Measuring Dynamic Changes in the Geometry of Isolated Cardiac Trabeculae Using Optical Coherence Tomography

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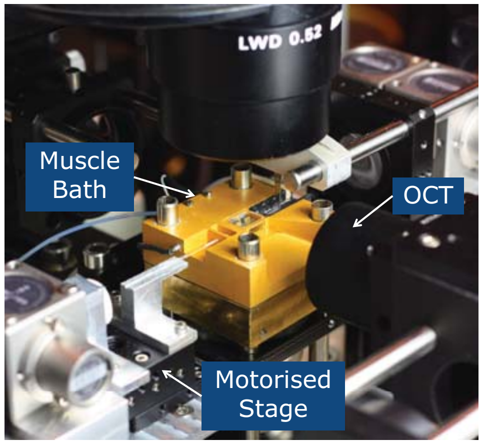
Background

The calculation of stress (force per cross-sectional area) developed across a muscle is critically dependent on its geometry. In previous studies, cross-sectional area has commonly been inferred from the measurement of average muscle width in the quiescent state. However, the non-uniformity of shape and changes in the geometry during contraction will affect the resulting stress.

We have developed an instrument capable of measuring the 3D geometry of actively contracting trabeculae using Optical Coherence Tomography (OCT). In this study, we scan a representative muscle used in typical muscle experiments and capture its geometric profile and stress distribution.



Methods

1. A trabecula dissected from a healthy rat was mounted in a glass capillary containing oxygenated Tyrode's solution.
2. An electrical stimulus was applied at a rate of 1 Hz.
3. Cross-sectional scans were taken at a rate of 100 Hz, synchronised with the stimulus. Measurement of force was made simultaneously.
4. Images were segmented with a trainable classifier and the cross-sectional areas over length and time were calculated.

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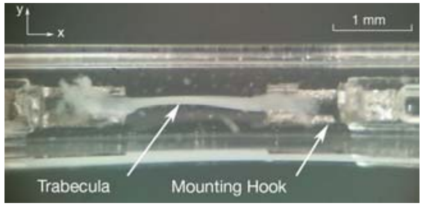

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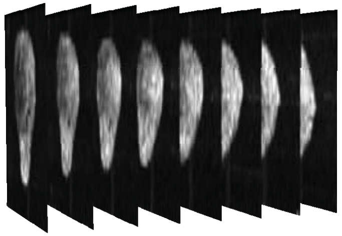
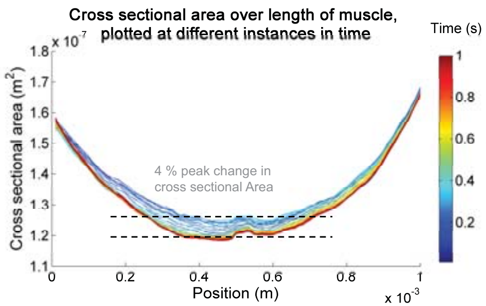
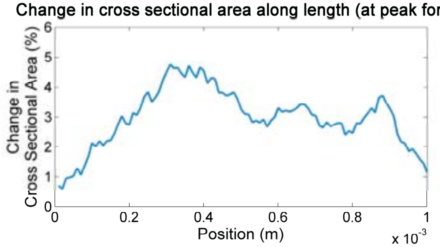


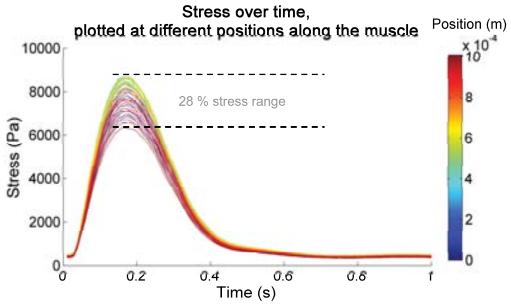
Results

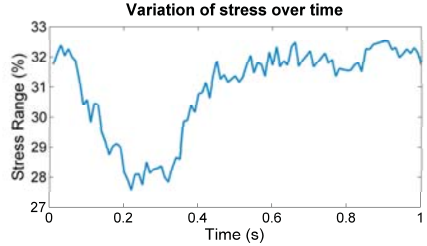
Geometric Variation



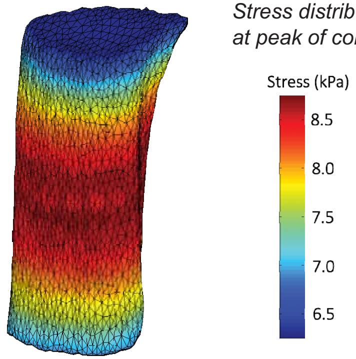


Stress Variation





Stress Visualisation



Conclusions

- Cross-sectional areas along the sample increased by up to 4% during contraction.
- On average, stress varied by 31% along the sample.
- Variation in stress was *lowest* at peak force (highest tissue deformation).
- The ability to measure 3D geometry allows for more detailed analysis of stress and can be incorporated into a finite element model.

Acknowledgements

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