From Muscle-Tendon Work to Whole-Body Energy Change

Towards a Unified Multi-Scale Understanding of Human Movement Biomechanics

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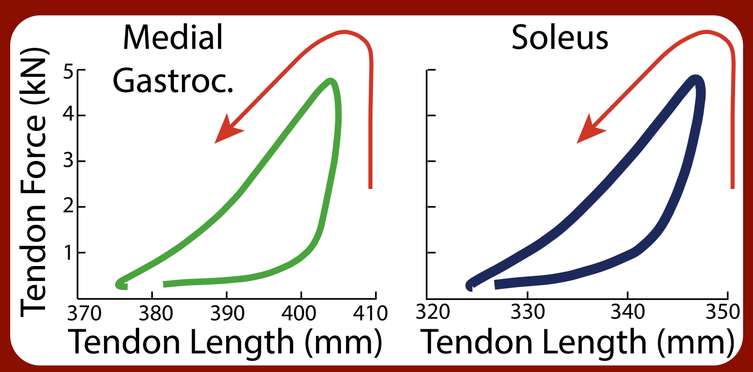
Gaps & Challenges with Empirical Estimates:

Troubling

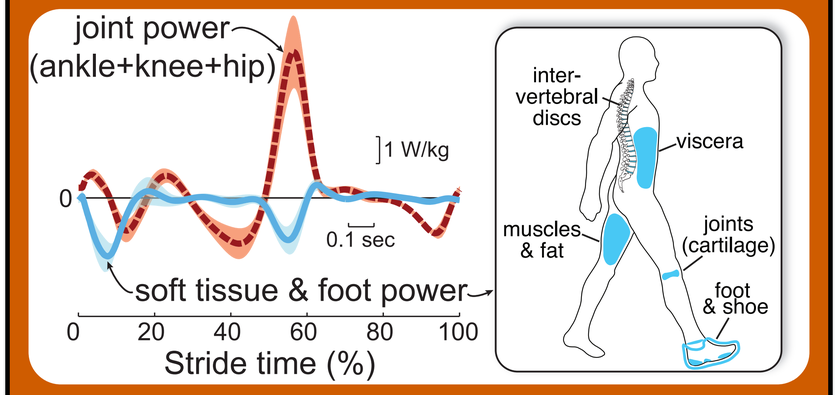
Net positive work by passive tendons (estimates indicate tendons act like motors)



1. Muscle-tendon unit (MTU) dynamics can be estimated by combining force sensors, motion capture & ultrasound.
2. However, estimates based on subtracting muscle from MTU length indicate that passive tendons generate net positive work (e.g., Sakuma et al. 2012, figure above), a red flag.
3. Alternate tendon estimates (ultrasound speckle tracking or MTU junction) may resolve issue.

Concerning

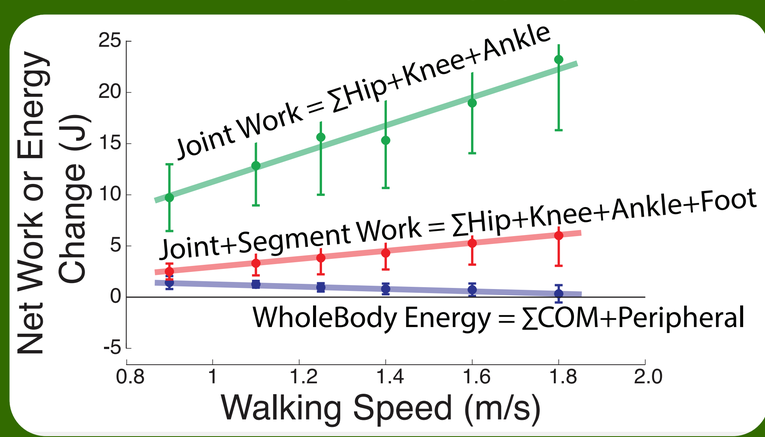
Most studies neglect soft tissues & feet, but these perform substantial work



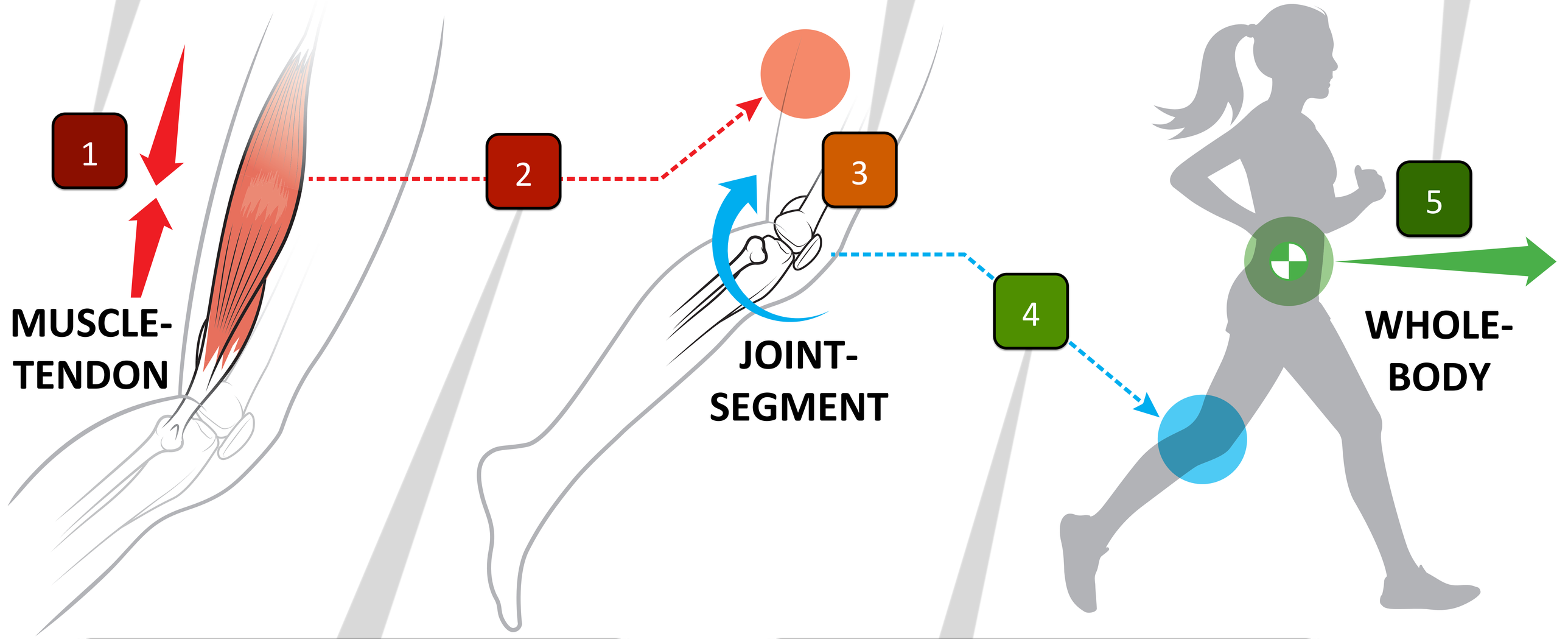
1. Soft tissues perform 60-85% of negative collision work after foot contact in walking (Zelik & Kuo 2010; Fu et al. 2015, figure above), 25% in running (Riddick & Kuo 2016), & 16% in jump landing (Zelik & Kuo 2012).
2. Foot may absorb 25% of positive work performed during push-off phase of walking (Takahashi & Stanhope 2013; Zelik et al. 2015).

Mostly Resolved

Trust whole-body dynamics estimates because they add up properly



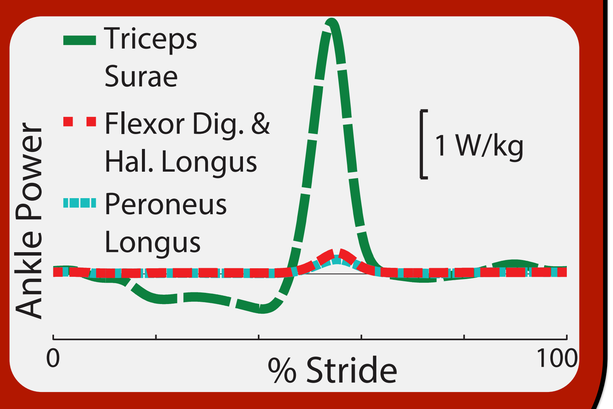
1. Whole-body energy change can be estimated by summing COM & Peripheral (motion relative to COM) dynamics, which are computed from ground reaction force & motion data.
2. Whole-body energy change is net zero for cyclic tasks, as expected, giving confidence in this estimate (Zelik & Kuo 2010; Zelik et al. 2015, figure above); but net joint work is non-zero.



Unknown

Consistency between MTU & joint-segment work estimates is difficult to assess

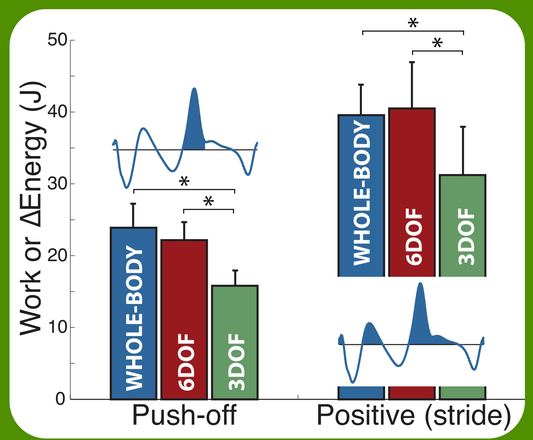
1. Uncertainty due to limitations in measuring MTU-specific force & length change
2. EMG-driven modeling may provide practical solution for partitioning joint power into contributions from individual MTUs (Honert & Zelik, in review, figure to right).



Partly Resolved

6DOF joint-segment work explains whole-body energy change, but commonly-used 3DOF analysis does not

1. 3DOF (rotational) joint work fails to capture 25-35% of whole-body energy change in gait (Duncan et al. 1997; Zelik et al. 2015, figure to right).
2. 6DOF (rotational & translational) work estimates resolve issue, except during impulsive collisions, due to energy absorption in soft tissues.



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Abbreviations

COM – center-of-mass
DOF – degree-of-freedom
MTU – muscle-tendon unit

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