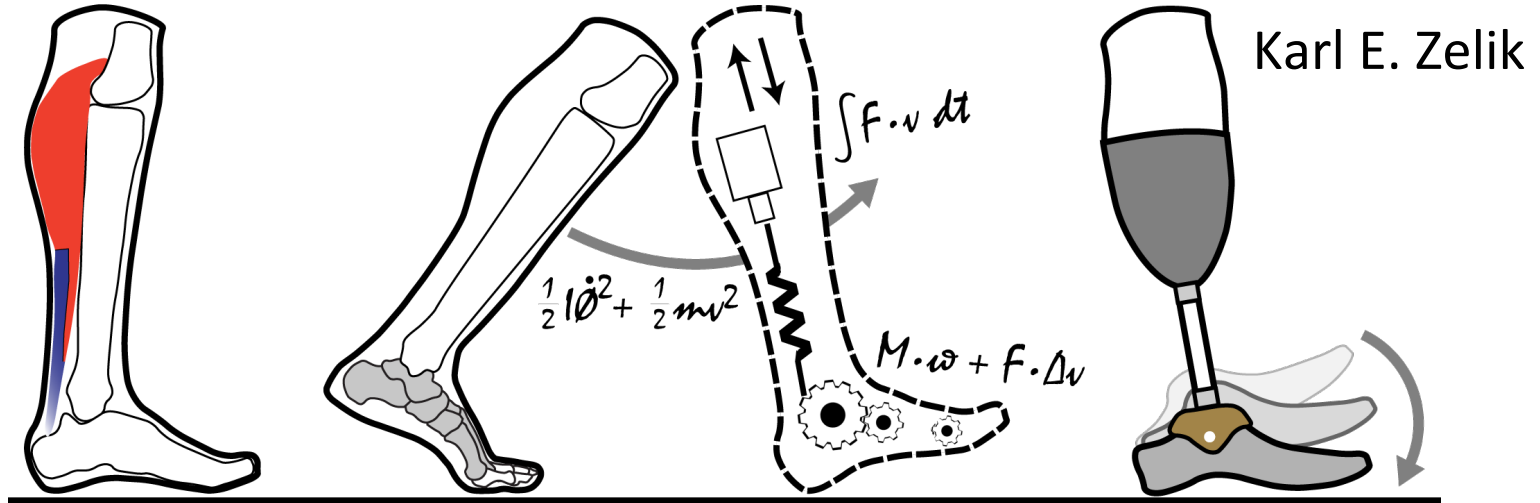


# Unifying Perspectives in Biomechanics

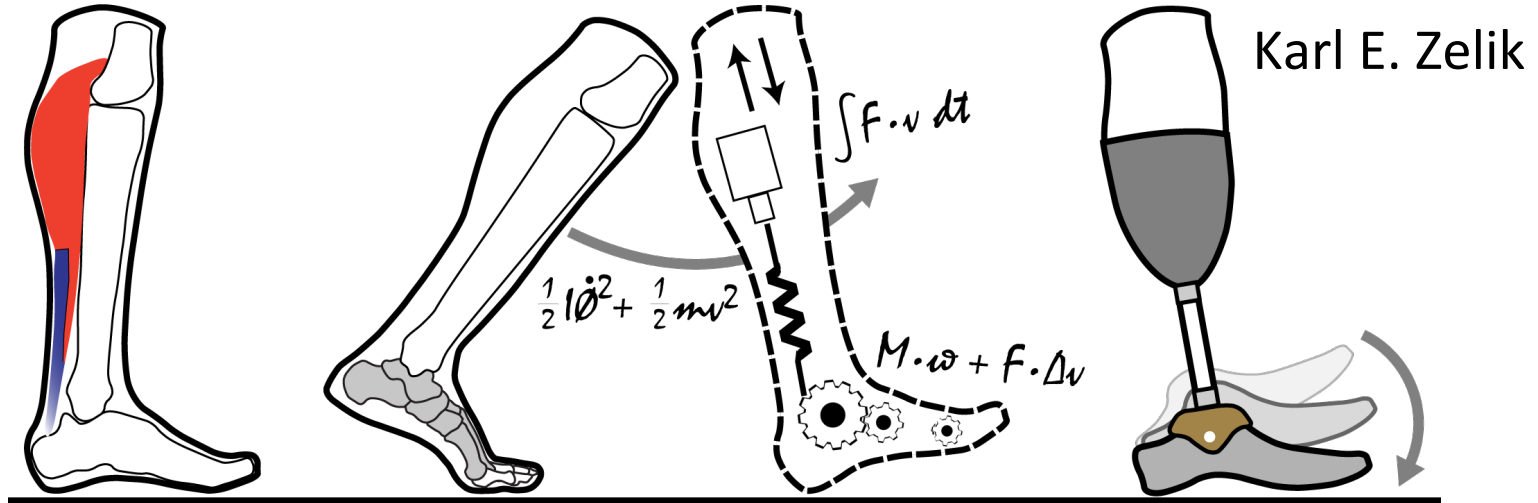


Karl E. Zelik

**Ankle Push-off During Human Walking Contributes to Accelerating Both Swing Leg & Center-of-Mass**



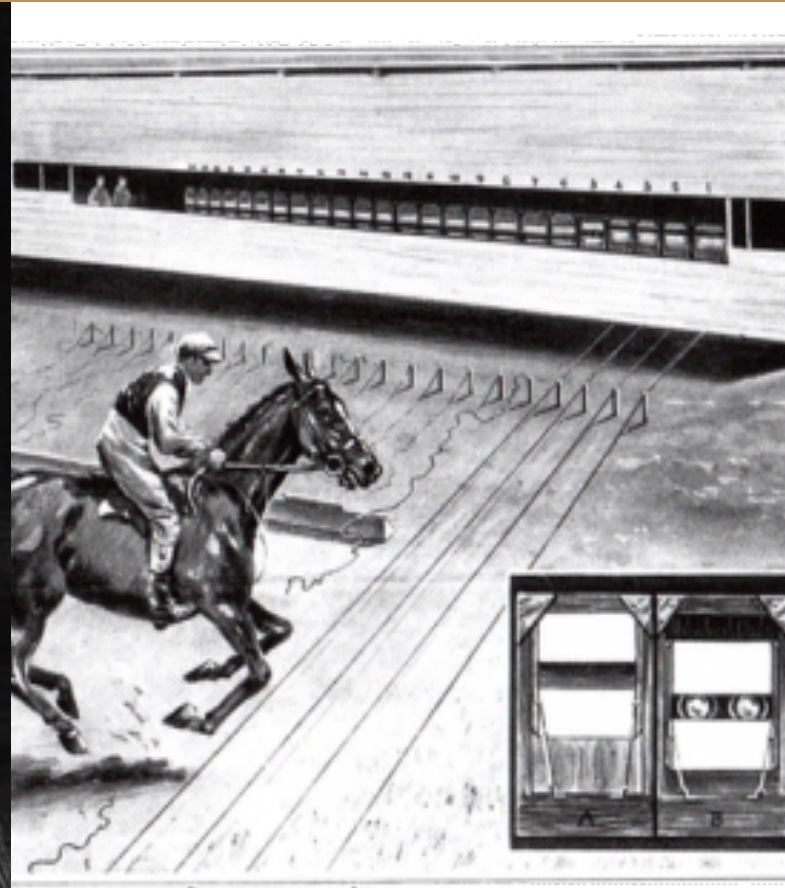
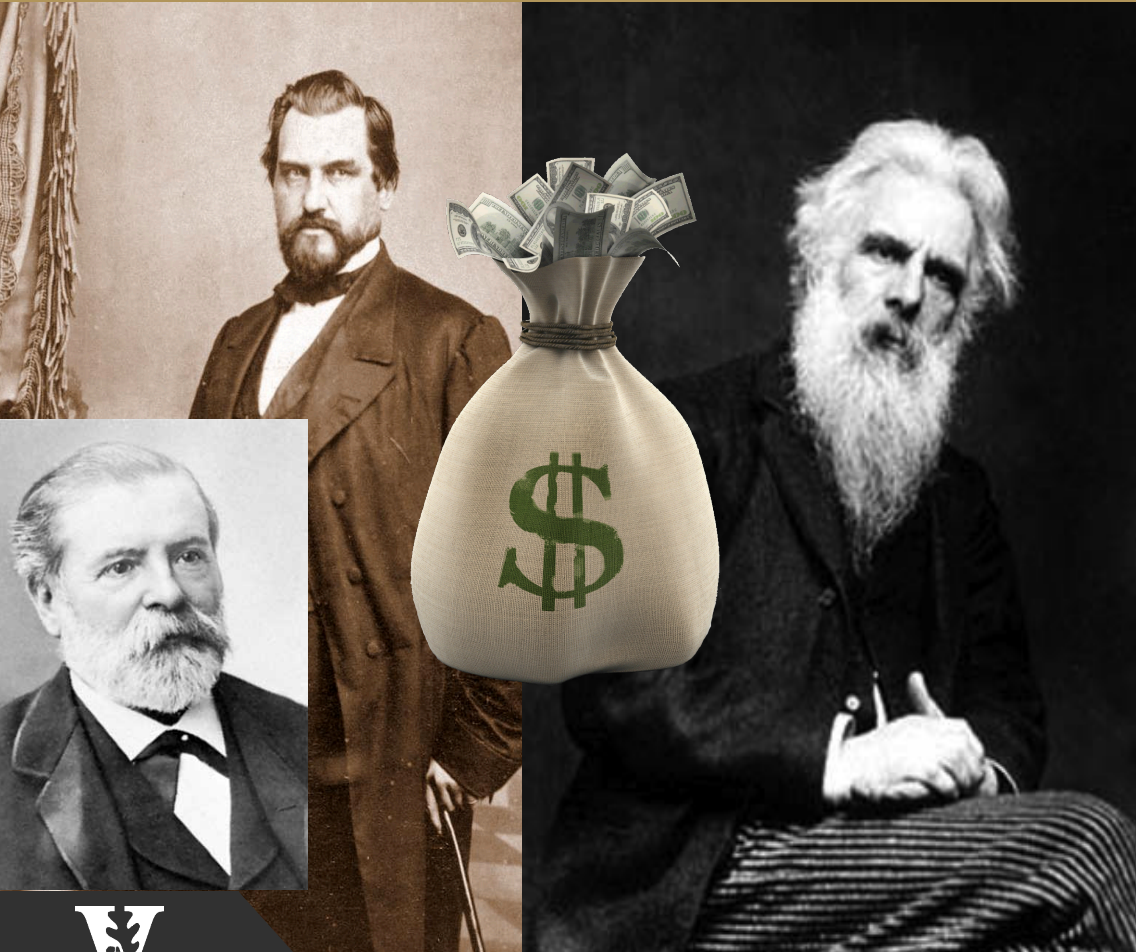
# Unifying Perspectives in Biomechanics



**Ankle Push-off During Human Walking Contributes to Accelerating Both Swing Leg & Center-of-Mass**

## 1870s: BIRTH OF MOTION PICTURES & SEEDS OF MODERN BIOMECHANICS

### Marey, Stanford, Muybridge, an Expensive Horse Bet & a Homicide



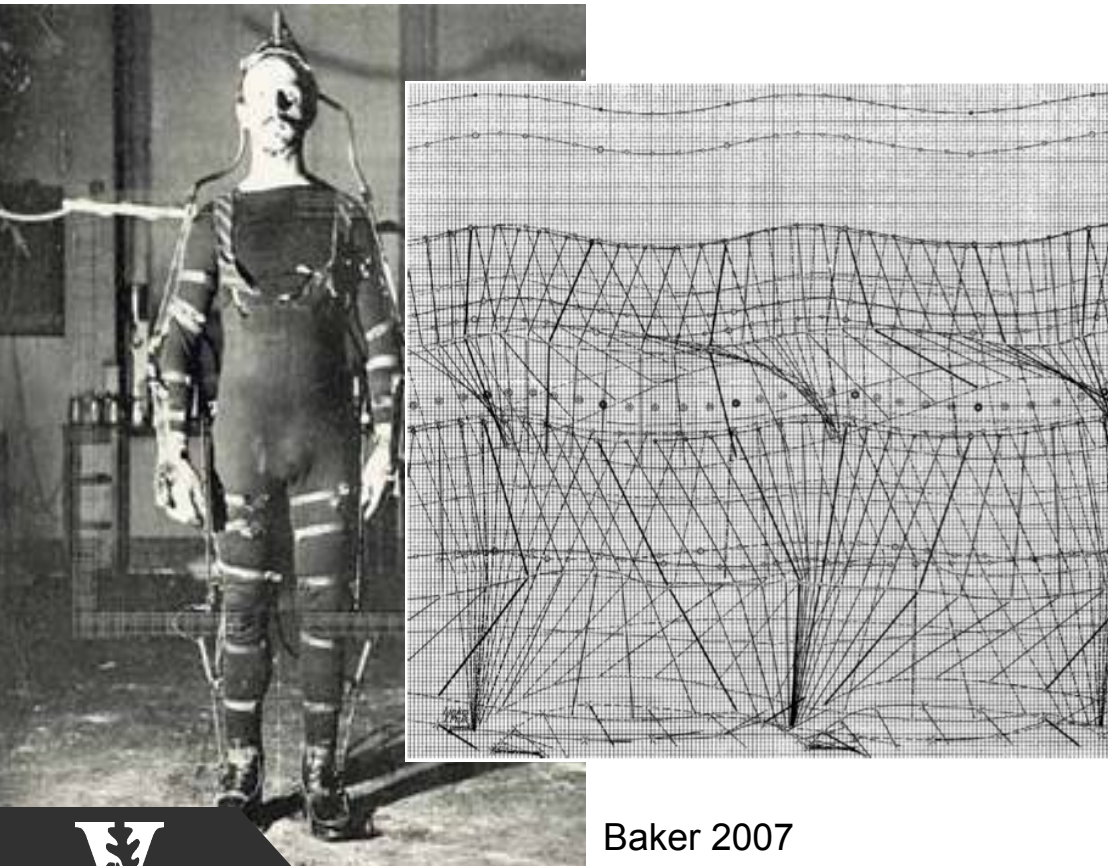
create



1890s

# Motion capture – 1<sup>st</sup> 3D gait analysis (Braune & Fischer)

## THEN



Baker 2007

## NOW



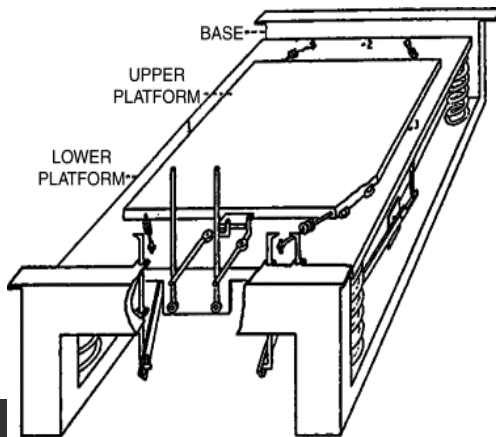
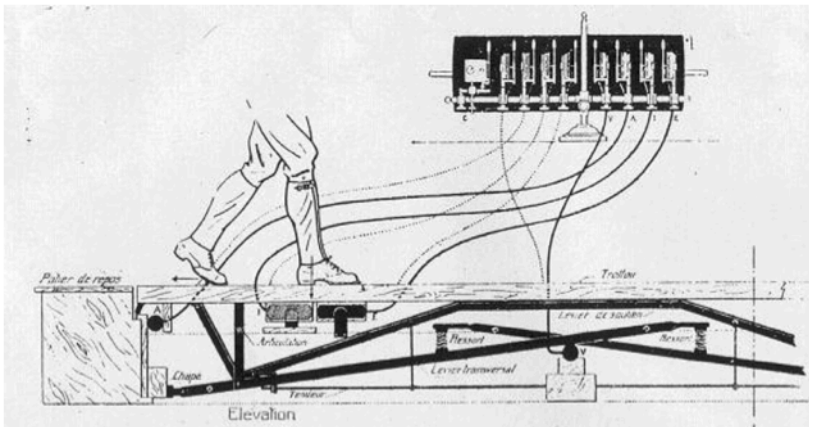
create



1910-1930s

Force plates: pneumatic (Amar), mechanical (Fenn & Elftman)

THEN



NOW



Baker 2007, Medved 2000, Sutherland 2005

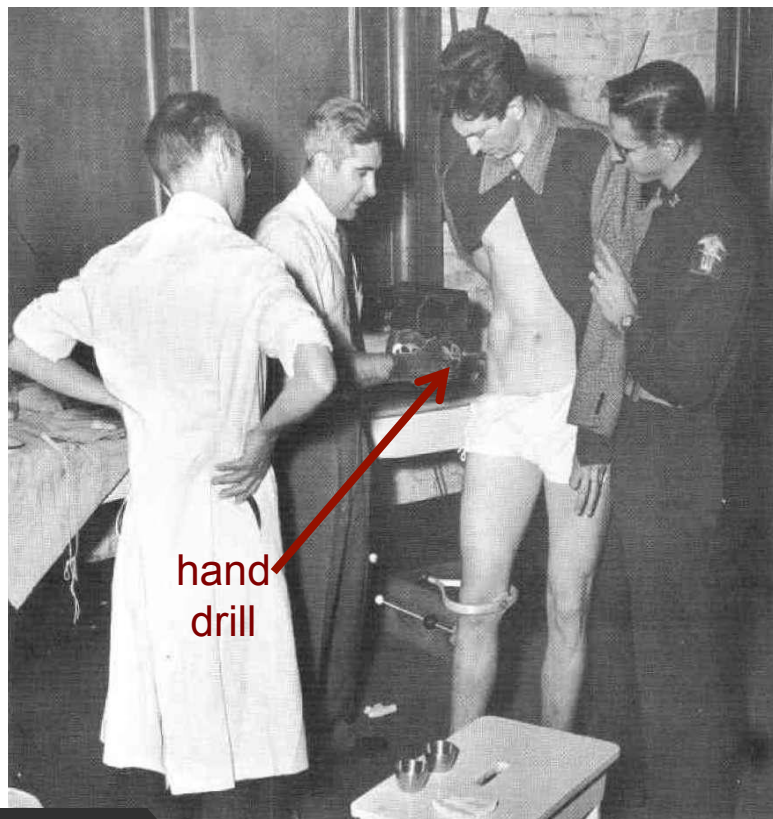


CREATE

1950s

# Motion capture markers

## THEN



Inman, Ralston & Todd 1981

## NOW

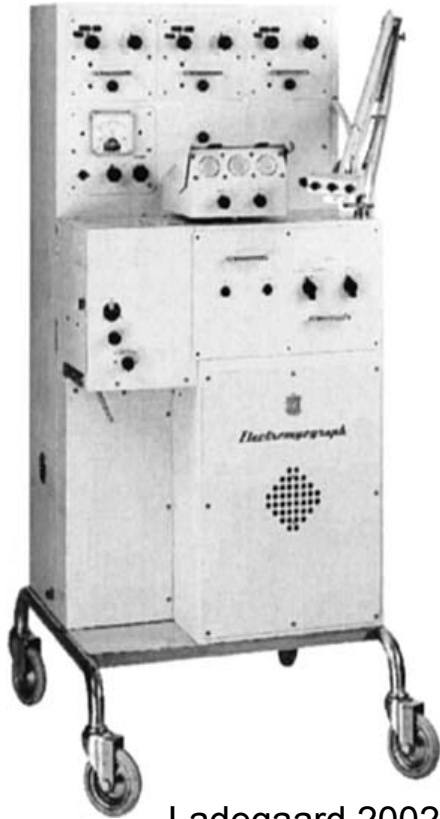


create

1950s

# EMG – First commercially-available system (Denmark)

THEN



Ladegaard 2002

NOW



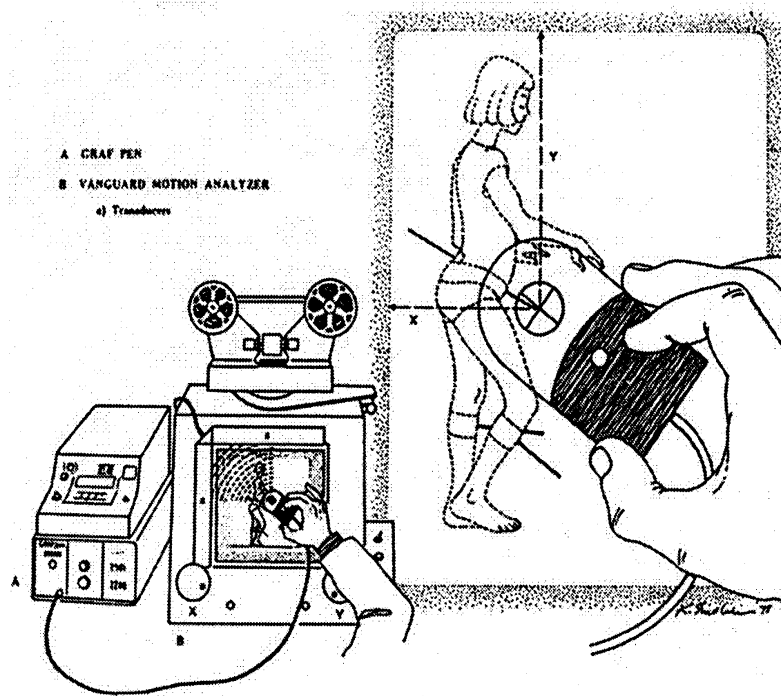
create



1970s

# Semi-automated motion tracking (Sutherland & Hagy)

## THEN

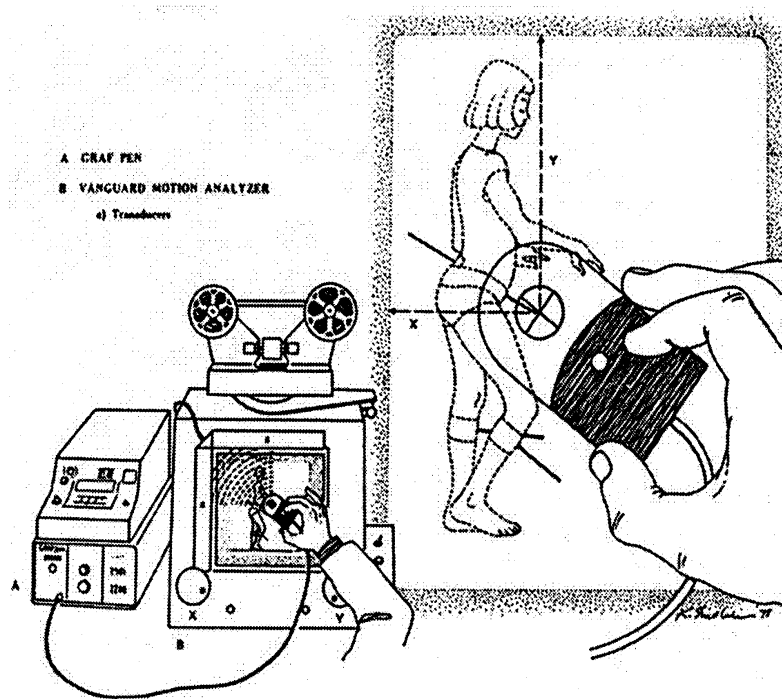


Sutherland 2002

1970s

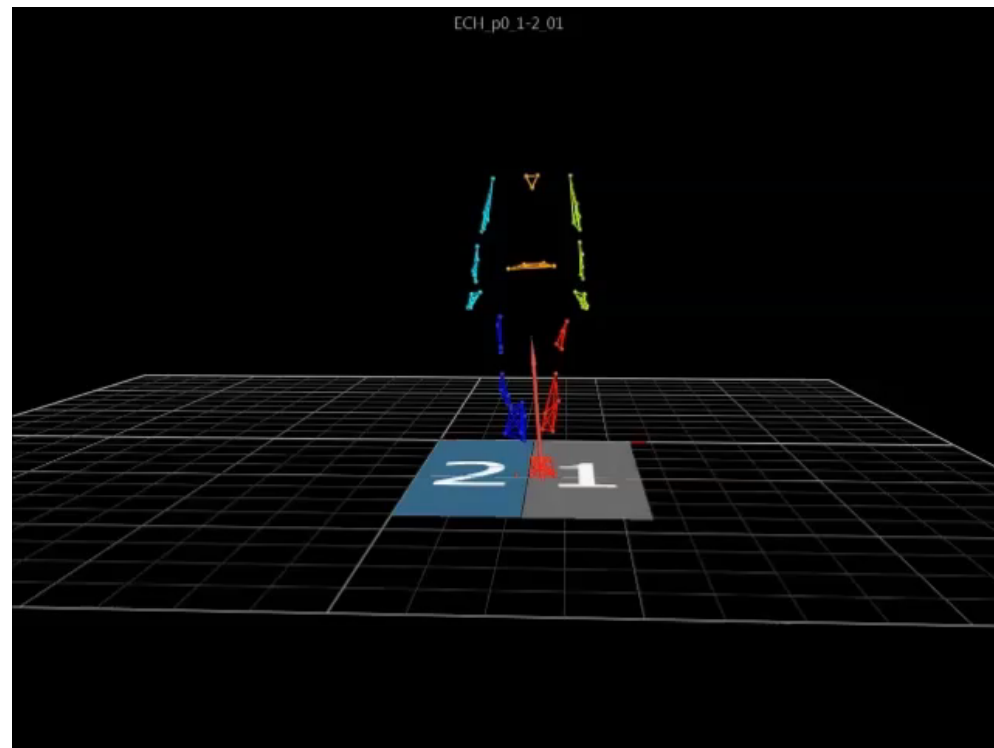
# Semi-automated motion tracking (Sutherland & Hagy)

## THEN



Sutherland 2002

## NOW




# Intro takeaways

1. We're pretty spoiled now in terms of measurement tools (& fewer bone pins).
2. Motion, force & EMG are still research workhorses today; just easier to use & with lots of new ways to analyze data





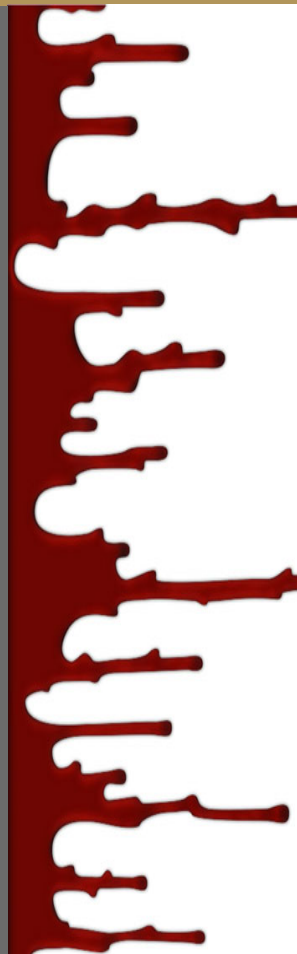
# Intro takeaways

1. We're pretty spoiled now in terms of measurement tools (& fewer bone pins).
2. Motion, force & EMG are still research workhorses today; just easier to use & with **lots of new ways to analyze data**  
  
**competing perspectives in biomechanics**

# Differing/competing perspectives in biomechanics

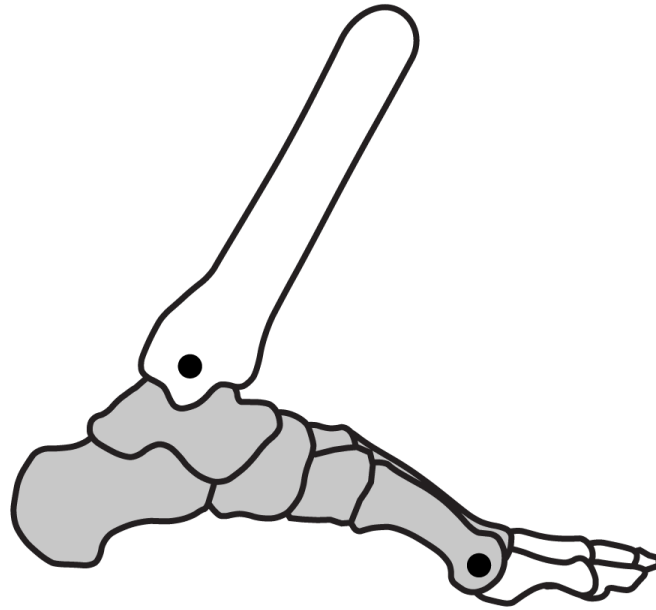
what we think  
we know

bleeding edge of science



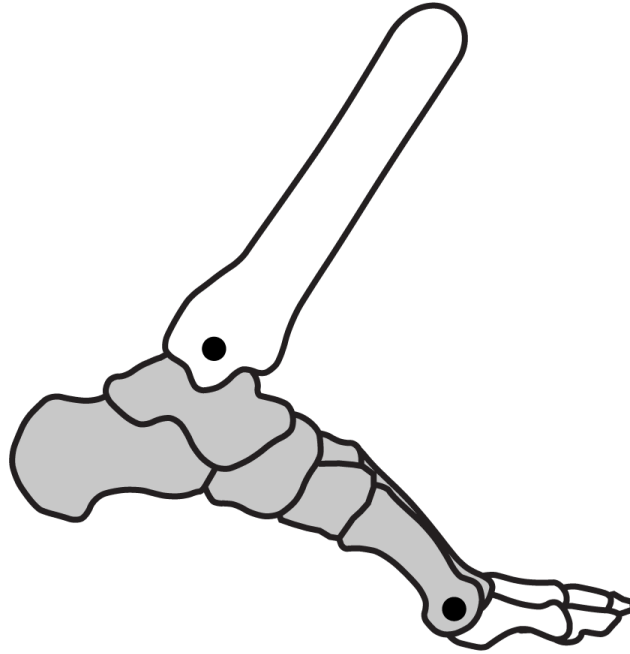
what we  
don't know

To what does ankle Push-off power contribute in human gait?

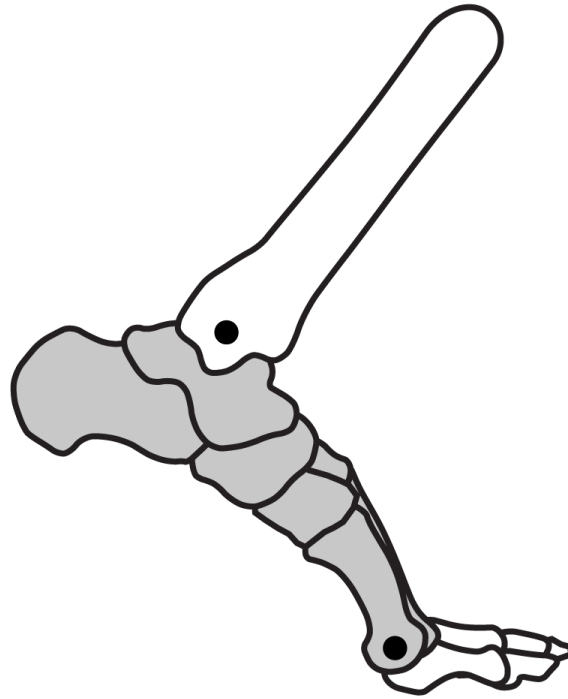




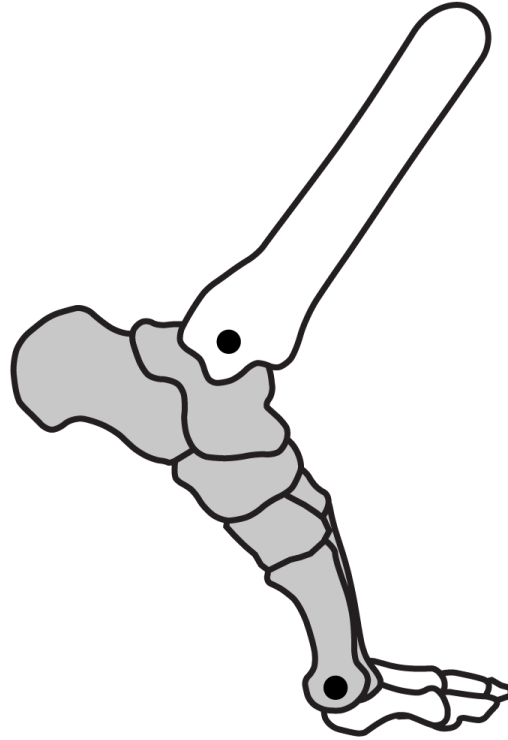
To what does ankle Push-off power contribute in human gait?



To what does ankle Push-off power contribute in human gait?

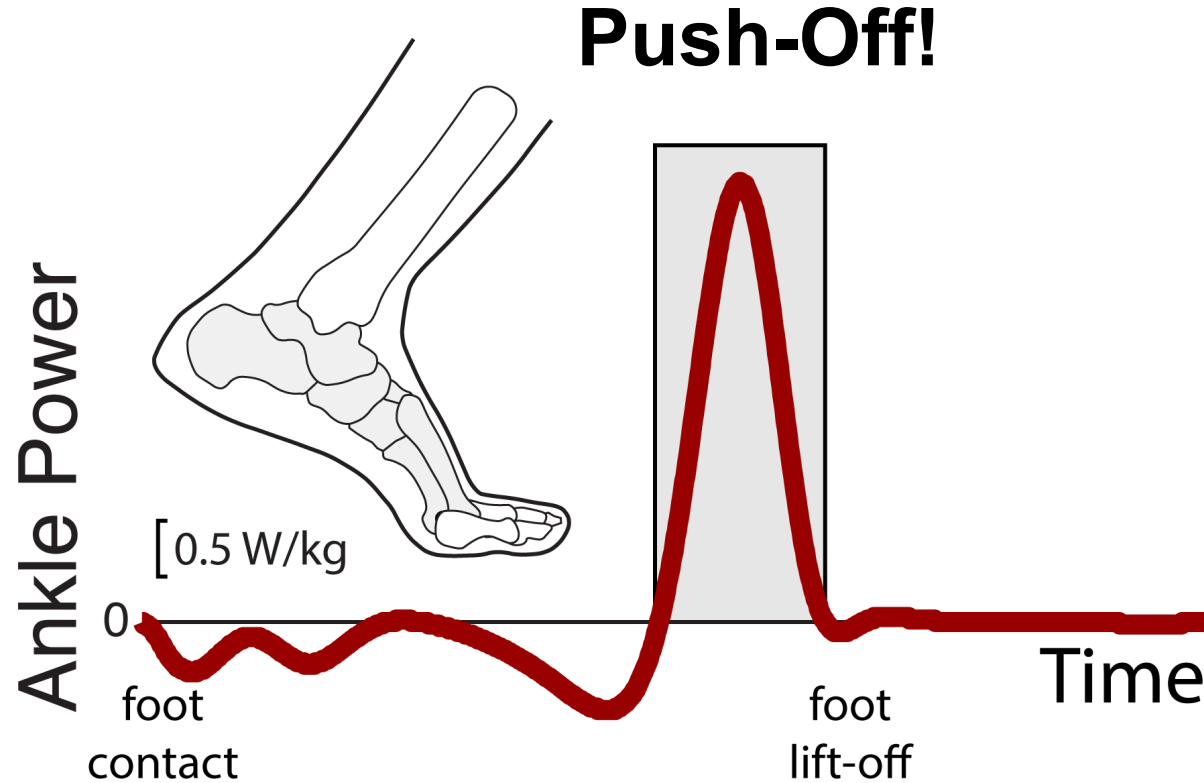


To what does ankle Push-off power contribute in human gait?





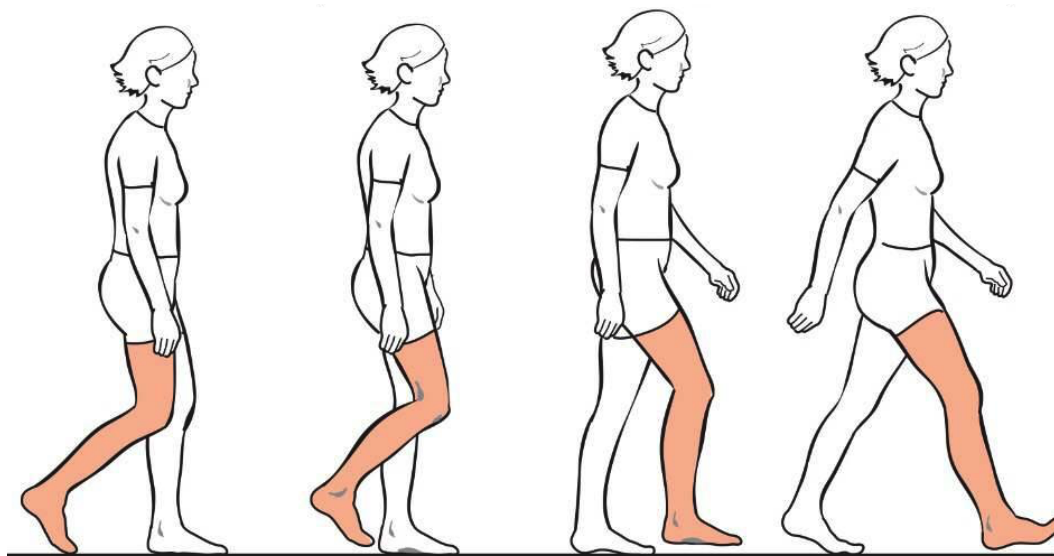
# Ankle Push-off (burst of power) or Roll-off (restrain falling)?



Winter 1983, Hof et al. 1993, Neptune et al. 2001

# Ankle Push-off power primarily accelerates swing leg or trunk?

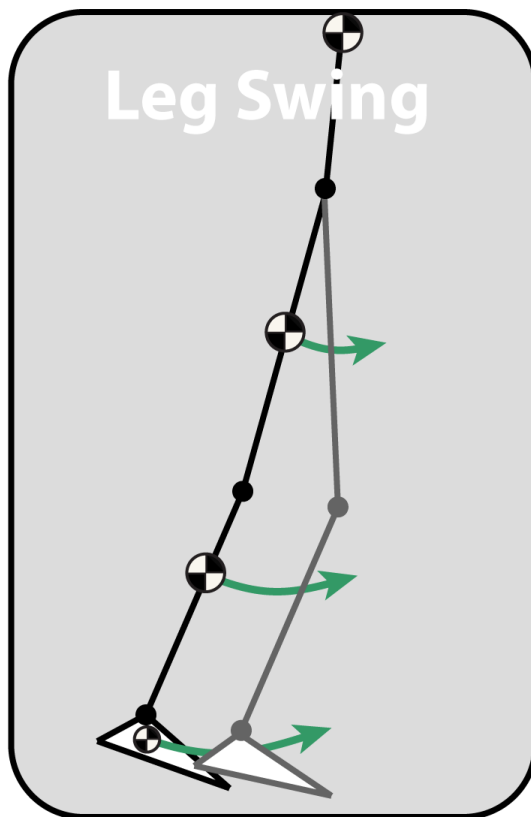
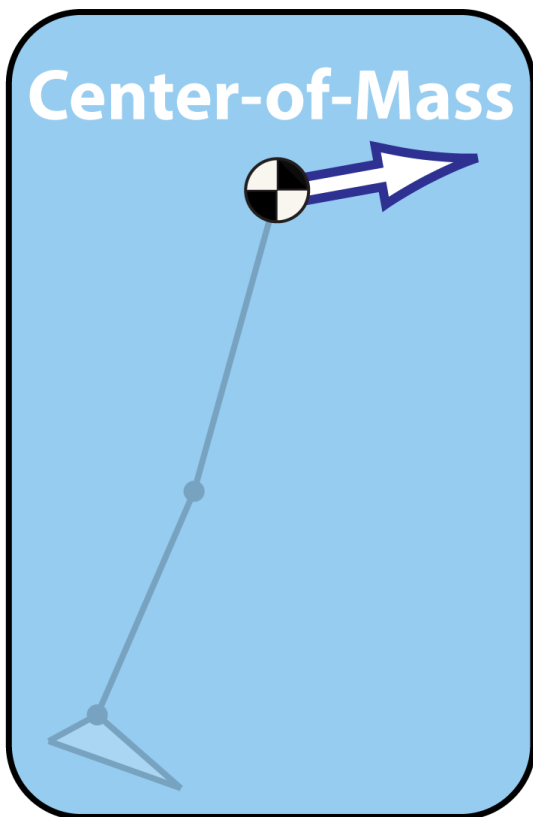
## Swing Leg!



Winter & Robertson 1978, Meinders et al. 1998, Neptune et al. 2001, etc.



# Ankle power primarily accelerates swing leg or body's COM?



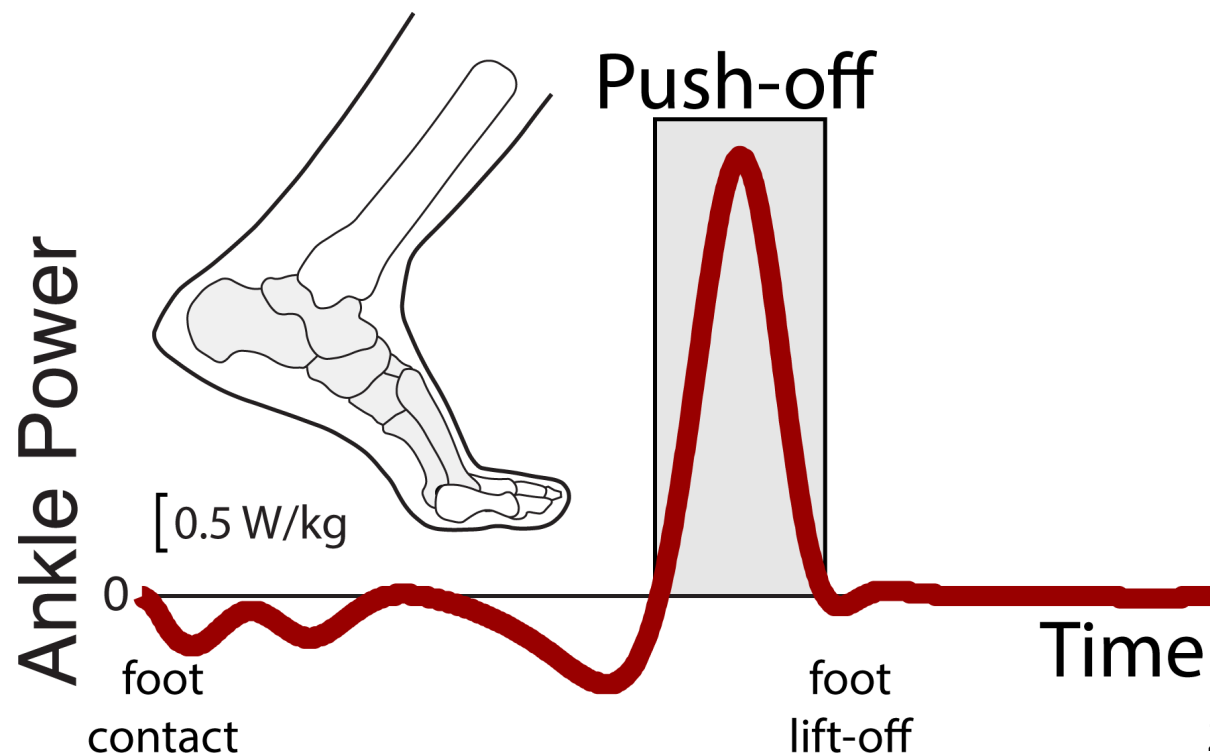
COM = Center-of-Mass



Peter Adamczyk  
(Wisconsin)

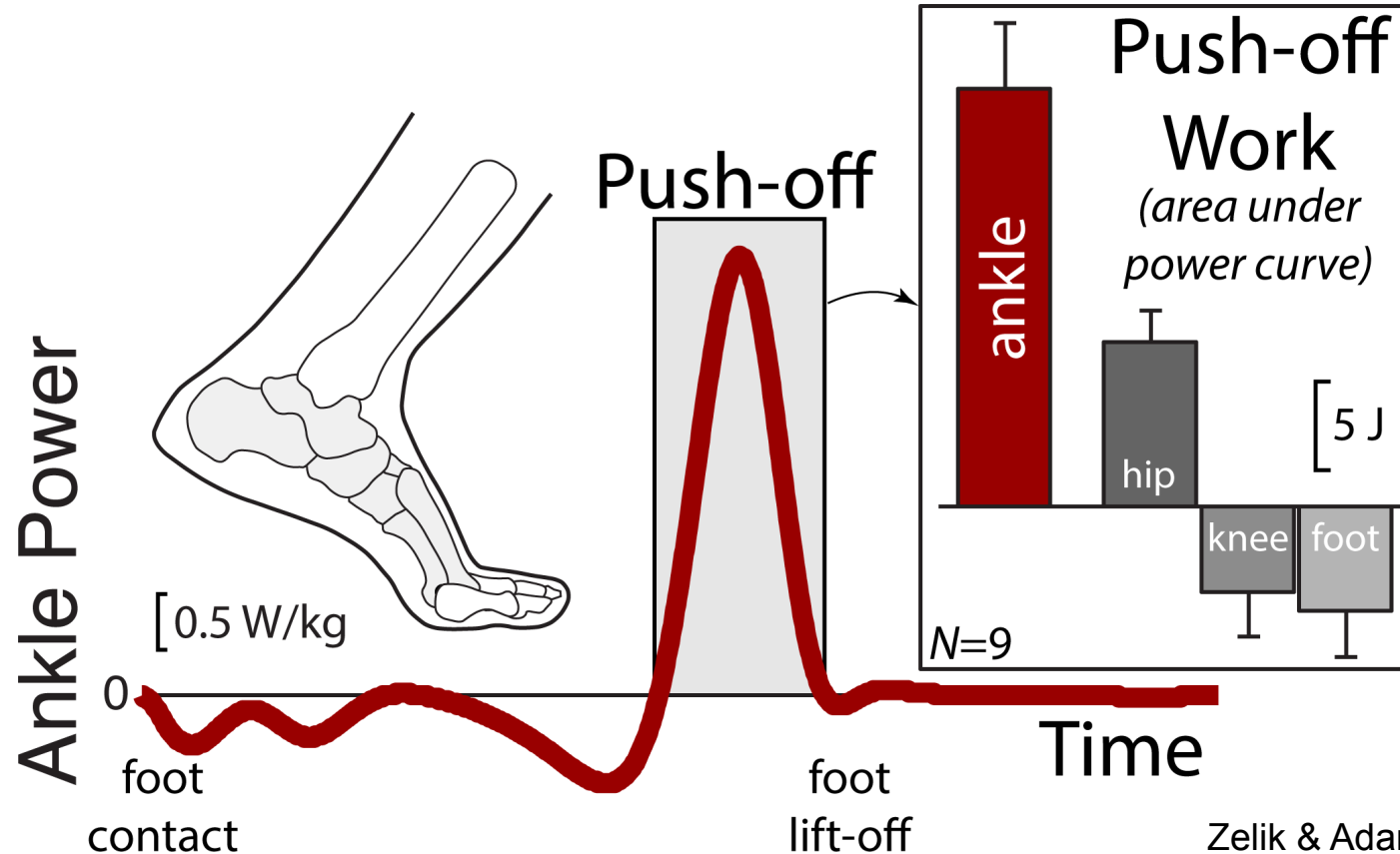
## DEFINITION (DURING WALKING)

Ankle Push-off: burst of power generated at end of stance



Zelik & Adamczyk 2016 (JEB)

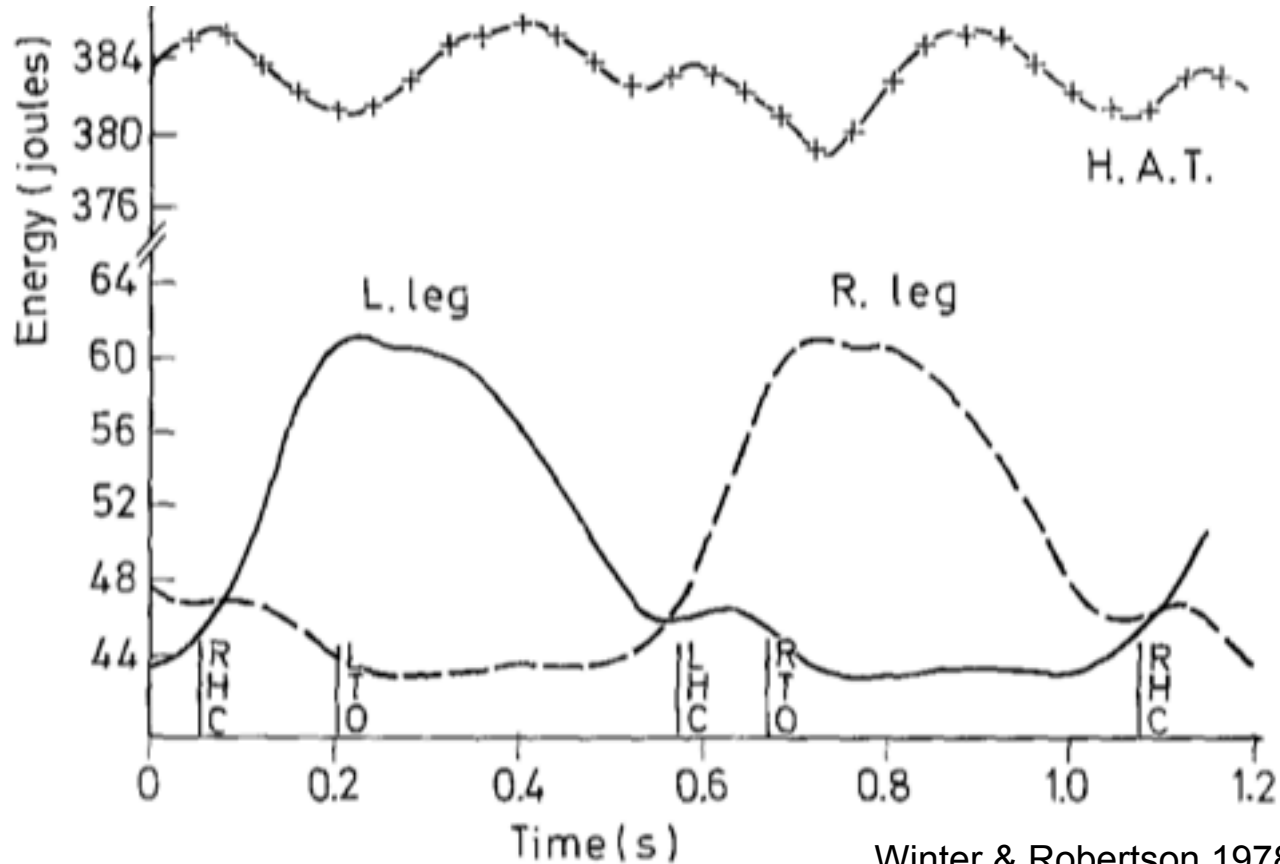
# Ankle Push-off: burst of power generated at end of stance



Zelik & Adamczyk 2016 (JEB)



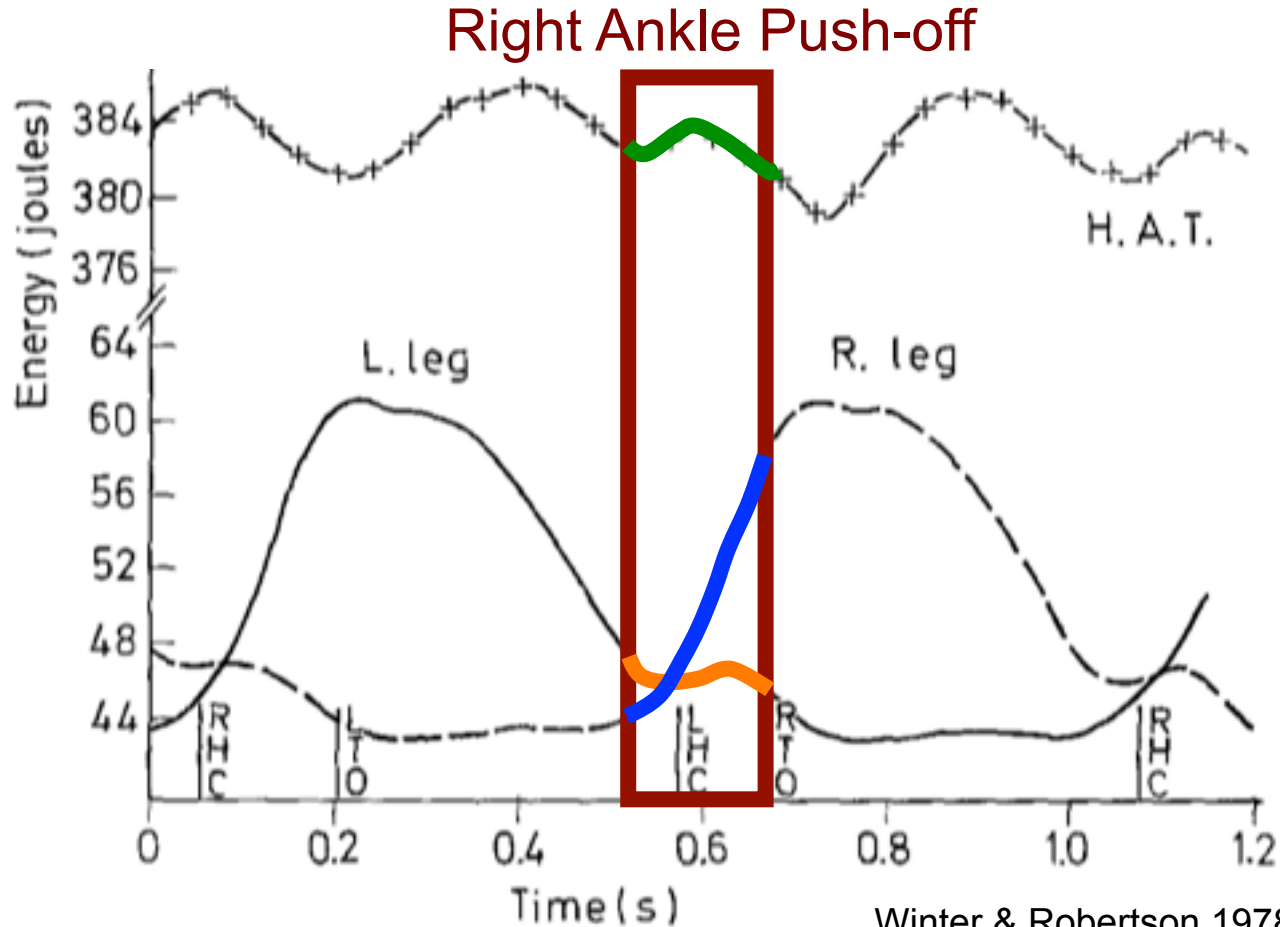
Push-off accelerates limb segments; little trunk energy change



Winter & Robertson 1978



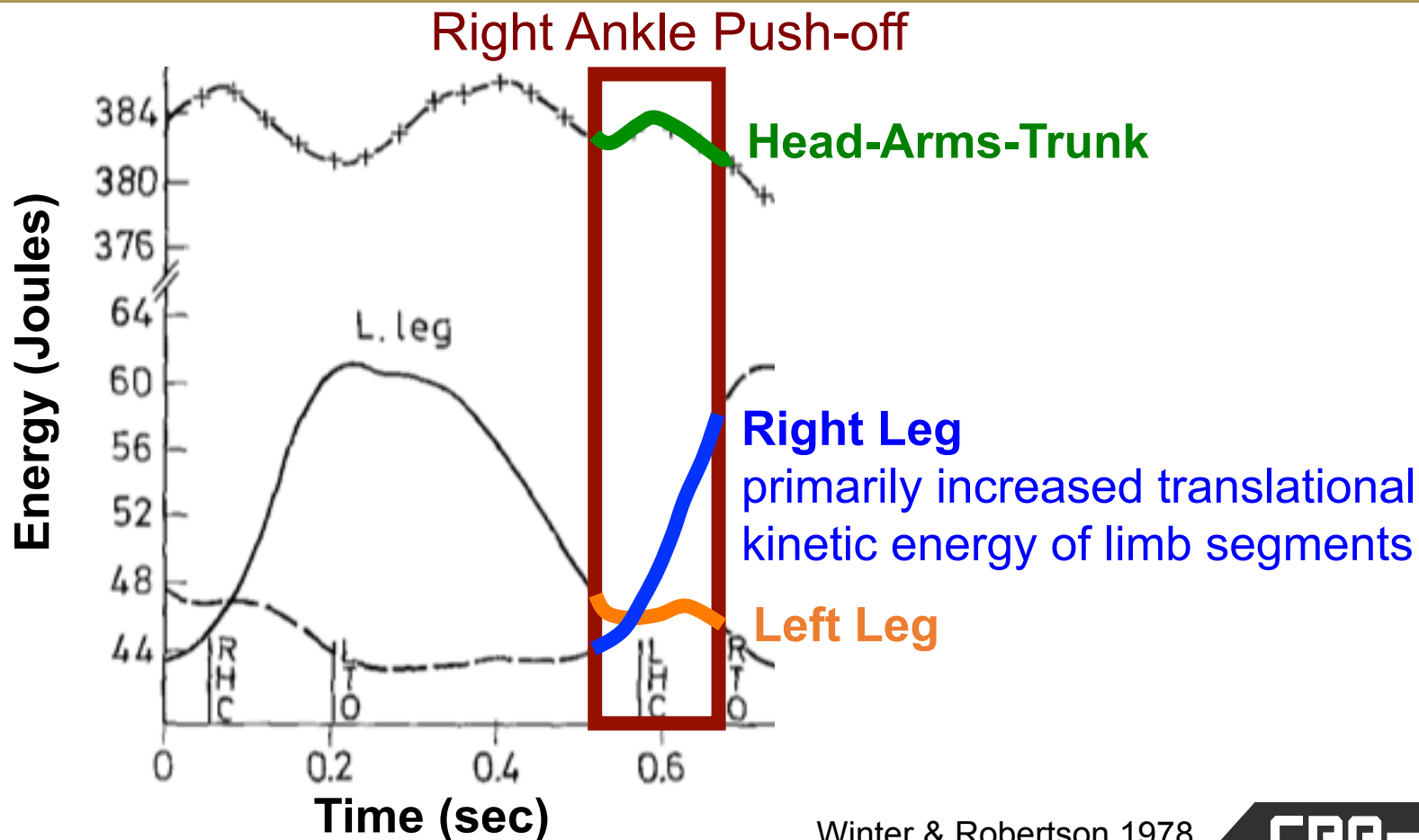
Push-off accelerates limb segments; little trunk energy change



Winter & Robertson 1978



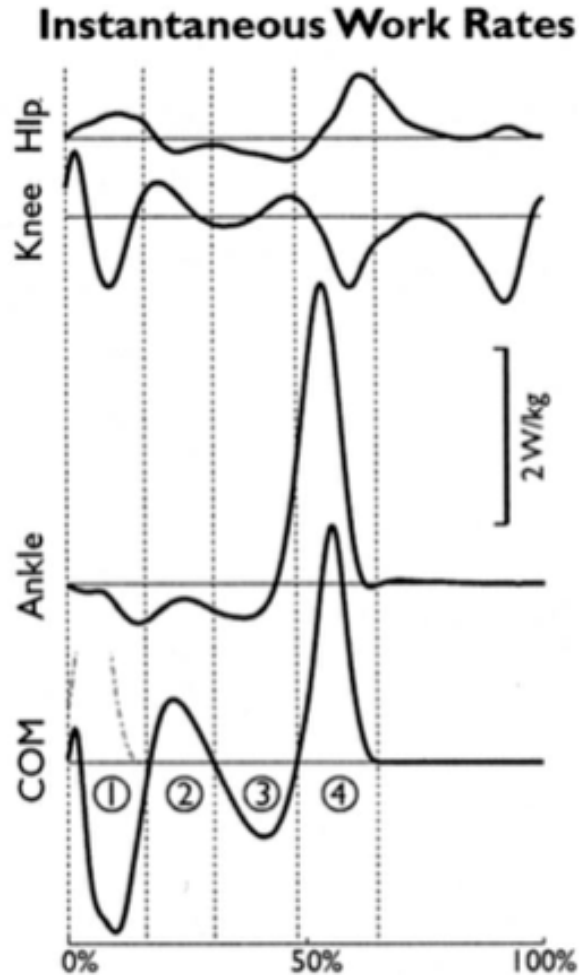
Push-off accelerates limb segments; little trunk energy change



Push-off accelerates limb segments; little trunk energy change

Study	Takeaway
Hof et al. 1992	Ankle Push-off work matches timing & slope of swing leg energy change
Meinders et al. 1998	32 J of ankle work & 29 J of swing leg energy change during Push-off
Lipfert et al. 2014	Power transfer analysis: most of Push-off power goes into swing limb

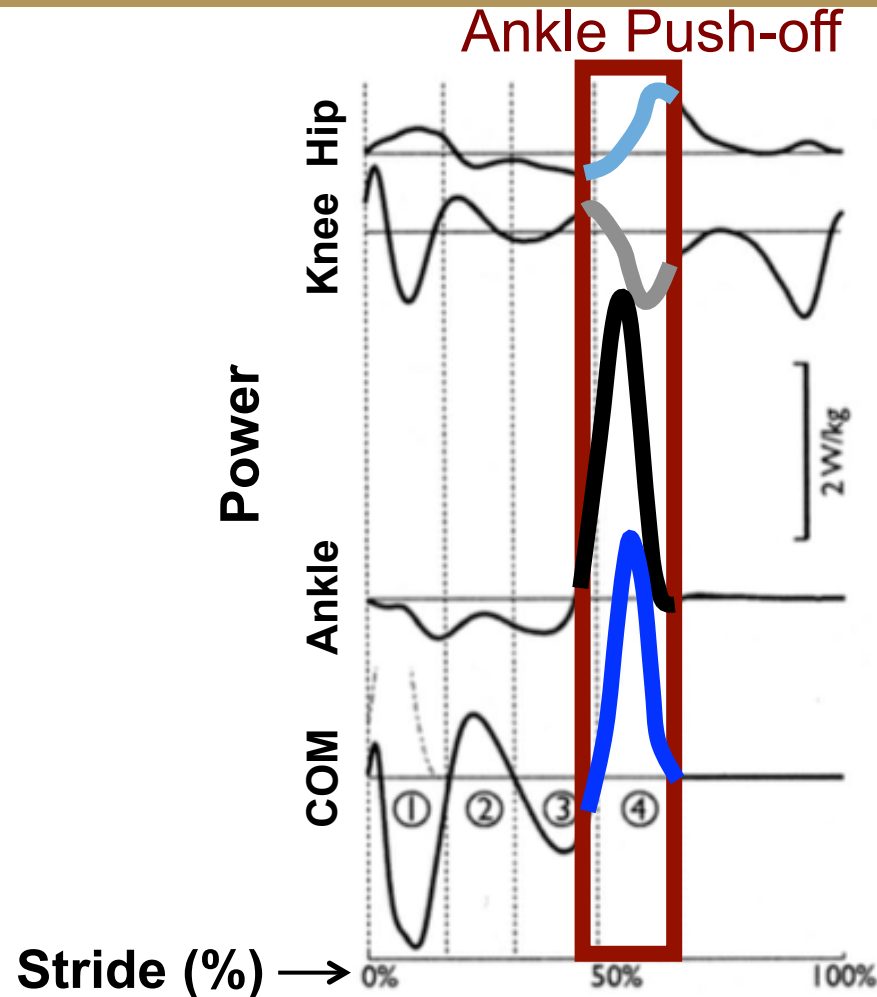
# Push-off accelerates COM; little energy change relative to COM



Kuo, Donelan & Ruina 2005



## Push-off accelerates COM; little energy change relative to COM



Kuo, Donelan & Ruina 2005



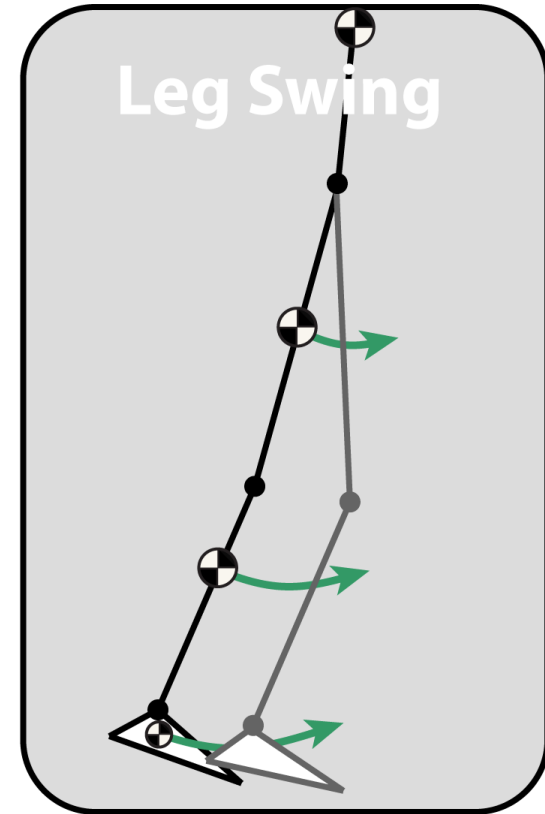
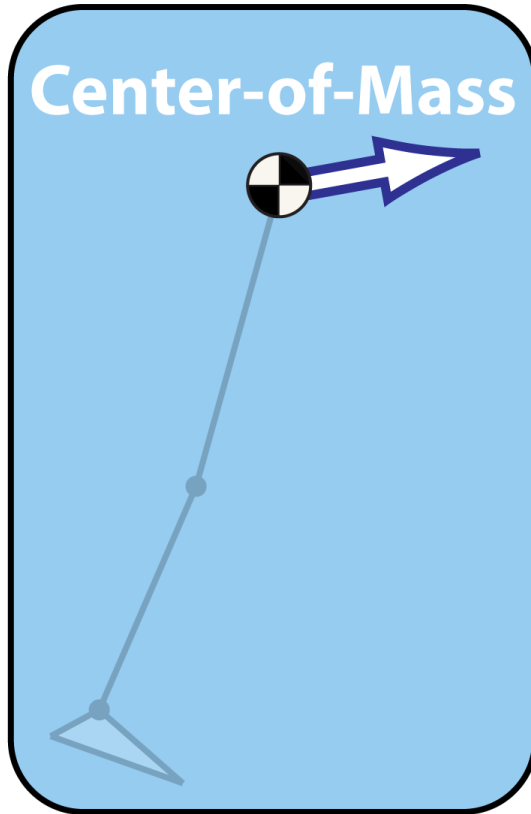
# Push-off accelerates COM; little energy change relative to COM

Study	Takeaway
<b>Donelan et al. 2002</b> <b>Zelik &amp; Kuo 2010</b>	Ankle & COM Push-off work increase together with gait speed
<b>Houdijk et al. 2009</b> <b>Caputo &amp; Collins 2014</b>	Ankle & COM Push-off work are both reduced for prosthetic users
<b>Huang et al. 2015</b>	Restrictive orthosis: COM work decreased linearly with ankle work



## CAN PERSPECTIVES BE RECONCILED?

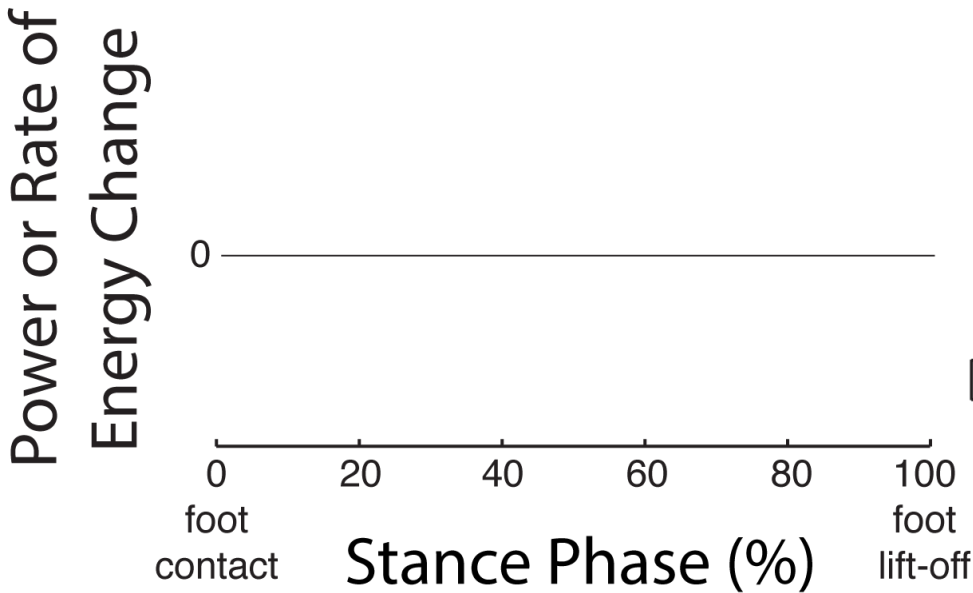
Two perspectives. Each with evidence. Conflicting conclusions



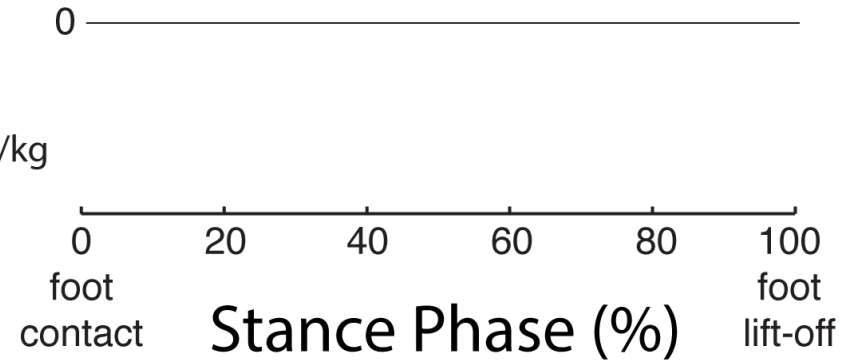


# Combining work & energy estimates to coalesce perspectives

## COM Perspective



## Swing Leg Perspective

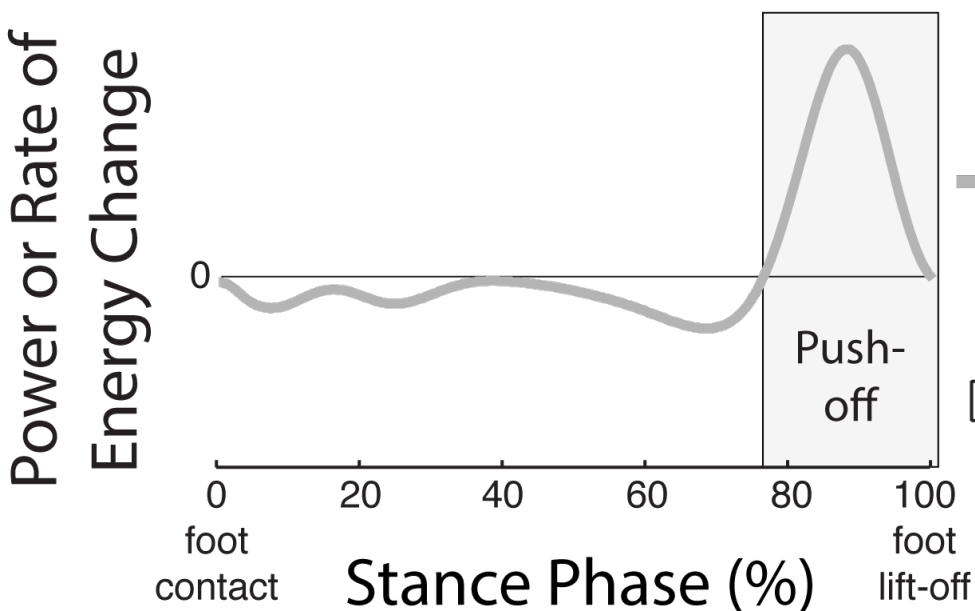


Zelik & Adamczyk 2016 (JEB)

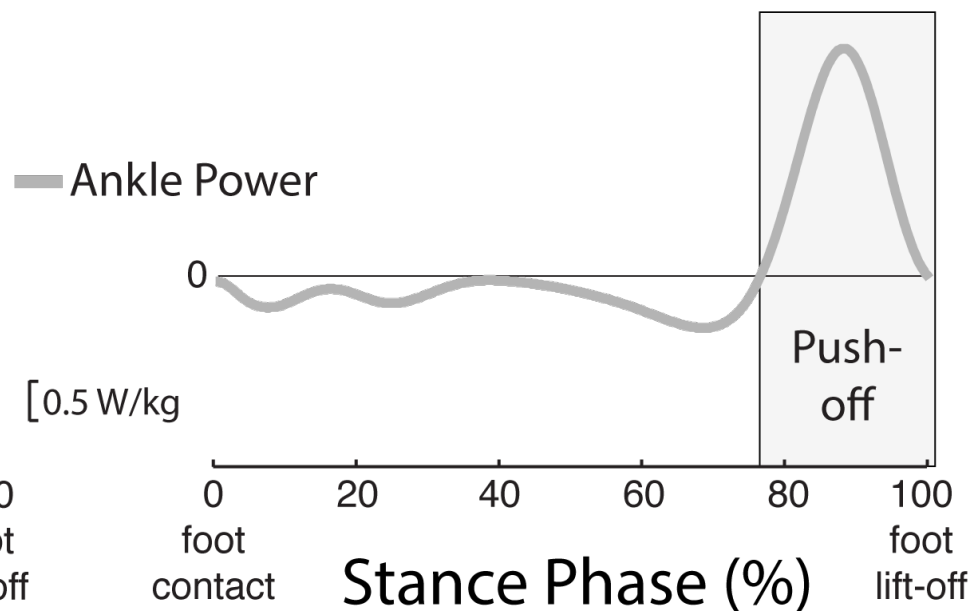


## Combining work & energy estimates to coalesce perspectives

### COM Perspective



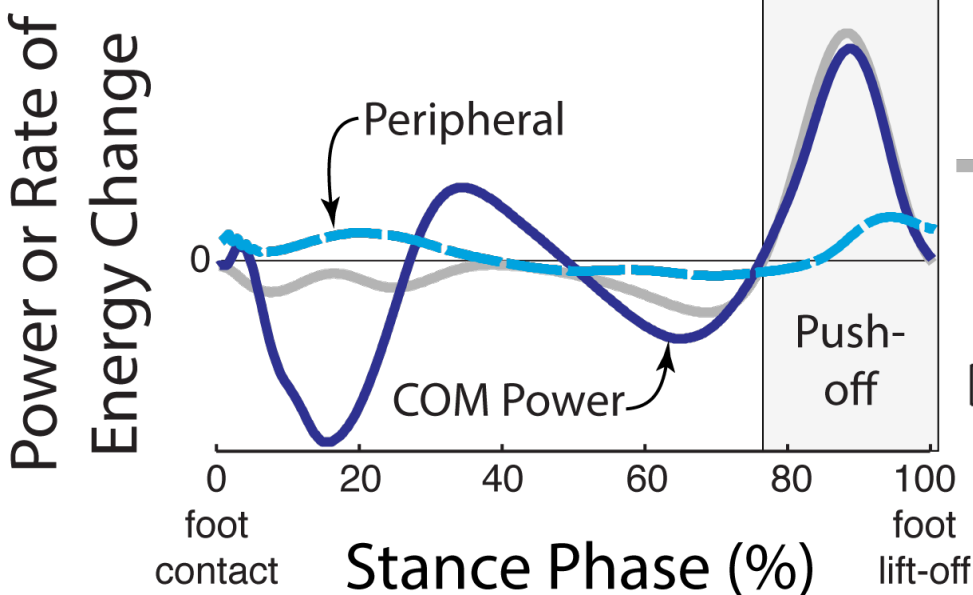
### Swing Leg Perspective



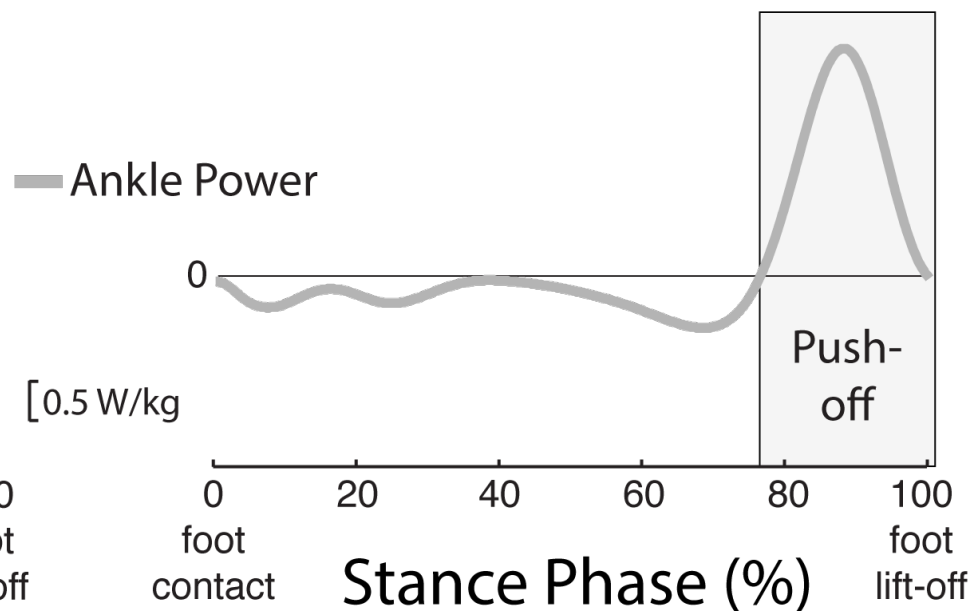
Zelik & Adamczyk 2016 (JEB)

## Combining work & energy estimates to coalesce perspectives

### COM Perspective



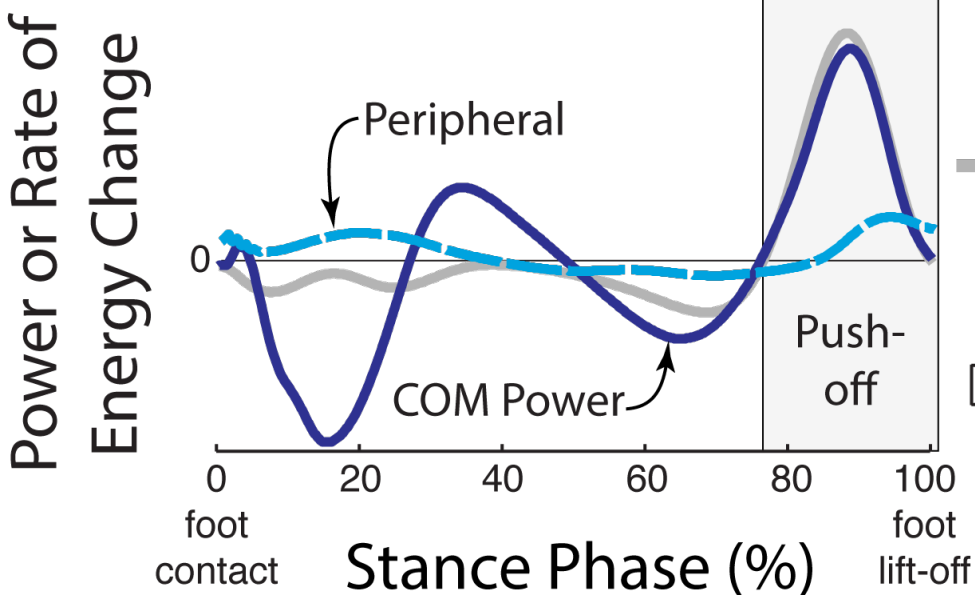
### Swing Leg Perspective



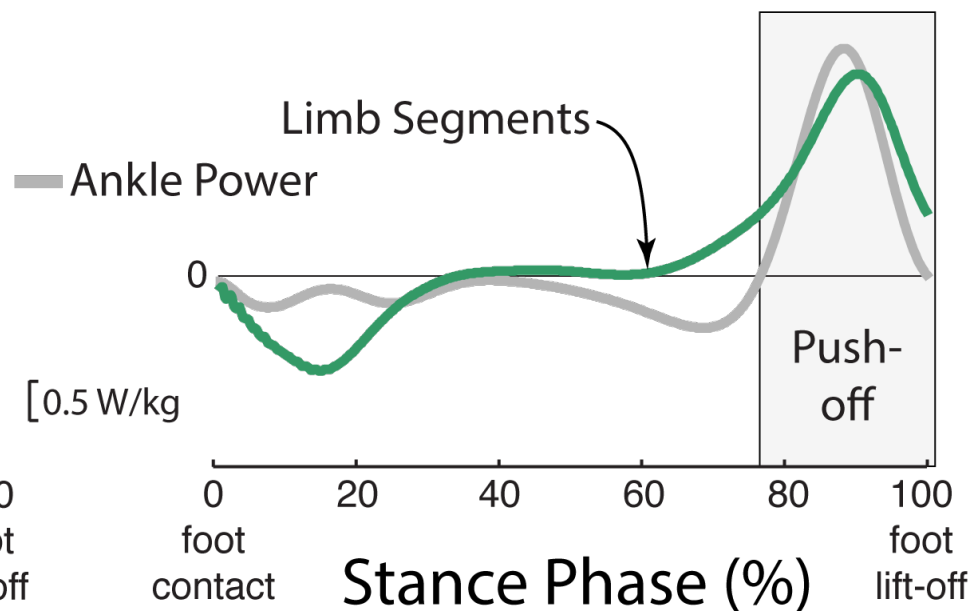
Zelik & Adamczyk 2016 (JEB)

## Combining work & energy estimates to coalesce perspectives

### COM Perspective



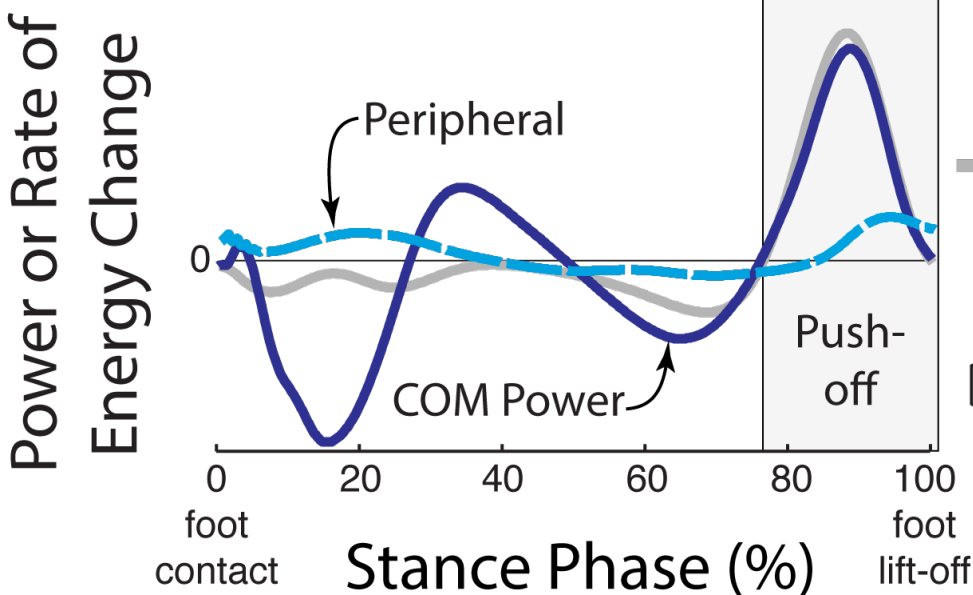
### Swing Leg Perspective



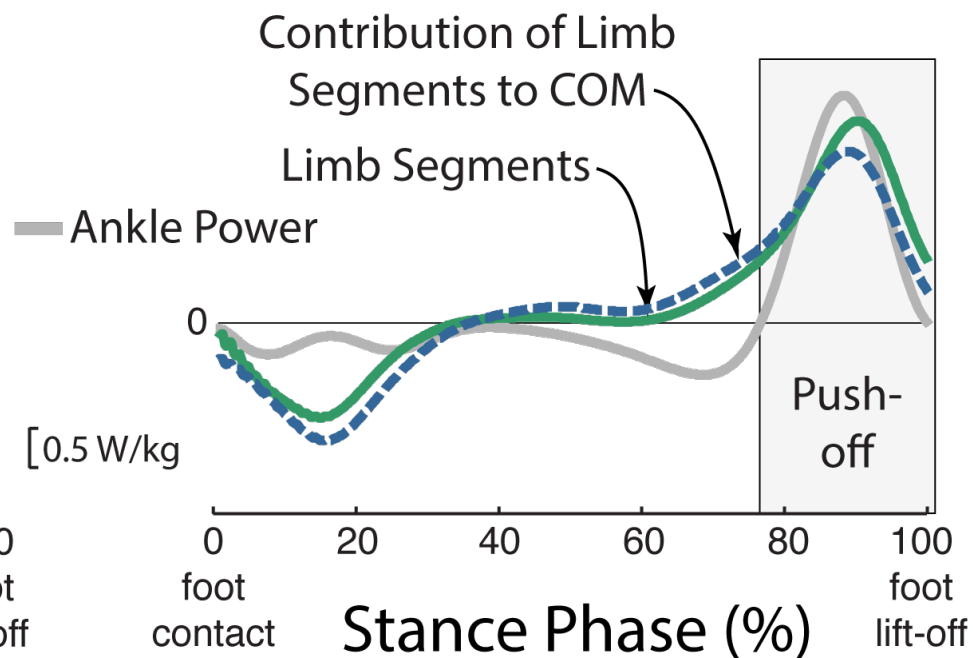
Zelik & Adamczyk 2016 (JEB)

## Combining work & energy estimates to coalesce perspectives

### COM Perspective



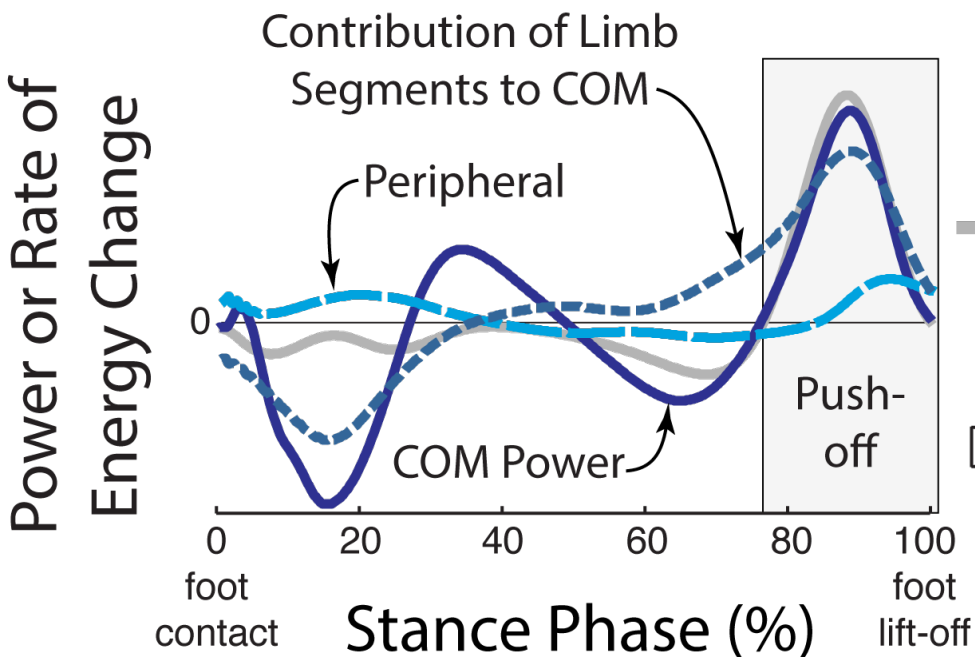
### Swing Leg Perspective



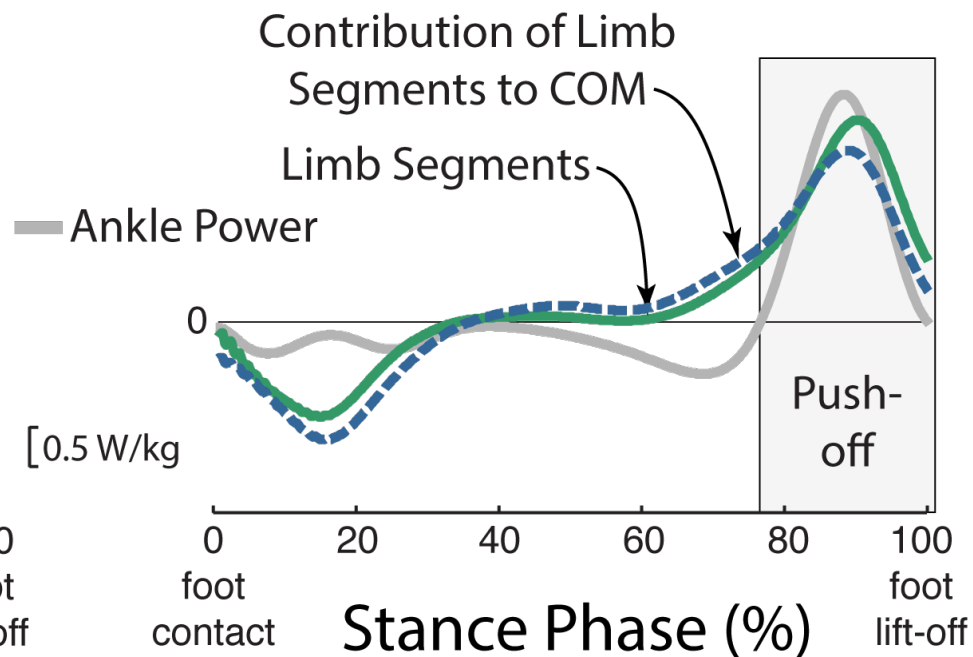
Zelik & Adamczyk 2016 (JEB)

## Combining work & energy estimates to coalesce perspectives

### COM Perspective



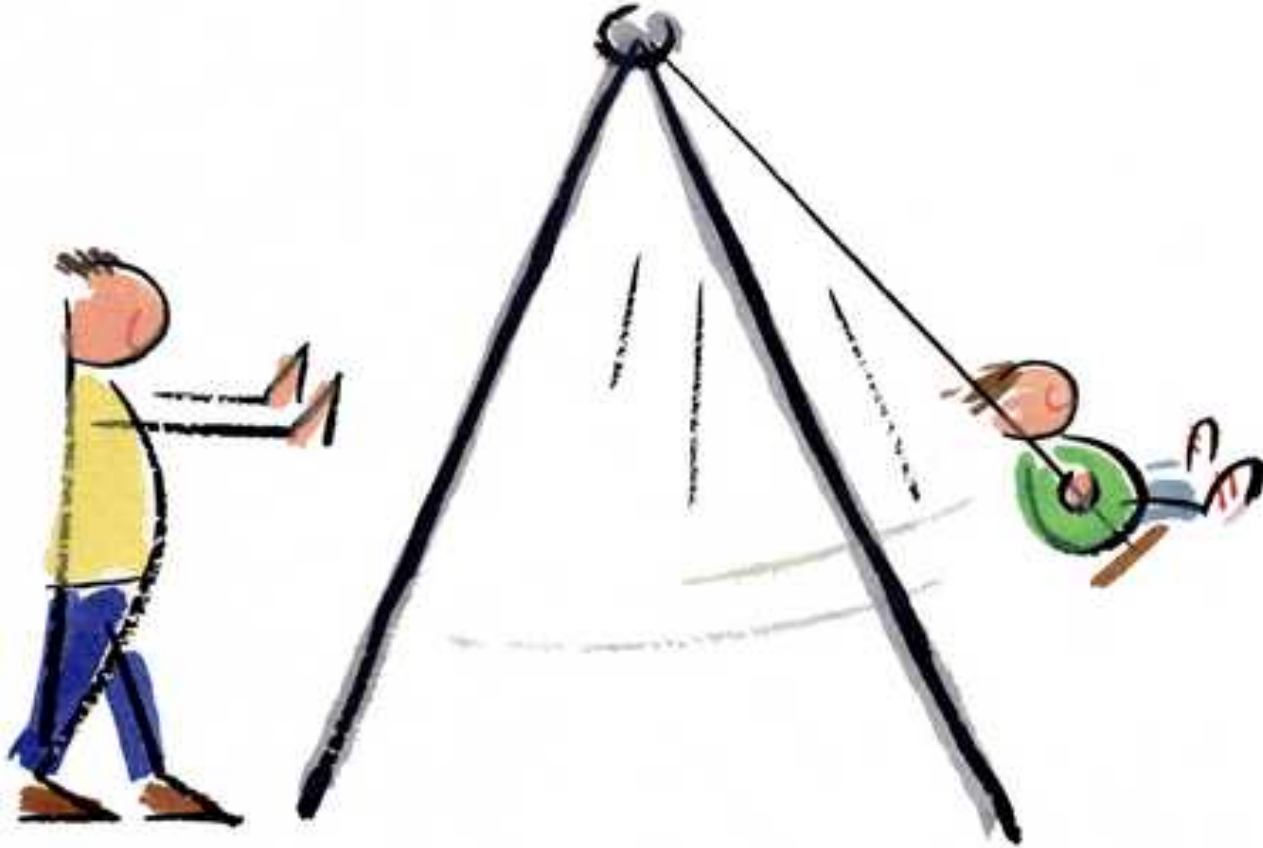
### Swing Leg Perspective



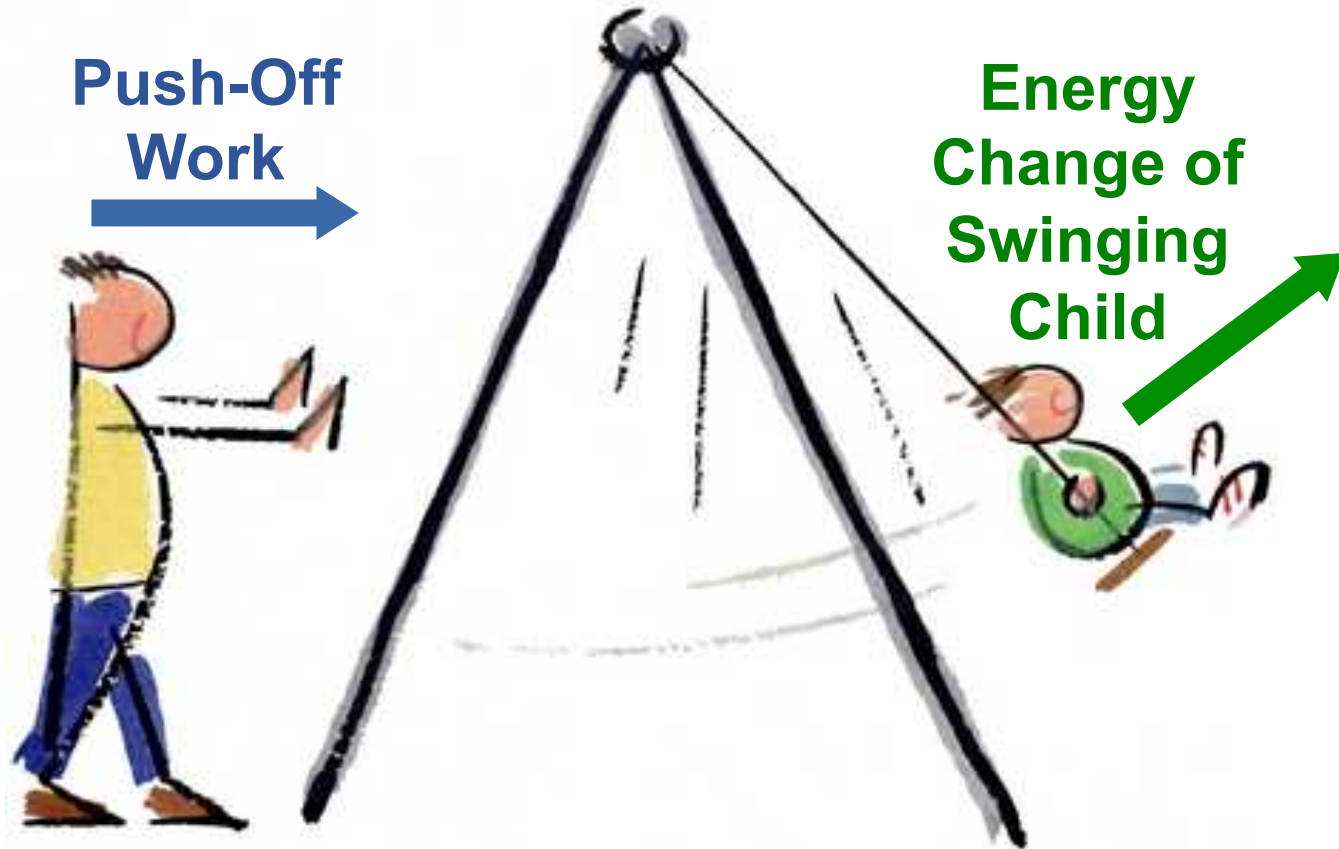
Zelik & Adamczyk 2016 (JEB)



# Combining work & energy estimates to coalesce perspectives

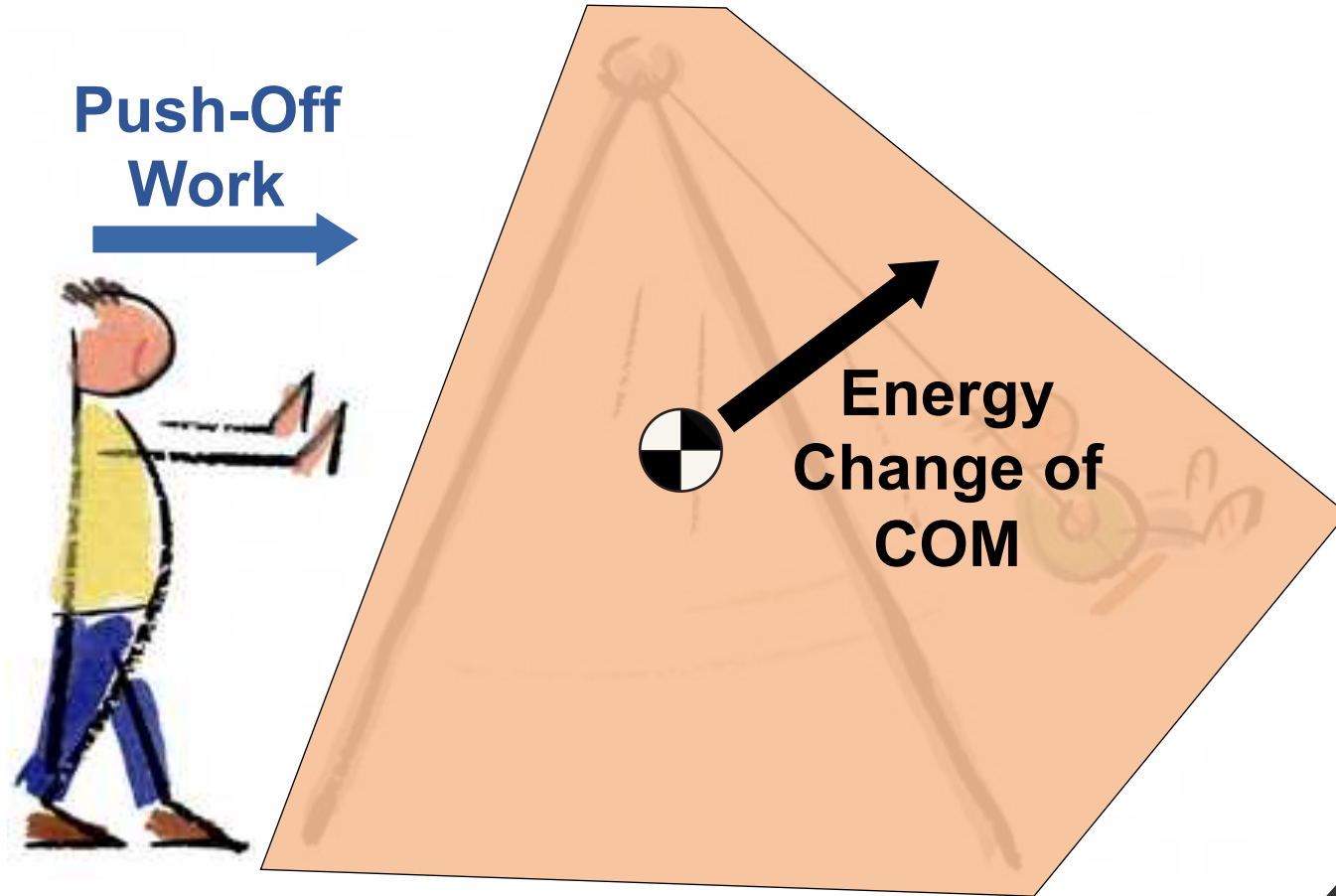


# Combining work & energy estimates to coalesce perspectives





# Combining work & energy estimates to coalesce perspectives



# Combining work & energy estimates to coalesce perspectives

The debate whether Push-off from ankles powers leg swing or COM rankles.  
But a unified view  
indicates both are true:  
Two effects inextricably tangled.

Zelik & Adamczyk 2016 (JEB)



*rankle* – to continue to cause irritation or annoyance



## Speaking the same language... a non-trivial problem



# COMMUNITY DISCUSSION



**American Society of Biomechanics**

Like This Page · May 30 ·

For as long as biomechanics has existed, there have been discrepancies in how biomechanical terms and concepts are phrased. For example while segmental power, the dot product of the equivalent joint moment and joint angular velocity, was defined by Dr. Felix Zajac as "net joint power", Dr. David Winter referred to this term as "muscle power". Can you think of any phrases that have several wording variations? What are some solutions for resolving this confusion?

Like Comment Share

18

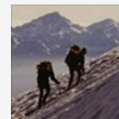
Chronological

1 share

6 Comments



**American Society of Biomechanics** P.S. For a fun read, check out Dr. Richard Baker's post called "Mind Your Language":  
<https://wwrichard.net/2015/06/11/mind-your-language-2/>



**Mind your language**

I've recently heard of a new history of gait analysis...

WWRICHARD.NET

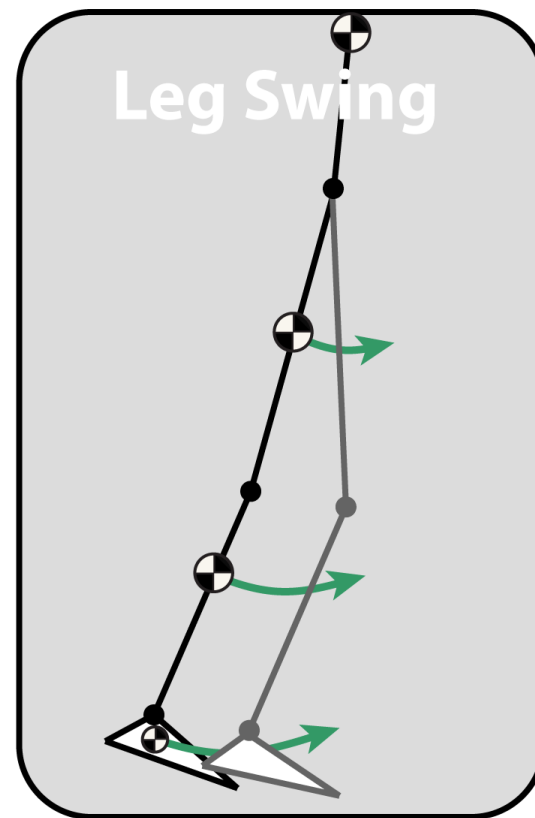
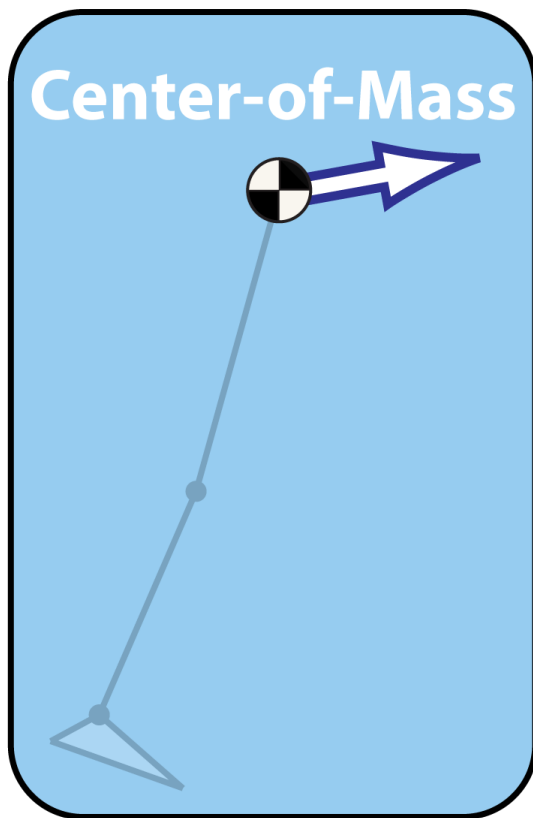
Like · Reply · 3 · May 30 at 1:24pm



Write a comment...

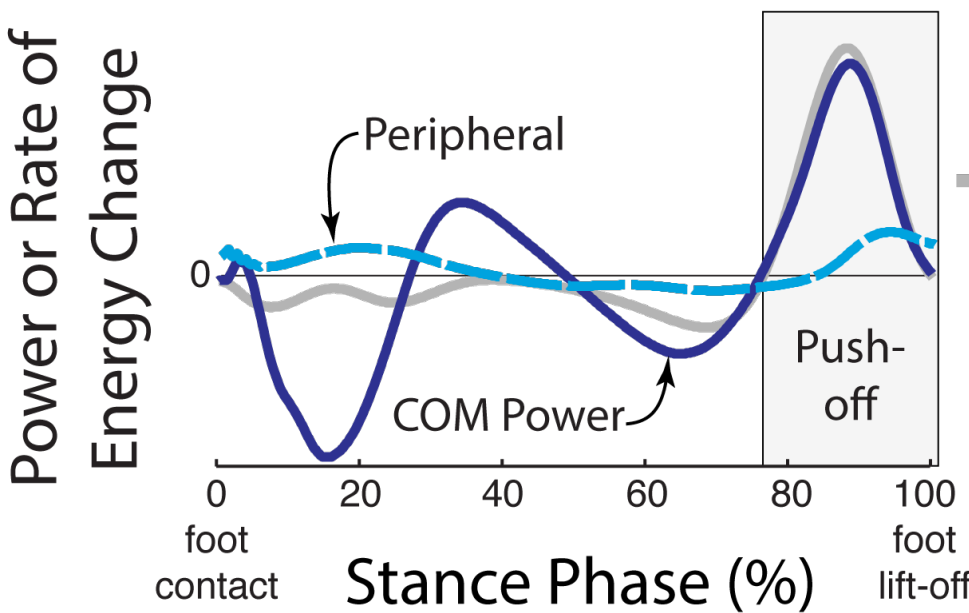


# Definition of “leg swing”?

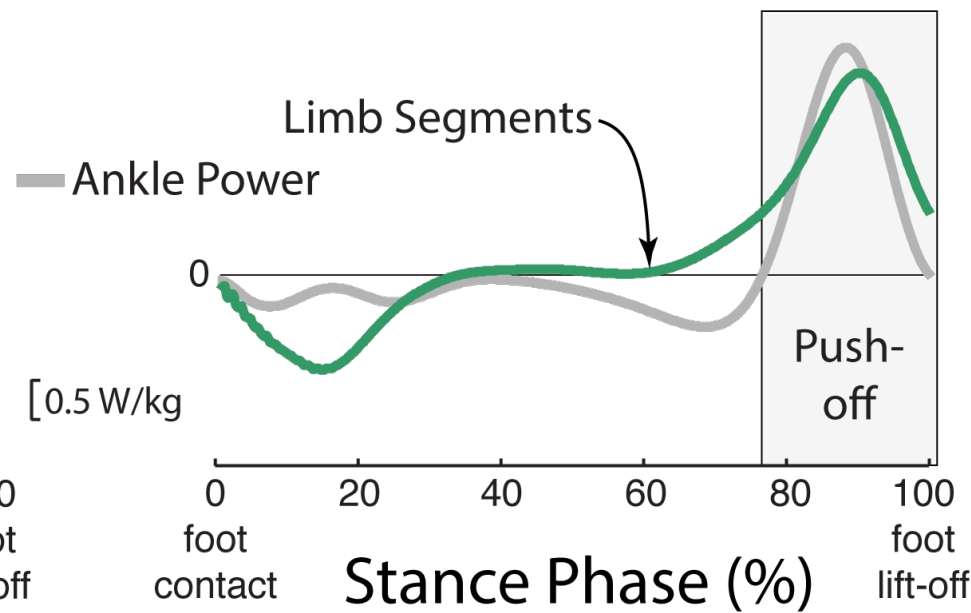


# Definition of “leg swing”?

## COM Perspective



## Swing Leg Perspective



# Unification in biomechanics

“Our job in physics [biomechanics] is to see things simply, to understand a great many complicated phenomena in a unified way, in terms of a few simple principles.”

– *Steven Weinberg (Nobel laureate in Physics, 1979)*





[illegible]

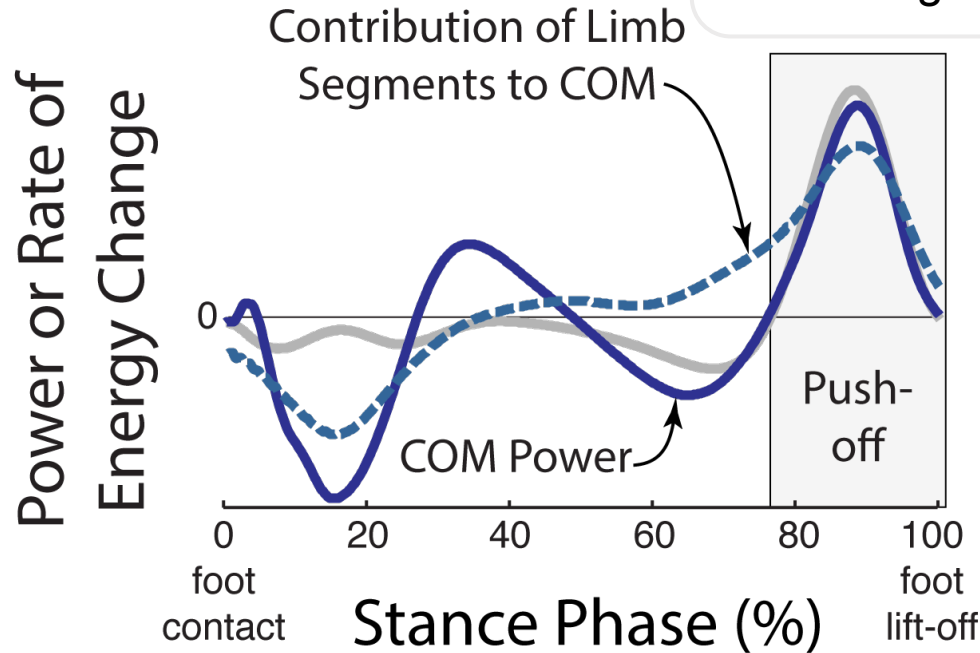
# National Biomechanics Day



## ACKNOWLEDGEMENTS

Thanks to mentors, collaborators, family, friends, students & ASB

Dad, it took me 1 year to figure out walking, what's taking you so long to understand it?



Funding: NIH, Vanderbilt University



CREATE