Magnetomicrometry: Real-Time Muscle Tissue Length Tracking for Biomechanics

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Summary

Muscle length and velocity are critical parameters for musculoskeletal modeling, but no off-the-shelf tools exist to robustly collect these metrics in an untethered setting. To meet this need, we developed magnetomicrometry – a real-time muscle tissue length tracking tool using implanted magnetic beads to robustly track muscle tissue lengths *in vivo* – and we demonstrate its use in untethered freely moving animals.

Introduction

Improved muscle tissue length and velocity sensing will be considered critical equipment in the biomechanist's toolbox of tomorrow. Electromyography (EMG) can provide the activity of individual spinal motor neurons [1]. However, as we have known for many decades, without muscle length and velocity information, EMG alone cannot determine accurate muscle force or joint movement in a way that generalizes to all activities an animal or person will engage in [2]. Unfortunately, however, while traditional methods for monitoring muscle motion, such as sonomicrometry [3], fluoromicrometry [4], and ultrasound [5], have enhanced our understanding of muscle movement, an unobtrusive sensor that consistently tracks real-world muscle motion previously remained to be demonstrated. To address this gap in the biomechanist's toolbox, we developed magnetomicrometry.

Methods

We implant two magnetic beads a distance apart in muscle and position a magnetic field sensor array outside the body over the beads. We use magnetic field measurements to compute 3D magnetic bead positions and use the distance between these beads as the length signal (Figure 1).

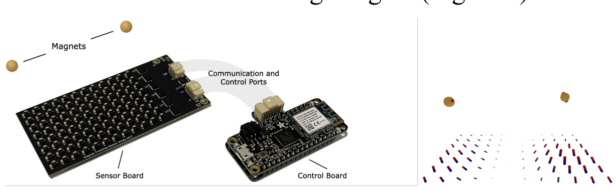

Figure 1: Real-Time Magnetic Bead Tracking.

Results and Discussion

Magnetomicrometry enables real-time wireless tracking of muscle tissue lengths via implanted magnetic beads [6] with submillisecond time delay [7]. Using an avian model, we demonstrated the submillimeter accuracy of magnetomicrometry against fluoromicrometry in a freely-roaming animal (Figure 2) [8], and we verified that the magnetic implants are stable and biocompatible [9].

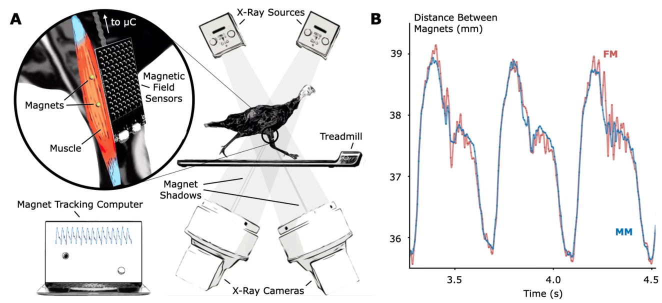

Figure 2: Untethered Real-Time Muscle Tissue Length Tracking.

Like other -micrometry strategies, magnetomicrometry can be used to monitor other tissues. In any case, it should be noted that the placement of the markers is of critical importance. If muscle fascicle length is desired, the markers must be placed along the fascicle. In other words, the WYPIWYM principle should be applied: where you place is what you measure.

Conclusion

While this tool isn't yet available as an off-the-shelf solution, our demonstration provides a positive outlook for muscle modeling. Biomechanists can hope to soon have easily-accessible tools for measuring the critical metrics of a muscle's length and its corresponding velocity.

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