not straight forward. Presently, we investigated the biceps brachii muscle (BB) with respect to elbow joint position and function and tested the hypotheses that SWE can detect the changes in BB mechanics (i) in passive state for different muscle lengths, (ii) during isometric ramp contractions at different activity levels.

Methods:

SWE, sEMG of BB and isometric elbow torque were measured simultaneously from 14 young volunteers (7 females, 28.1 ± 5.1 years, 77.2 ± 17.4 kg, 177.7 ± 7.5 cm). At five elbow angles (60°-180°), a passive trial, three maximum voluntary contractions (MVC) and nine isometric ramp contractions (up to 25%, 50%, 75% of MVC torque) were performed. Elastic modulus was deduced from SWE and root-mean squared amplitude (RMS) was calculated from sEMG. sEMG RMS/torque and elastic modulus/torque relationships were fitted to a linear model and coefficients of determination (R^2) were calculated.

Results:

At passive state, elastic modulus changed between 60° (11.8 ± 3.5 kPa) and 150°/180°, 90° (16.8 ± 7.0 kPa) and 150°/180° (26.0 ± 7.1 / 35.8 ± 8.0 kPa) elbow angles ($P<0.05$).

At MVC, the elbow torque (51.2 ± 19.5 Nm at 60°) decreased with the increasing elbow angle (26.1 ± 13.8 Nm at 180°). The elastic modulus and sEMG RMS did not show significant differences between elbow angles.

During ramp contractions, the elastic modulus reflected the major changes both due to activity levels and joint positions. sEMG RMS on the other hand showed significant differences only for activity levels. Linear regression of sEMG RMS over torque revealed good agreement for all angles tested. However, elastic modulus did not follow a linear relationship at extended joint positions (e.g. 150°, Figure 1).

Conclusions:

The present findings support the hypotheses posed and indicated that SWE can be used to characterize both active and passive mechanical properties of muscles. We found that even though normalized sEMG represents muscle activity, it cannot solely explain muscle's contribution to joint function at longer muscle lengths. Consequently, SWE providing more realistic results might be a promising new modality for detecting muscular changes due to exercise or pathological alterations in the course of neuromuscular diseases.

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References:

[1] Ates F. et al. 2018, Eur J Appl Physiol, 118: 585-593.

[2] Ates F. et al. 2015, J Electromyog Kinesiol, 25: 703-708.

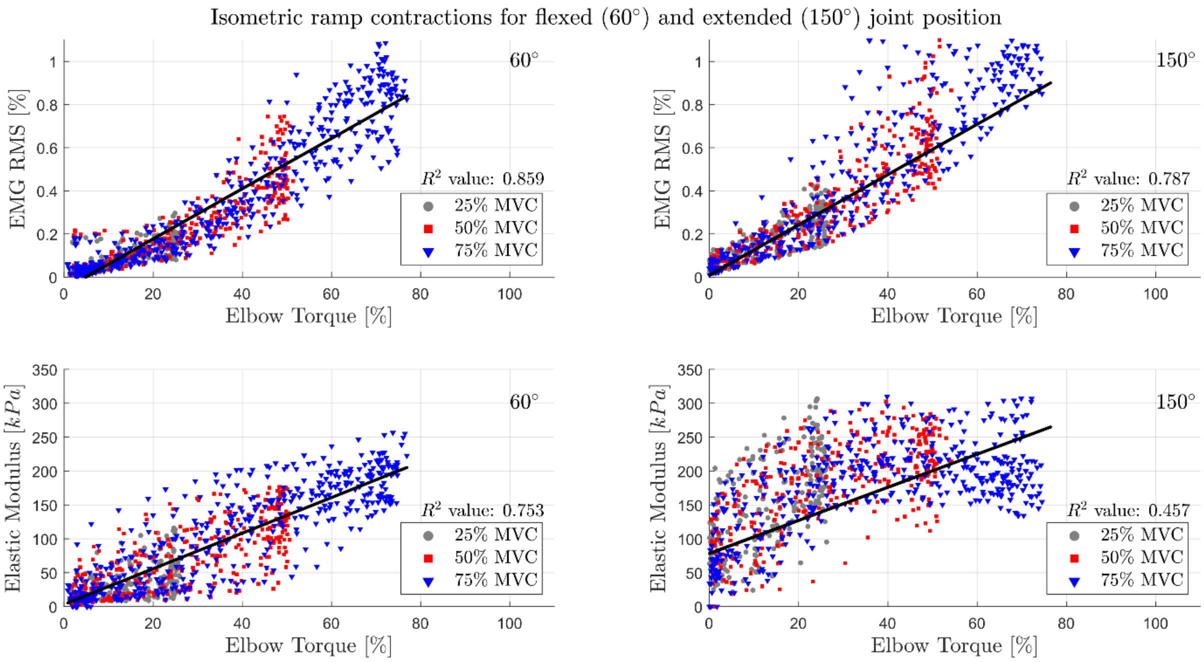

Figure 1: Elastic Modulus and EMG root-mean square (RMS) magnitude data extracted at different activity levels during isometric ramp contractions for flexed joint position (left column) at 60° elbow angle and extended joint position (right column) at 150° elbow angle. EMG RMS/torque and elastic modulus/torque relationships were fitted to a linear model and coefficients of determination (R^2) were calculated.