# Quantifying Physical Interface Dynamics

## Human-Prosthesis & Human-Exoskeleton Power Transmission

Karl E. Zelik
Biomechanics & Assistive Technology Lab
Vanderbilt University, Nashville, TN, USA

PROBLEM

# A poor transmission can ruin performance

2008 Smart ForTwo (ranked 34th worst car of all-time)

*"Not bad-looking, but unpleasant to drive in every conceivable way. May have the most annoying transmission ever made."*

– Edmunds.com

PROBLEM

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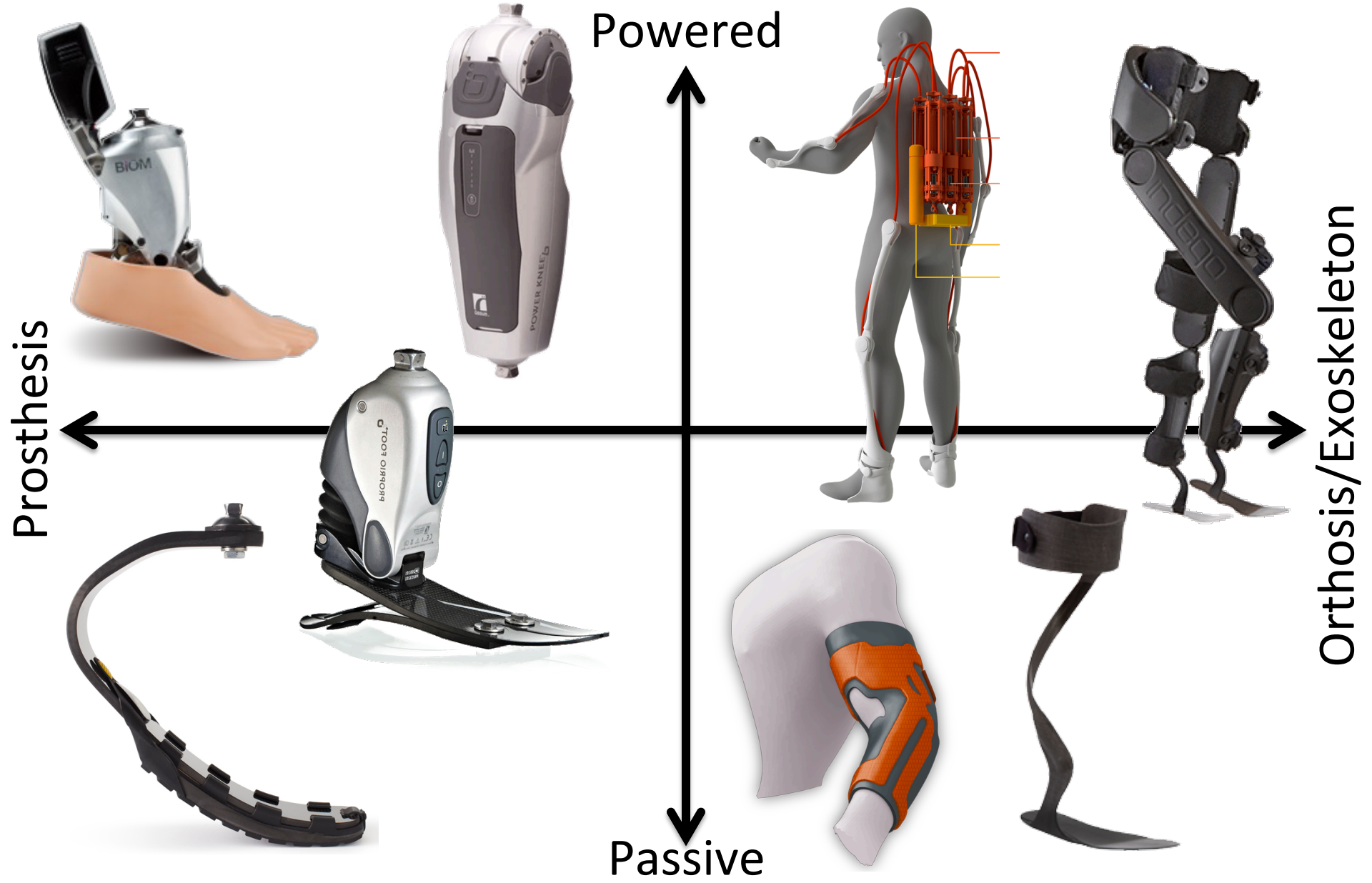

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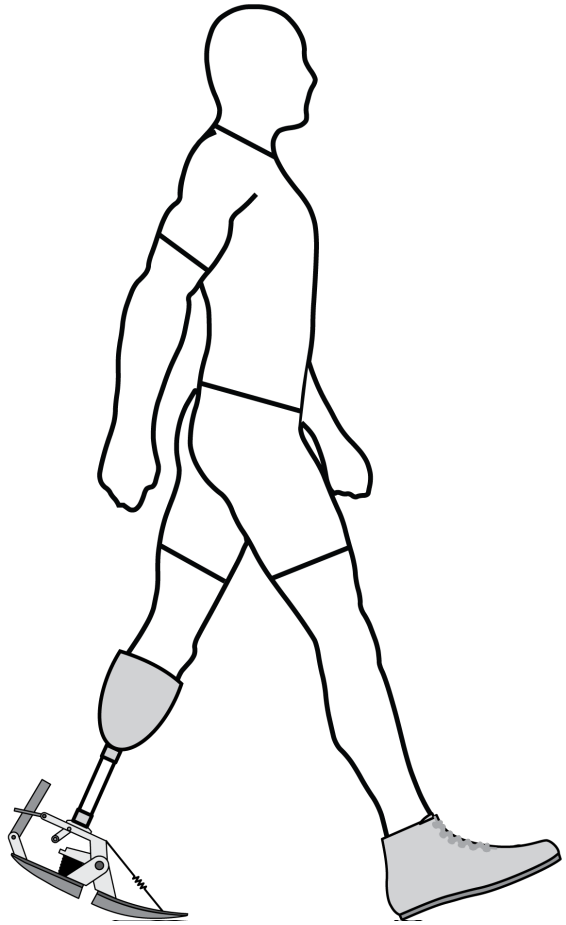

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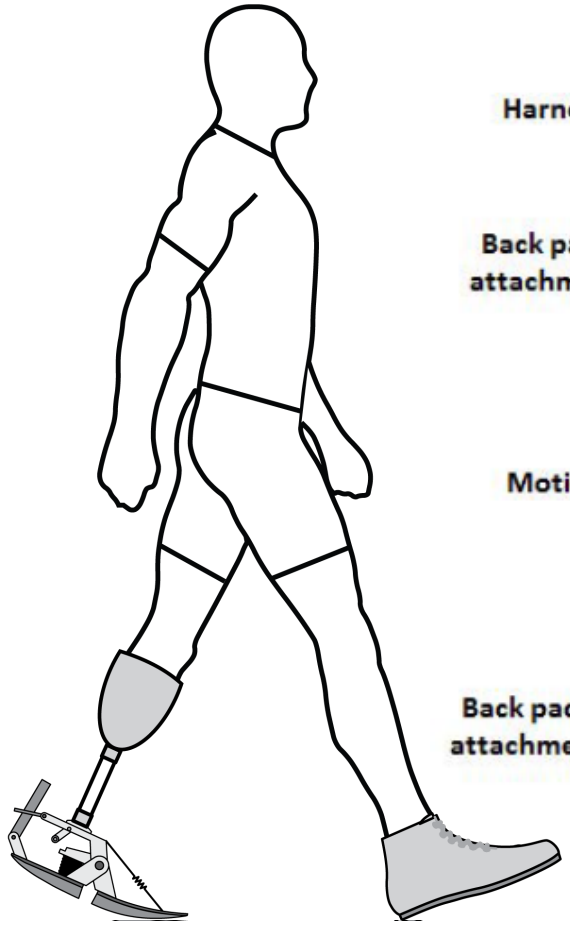

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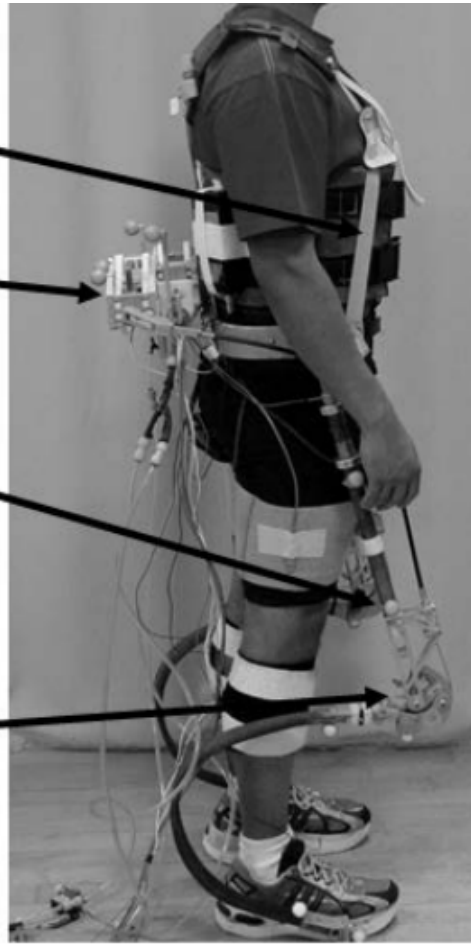


**Running Exoskeleton**
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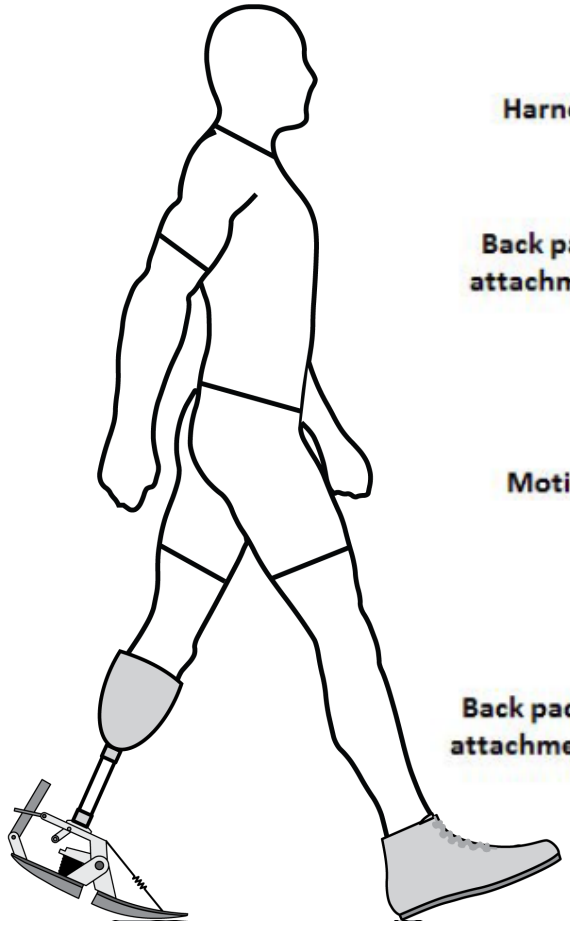

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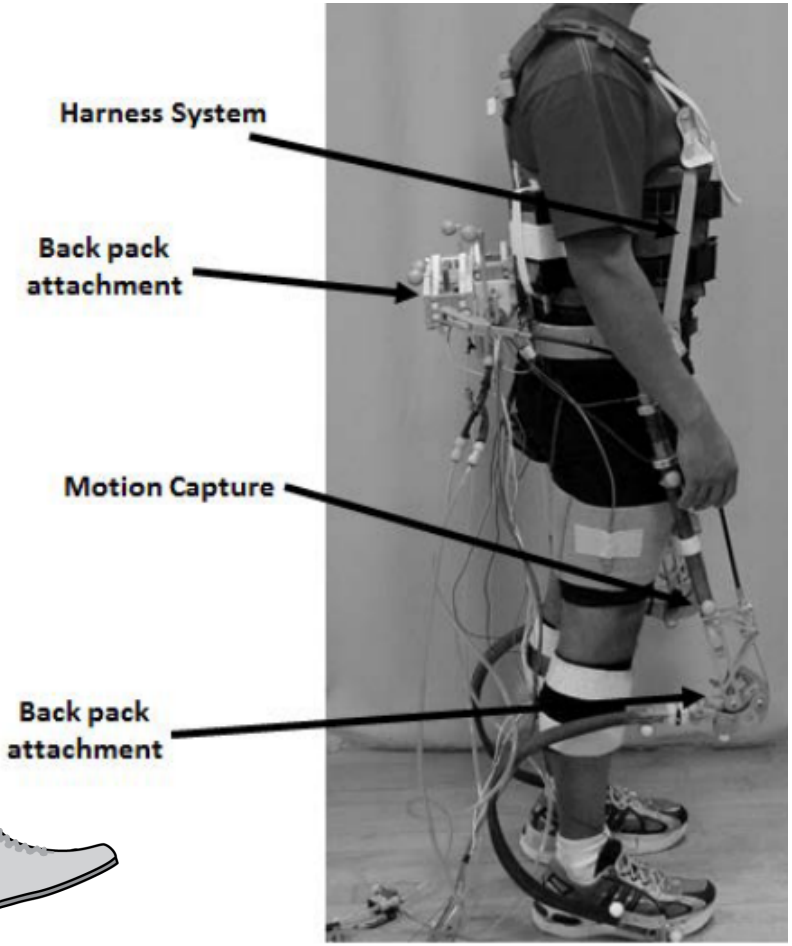


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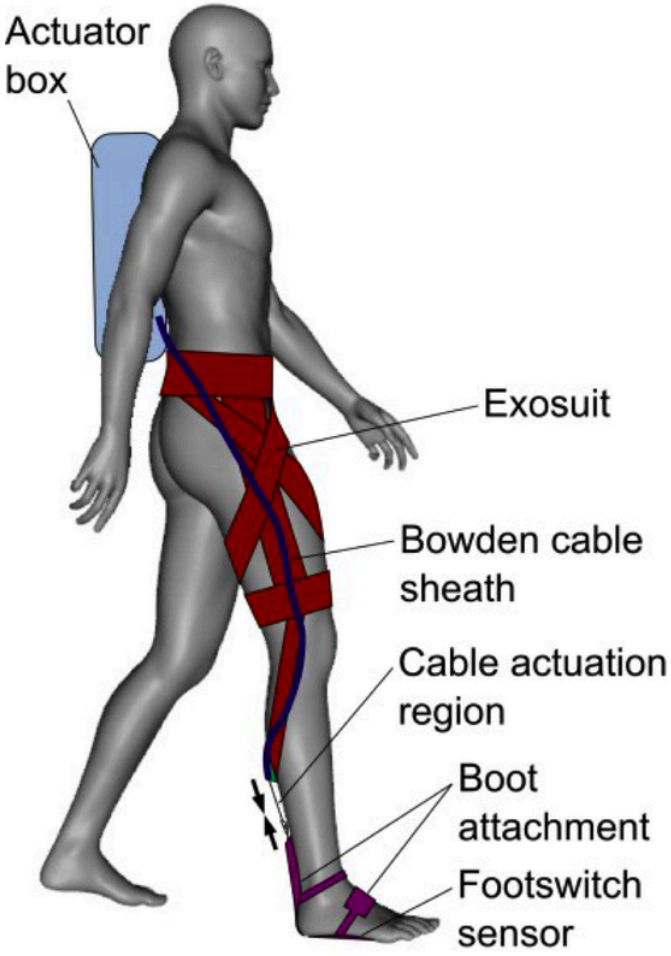
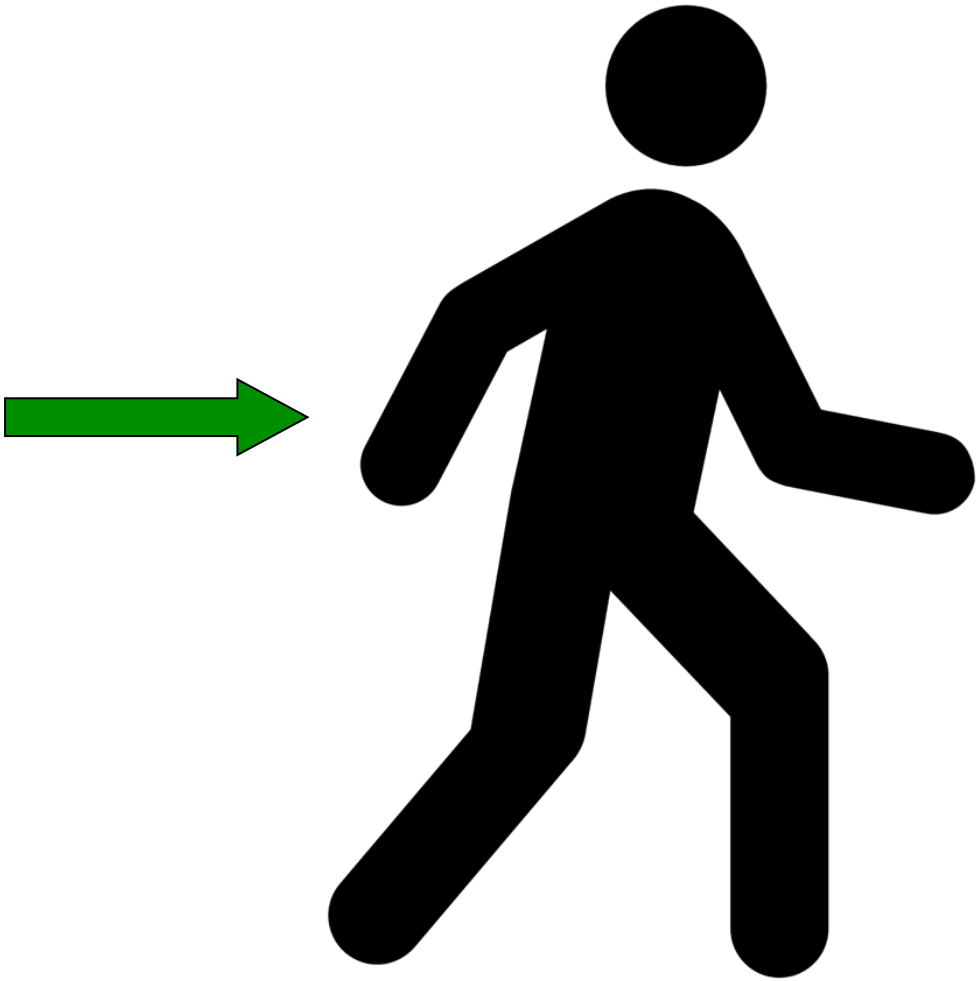



**Soft Exosuit**
(Asbeck et al. 2014)

# Imagine being pushed from behind while walking



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Can reduce metabolic cost, making it easier to walk (Gottschall & Kram 2003)

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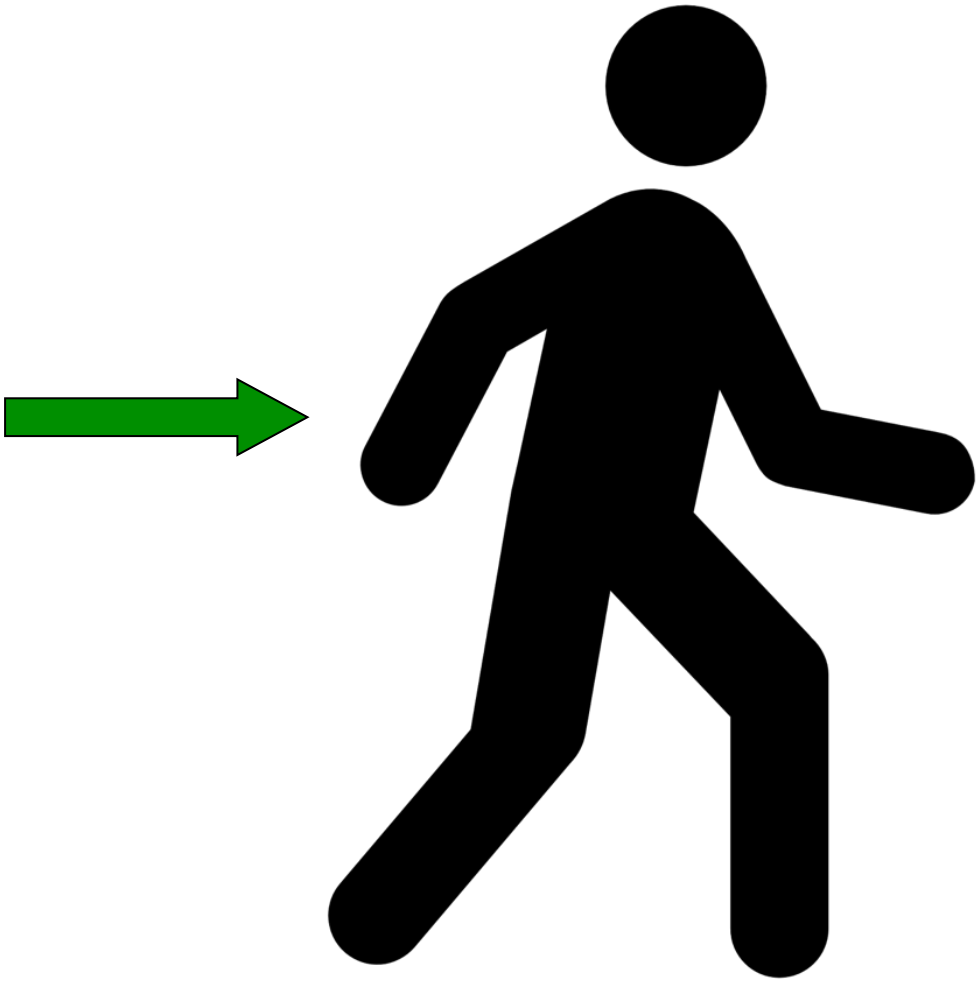

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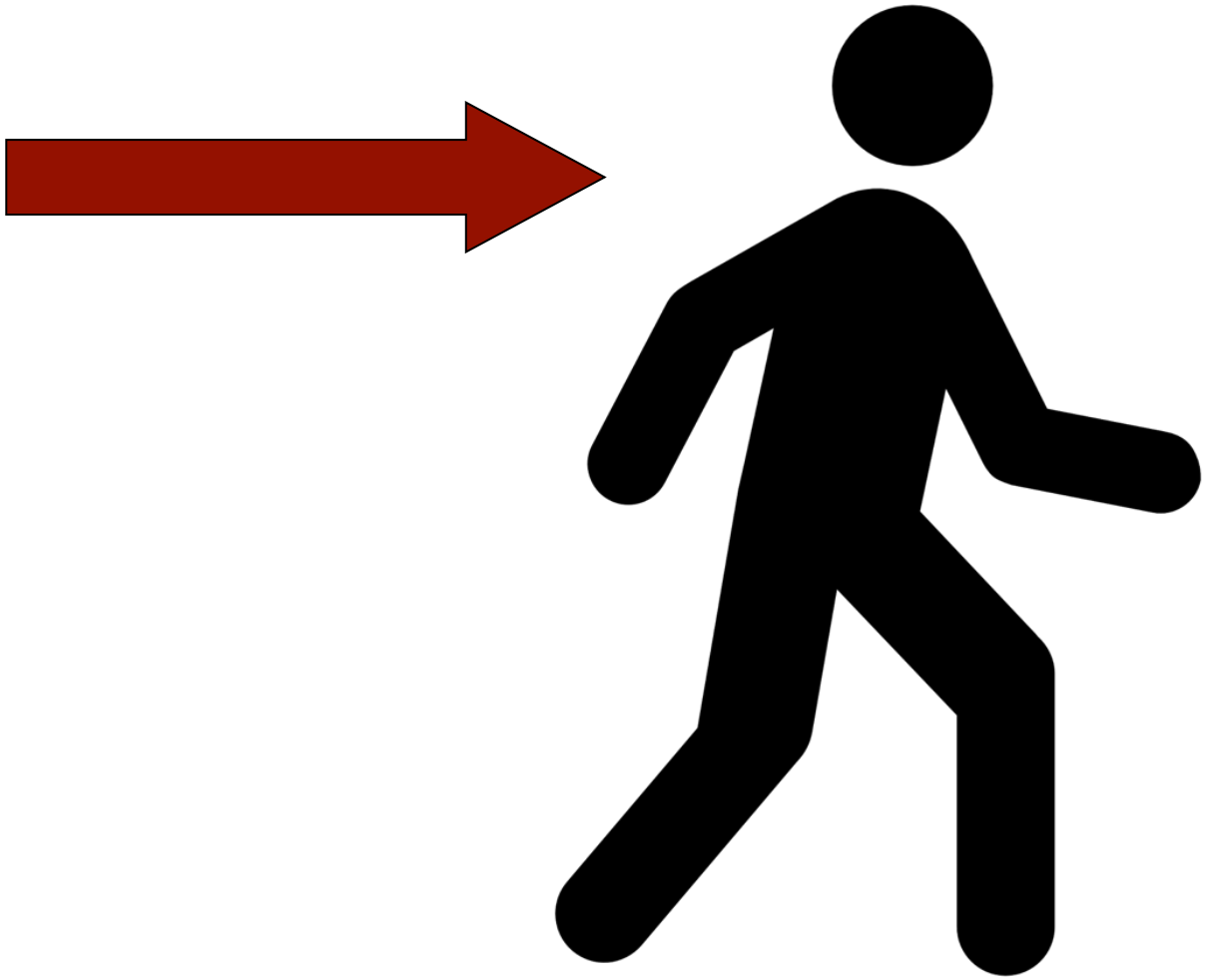

Extraneous Motion

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Extraneous Motion

## How Can Body Receive Power?

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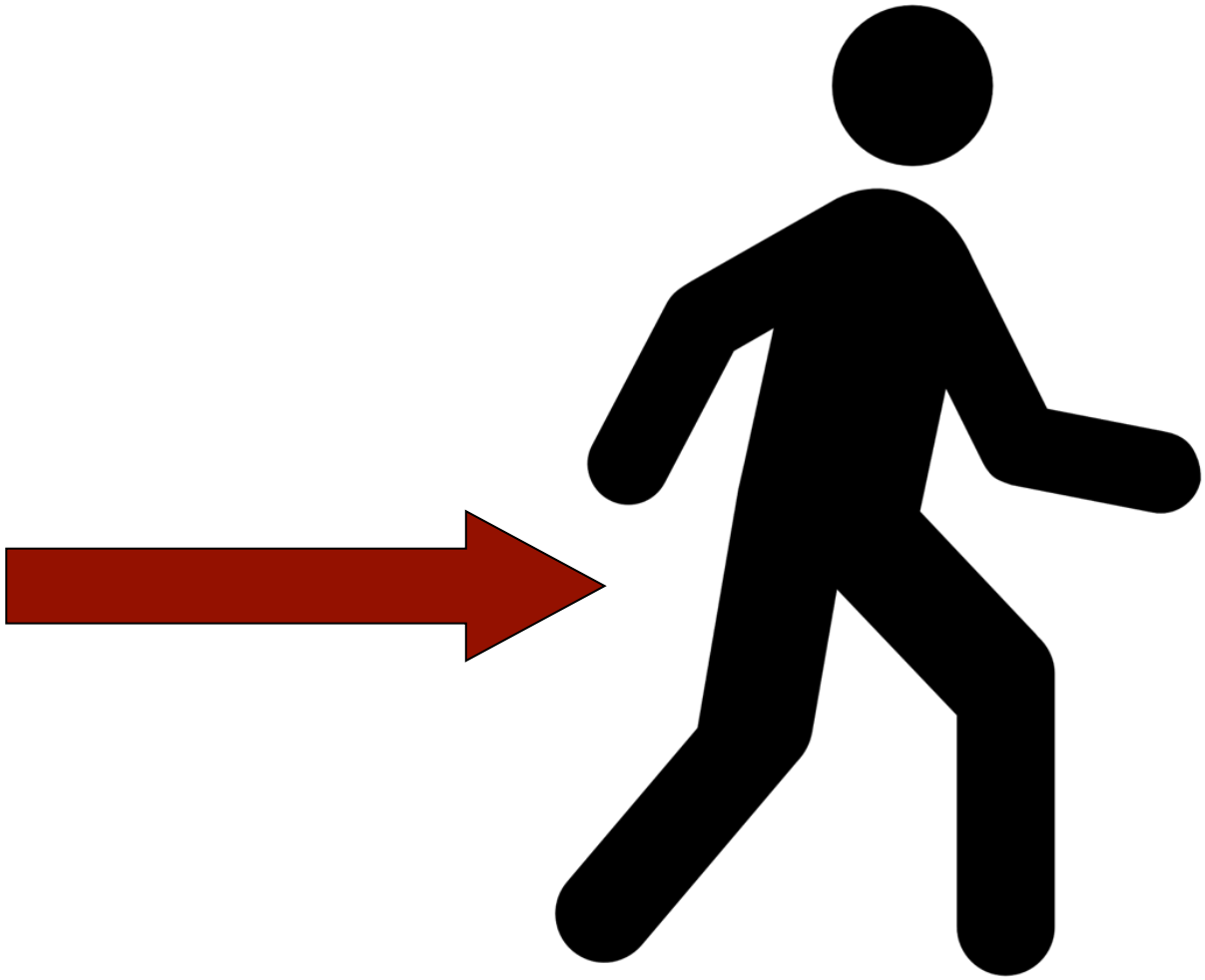
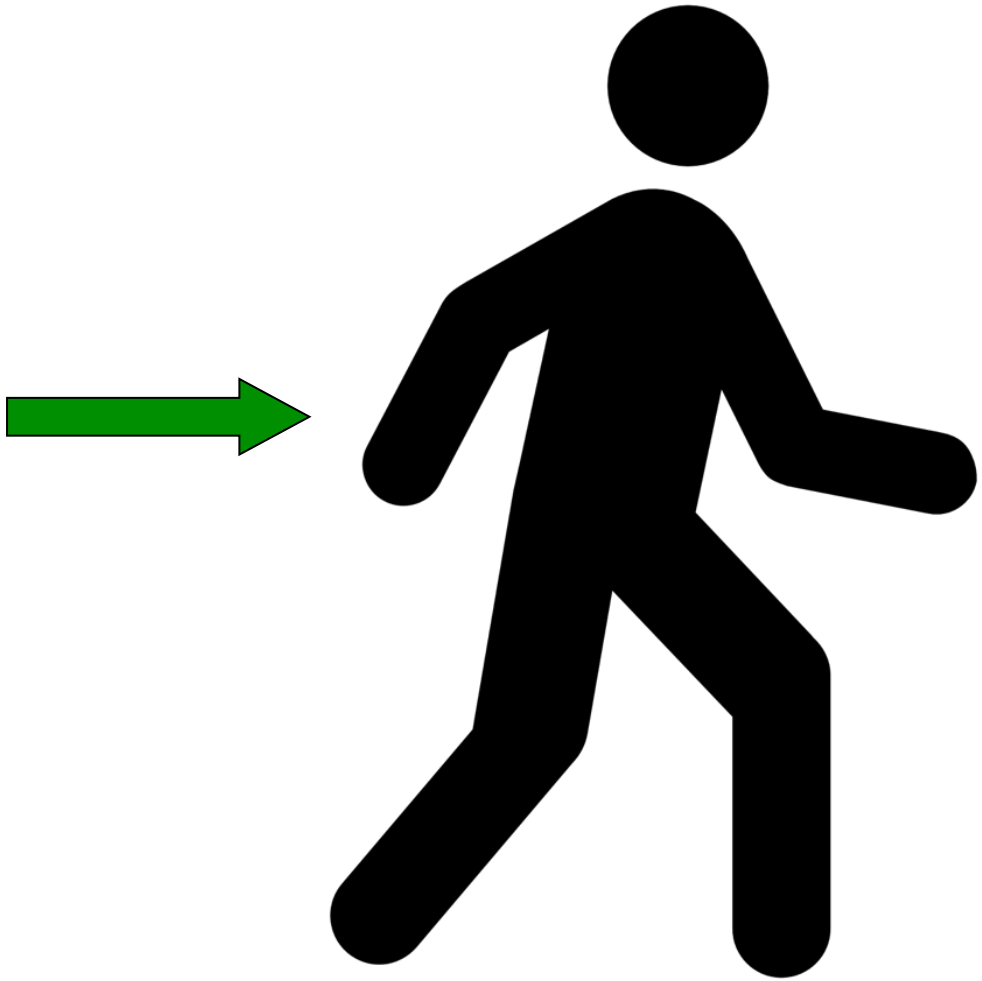


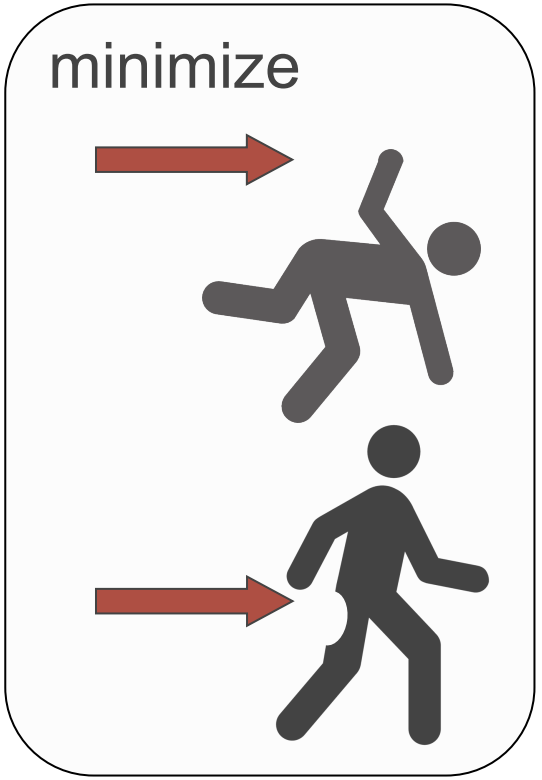
## Extraneous Motion

(soft tissue deformation)

# Goal: maximize useful power, minimize extraneous

Key Question: How can we measure effectiveness of power transmission?





# Estimating power transmission in soft exosuits

Harvard Exosuit

SRI SuperFlex

ETHZ MAXX

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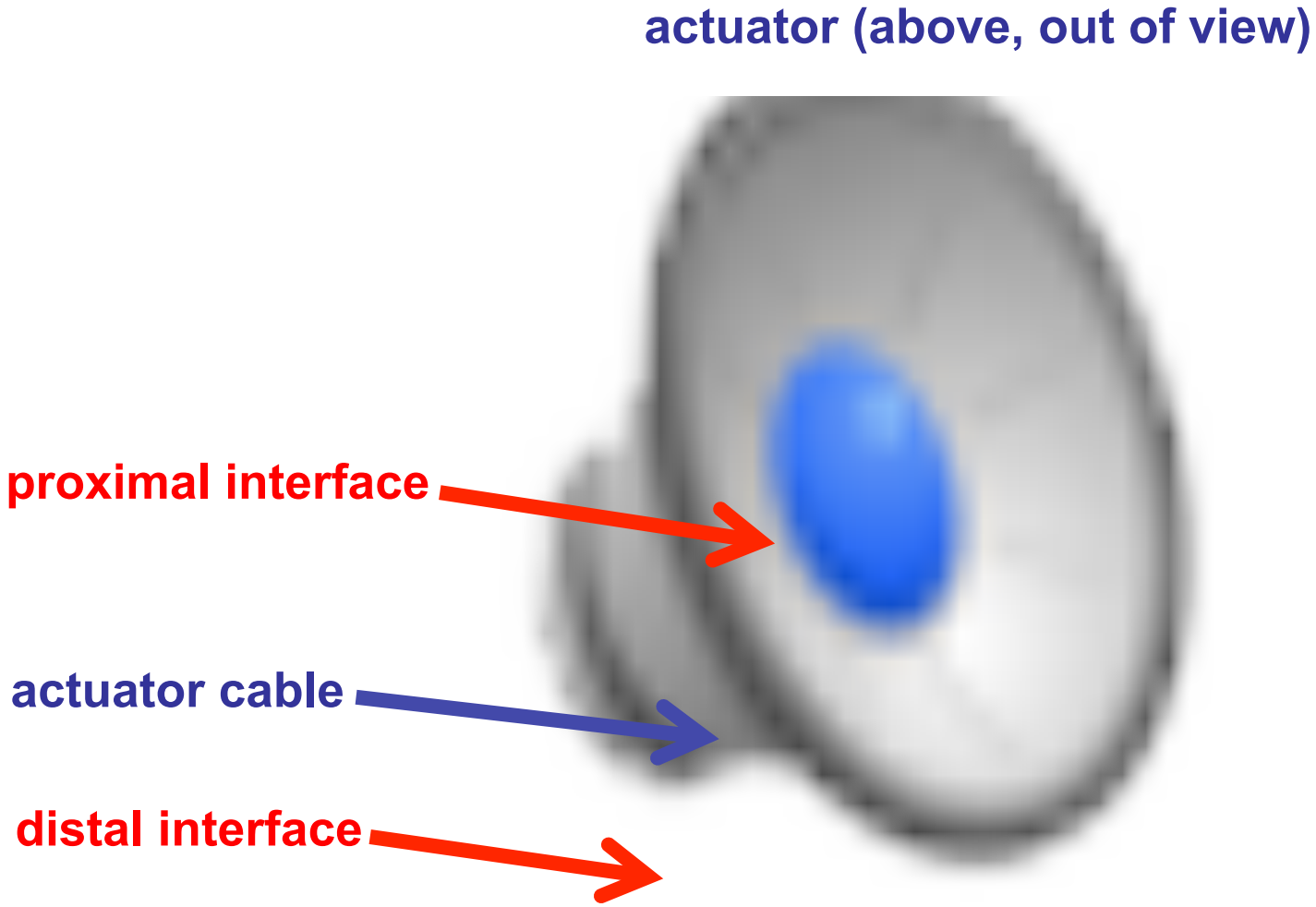
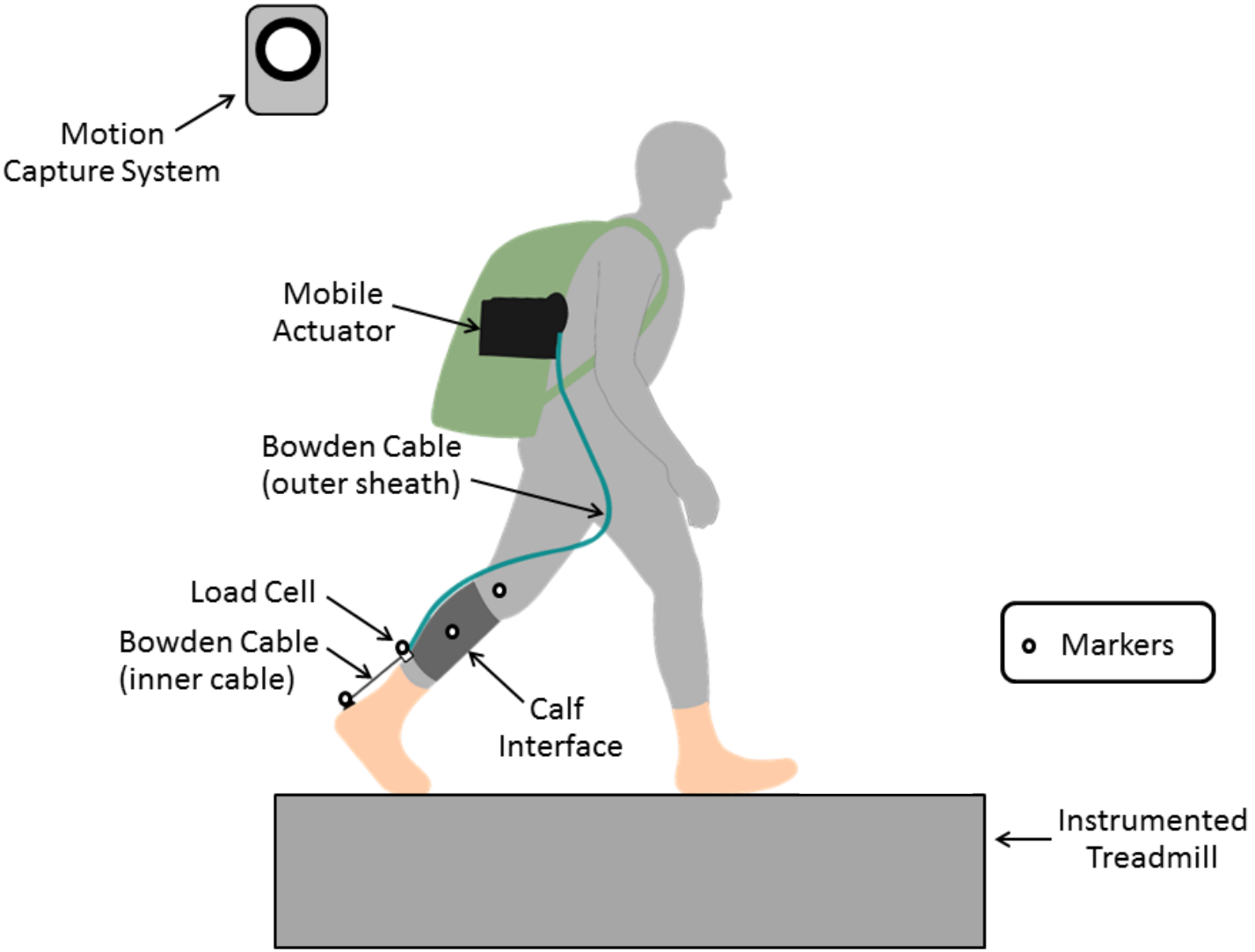
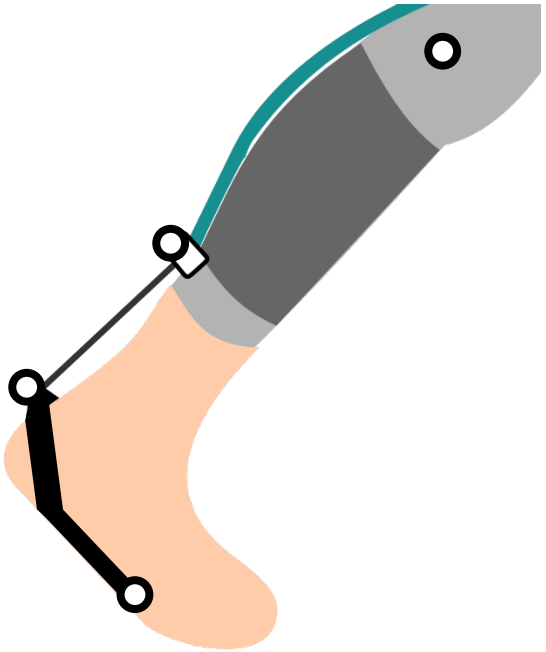
# Power absorbed into soft tissue & interface deformation



# Experiment to quantify power transmission in exosuits



# Simple method to parse power transmission



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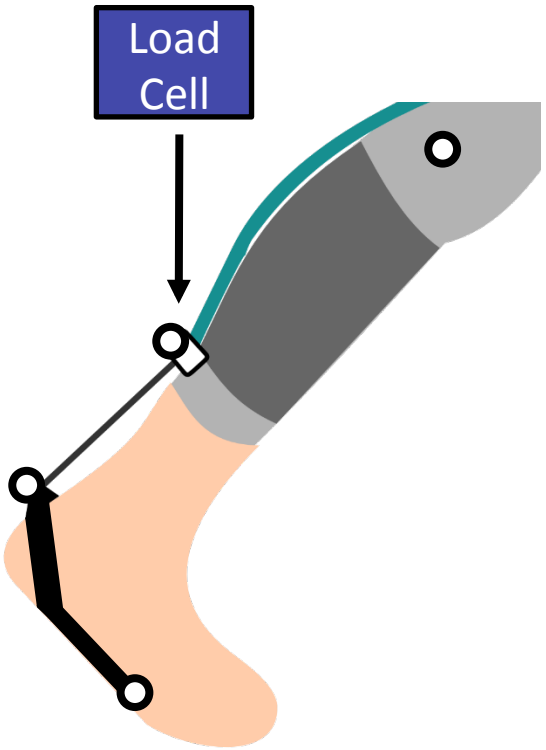

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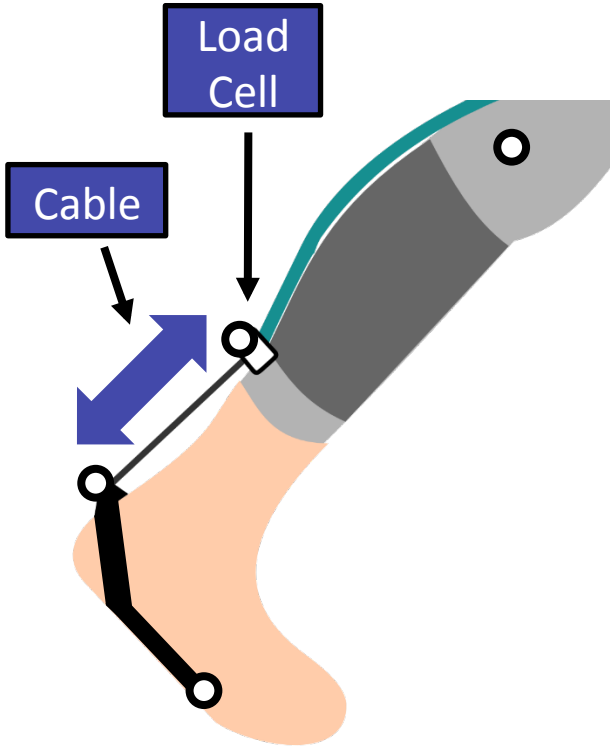

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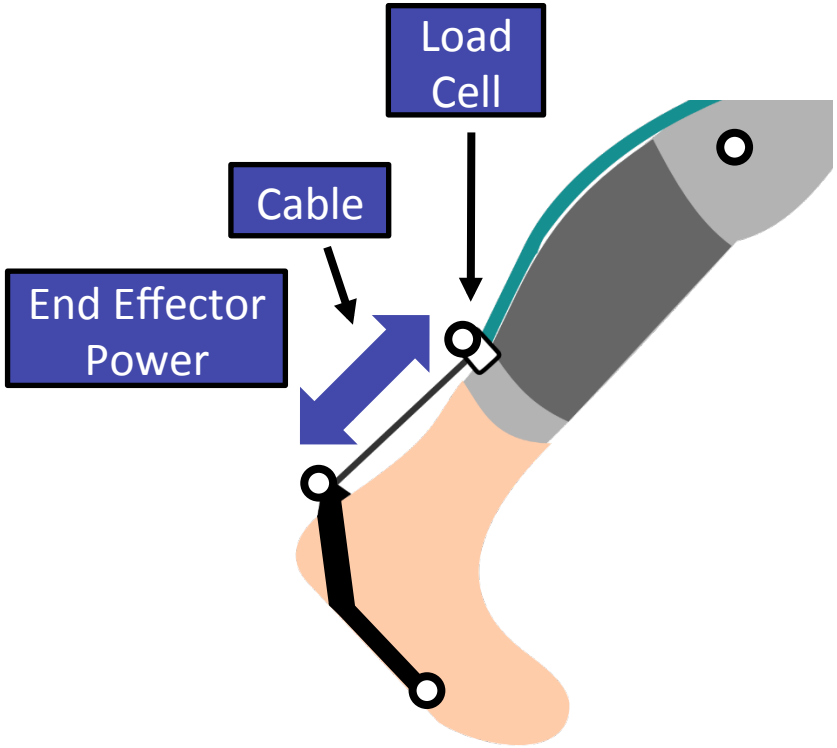

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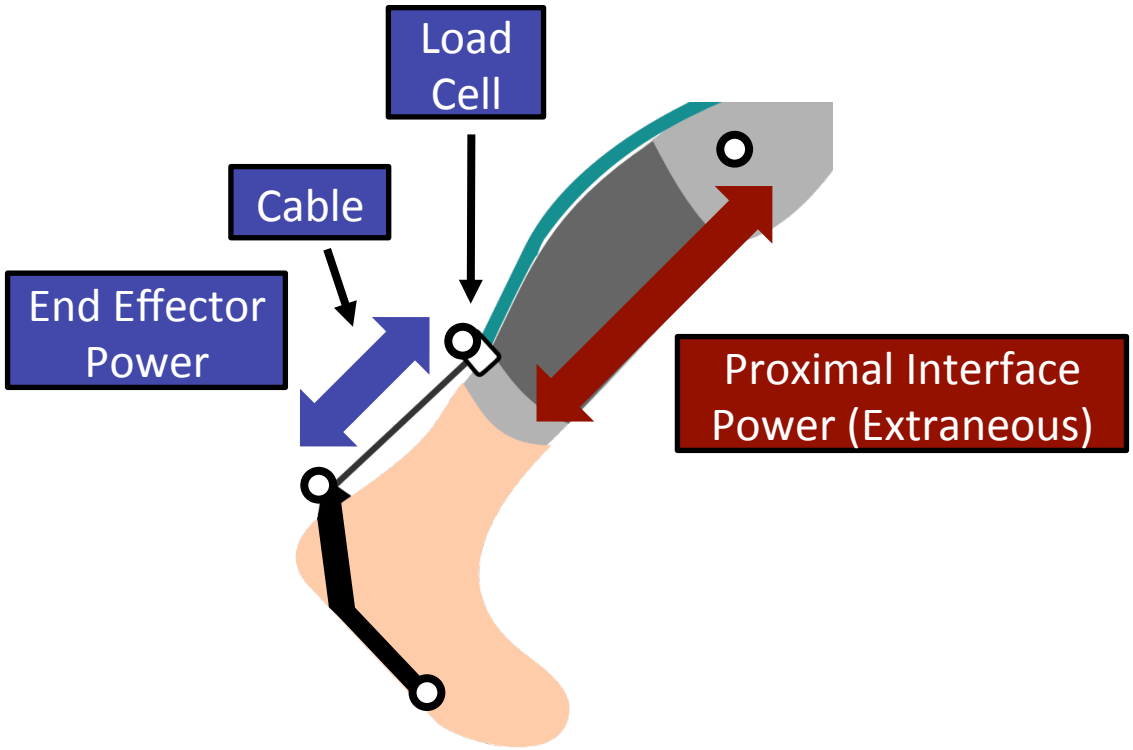

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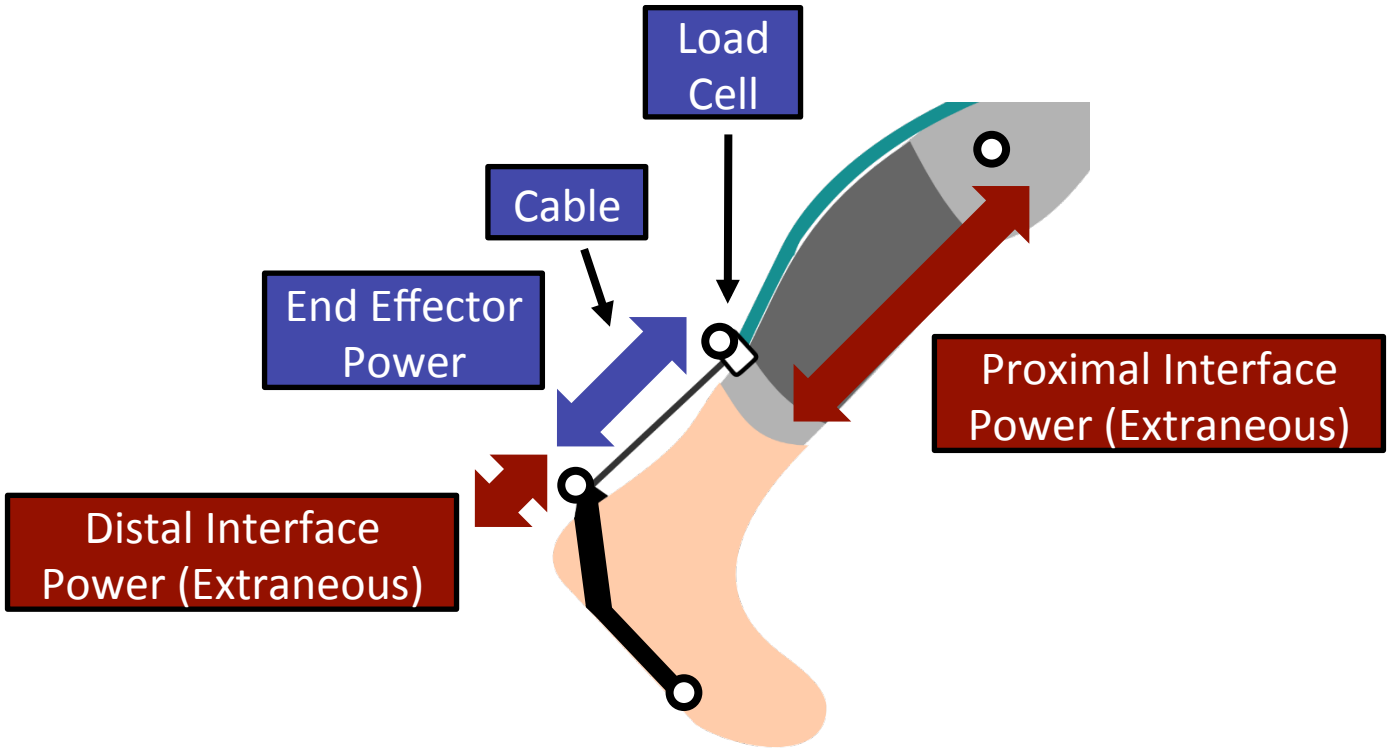

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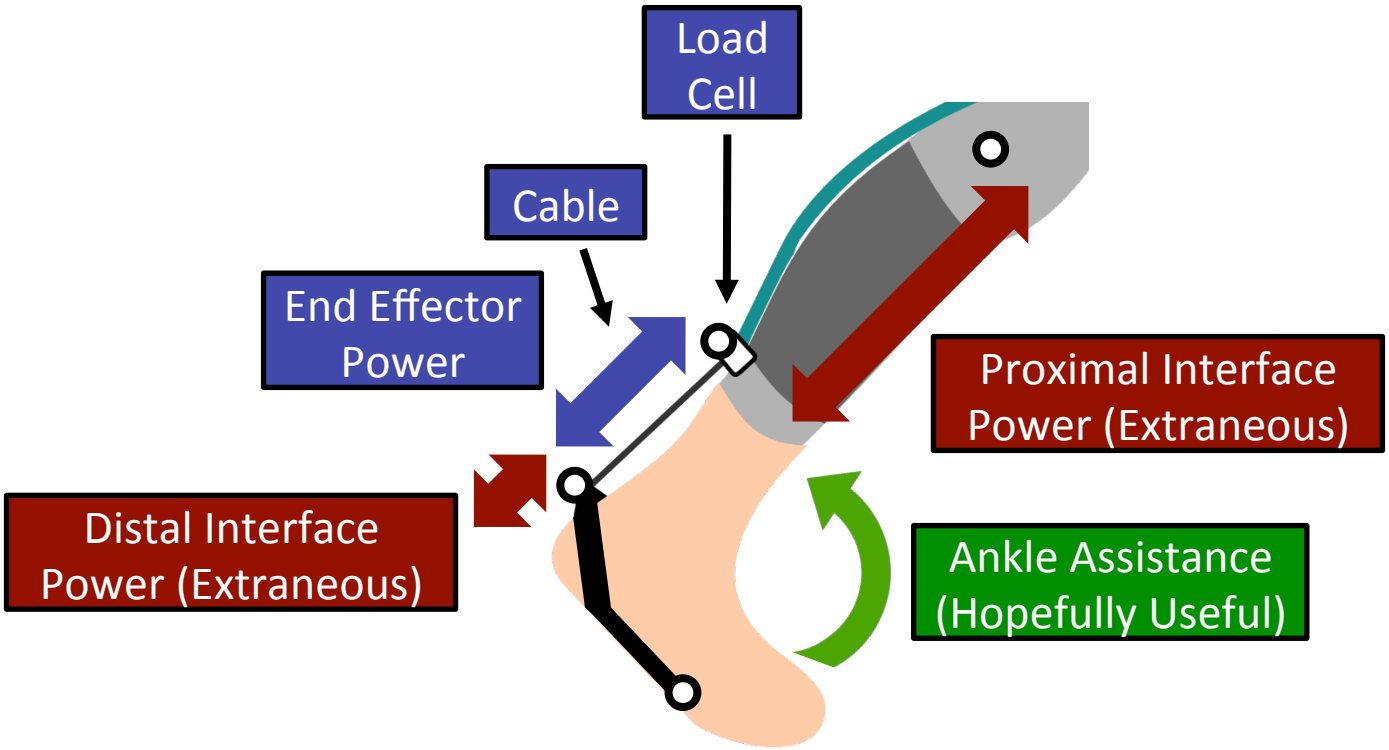

# Simple method to parse power transmission

## End Effector Power

# Simple method to parse power transmission

| Ankle Assistance | Proximal & Distal Interface Absorption |
| --- | --- |

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ratios depend on physical interface & device control

# Validation test: method can partition power as theorized

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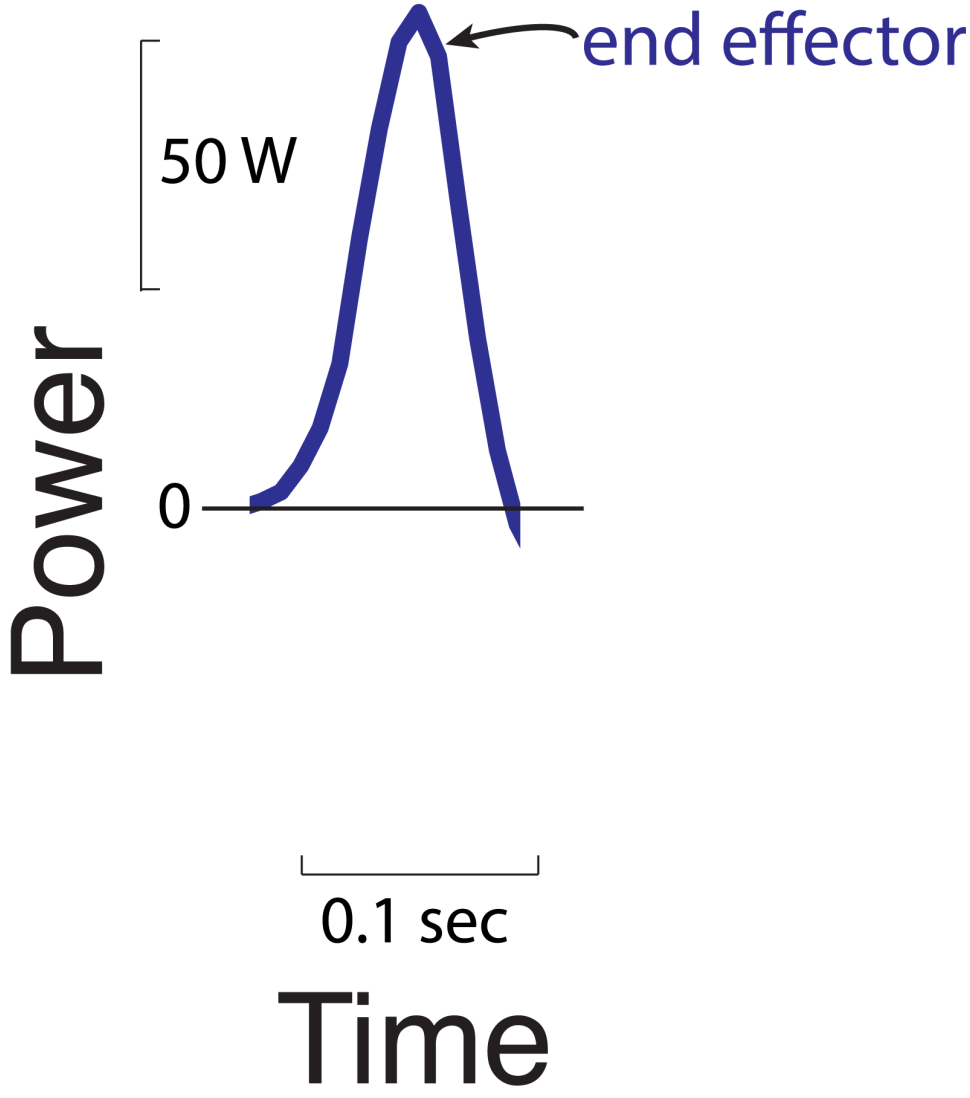


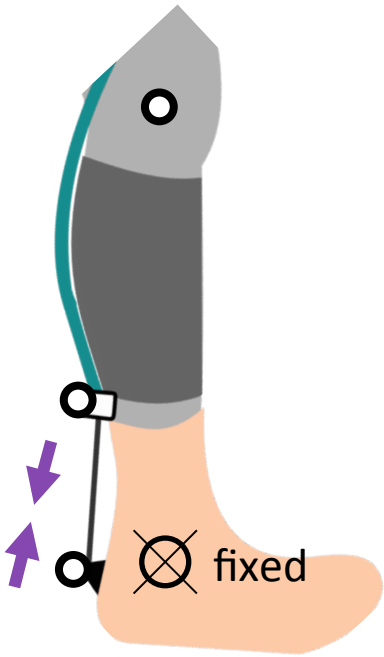

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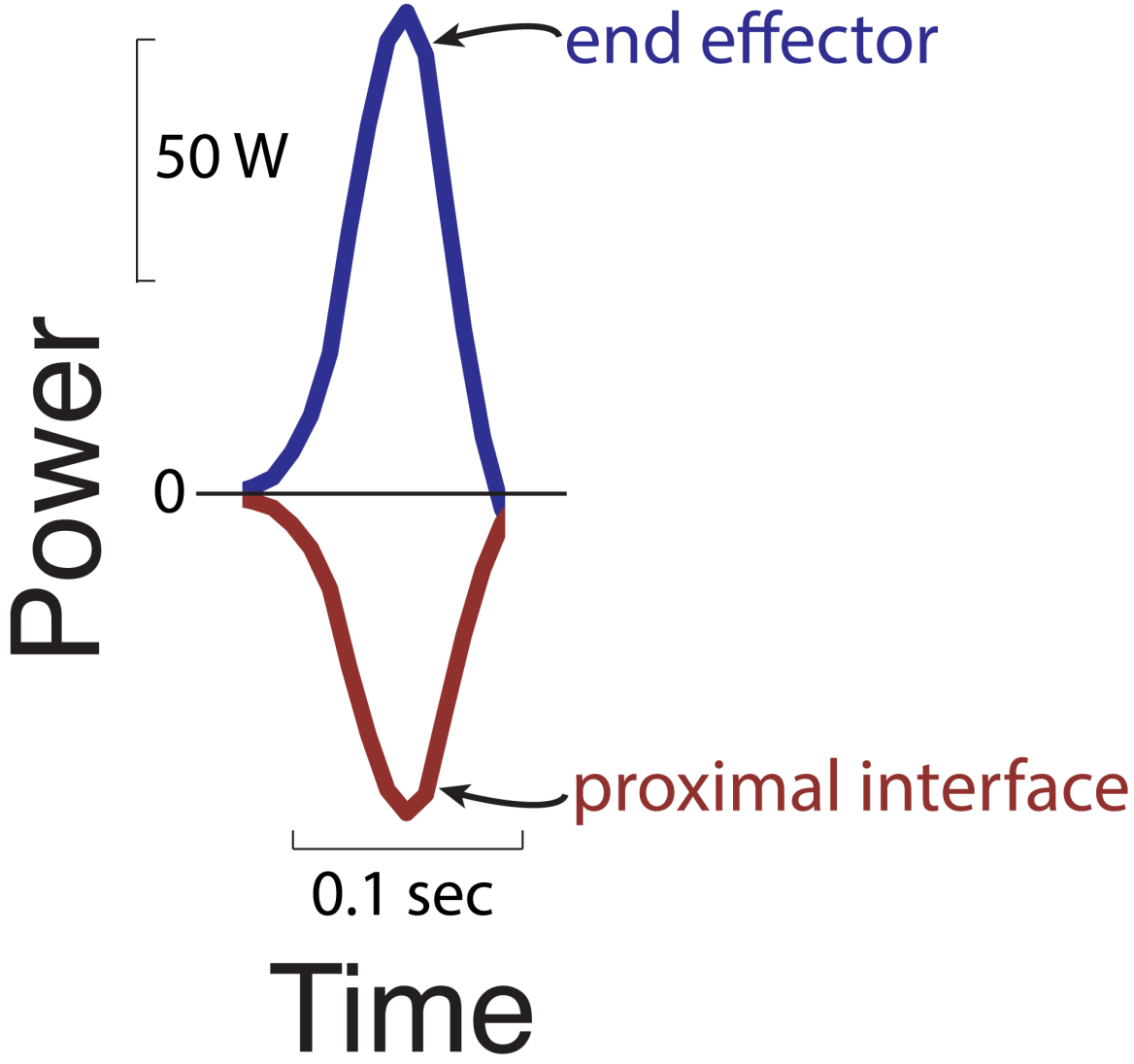


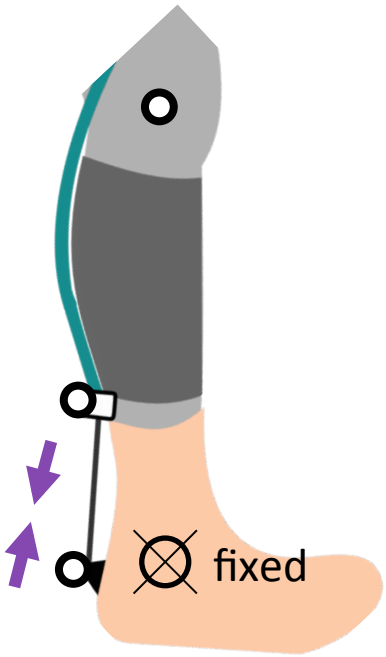

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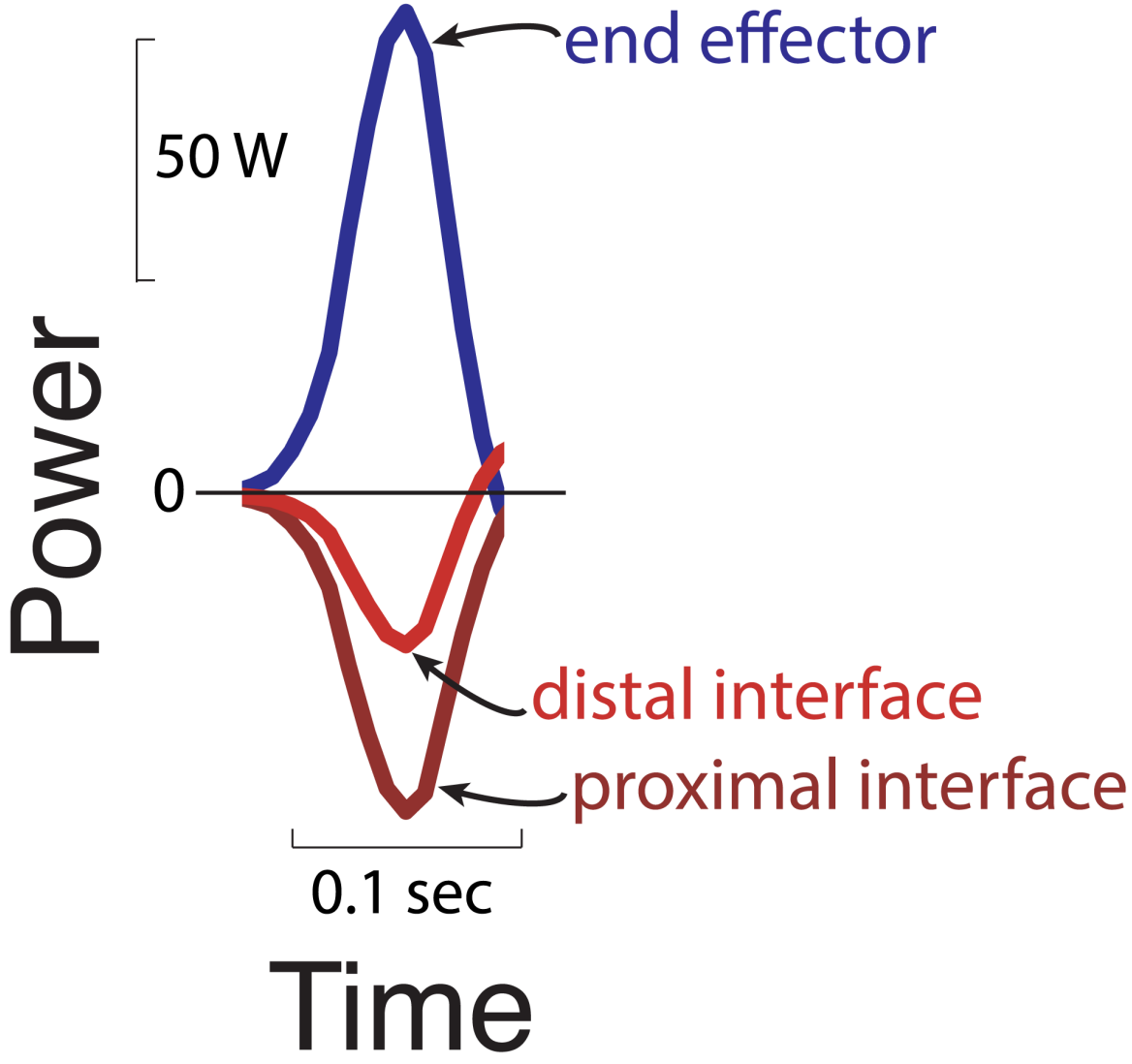


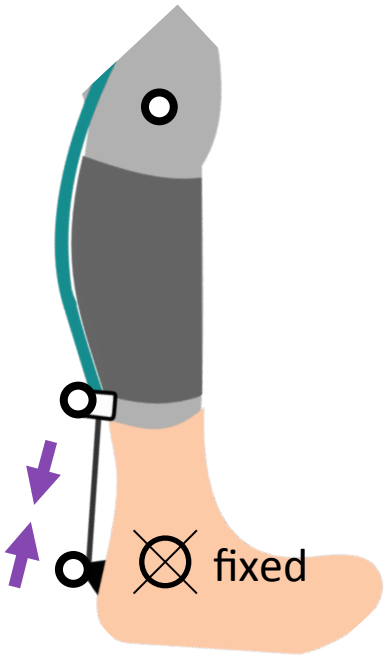

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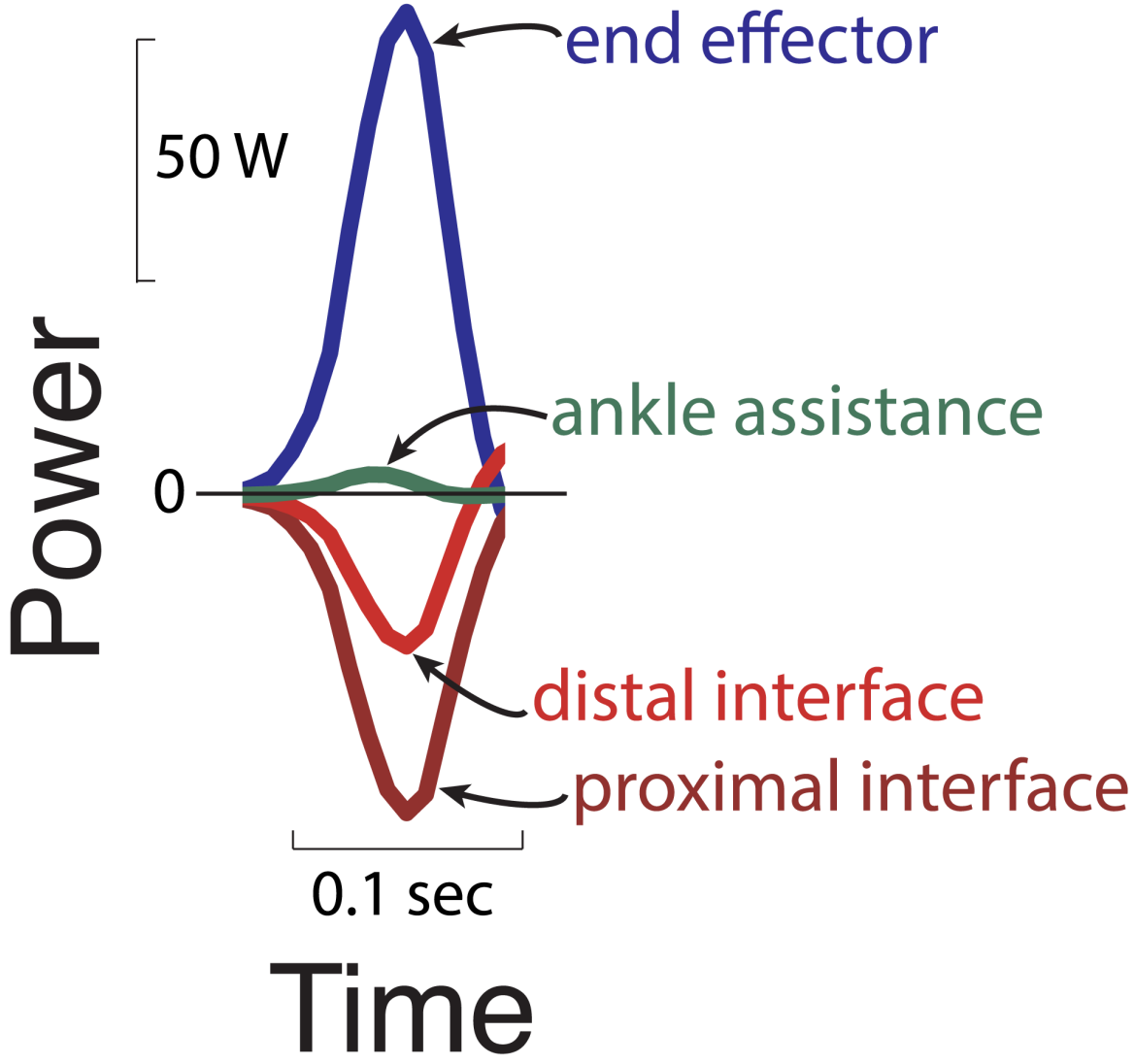
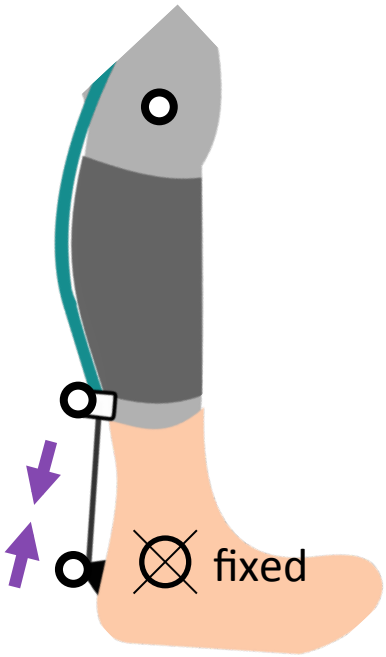
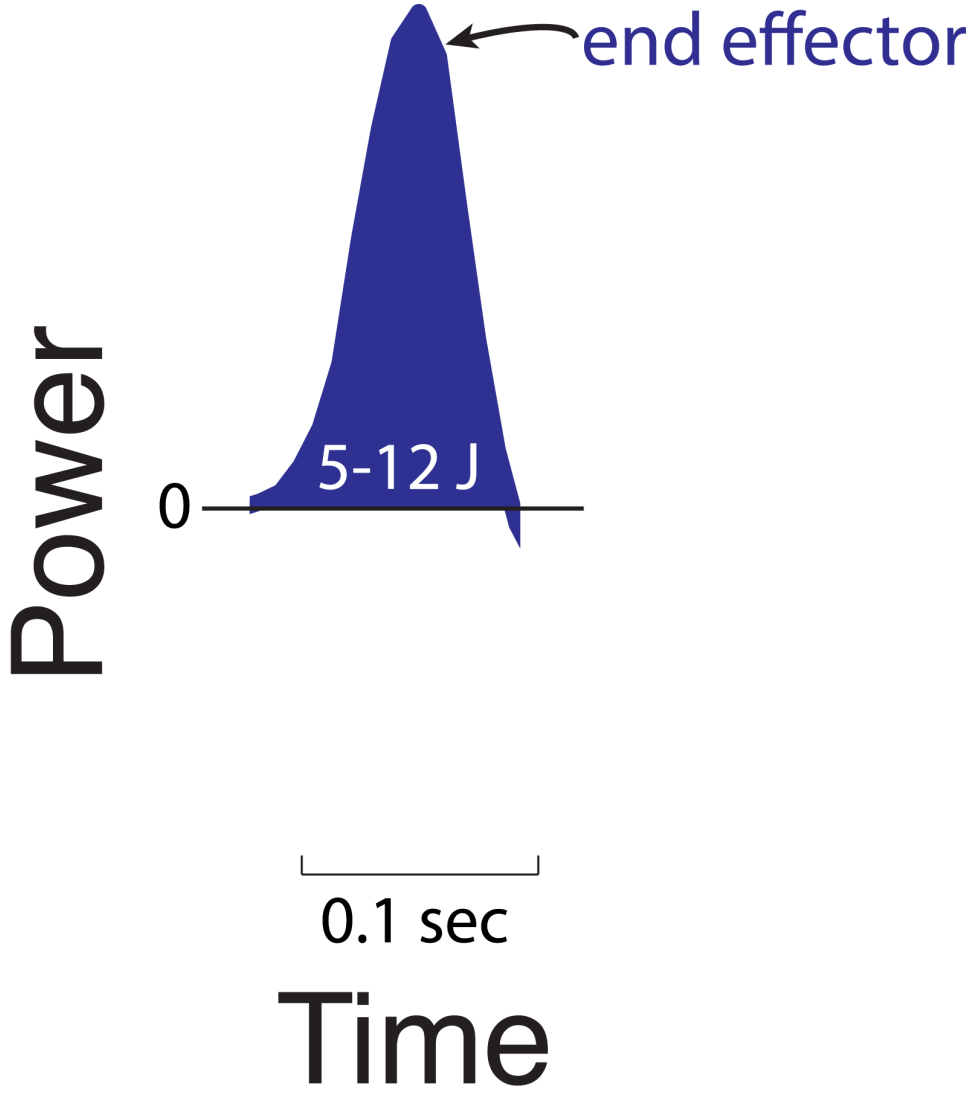
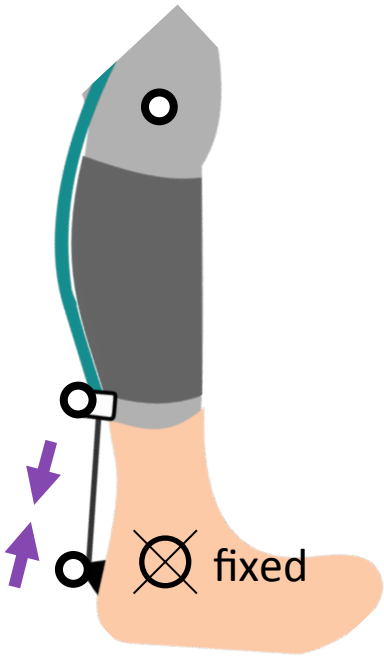


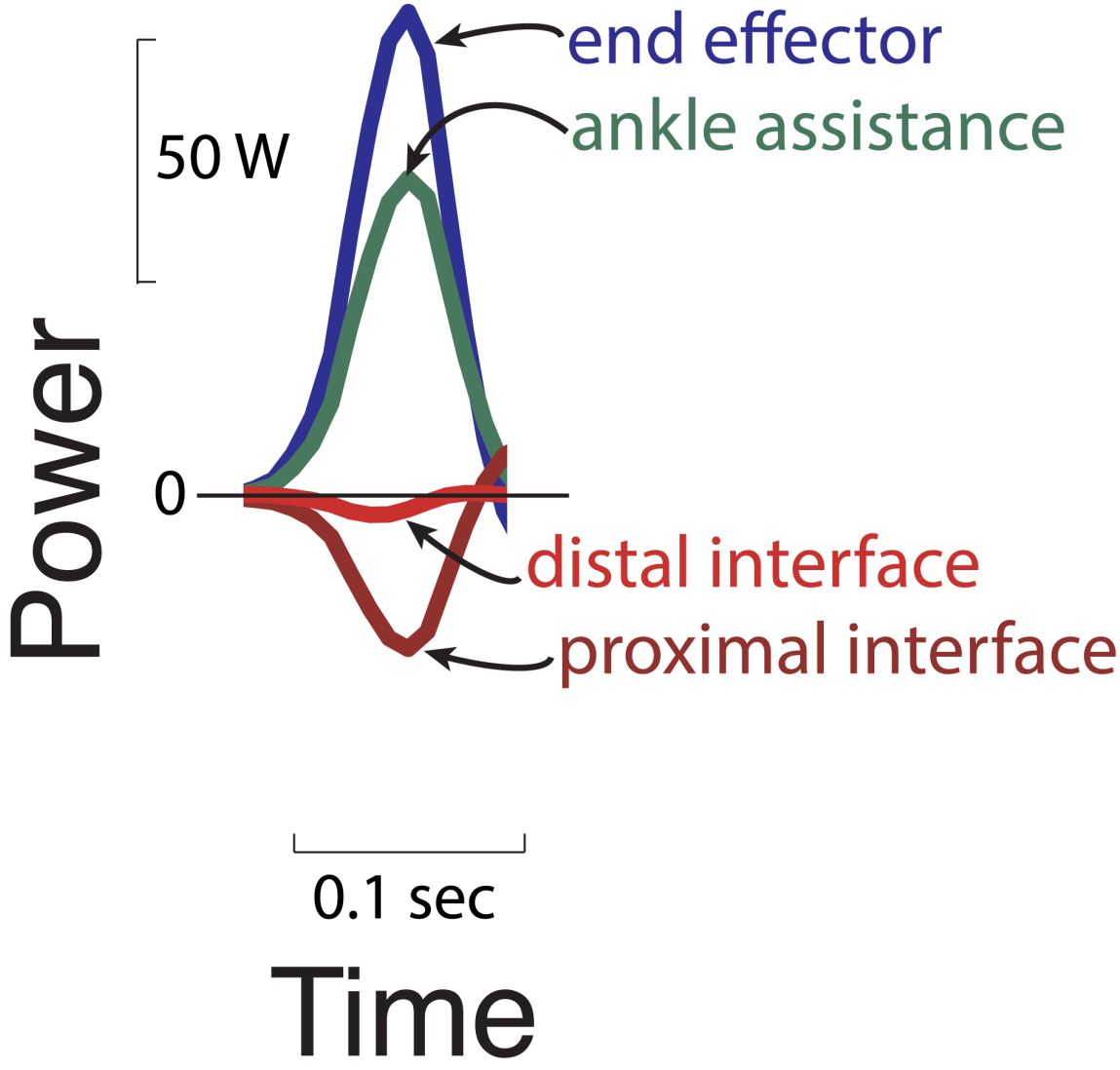



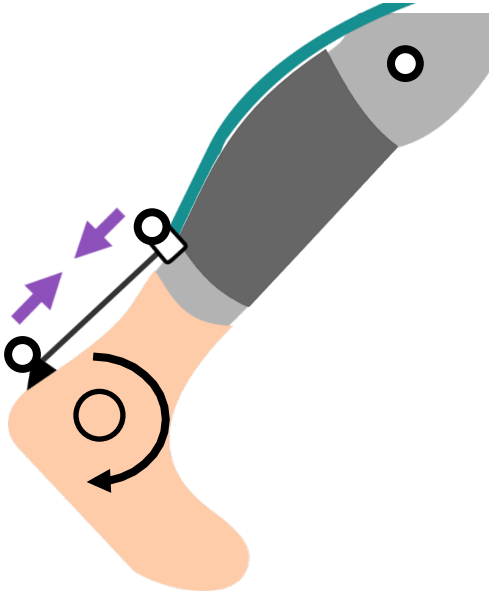
# Validation test: interface can absorb substantial energy



# Walking tests: projected results



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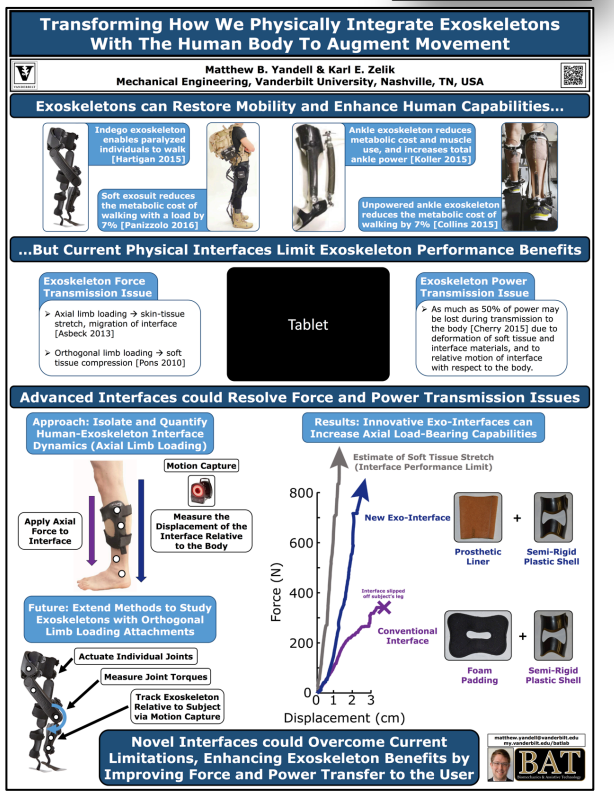
Matthew Yandell




my.vanderbilt.edu/batlab

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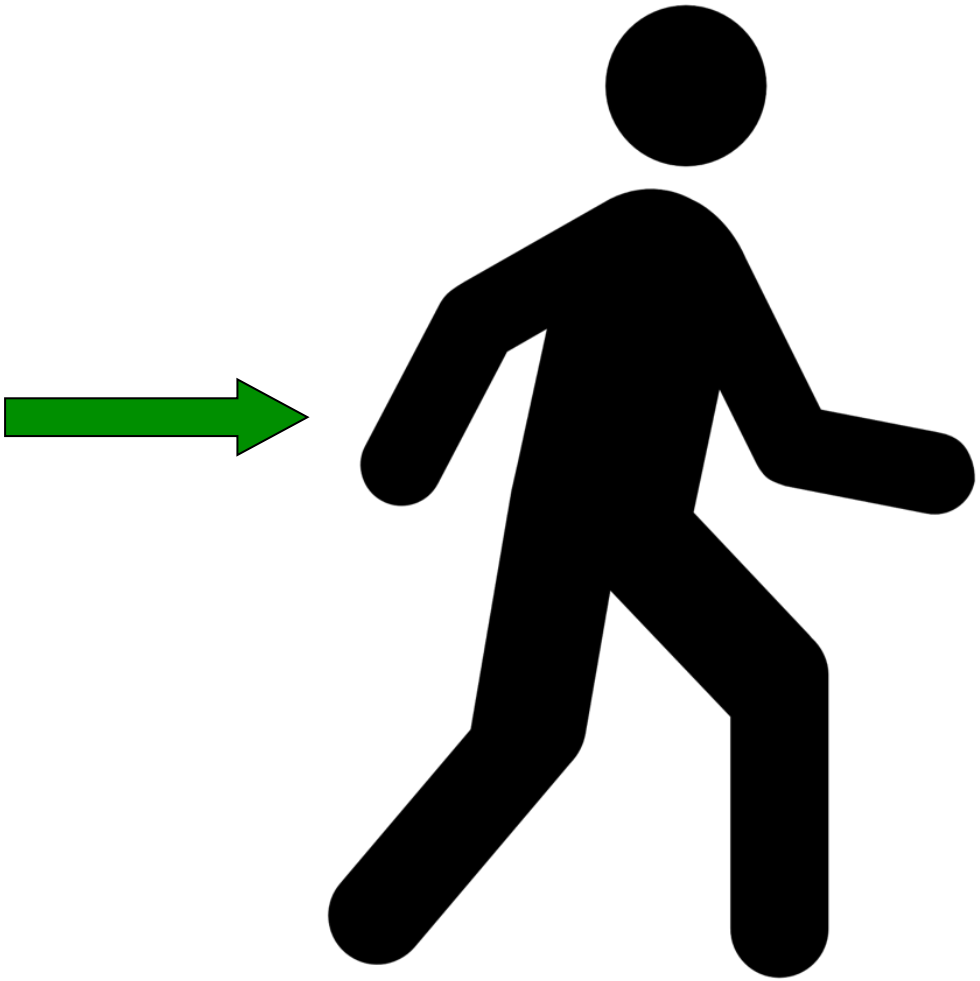

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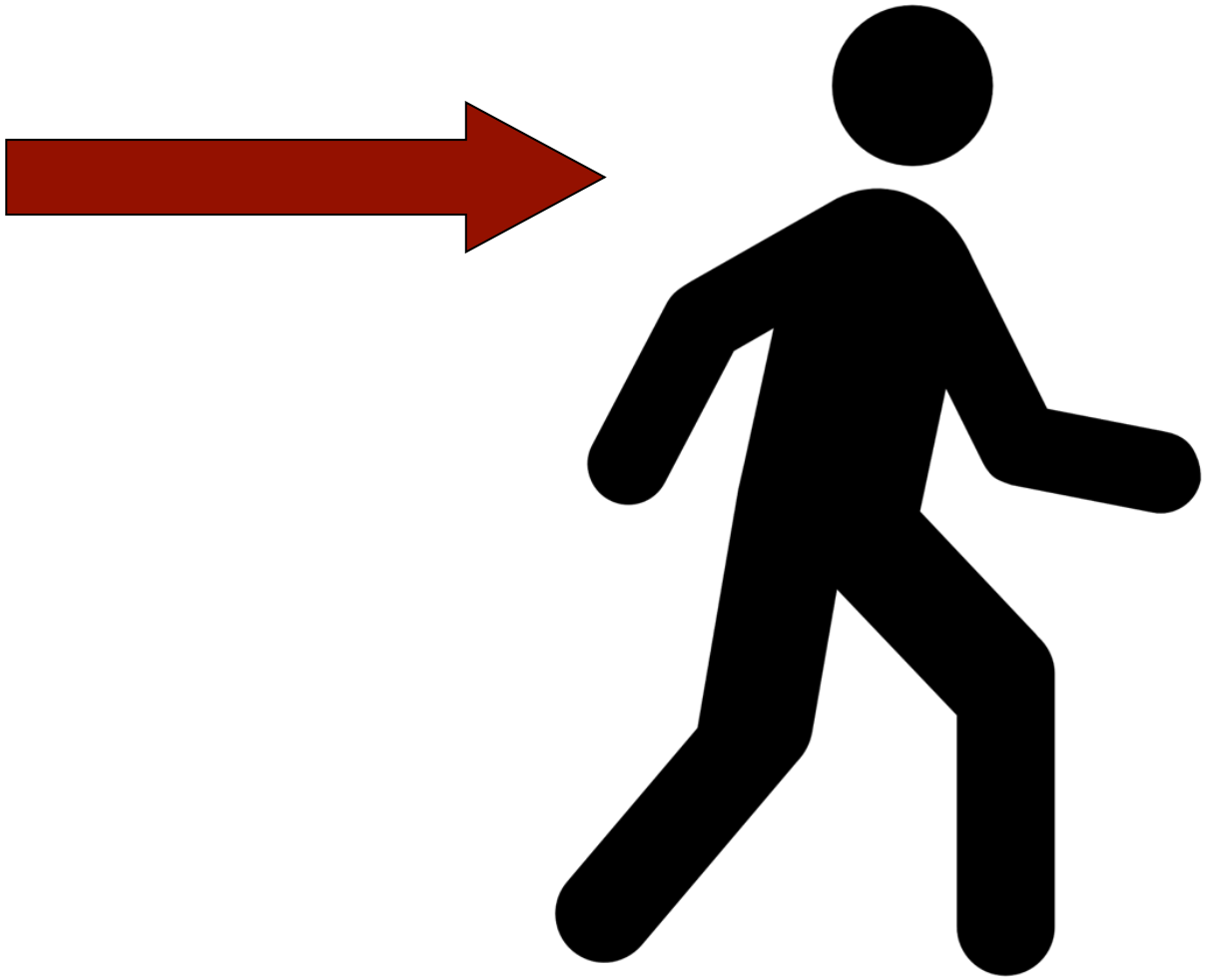

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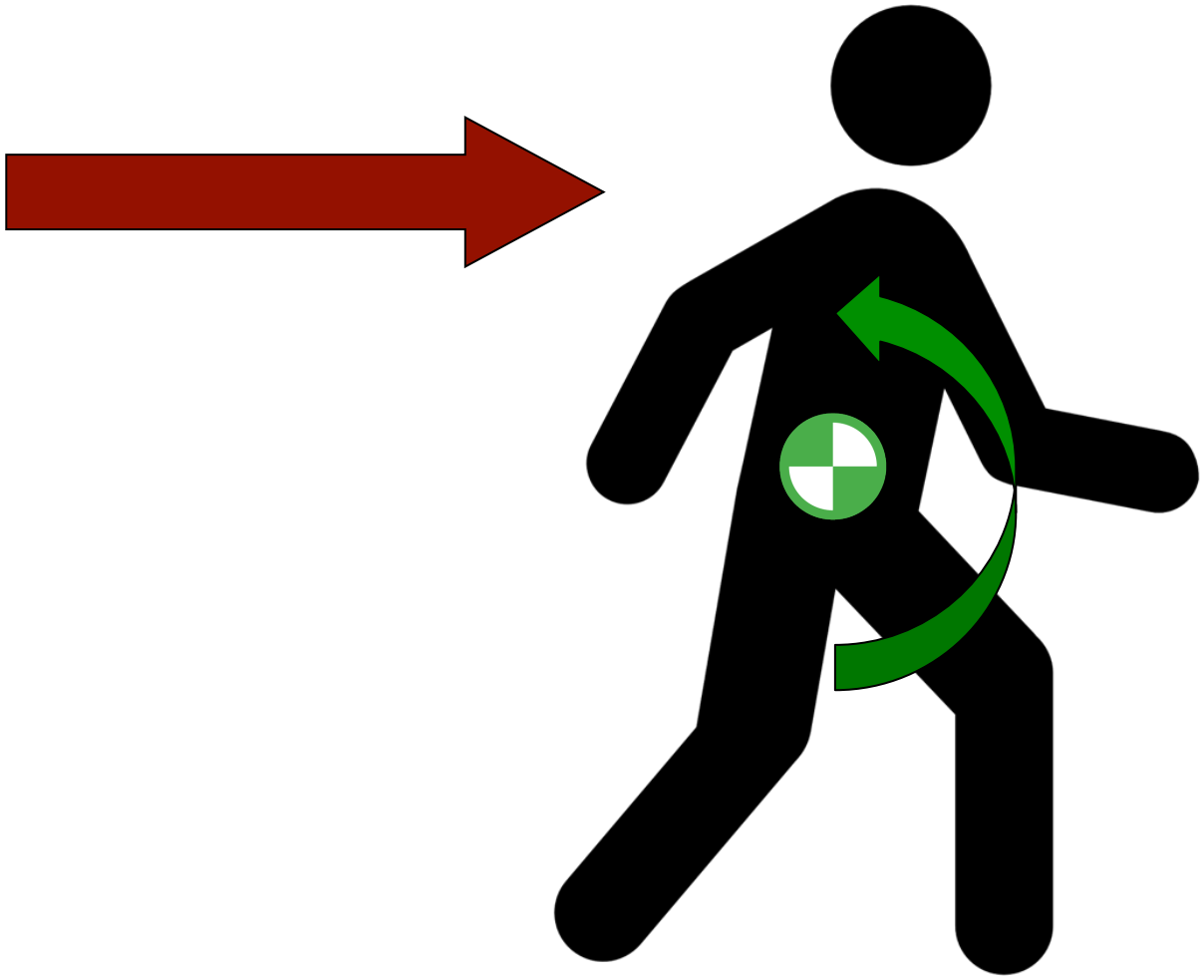
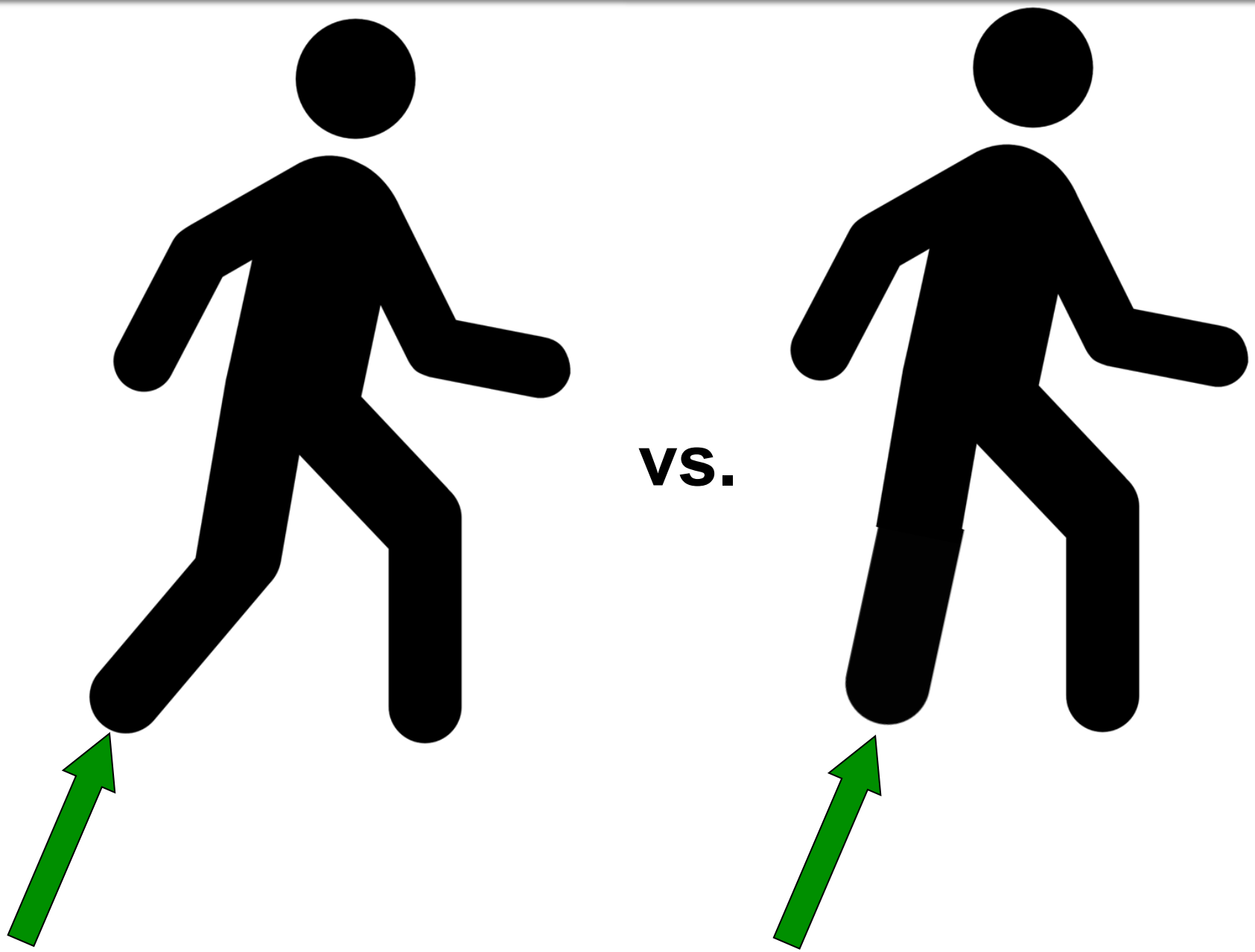
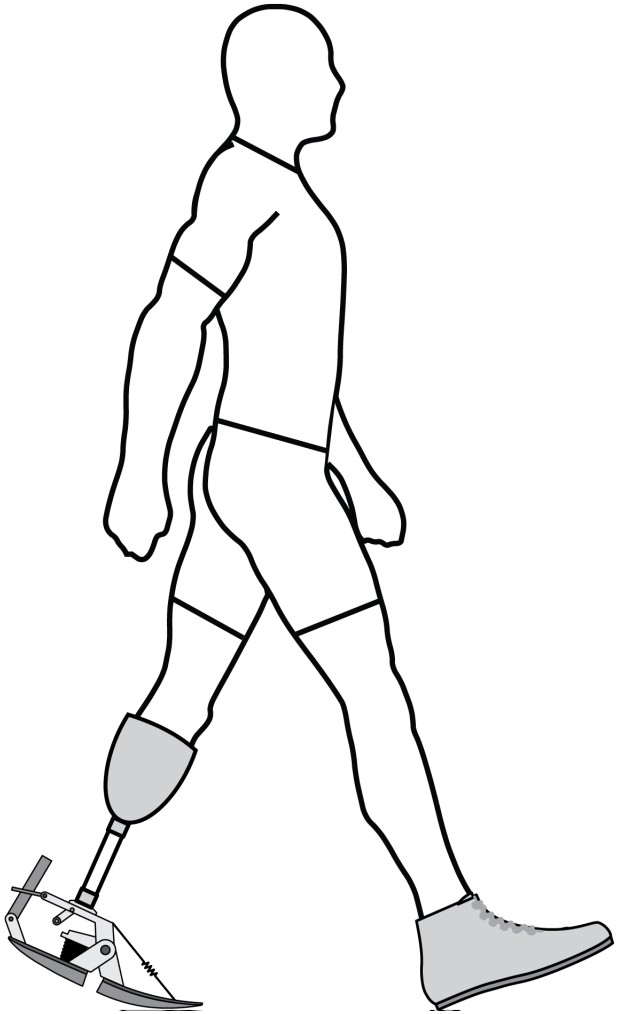


## Neuromotor Response to Extraneous Motion

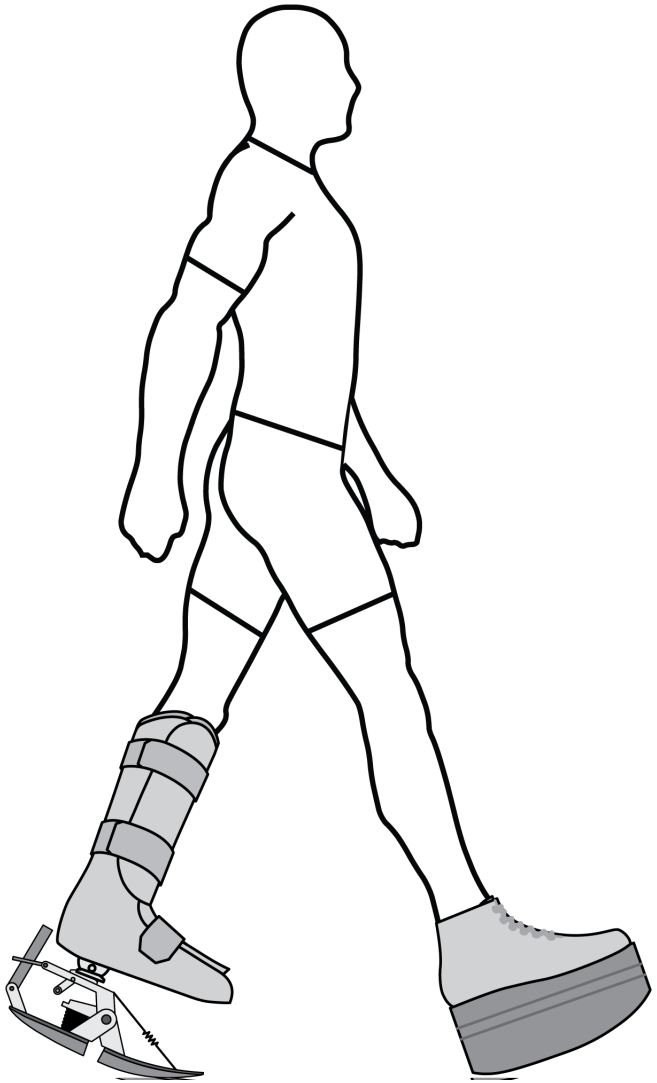
# Preemptive adjustments can also alter effect of power



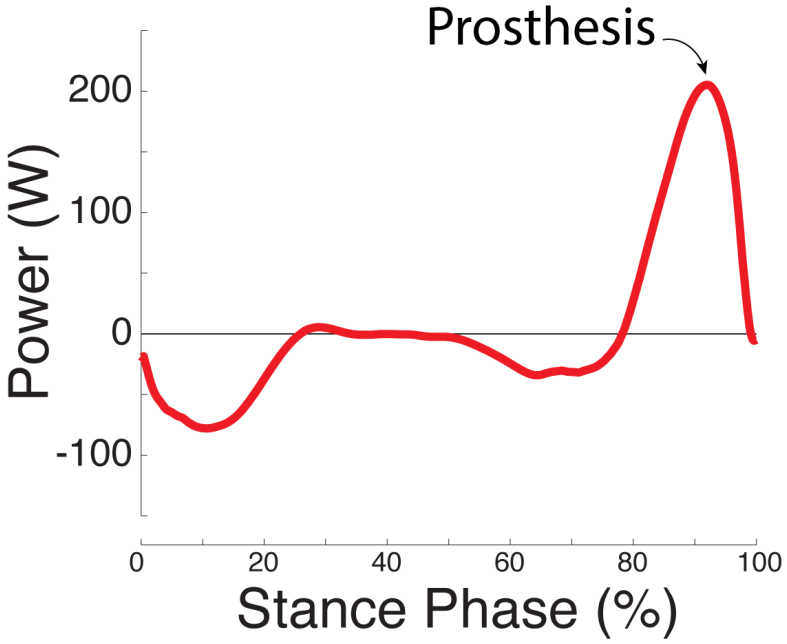
# Individuals/groups can respond completely differently

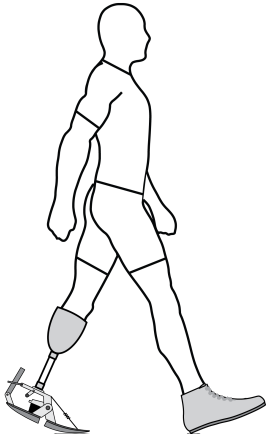


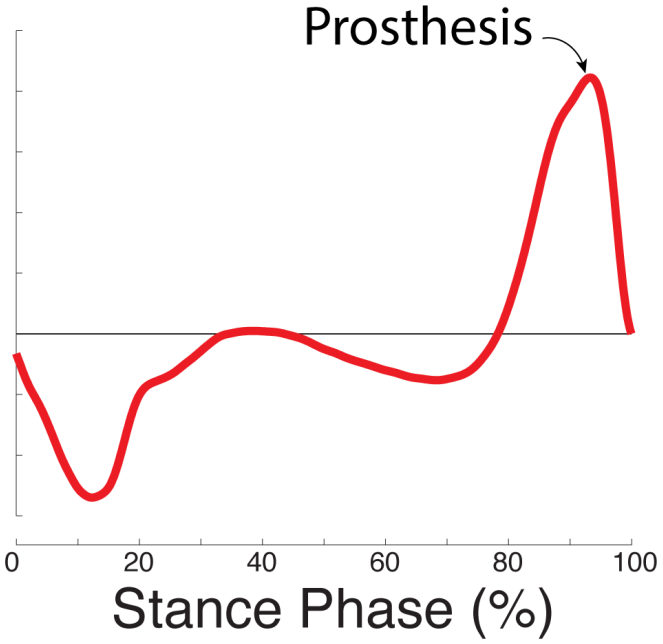
to bionic prosthesis

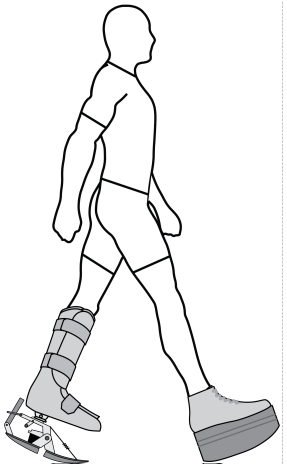


# Prosthesis functioned the same for both groups



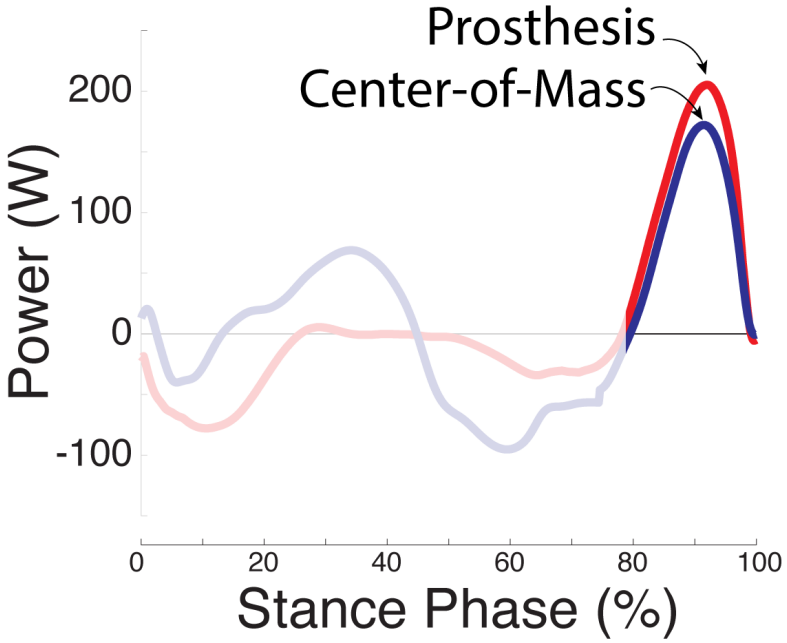



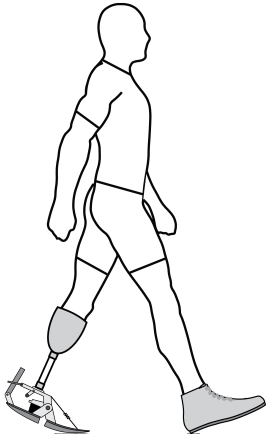


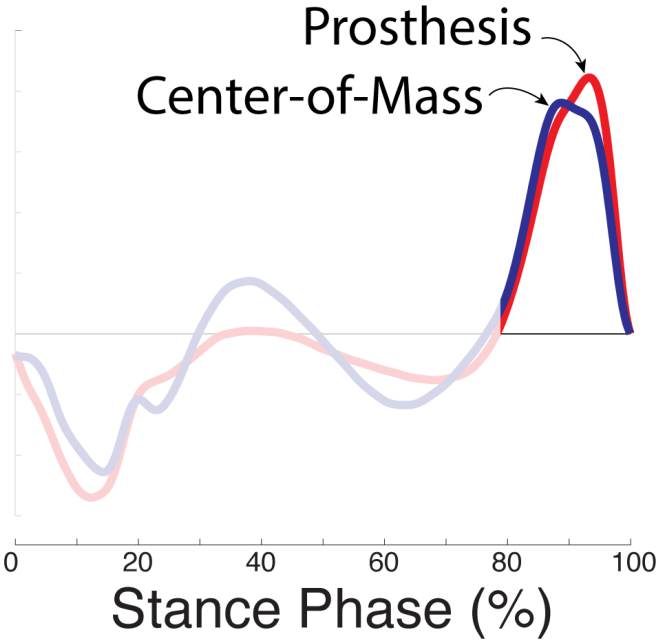



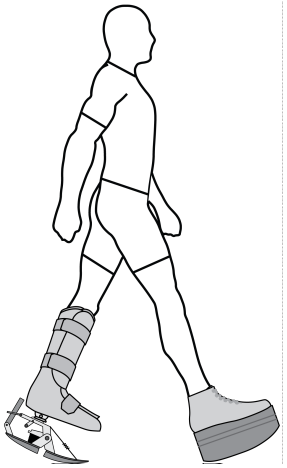
Zelik et al. 2011

# Center-of-mass power was similar for both groups



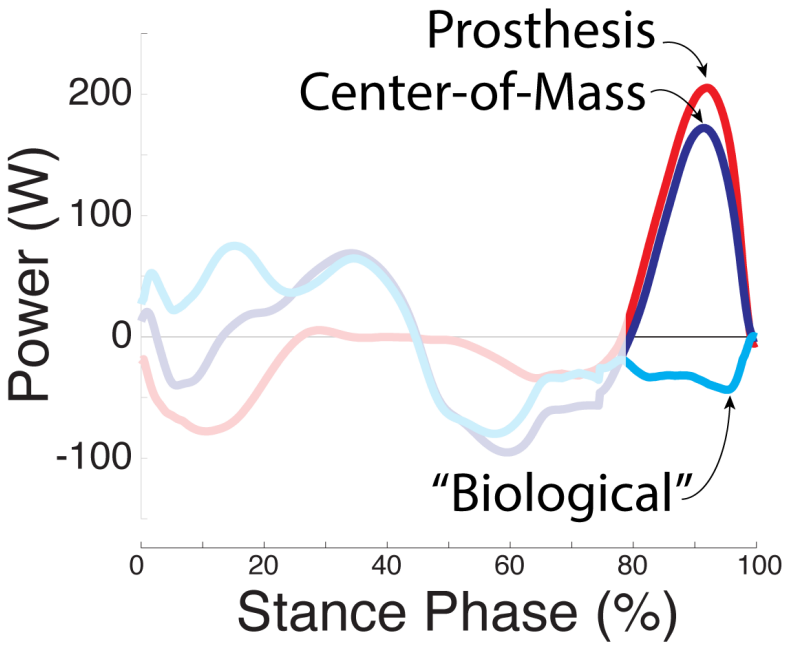



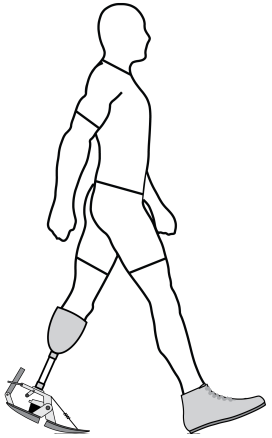


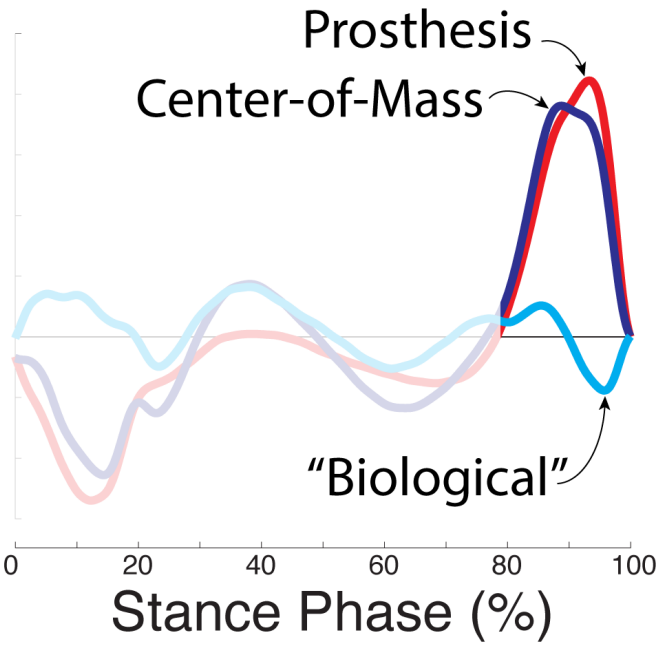



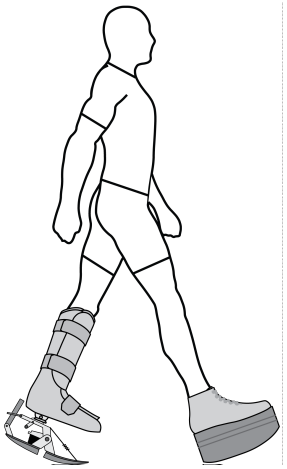
Zelik et al. 2011

# "Biological" power was similar for both groups



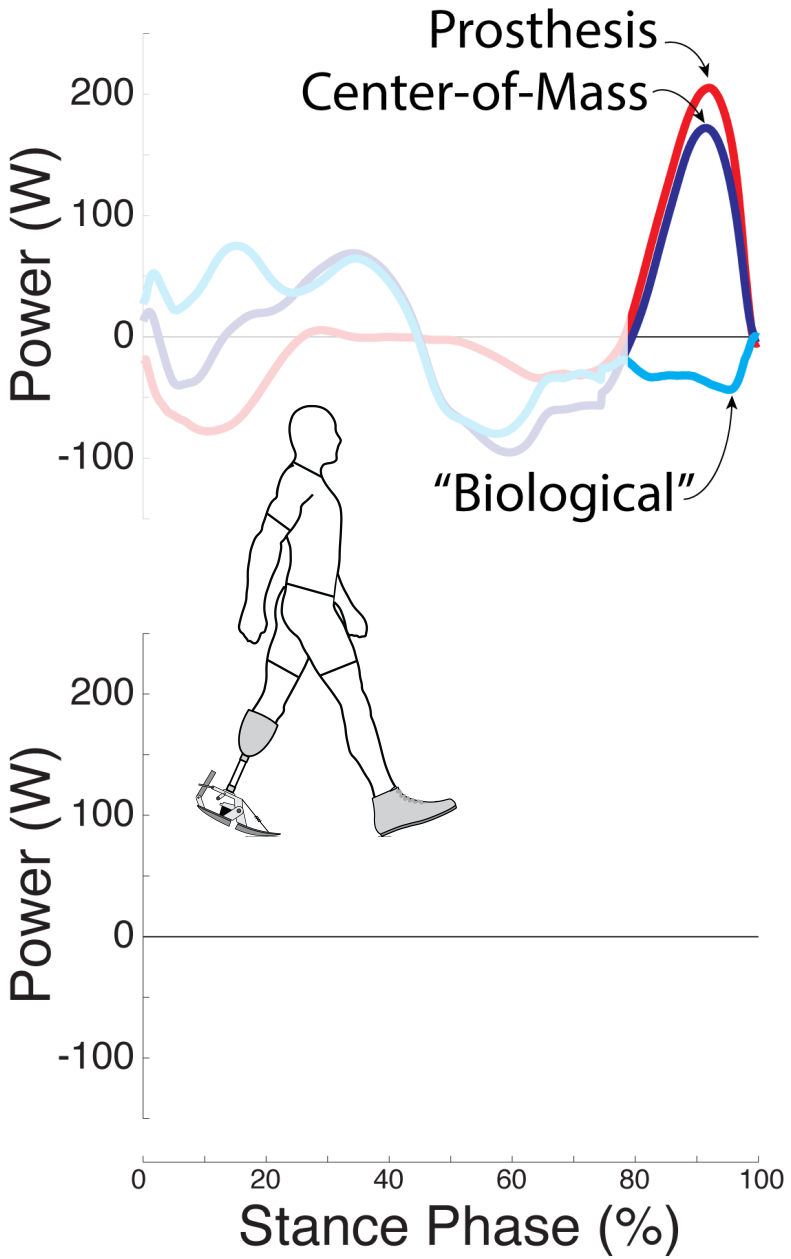



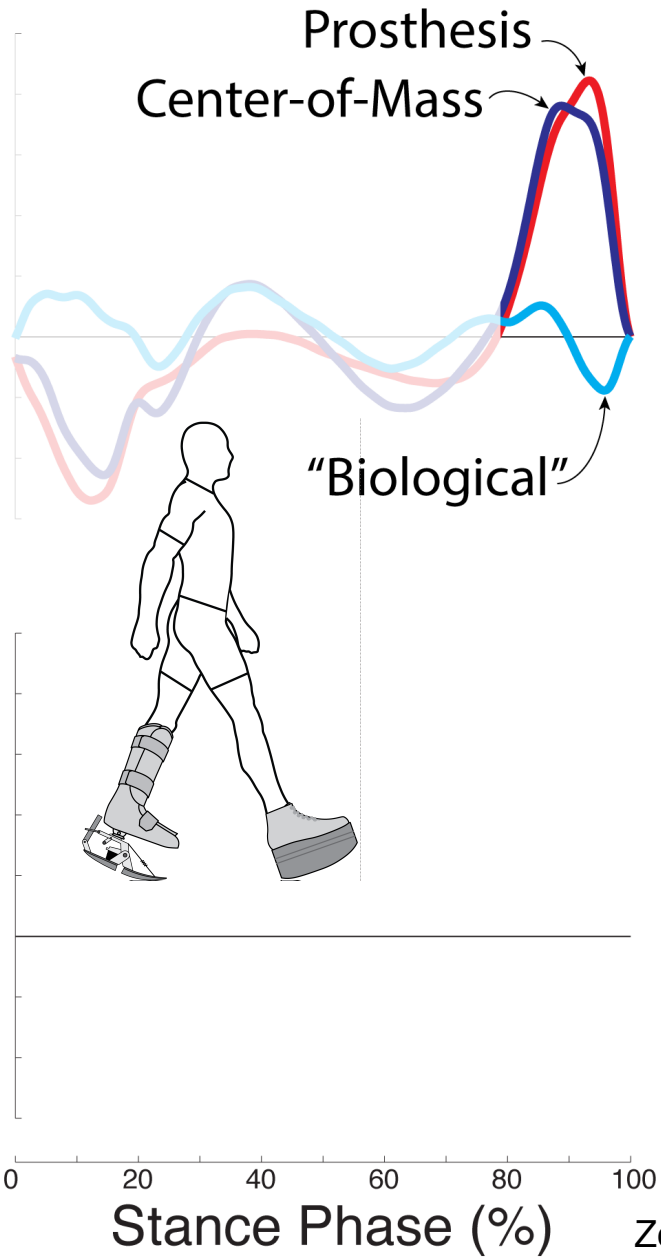


Zelik et al. 2011

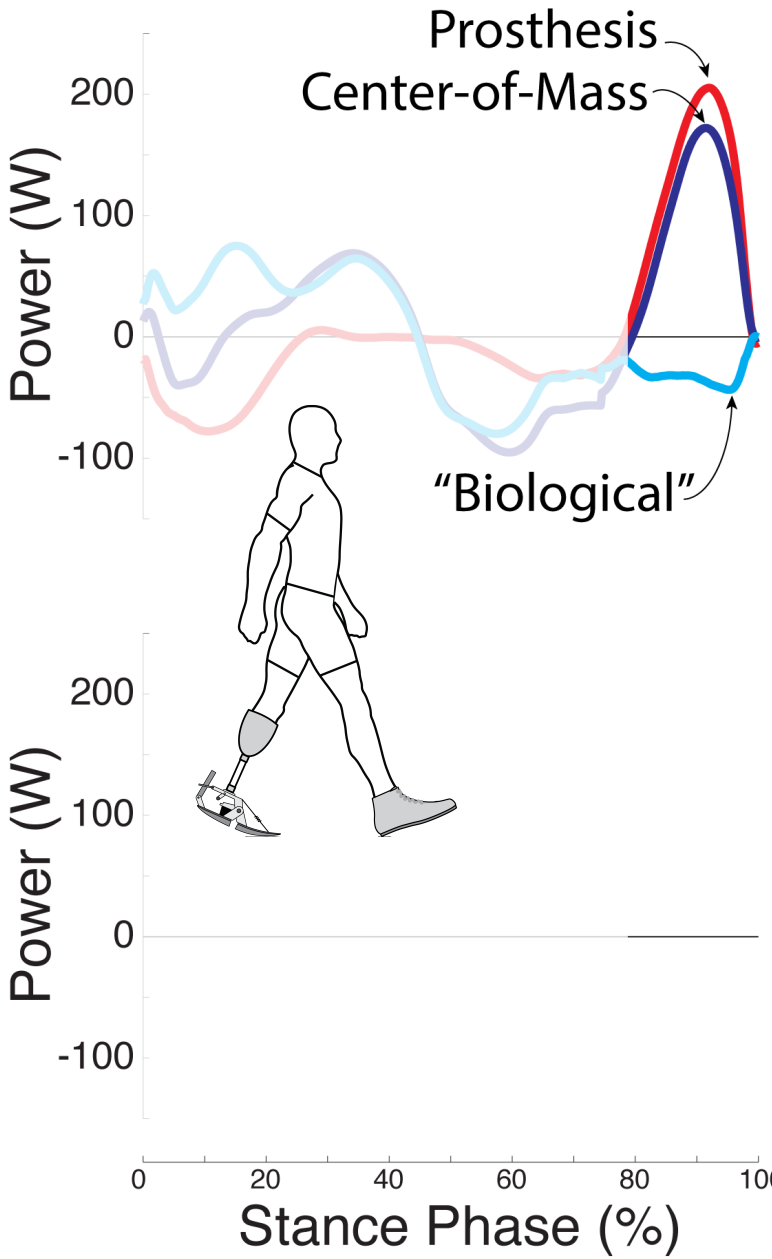
# What happens to knee & hip joint power?

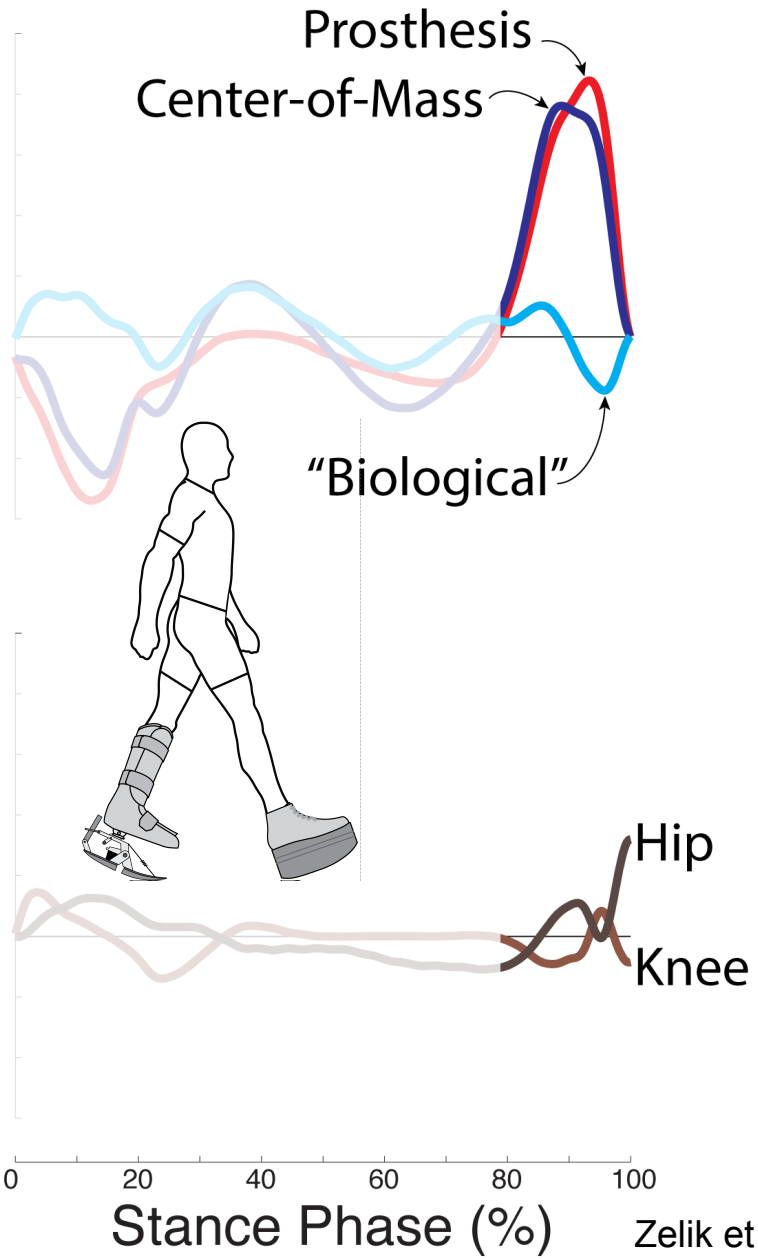



Zelik et al. 2011

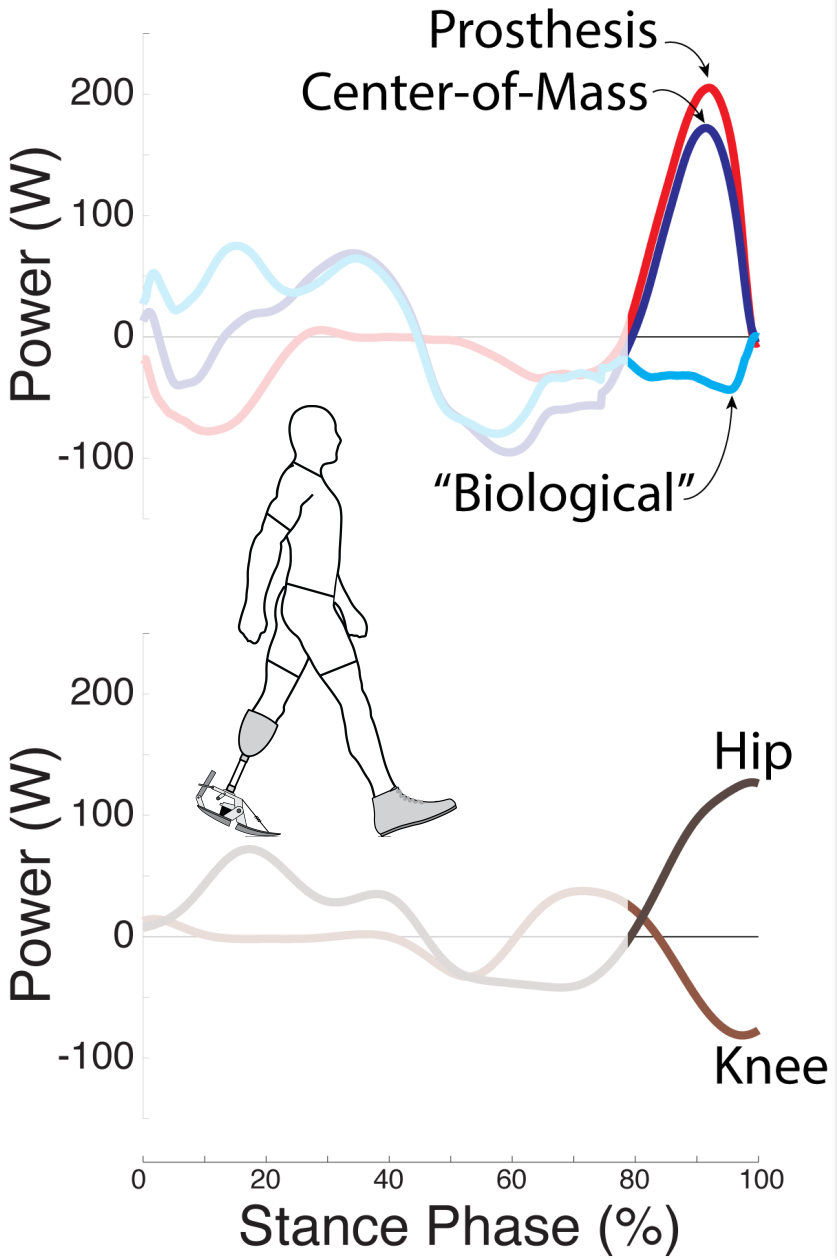
# Non-amputees: knee & hip power is small

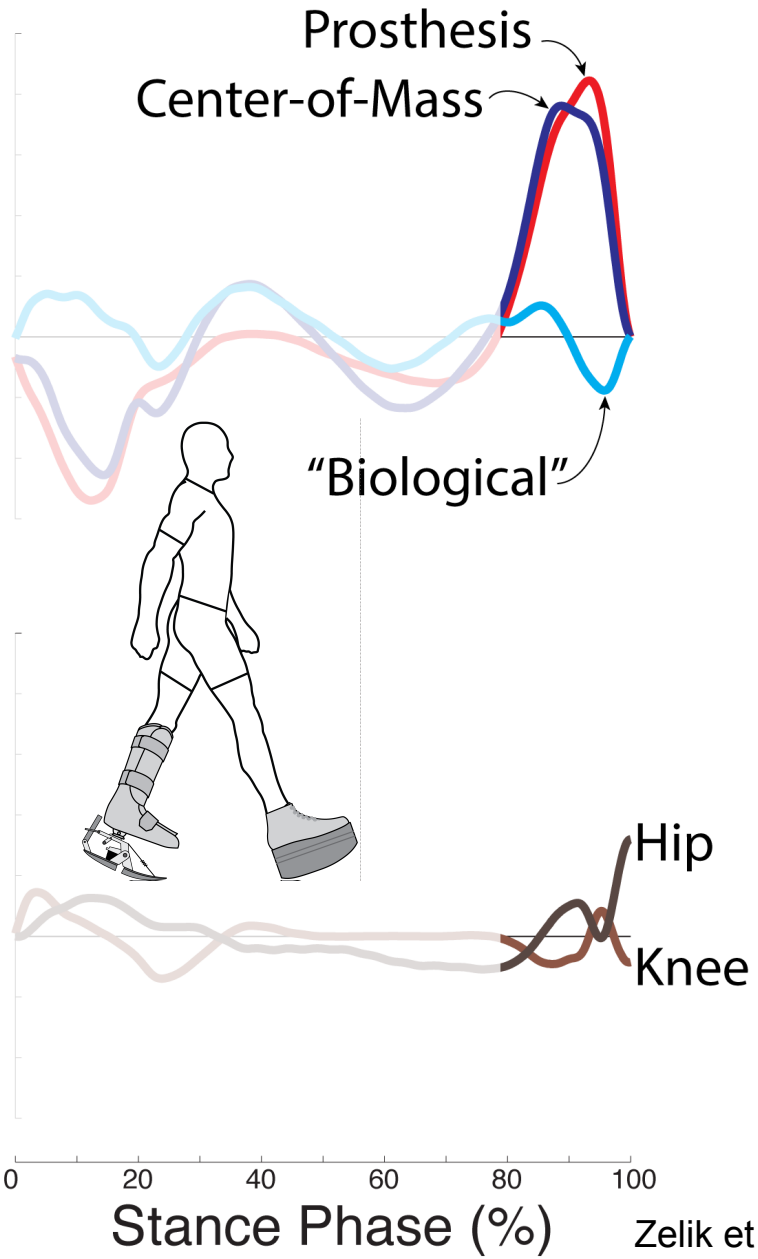



Zelik et al. 2011

# Amputees adapt differently, with higher knee & hip power

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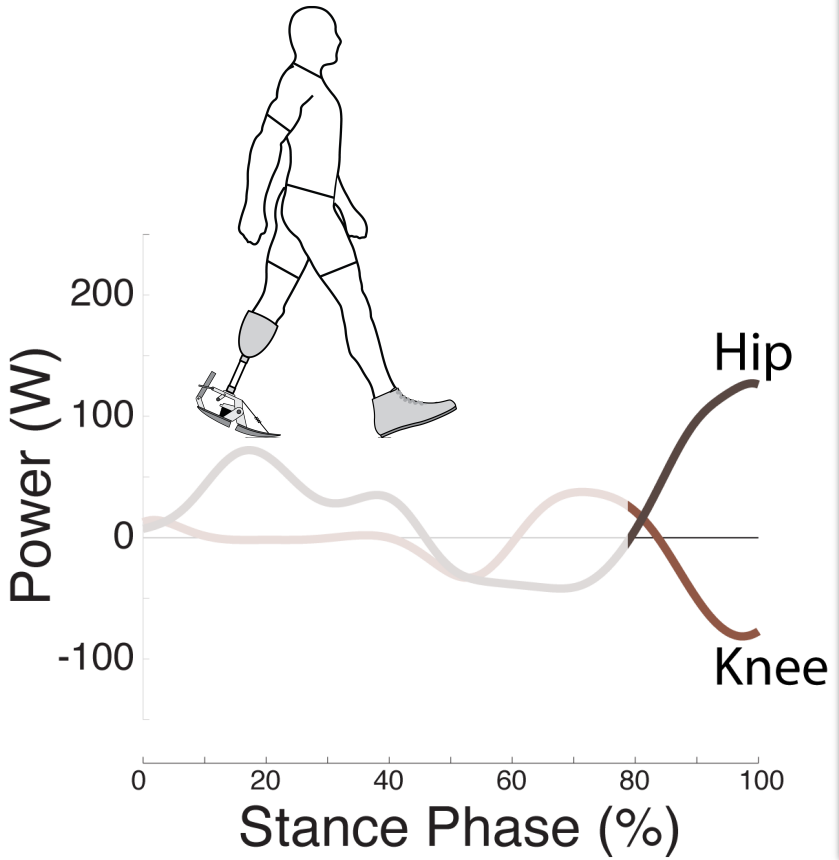
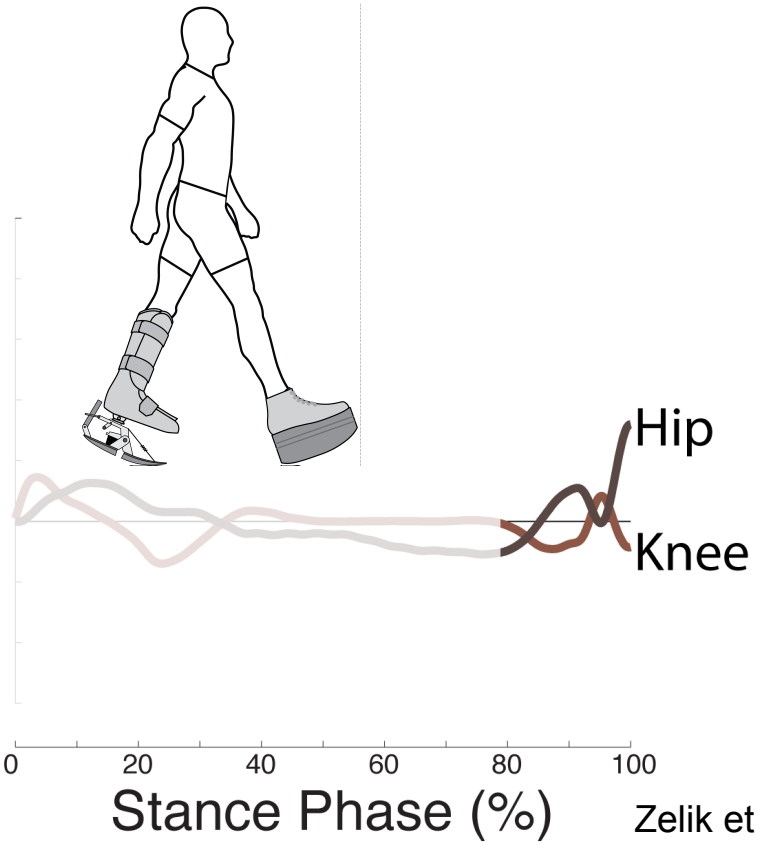
# Key challenge: quantifying & understanding coordination

how user & device adapt to each other




Zelik et al. 2011

# Studying how to physically integrate human & device

## & how to quantify human-device interaction


Vanderbilt (Goldfarb)

Vanderbilt (Goldfarb)

Harvard (Walsh)

# Studying how to physically integrate human & device

**Post-Doc Opening**
my.vanderbilt.edu/batlab


Vanderbilt (Goldfarb)

Vanderbilt (Goldfarb)

Harvard (Walsh)

THIS FALL

# New Vanderbilt Rehabilitation Engineering Center

**Post-Doc Opening**

my.vanderbilt.edu/batlab

3000 sq. ft. motion analysis lab + 3000 sq. ft. engineering space

# A poor transmission can ruin performance

**Human augmentation:** we need new methods to understand human-device power transmission & coordination

2008 Smart ForTwo (ranked 34th worst car of all-time)

SUMMARY

# A poor transmission can ruin performance

**Human augmentation:** we need new methods to understand human-device power transmission & coordination

2008 Smart ForTwo (ranked 34th worst car of all-time)

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