Are biceps femoris muscle length changes influenced by in-series compliance across locomotor demand?

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Hypothesis

Across speeds and slopes, biceps femoris muscle velocities and muscle-tendon unit (MTU) velocities remain highly correlated, despite varying forces on the MTU

Background and Motivation

Current viewpoint within neuromechanics [1]:

Proximal joints
  • Short, stiff tendons
Distal joints
  • Long, compliant tendons

Extent of decoupling caused by in-series compliance at proximal joints remains unknown

Implications:
  • More accurate musculoskeletal simulations
  • Understanding proximal muscle force generation capabilities
  • Understanding economy of proximal muscle contractions

Methods

1 subject (28 yrs, 74.3 kg) completed 1 minute trials at 26 randomized walking-running speed-slope combinations (Fig 1A)
  • 10 strides collected for each condition
Biceps femoris longhead (BFllh) muscle-tendon unit (MTU) lengths and joint moments were calculated using OpenSim 4.0
BF muscle lengths were calculated from B-mode ultrasound images tracked using an adapted semi-automated tool [2] (Fig 1B)

Correlations for each condition were between the ensemble averaged gait cycle normalized MTU velocity and muscle velocity [3]

Muscle velocity $= \frac{d}{dt}(\text{fascicle length} \times \cos(\text{pennation angle}))$

Correlations between BFllh Muscle and MTU Velocities

↑ speed = ↓ correlation, but not significant (p = 0.13)
  • Trend suggests ↑ speed = ↑ decoupling of muscle from MTU
↑ slope = ↓ correlation (p < 0.001)
  • Suggests ↑ slope = ↑ decoupling of muscle from MTU
↑ peak hip ext. moment = ↓ correlation, but not significant (p = 0.23)
  • Trend suggests ↑ load = ↑ decoupling of muscle from MTU

Results and Discussion

Biceps Femoris Forces Across Conditions

Peak hip ext. moment was used as a proxy for BFllh force
  • Peak hip ext. moment was positively correlated with speed (p < 0.001)
  • Peak hip ext. moment was not correlated with slope (p = 0.90)

Correlations between BFllh Muscle and MTU Velocities

Peak Hip Extension Moment (Nm/kg)

Biceps Femoris Forces Across Conditions

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Acknowledgements

PRG is supported by a NSFGRFP: DGE-1650044. This project was supported by the U.S. Army Natick Soldier Research, Development and Engineering Center (W911QY18C0140)

References


Key Take-Away Points

1. Biceps femoris forces may be more sensitive to speed than slope
2. Speeds and peak extension moments did not indicate influence of in-series compliance
3. Slopes did indicate influence of in-series compliance