Tracking skin deformations using optical motion capture

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Summary

We present and validate a novel method for studying elastic tissue (skin, muscles, and connective tissues) motions during human movement. We track skin deformations with optical motion capture and relate these measurements to the motions of underlying muscles and connective tissues using ultrasound imaging. This approach enables measurement of elastic tissue dynamics during natural movements.

Introduction

Elastic energy plays a crucial role in efficient movement, allowing for explosive actions like jumping while reducing the metabolic cost of locomotion [1–3]. However, traditional methods for studying elastic tissue motions *in vivo*, such as ultrasound imaging, often constrain natural movement patterns. This study explores the potential of using skin deformation measurements as a proxy for underlying tissue dynamics, offering a less restrictive approach to studying movement mechanics.

Methods

We developed a dual-measurement system combining optical motion capture and ultrasound imaging. Infrared-reflective markers were placed along major superficial muscles, while simultaneous ultrasound imaging provided validation of underlying tissue motion. Participants performed treadmill walking while both measurement systems recorded tissue dynamics. Custom 3D-printed attachments secured the ultrasound probe, and an optical flow algorithm analyzed ultrasound data.

Results and Discussion

Our preliminary findings demonstrate a strong correlation between skin surface deformations and underlying tissue dynamics (Figure 1). Motion capture measurements of inter-marker distances closely matched tissue displacement patterns observed in ultrasound imaging. This validation supports the use of skin-based tracking as a reliable method for studying elastic tissue dynamics during natural movements. However, the relationship between skin deformations and underlying tissue dynamics may vary across different types of movements and anatomical regions, necessitating further validation studies before generalizing these findings.

Future work should investigate whether skin deformations themselves, beyond serving as proxies for muscle and connective tissue dynamics, reveal distinct patterns that could inform our understanding of efficient and sustainable movement.

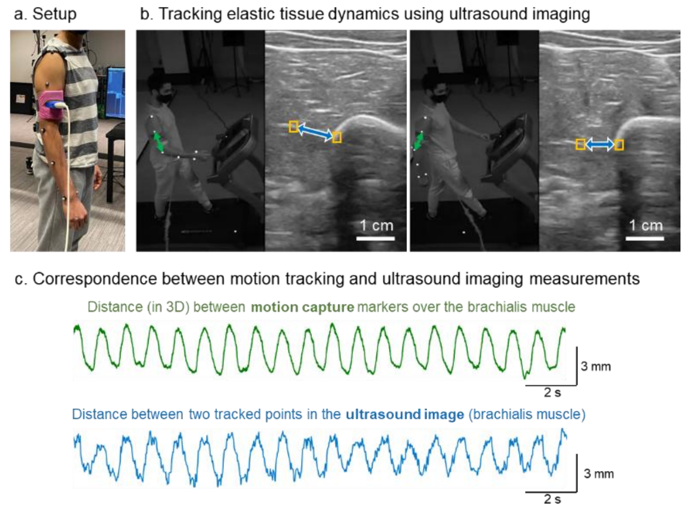

Figure 1. Measurement of elastic tissue motions during treadmill walking. (a) Setup for measuring muscle length dynamics using motion capture, and validating using ultrasound imaging. Infrared reflective markers (silver dots) are placed along the length of muscles, and the distance between the markers is tracked using a commercial optical motion tracking system. A commercial ultrasound probe is mounted on the upper arm using a custom 3d-printed attachment. (b) Representative reference images (left panels) and ultrasound images (right panels) from the upper arm during two phases of the gait cycle. Relationship between a point in the elastic tissue, and a point on the surface of the humerus (yellow squares) is highlighted with a blue double arrowhead. (c) The distance between these two points was extracted by tracking the points within the ultrasound scans using an optical flow algorithm (blue line, ground truth of soft tissue deformation). Distances between points tracked on the surface of the skin using motion capture (green line) followed this distance closely, validating muscle length measurements based on tracking points on the surface of the skin along the muscle.

Conclusions

This study establishes a new approach for investigating elastic tissue dynamics during human movement. The validated skin-based tracking method enables the study of elastic tissues during more naturalistic movements. This technique opens new possibilities for understanding the role of elastic tissues in movement efficiency and may provide insights into injury risk during naturalistic movements.

References

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