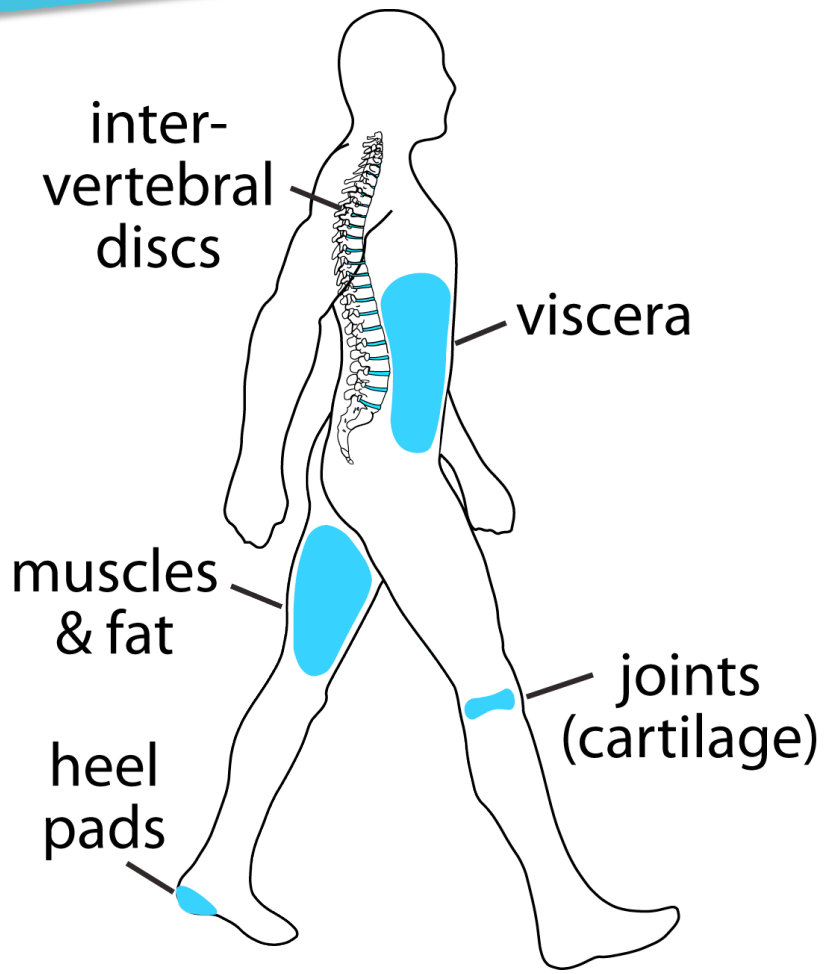
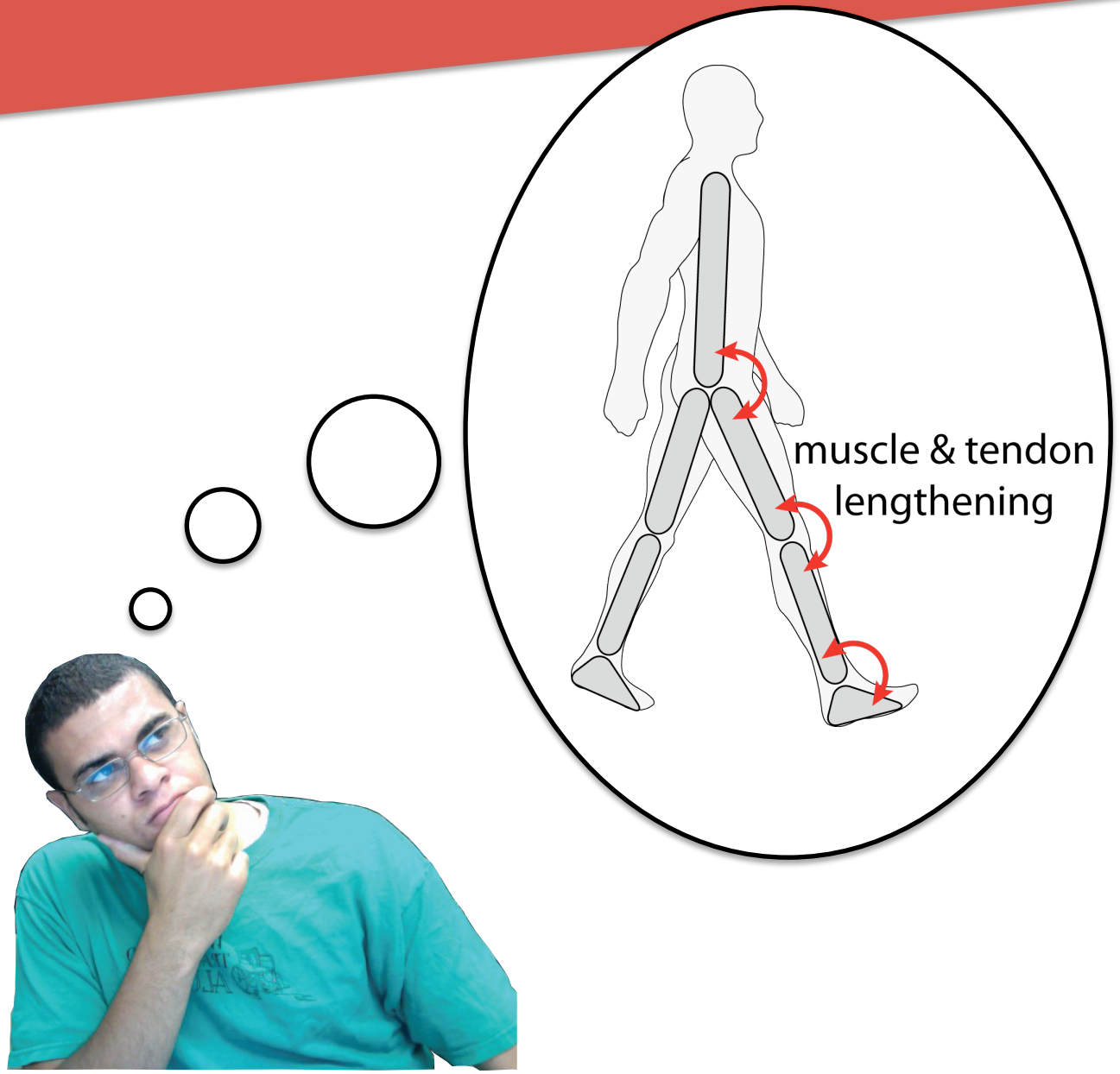
Moving & Shaking:
Soft Tissue Work in Human Walking



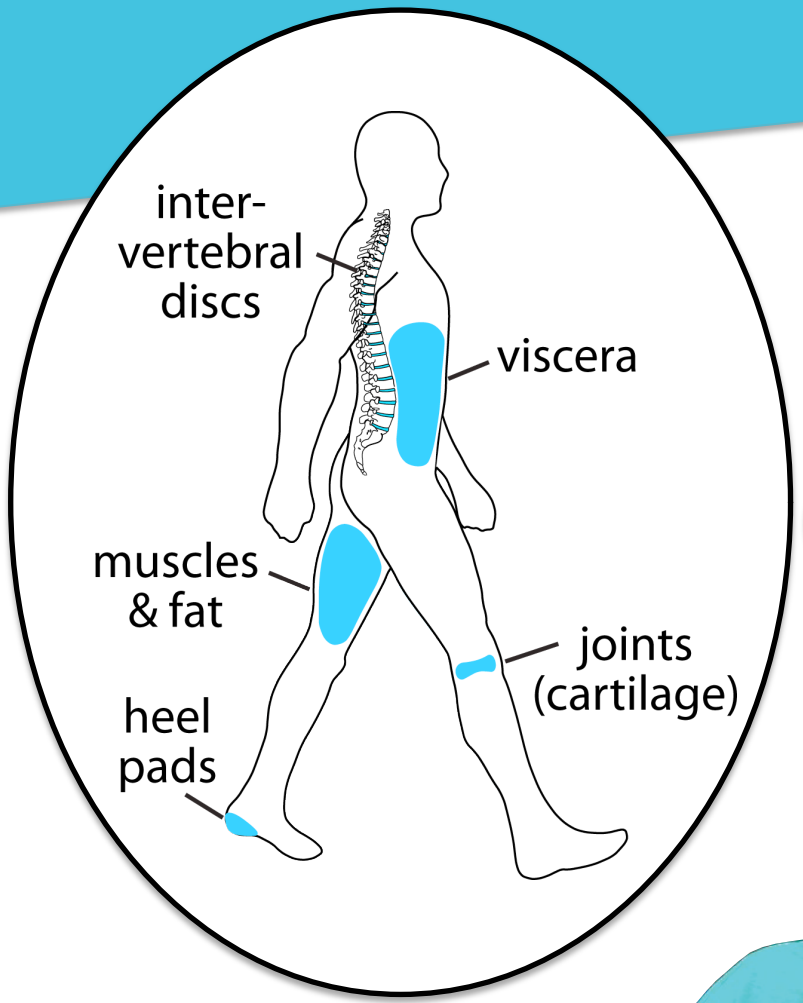
Karl E. Zelik & Art D. Kuo | University of Michigan

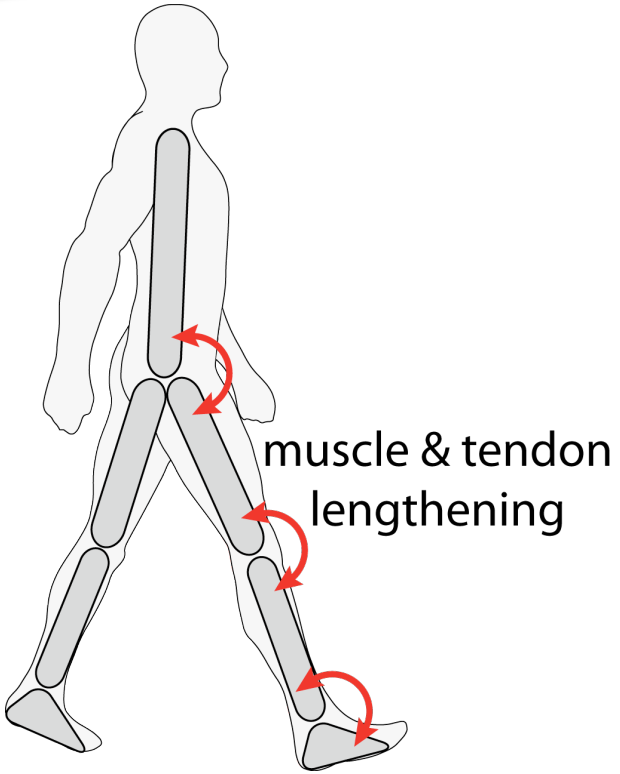
Mmmm… rigid-body dynamics



But >80% of the body is “soft”

Prange 1979



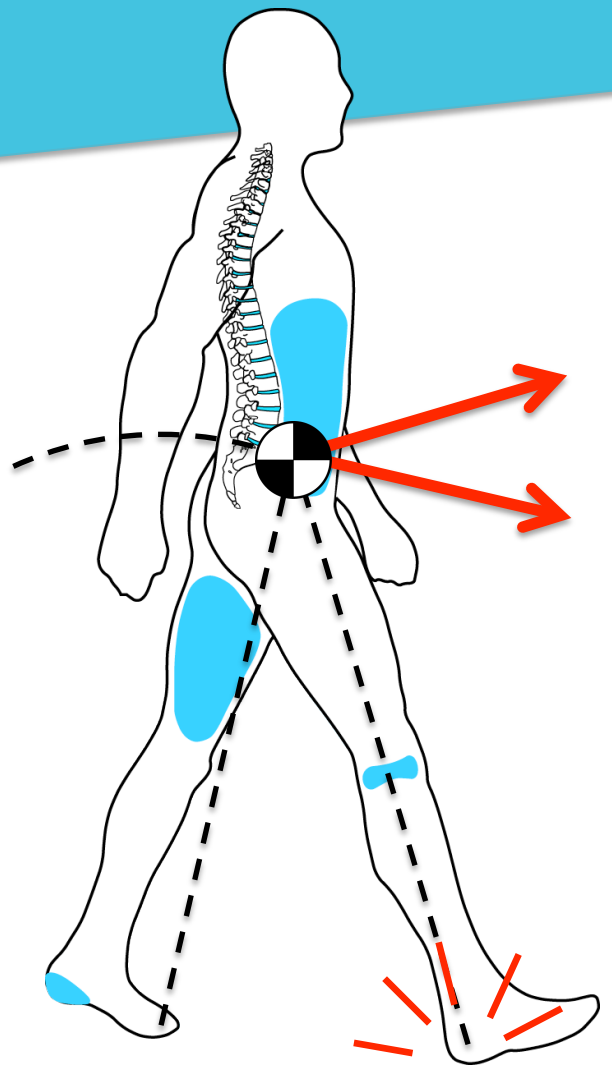


DeVita 2007, Gruber 1998,
Pain 2003

More like Jello than rigid?

youtube.com, bofunk.com

Walking has heelstrike collisions



Hypothesis: Soft tissue work during/after collisions
Increasing with speed

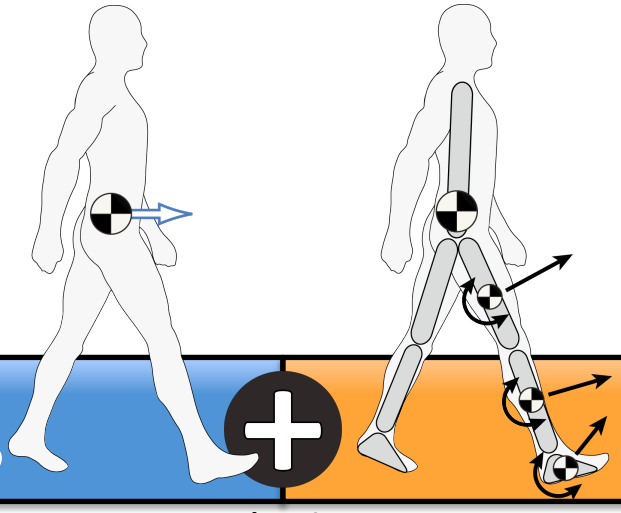
Kuo 2002

Soft tissue work in walking? How much? When?

1) Method for estimating soft tissue power and work

2) Normal walking

"External" power, due to motion of the CoM



"Internal" power, due to motion of segments relative to the CoM

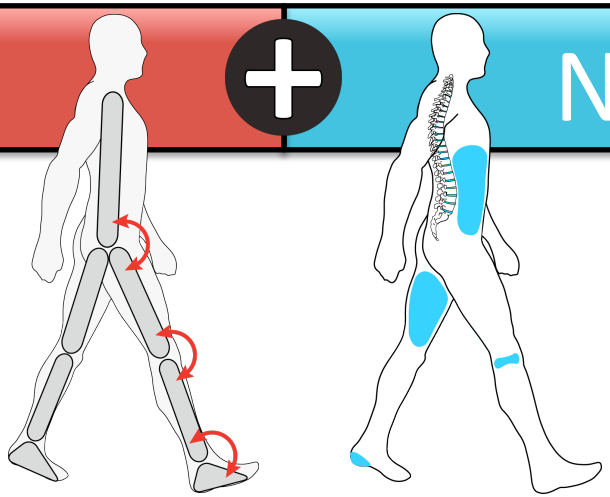
Center-of-Mass + Peripheral

König's Theorem

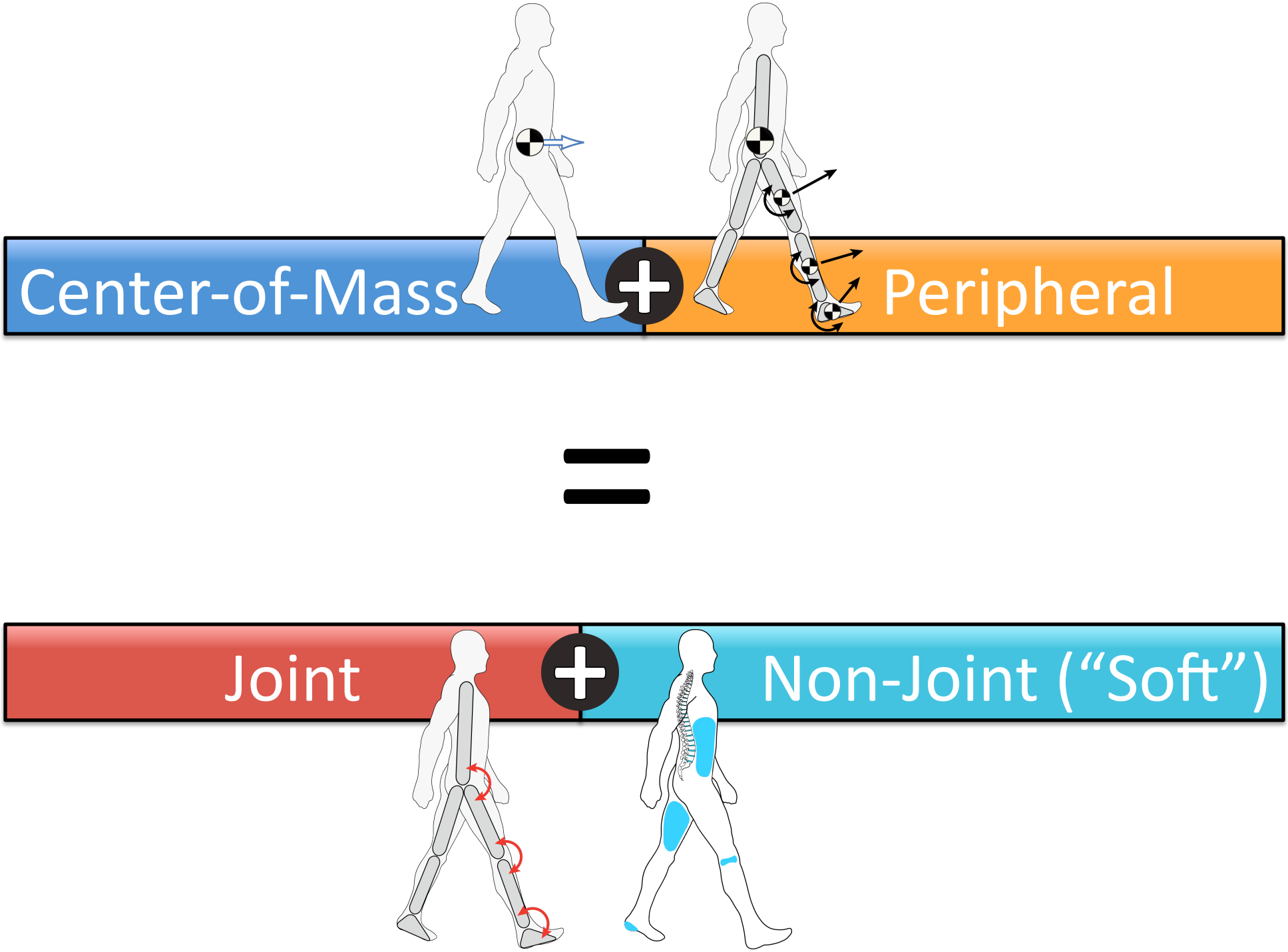
Total Mechanical Power

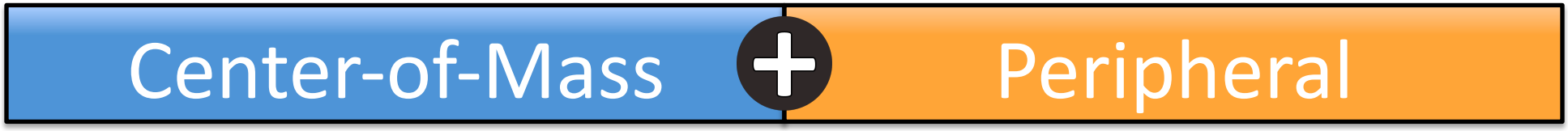
Joint + Non-Joint ("Soft")

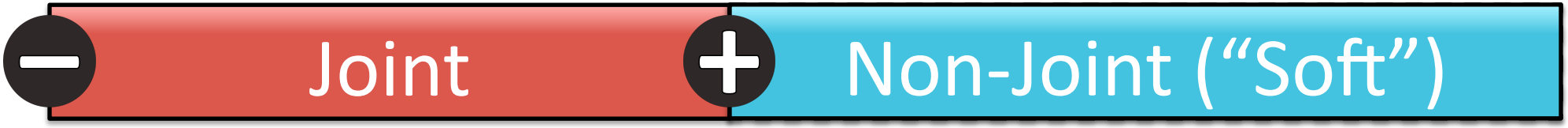
Rotational power due to muscles/tendons (inverse dynamics)



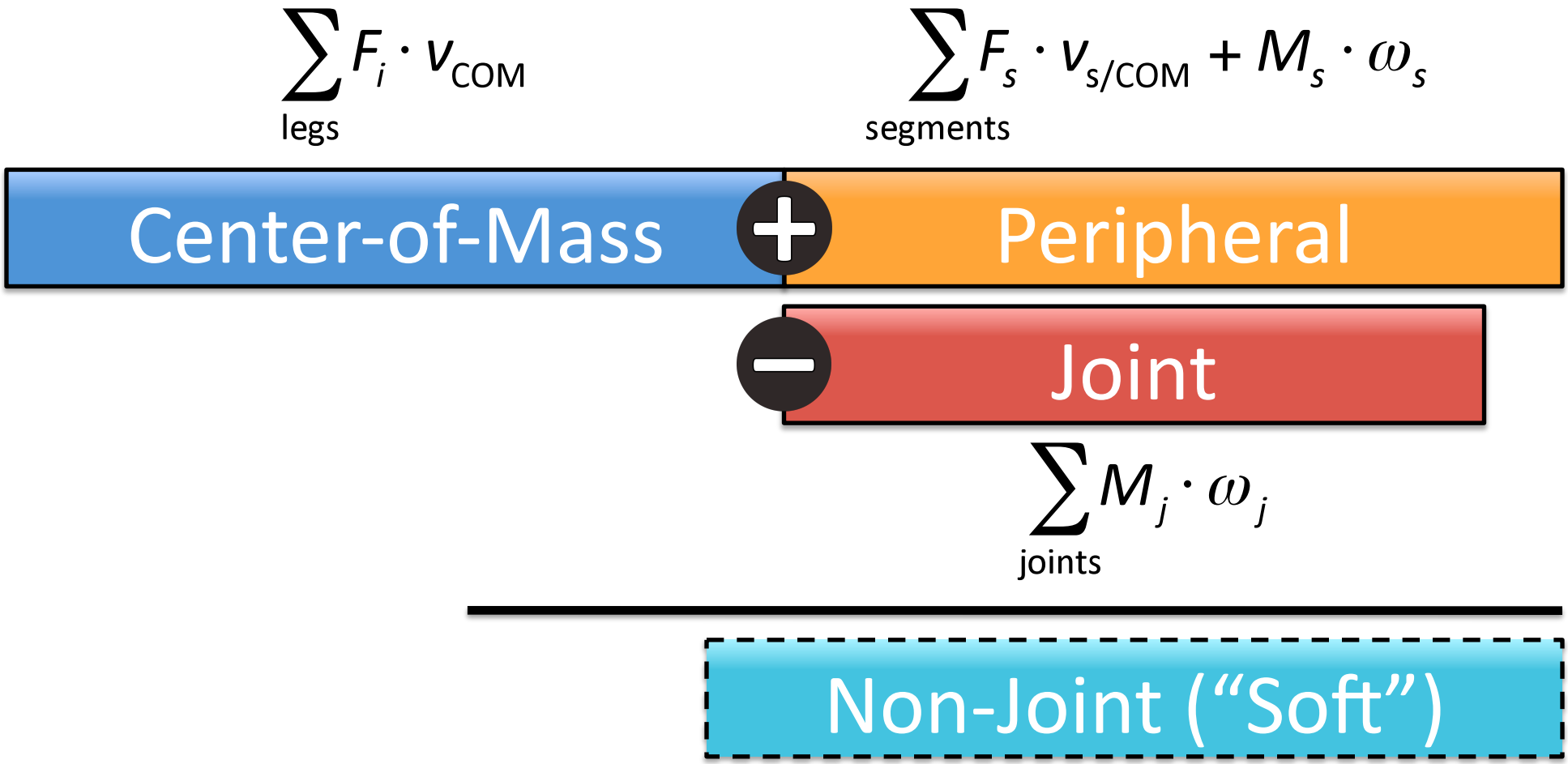
Everything else, notably power due to deformations of non-rigid bodies


Center-of-Mass
Peripheral
Joint
Non-Joint ("Soft")





no direct measure


$\sum_{\text{legs}} F_i \cdot v_{\text{COM}}$
$\sum_{\text{segments}} F_s \cdot v_{\text{s/COM}} + M_s \cdot \omega_s$
Center-of-Mass
+
Peripheral
−
Joint
$\sum_{\text{joints}} M_j \cdot \omega_j$
Non-Joint ("Soft")

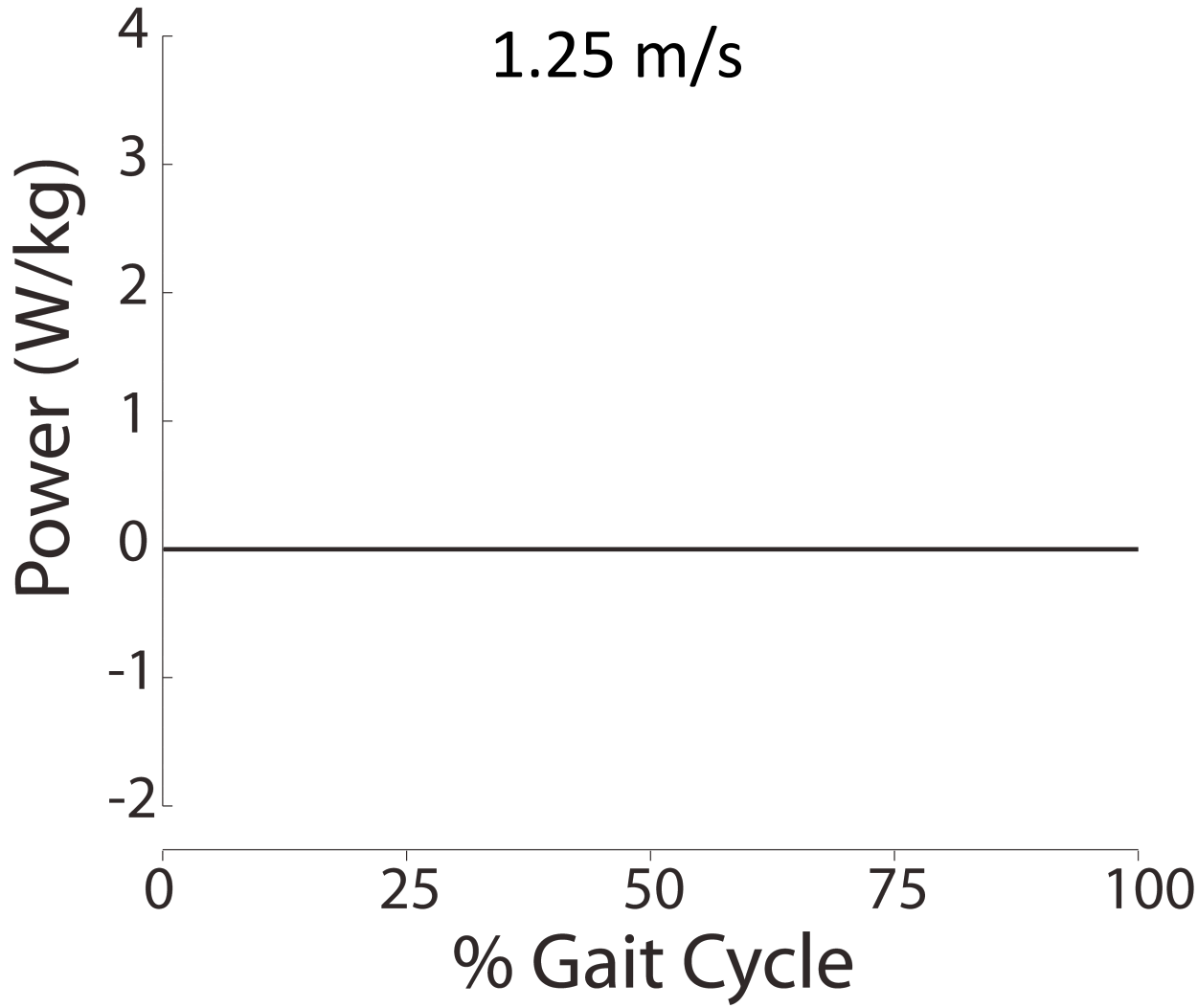
Center-of-Mass | Peripheral

Walking Experiment

- Young, healthy adults (*N*=10)
- Speeds 0.7 – 2.0 m/s
- Instrumented treadmill
- Collected forces & kinematics

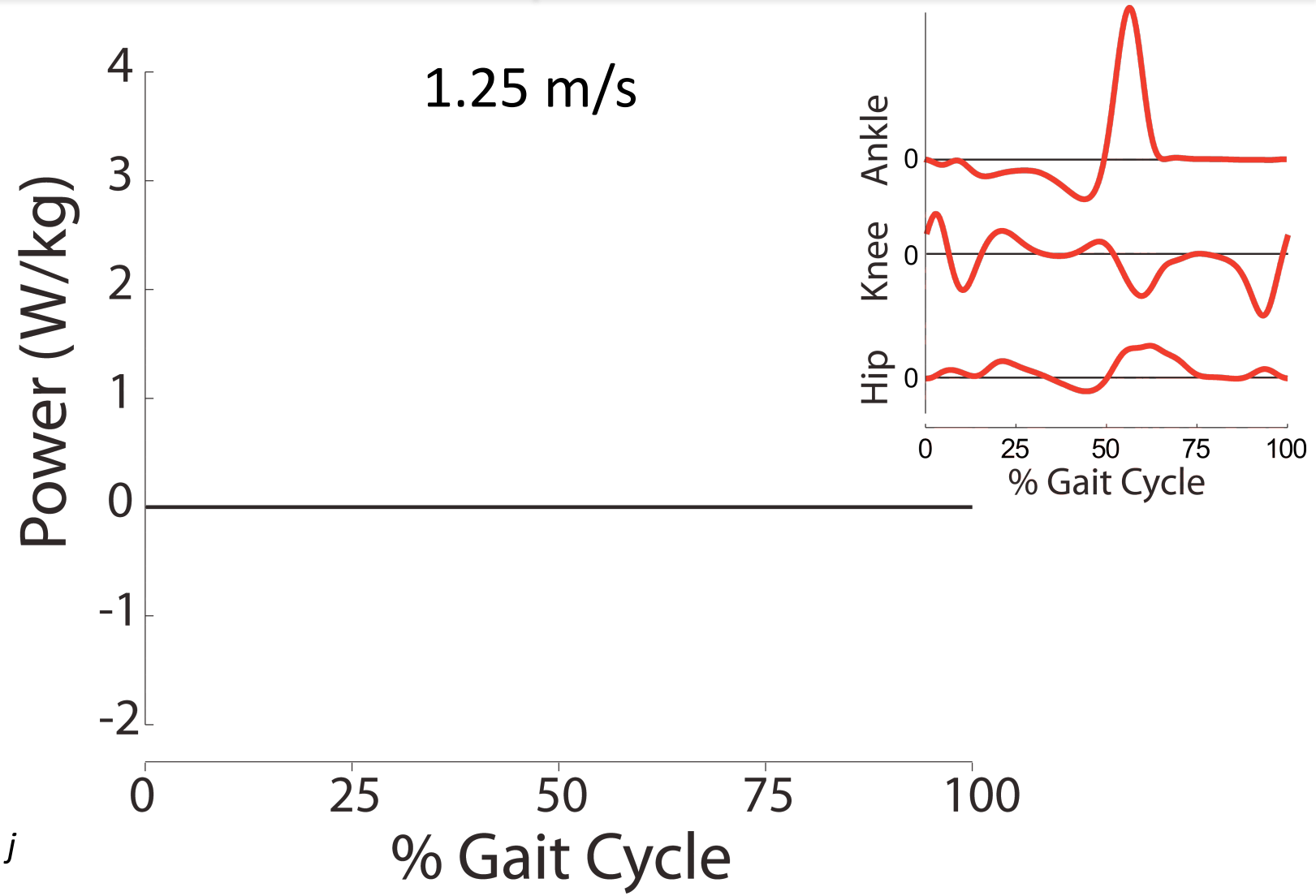
Joint | Non-Joint ("Soft")

Center-of-Mass | Peripheral



Joint | Non-Joint ("Soft")

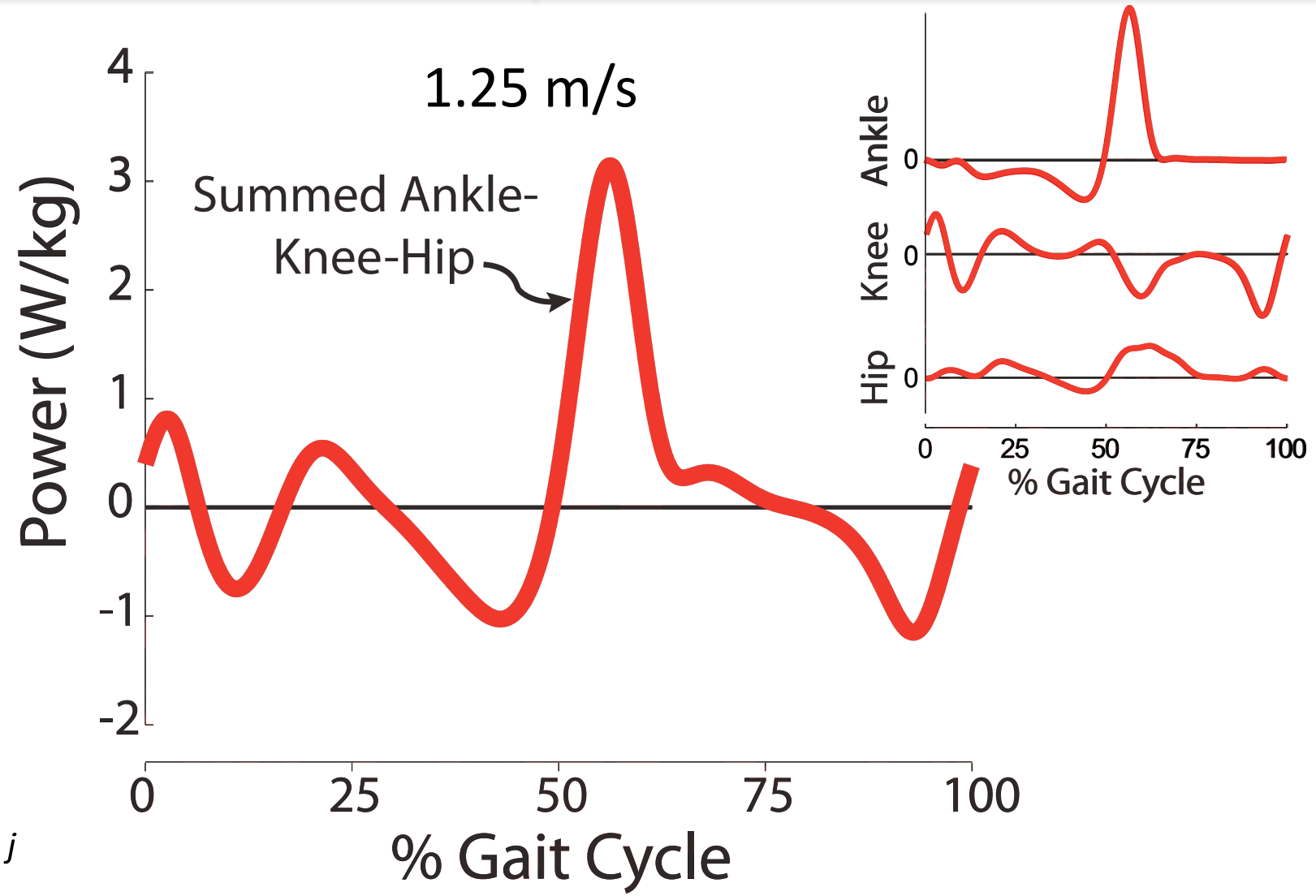
Center-of-Mass | Peripheral



$$\sum_{\text{joints}} M_j \cdot \omega_j$$

Joint | Non-Joint ("Soft")

Center-of-Mass | Peripheral

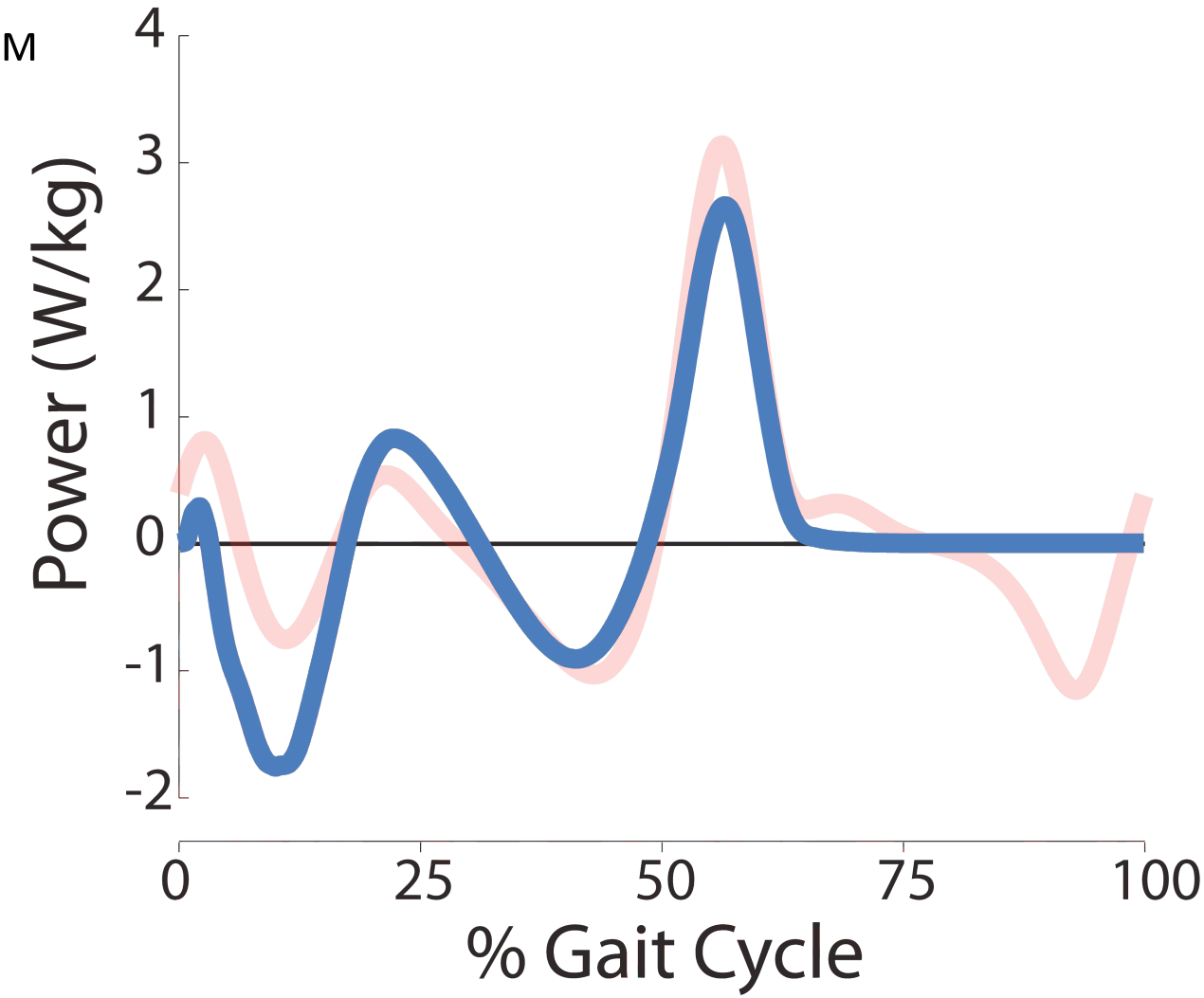


$$\sum_{\text{joints}} M_j \cdot \omega_j$$

Joint | Non-Joint ("Soft")

Center-of-Mass | Peripheral

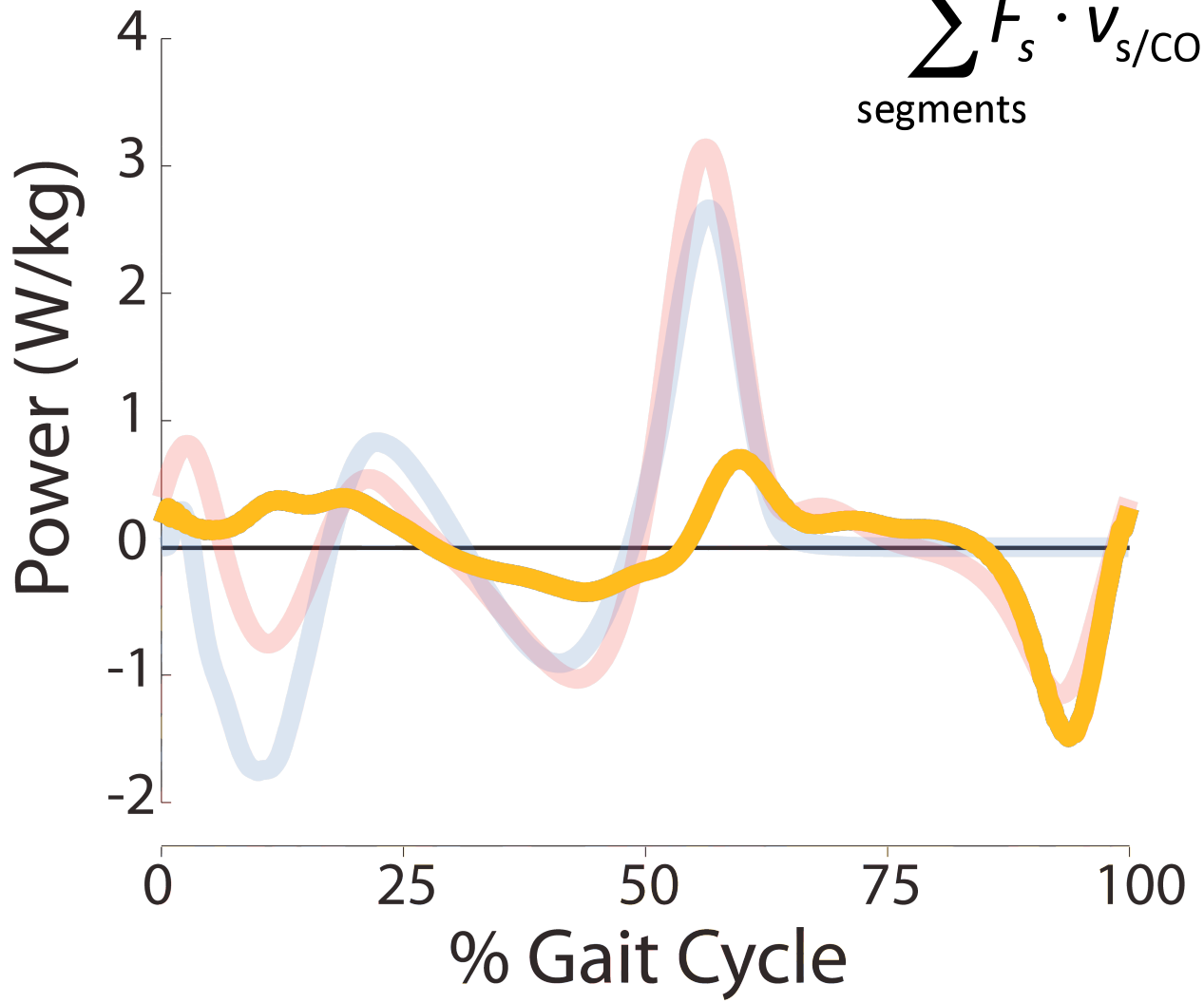
$$\sum_{\text{legs}} F_i \cdot v_{\text{COM}}$$



Joint | Non-Joint ("Soft")

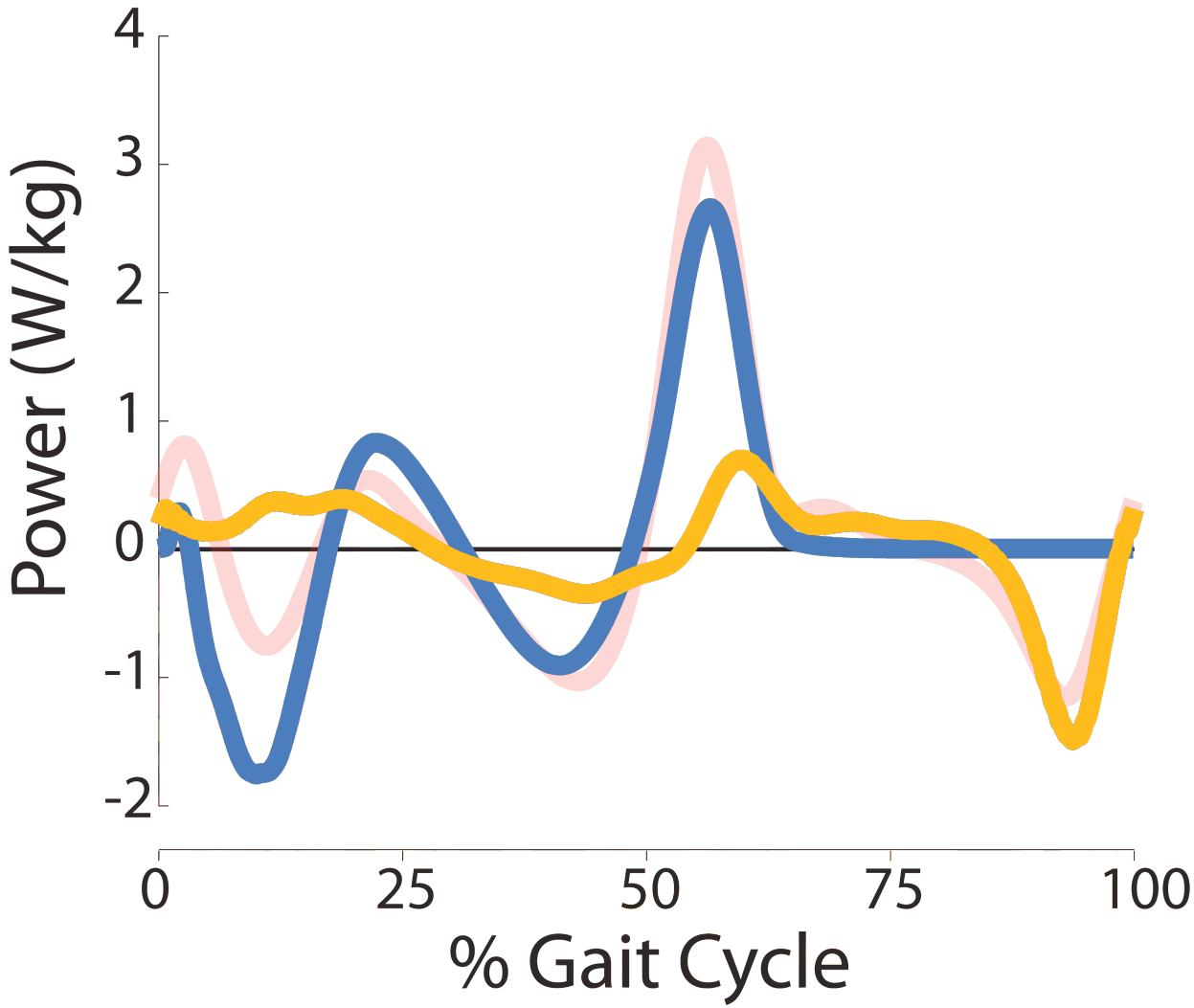
Center-of-Mass | Peripheral

$$\sum_{\text{segments}} F_s \cdot v_{s/\text{COM}} + M_s \cdot \omega_s$$



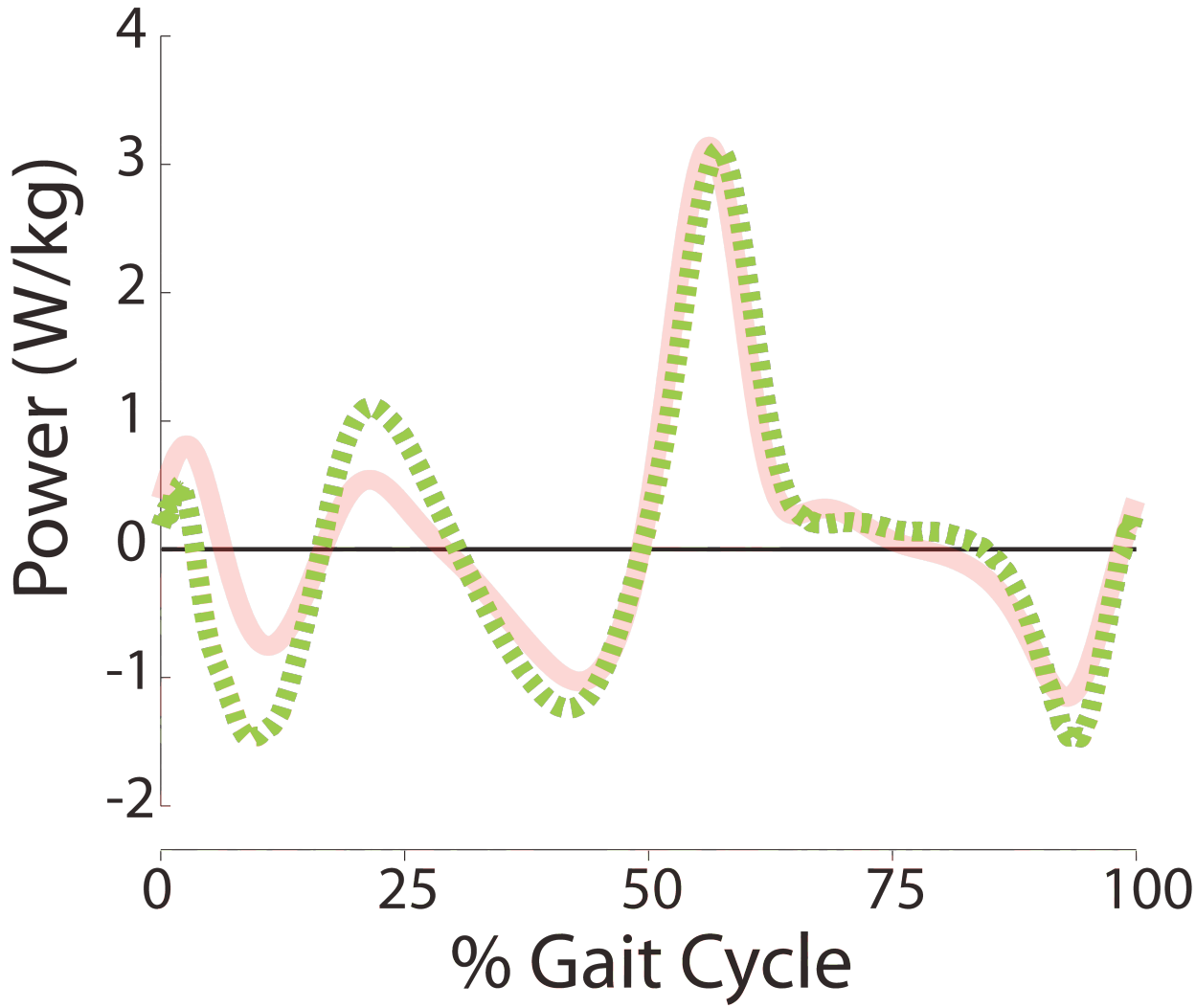
Joint | Non-Joint ("Soft")

Center-of-Mass + Peripheral



Joint | Non-Joint ("Soft")

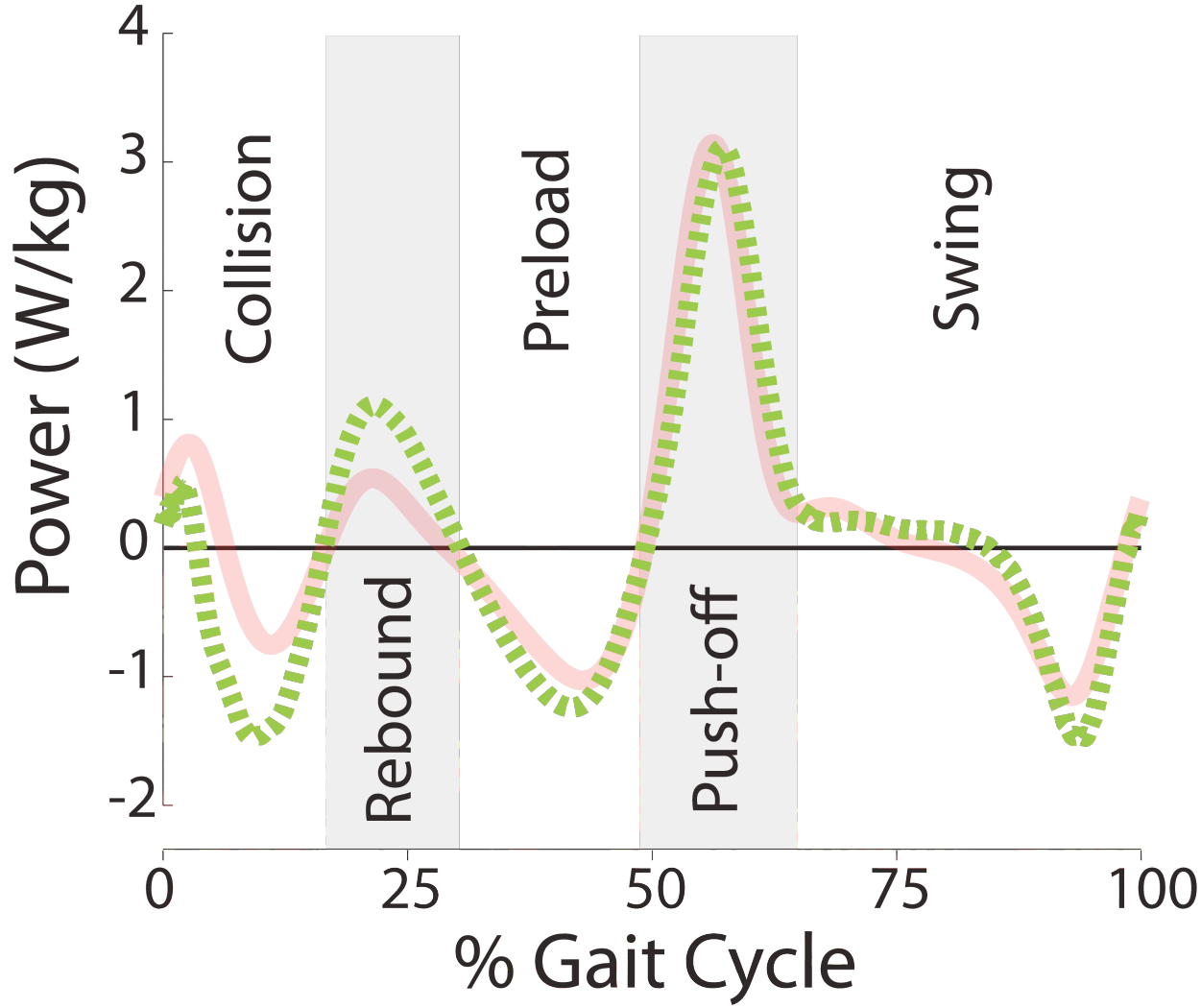
Total Mechanical Power



Joint

Non-Joint ("Soft")

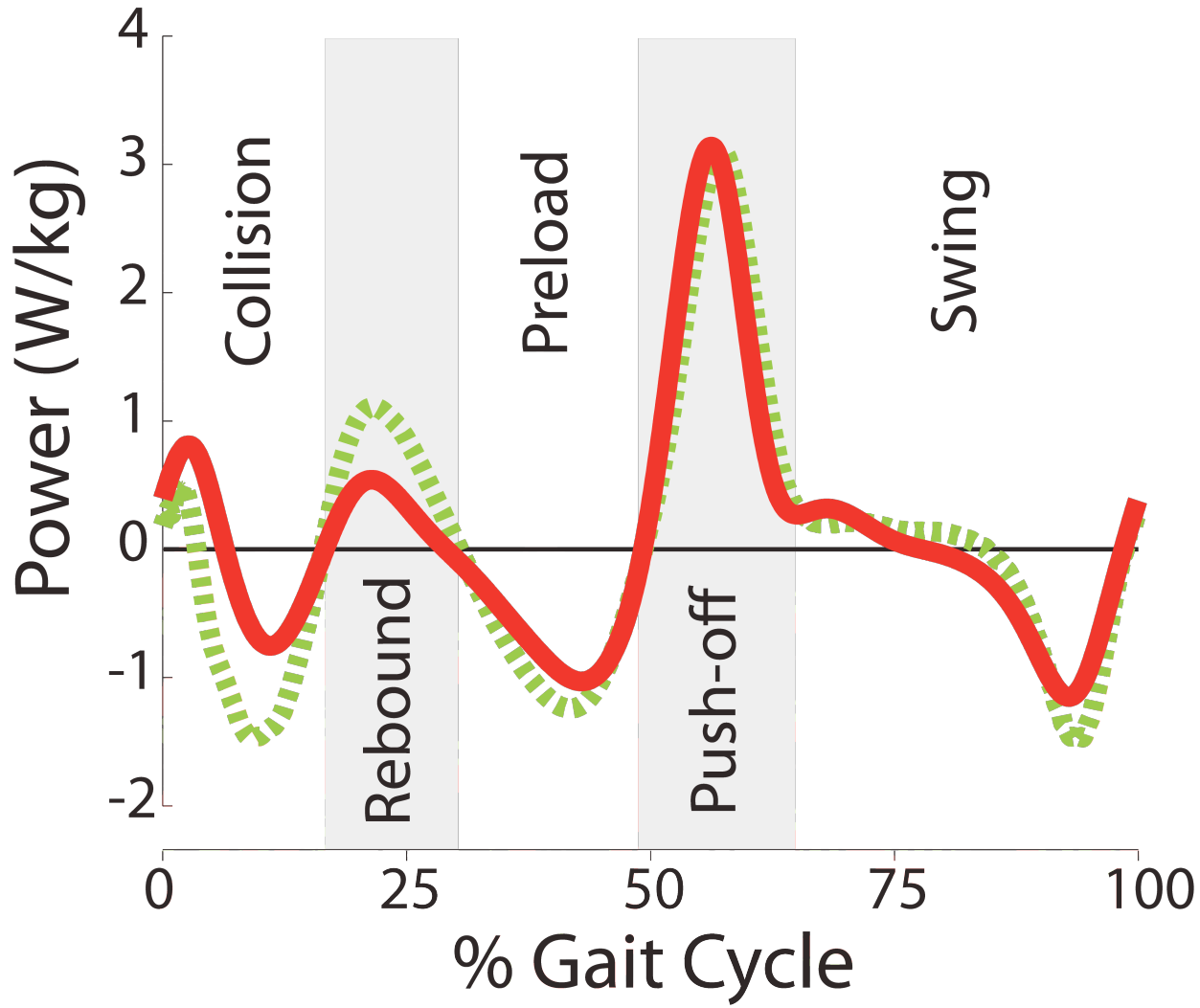
Total Mechanical Power



Joint

Non-Joint ("Soft")

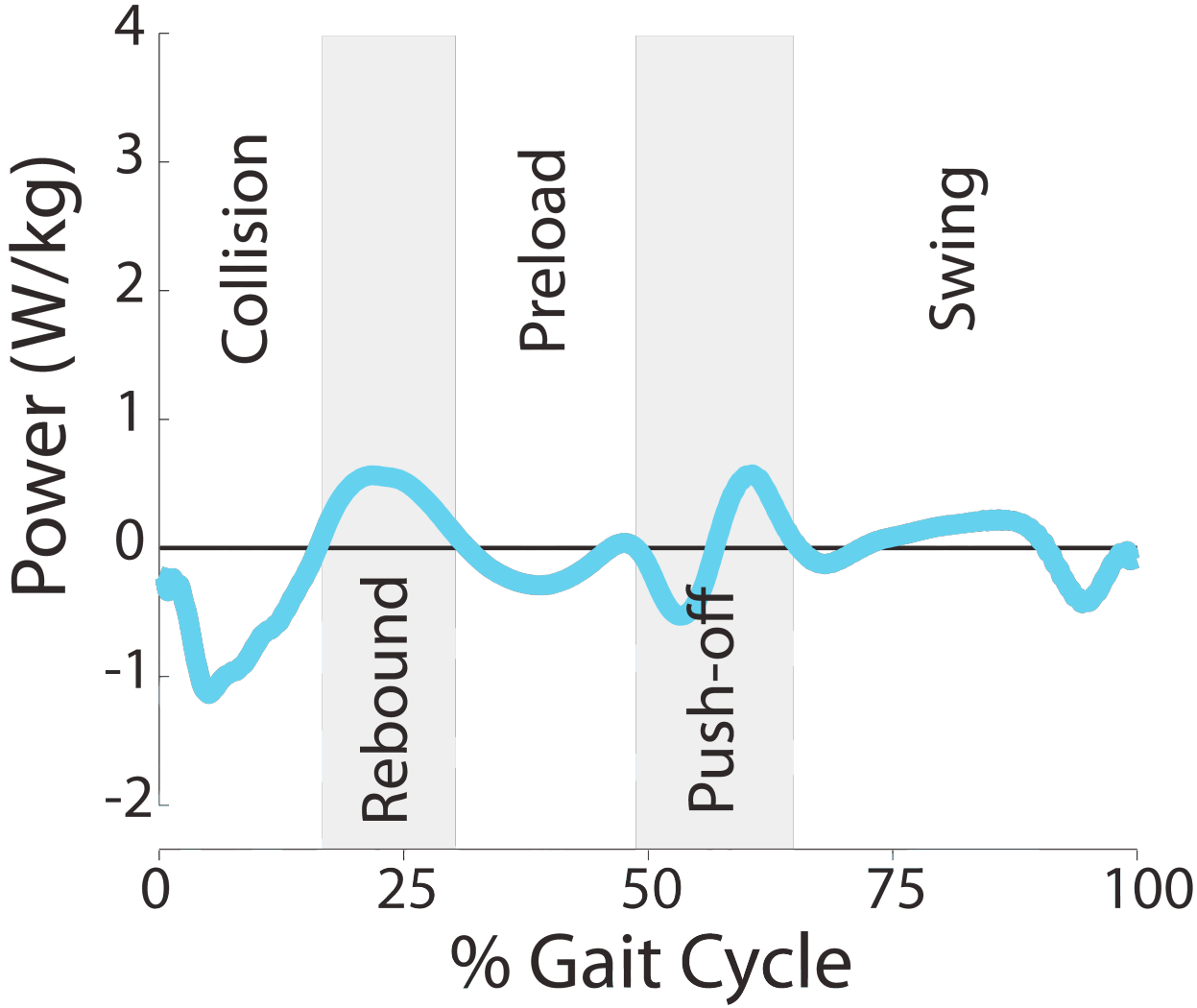
Total Mechanical Power



Joint

Non-Joint ("Soft")

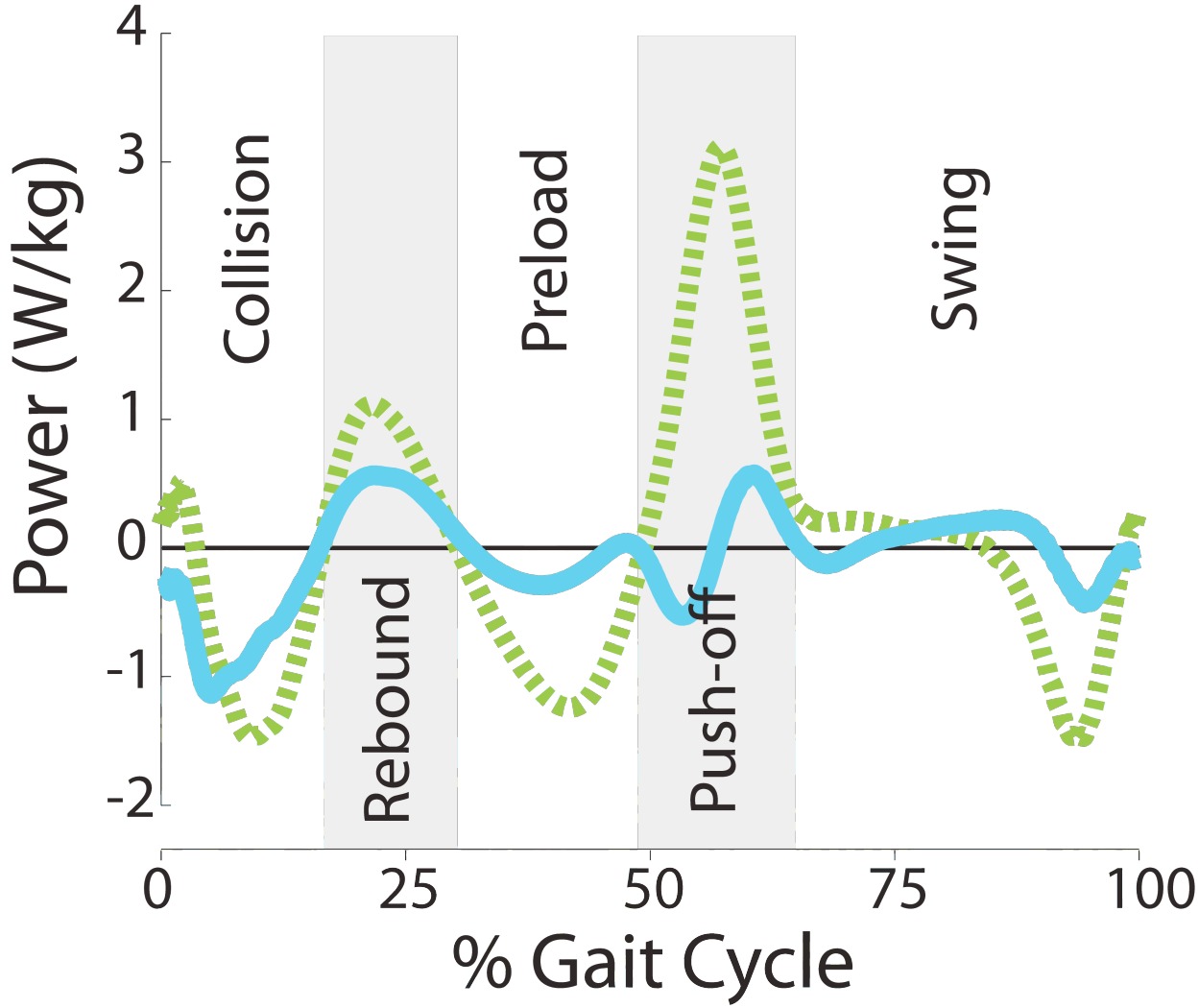
Total Mechanical Power



Joint

Non-Joint ("Soft")

Total Mechanical Power



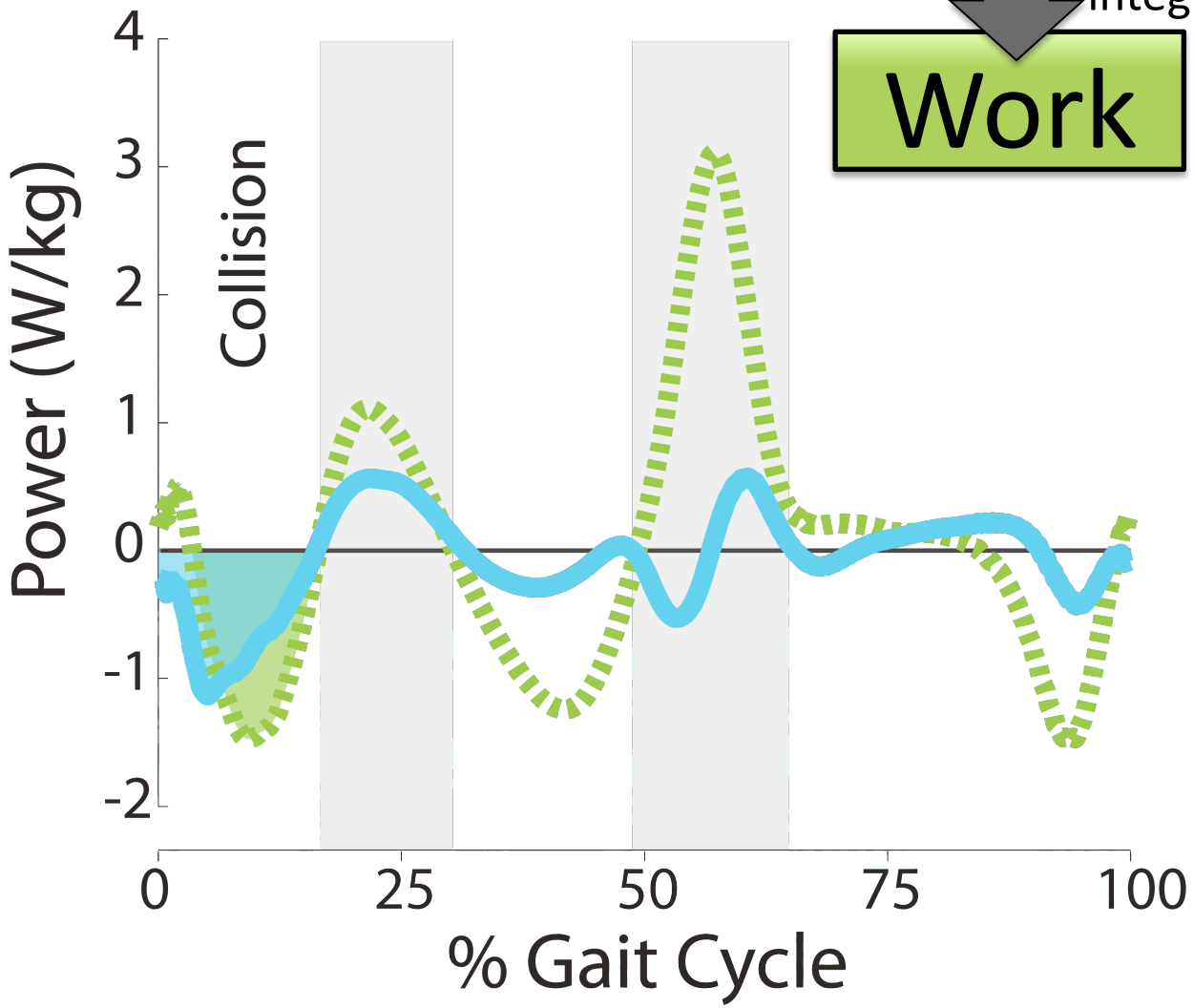
Joint

Non-Joint ("Soft")

Total Mechanical Power

integrate over time

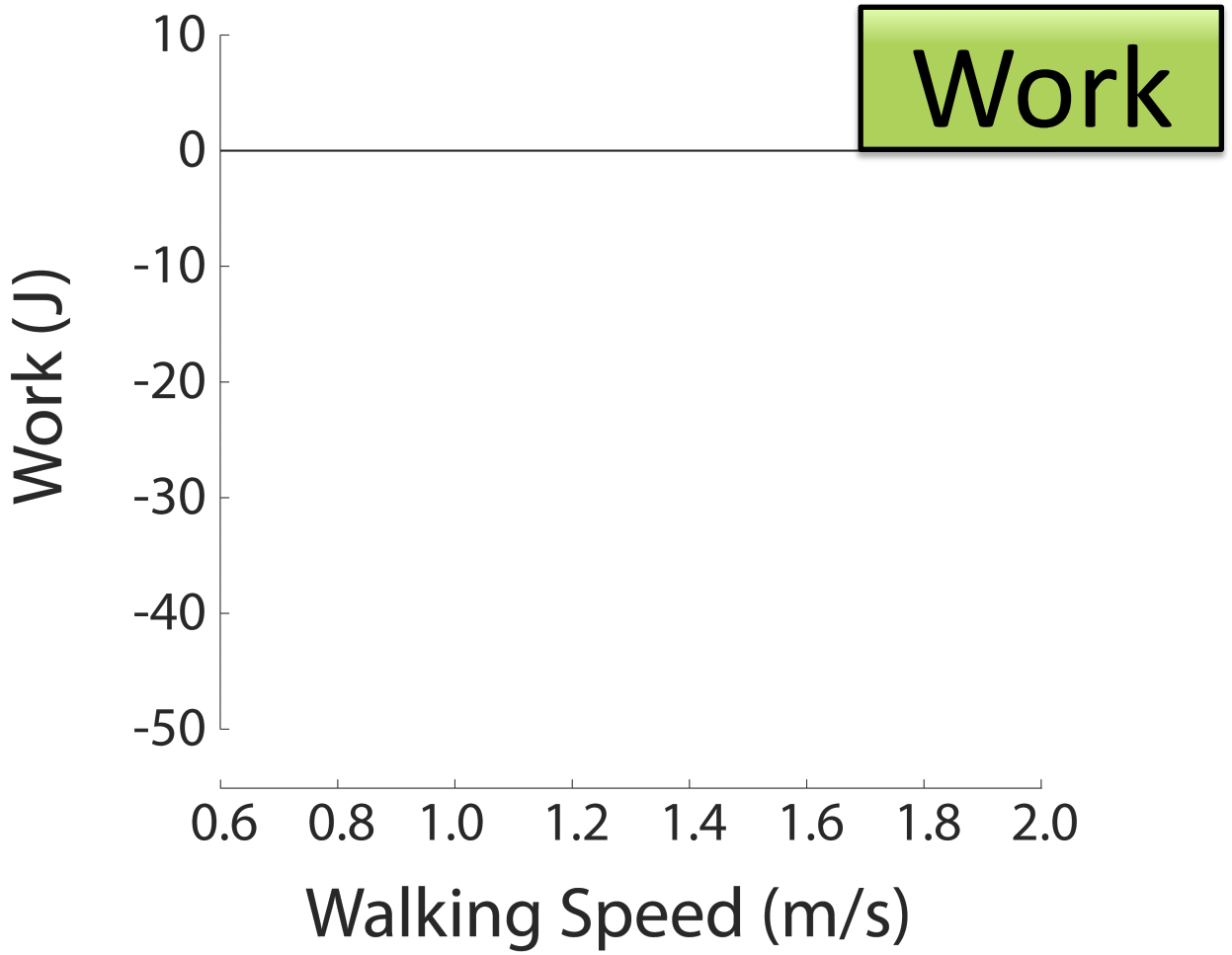
Work



Joint

Non-Joint ("Soft")

Negative Collision Work

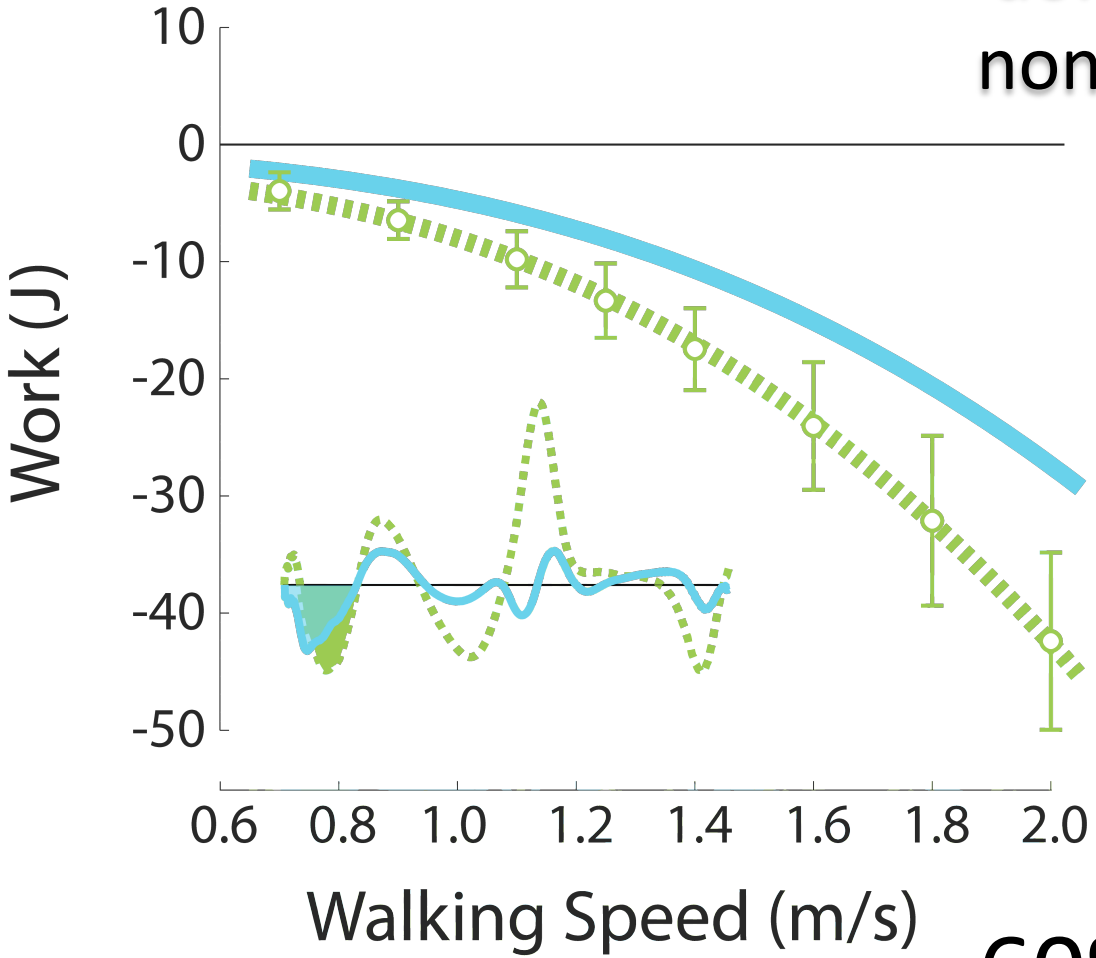


Joint

Non-Joint ("Soft")

Negative Collision Work

dominated by non-joint work



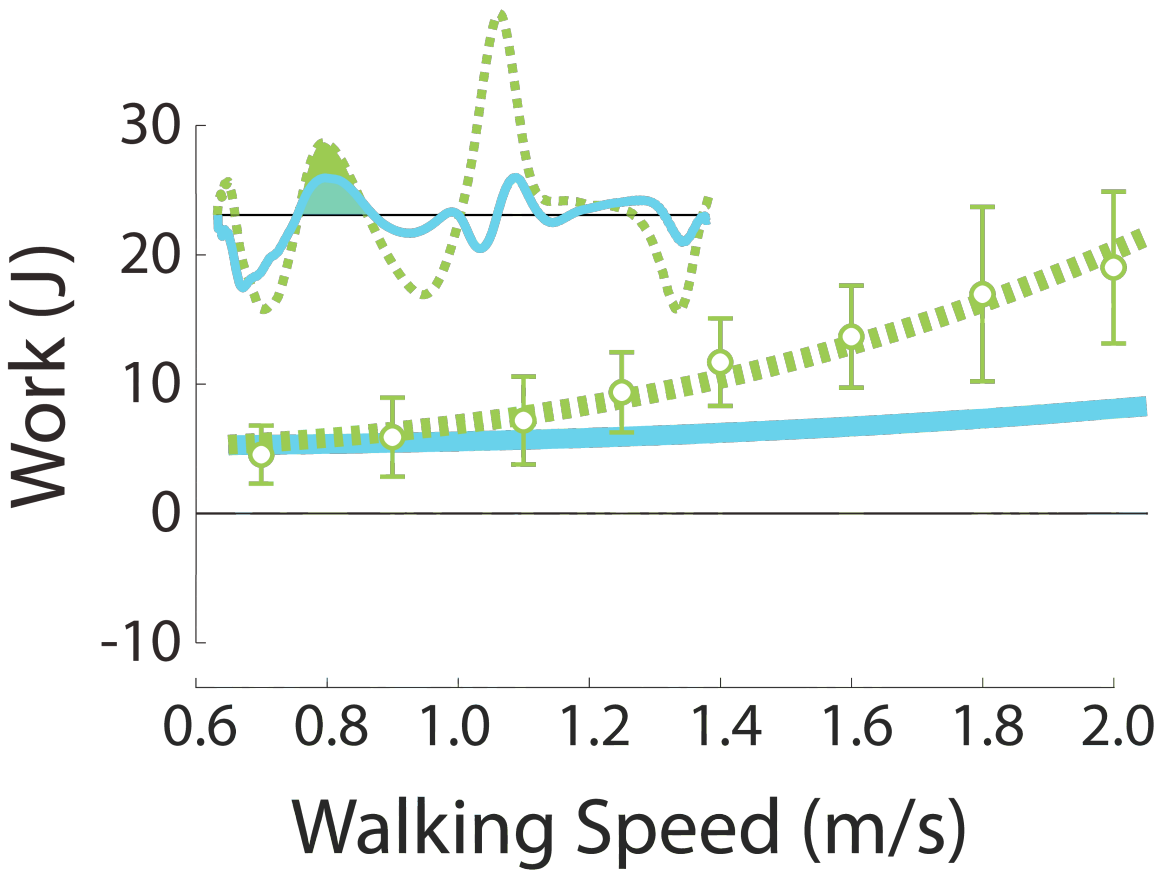
60%

Joint

Non-Joint ("Soft")

Positive Rebound Work

damped elastic rebound of soft tissues?



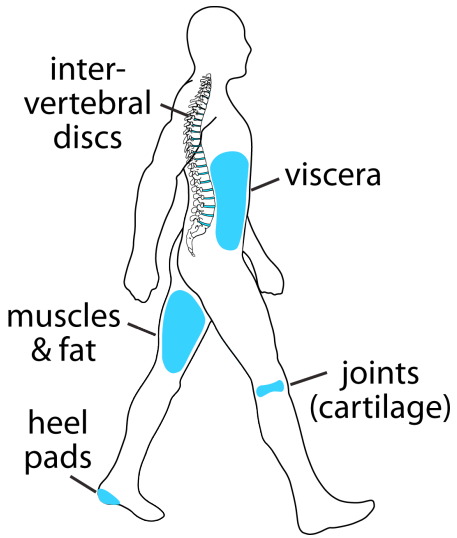
Joint

Non-Joint ("Soft")

Center-of-Mass | Peripheral

Limitations

- Indirect estimate
- Soft tissue work loosely defined as non-joint
- No indication of where work is done



Joint | Non-Joint ("Soft")

Center-of-Mass | Peripheral

Soft Tissue…

- Power estimated from GRFs and kinematics
- 60% of collision work in walking
- Not only dissipative, ~5-8 J elastic rebound

Joint | Non-Joint (“Soft”)

Thanks

*There is a **collision** in gait*
when the foot hits the ground and bears weight.
Joint work measures miss
three-fifths of the squish,
*which **soft tissues** perhaps **dissipate**.*

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