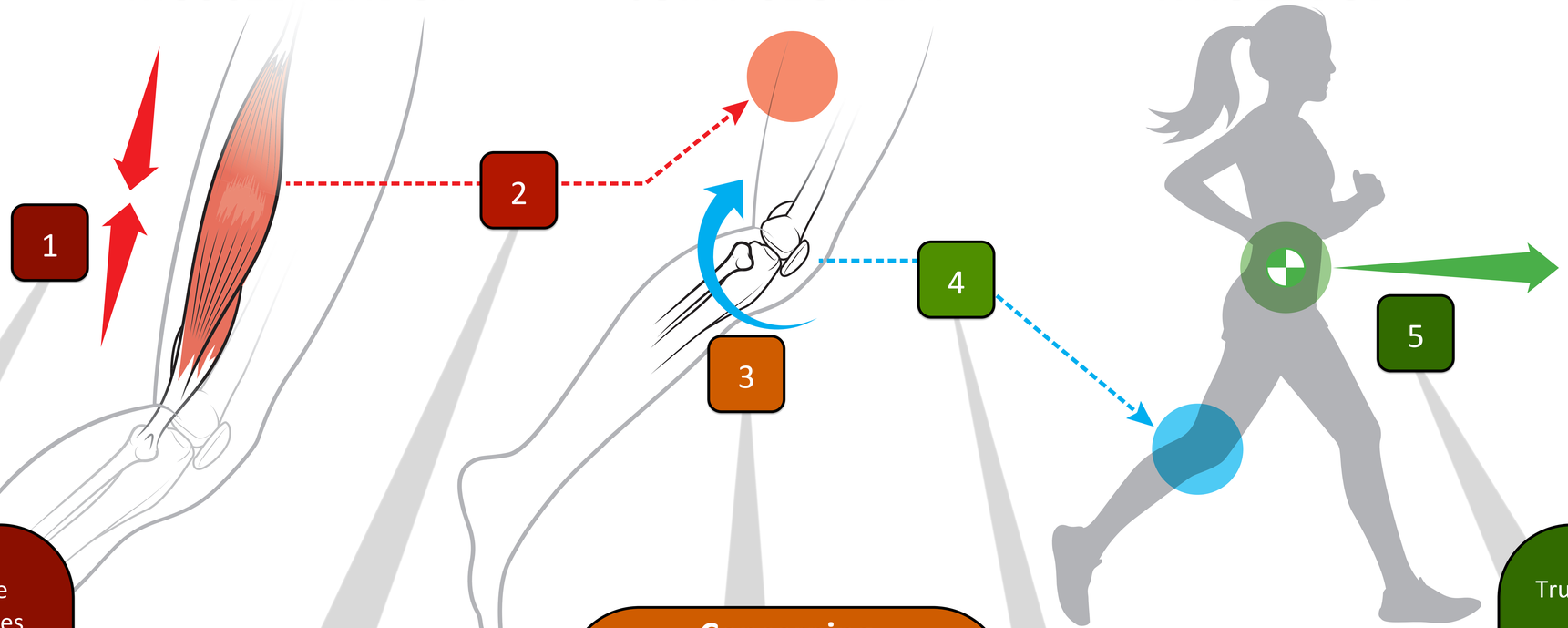
From Muscle-Tendon Work to Whole-Body Energy Change

Towards a Unified Multi-Scale Empirical Understanding of Human Movement Biomechanics

Karl E. Zelik, Vanderbilt University

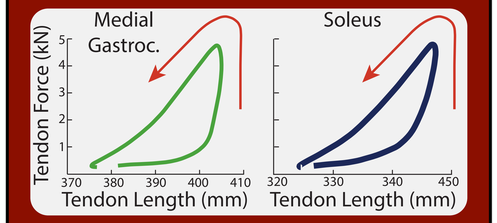
MUSCLE-TENDON **JOINT-SEGMENT** **WHOLE-BODY**



Gaps & Challenges:

Troubling

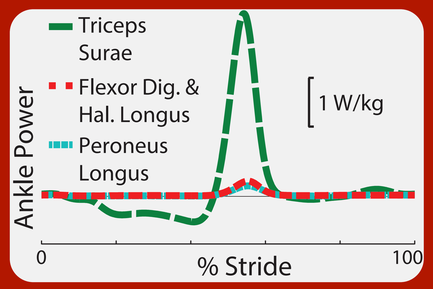
Net positive work by passive tendons (i.e., current estimates indicate tendons act like motors)



- Muscle-tendon unit (MTU) dynamics can be estimated by combining force sensors, motion capture & ultrasound
- However, current methods estimate that passive tendons generate net positive work (e.g., Sakuma et al. 2012, results above), a troubling red flag warranting further study

Unknown

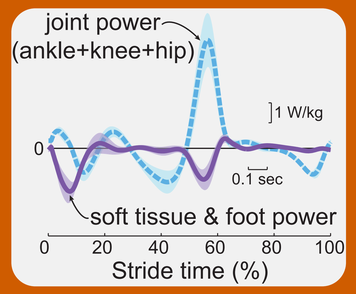
Consistency between MTU & joint-segment work estimates hard to assess



- Uncertainty due to limitations in measuring MTU-specific force & length
- Data-driven modeling may provide a pragmatic solution for partitioning joint kinetics into individual MTU contributions (Honert & Zelik, in review, figure above)

Concerning

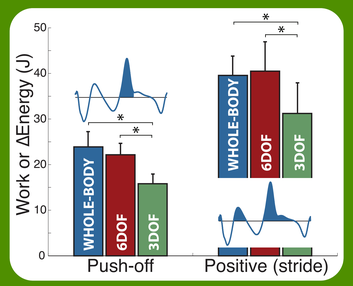
Most studies neglect soft tissues & feet, but these perform substantial work



- 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)
- Foot may absorb ~25% of work during push-off phase of walking (Takahashi & Stanhope 2013; Zelik et al. 2015)

Partly Resolved

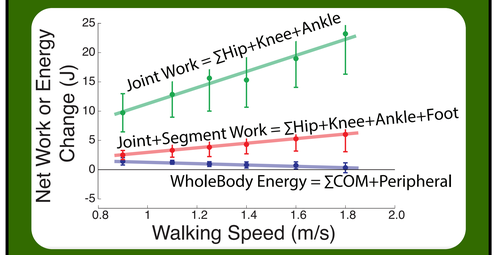
6DOF joint-segment work explains whole-body energy change, but commonly-used 3DOF analysis does not



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

Mostly Resolved

Trust whole-body kinetics because they add up properly



- Whole-body energy change can be estimated by summing COM & Peripheral (motion relative to COM) kinetics, which are computed from ground reaction force & motion data
- 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
- Limitation: Peripheral estimates still depend on rigid-body assumptions

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

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