Skeletal muscle mechanical properties quantification: comparison between ultrasound shear wave elastography and magnetic resonance elastography

Zhongzheng Wang[1], Sven Petersson[2,3], Rodrigo Moreno[4], Ruoli Wang[1]
[1]KTH MoveAbility, Dept. Engineering Mechanics, KTH Royal Institute of Technology, Stockholm, Sweden
[2]Dept. Clinical Neuroscience, Karolinska Institutet, Stockholm, Sweden
[3]Dept. Medical Radiation Physics and Nuclear Medicine, Karolinska University Hospital, Stockholm, Sweden
[4]Division of Biomedical Imaging, Dept. Biomedical Engineering and Health Systems, KTH Royal Institute of Technology, Stockholm, Sweden
Email: zhowan@kth.se

Summary

The mechanical properties of skeletal muscle were quantified and compared using ultrasound shear wave elastography (SWE) and magnetic resonance elastography (MRE) in both ex vivo and in vivo conditions. A moderate to strong correlation was observed between the two imaging modalities.

Introduction

Due to the low cost and good accessibility, SWE is the most commonly used technique to quantify skeletal muscle mechanical properties but with the limitation of neglecting muscle anisotropy and viscosity [1]. In contrast, MRE, when combined with diffusion tensor imaging (DTI), accounts for muscle anisotropy and viscosity but is more expensive and less accessible. The correlation between muscle mechanical properties quantified by SWE and MRE remains unclear. Therefore, this study aimed to compare the muscle mechanical property quantification between a commercial ultrasound SWE system and MRE in both ex vivo and in vivo conditions.

Methods

Seven muscle samples were obtained from a butcher, two of which underwent three freeze-thaw cycles. The purpose of the free-thaw cycles was to increase the samples' stiffness range. Measurements were performed before the first and after each subsequent cycle, resulting in a total of 13 MRE and SWE sessions across all muscle samples. Additionally, nine able-bodied subjects (4 females, 27.7 ± 2.9 years, 167.7 ± 6.3 cm, 64.7 ± 8.5 kg) were recruited for in vivo comparison. The medial gastrocnemius (MG) was evaluated. The study was approved by the Swedish Ethical Review Authority.

SWE was performed using a diagnostic ultrasound system (Aixplorer, SuperSonic Imagine) with a 5-cm wide linear transducer (L18-5, SuperSonic Imagine) using the MSK preset. Shear wave velocity (SWV) was calculated with the assumption that muscle behaves as an isotropic and elastic material. For ex vivo comparison, both perpendicular and parallel SWV were measured by positioning the transducer perpendicular and parallel to muscle fascicles. For in vivo comparison, only parallel SWV was evaluated. MR scans were performed using a 3.0-Tesla scanner (Ingenia CX, Philips Healthcare). Three sequences were included, an anatomical scan, a DTI scan, and an MRE scan (50 Hz). SWV of the MG was calculated with the assumption that muscle behaves as an anisotropic and viscoelastic material. To determine perpendicular and parallel SWV, DTI was used to identify the MG fascicle direction.

The correlation between SWV estimates obtained between SWE and MRE was assessed using the Pearson correlation coefficient, with the significance level set at 0.05.

Results and Discussion

A moderate to strong correlation was observed between SWV estimates between SWE and MRE (ex vivo perpendicular SWV: r =0.777, ex vivo parallel SWV: r =0.673, in vivo parallel SWV: r =0.707) (**Figure 1**). On average, SWE consistently overestimated SWV compared to MRE across all conditions (ex vivo perpendicular SWV 0.42 m/s, ex vivo parallel SWV 0.67 m/s, in vivo parallel SWV: 0.53 m/s). The discrepancy might be attributed to the difference between the velocity types quantified using SWE (group velocity) and MRE (phase velocity). In biological soft tissues, group velocity is generally higher than phase velocity within the common elastography frequency range (1-500 Hz) [3].

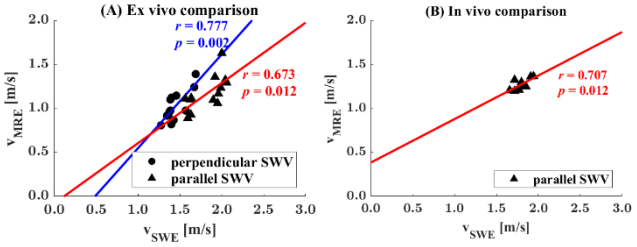

Figure 1: Correlation of SWV quantified by SWE and MRE in (A) ex vivo and (B) in vivo comparison.

Many studies regarded the neglection of muscle anisotropy as a major limitation of ultrasound SWE. However, we demonstrated for the first time that SWV quantification using the commercial SWE system still reached a moderate to strong correlation with anisotropic MRE measurement in a pennate muscle. Further research is needed to evaluate whether this agreement holds in muscles under pathological conditions.

Conclusions

Skeletal muscle mechanical property quantified using a commercial SWE system demonstrated good agreement with anisotropic MRE measurement in ex vivo muscle samples and able-bodied adult participants.

References

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