CENTER FOR
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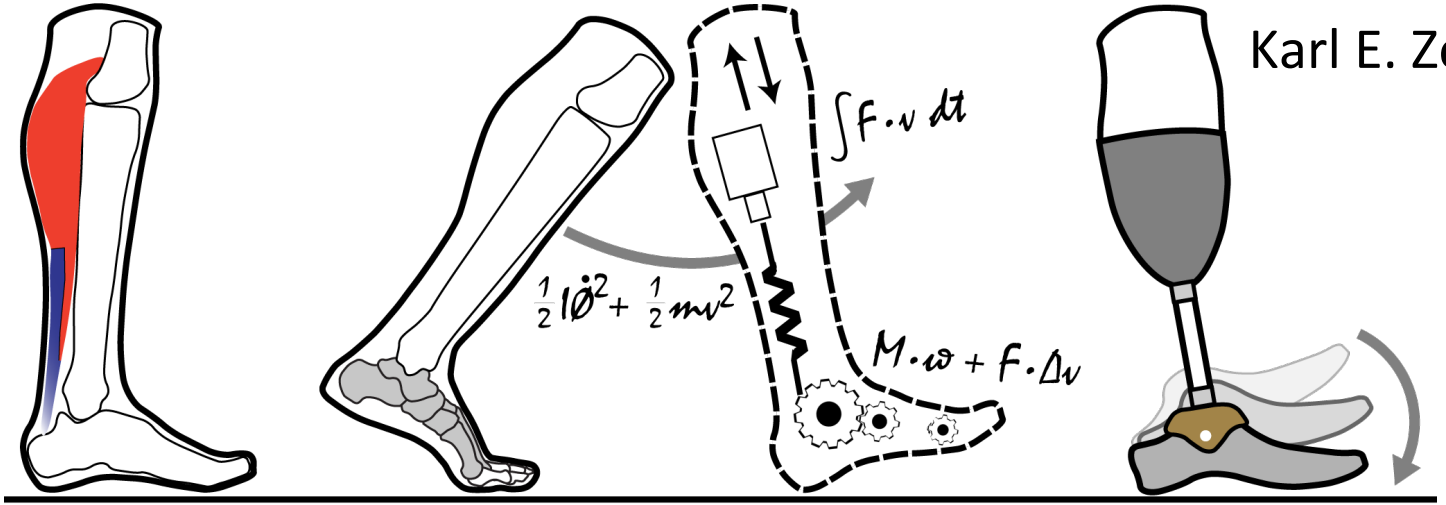
Unifying Perspectives in Biomechanics



Karl E. Zelik

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

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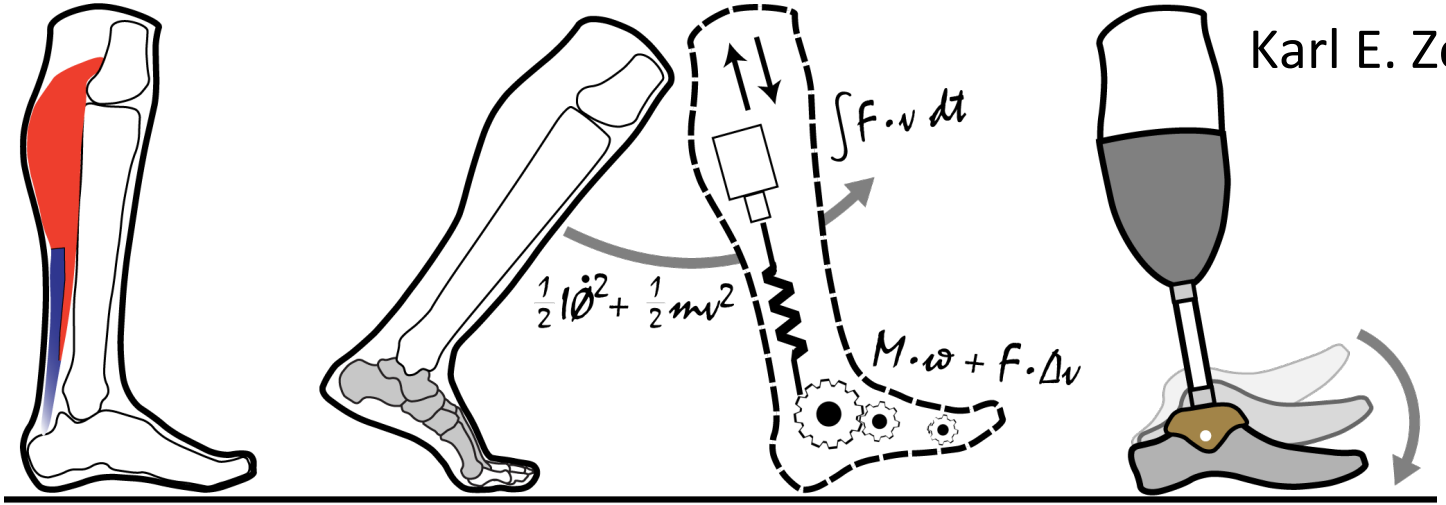

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Ankle Push-off During Human Walking Contributes to Accelerating Both Swing Leg & Center-of-Mass

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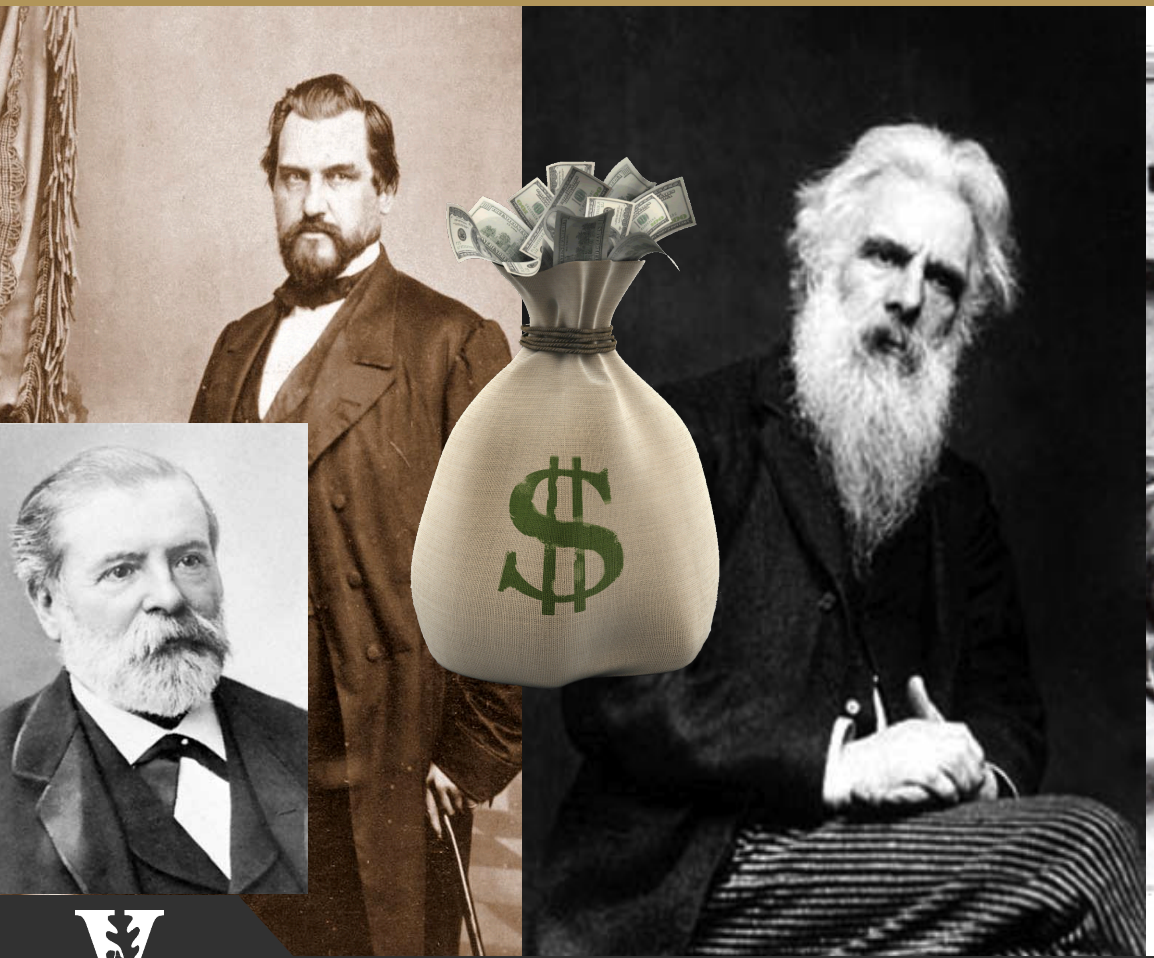
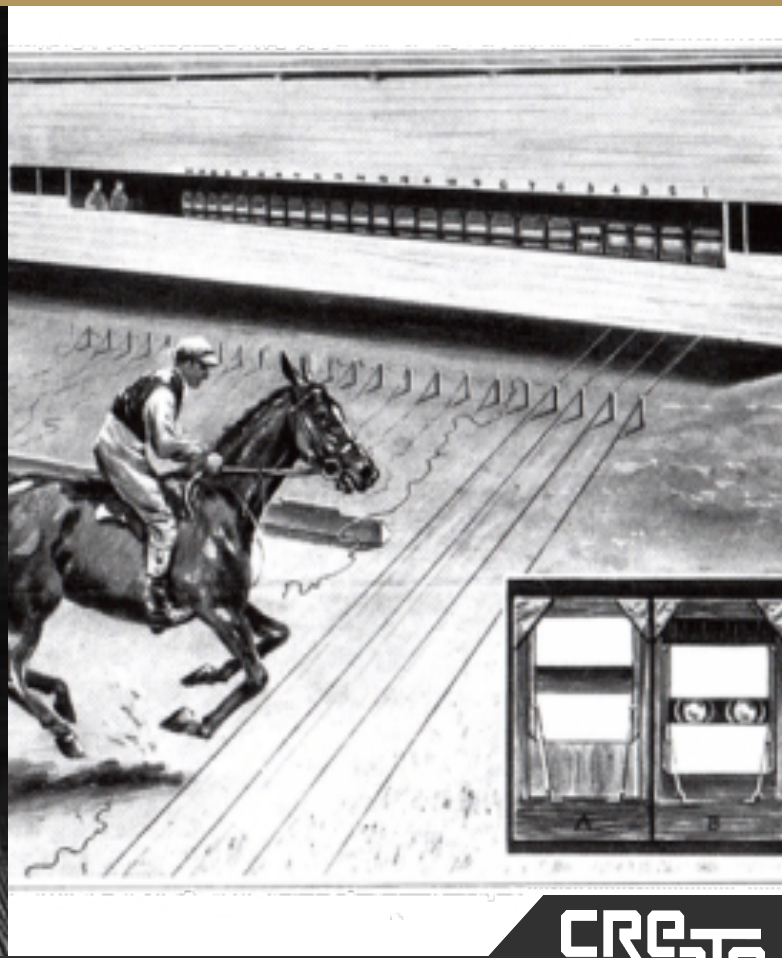
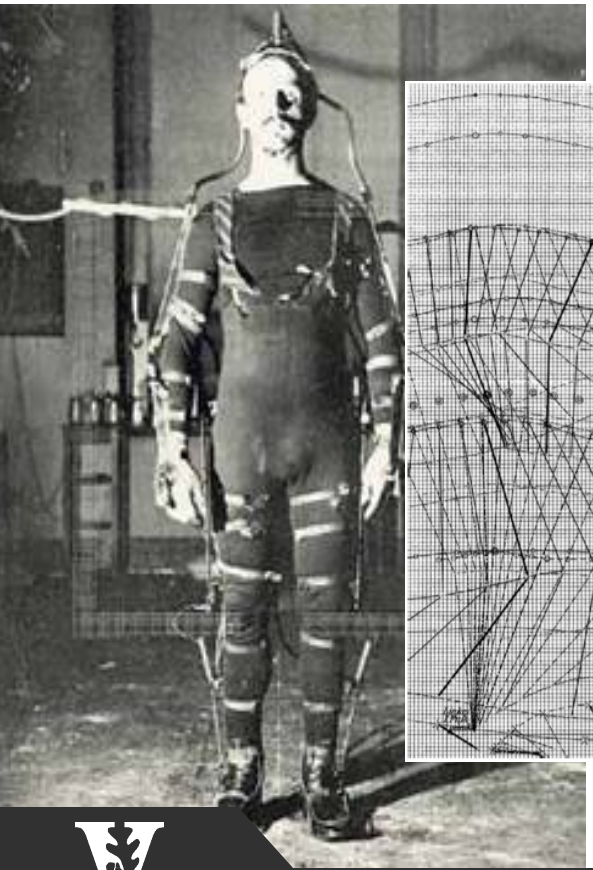
Marey, Stanford, Muybridge, an Expensive Horse Bet & a Homicide

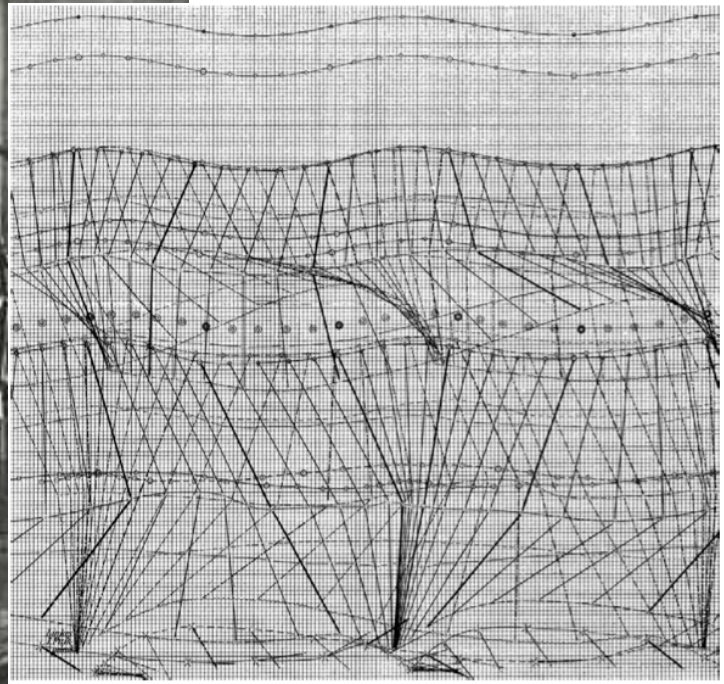




Motion capture – 1st 3D gait analysis (Braune & Fischer)

THEN



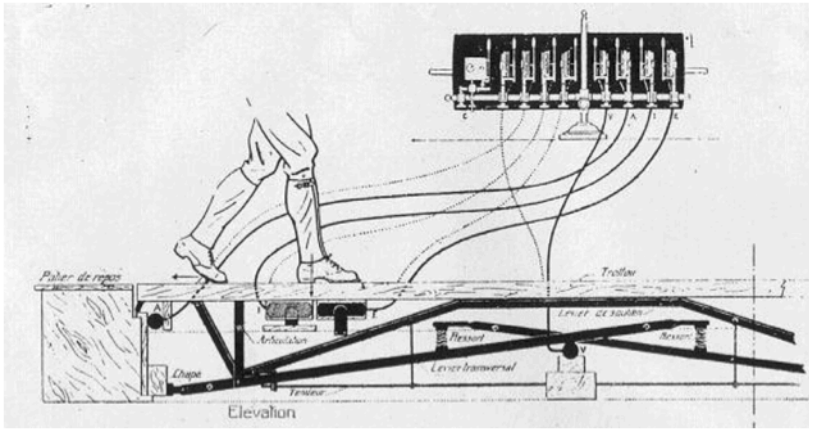


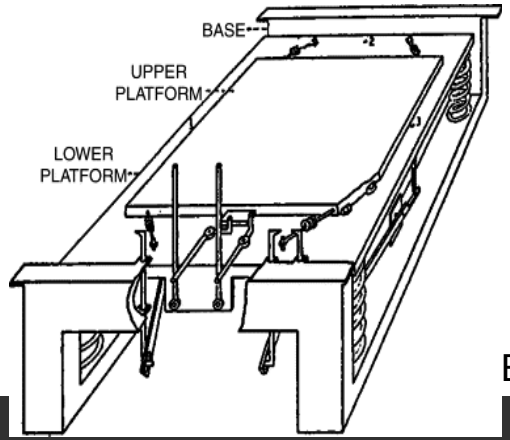
NOW

Baker 2007

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

THEN



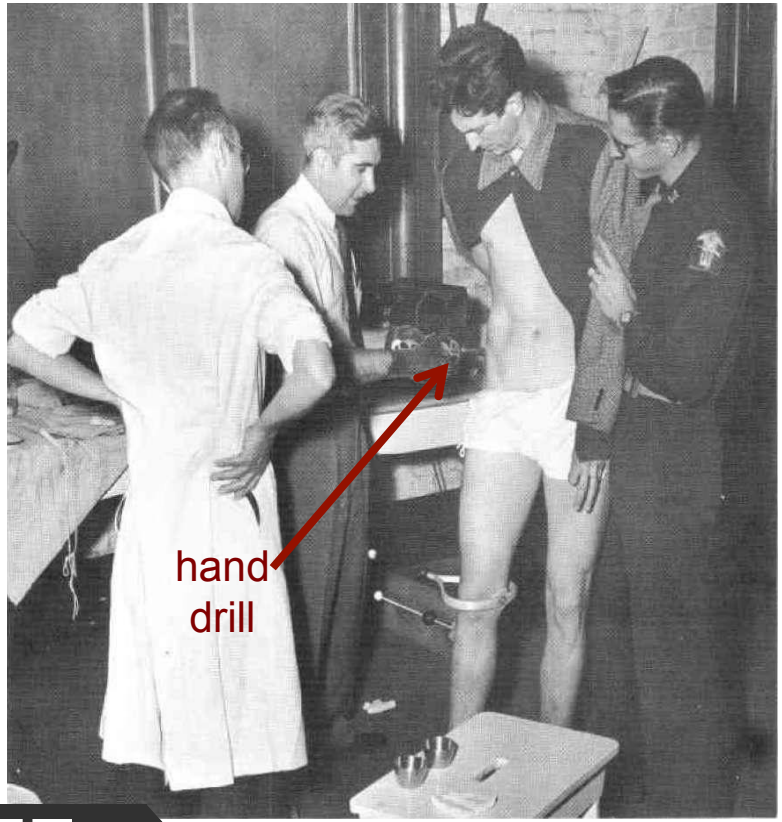


NOW

Baker 2007, Medved 2000, Sutherland 2005

Motion capture markers

THEN



Inman, Ralston & Todd 1981

NOW

EMG – First commercially-available system (Denmark)

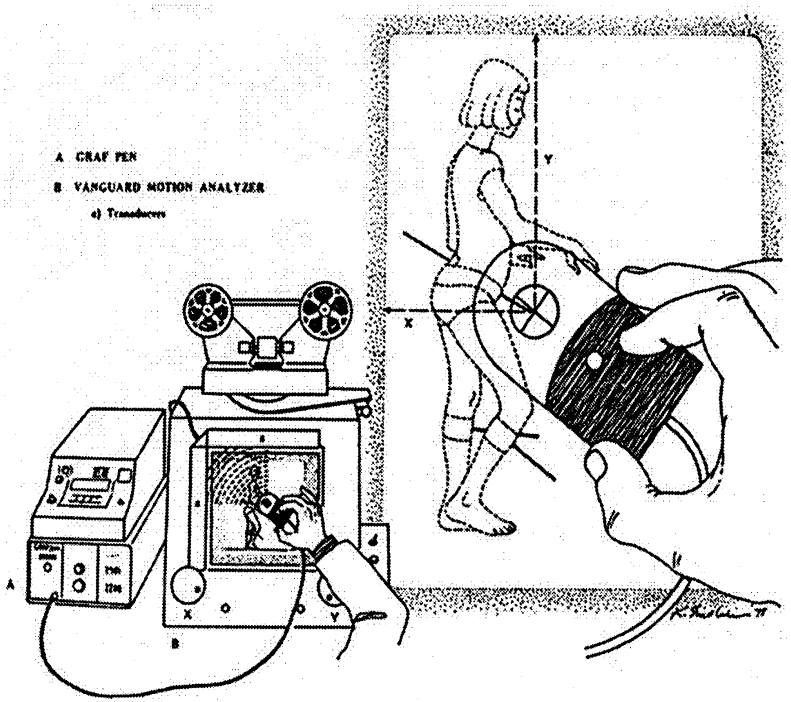
THEN

Ladegaard 2002

NOW

Semi-automated motion tracking (Sutherland & Hagy)

THEN



Sutherland 2002

Semi-automated motion tracking (Sutherland & Hagy)

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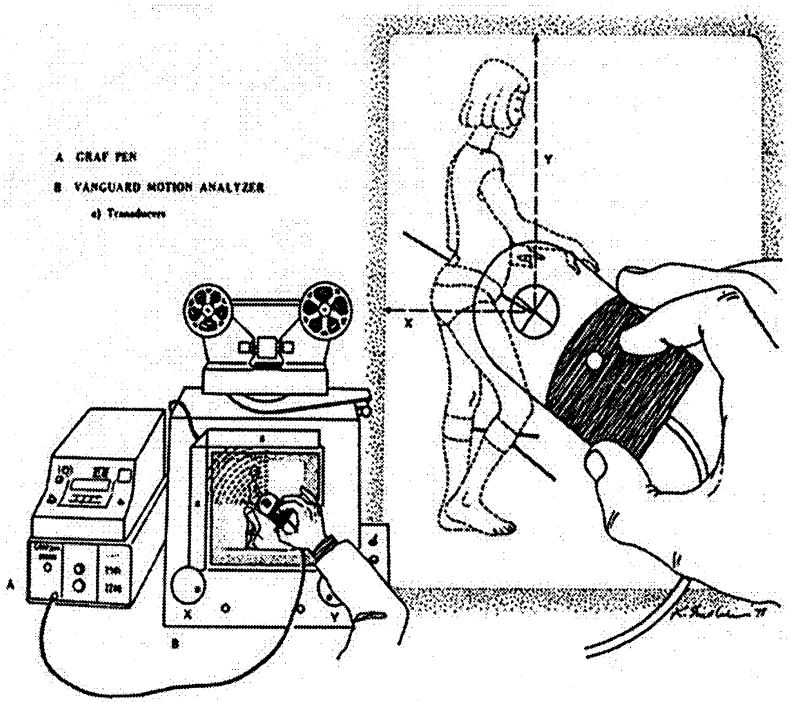

Sutherland 2002

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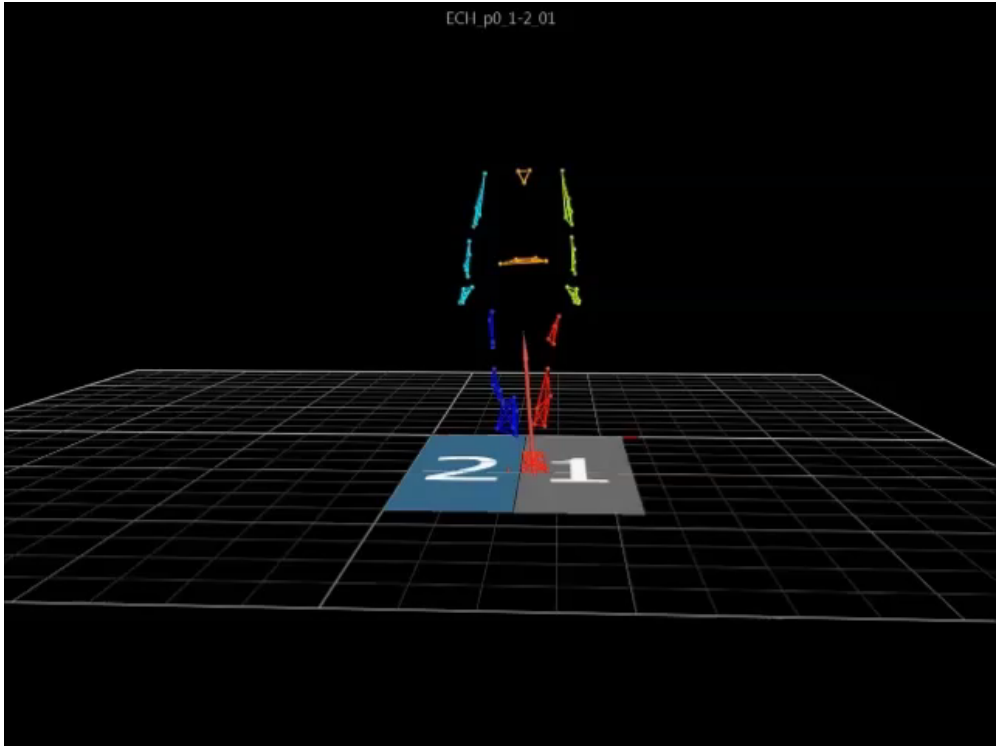

Intro takeaways

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

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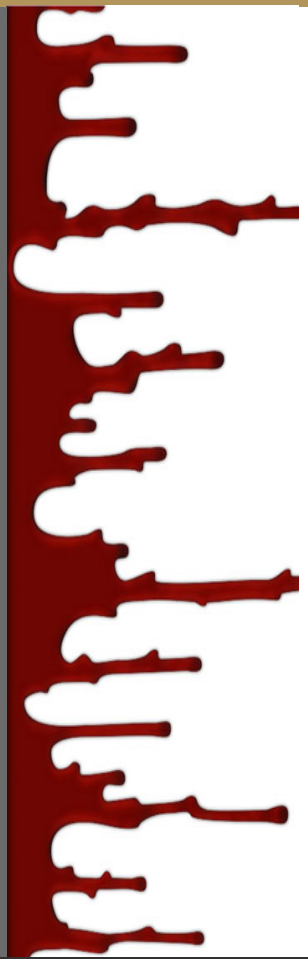
2. Motion, force & EMG are still research workhorses today; just easier to use & with **lots of new ways to analyze data**

competing perspectives in biomechanics

Differing/competing perspectives in biomechanics

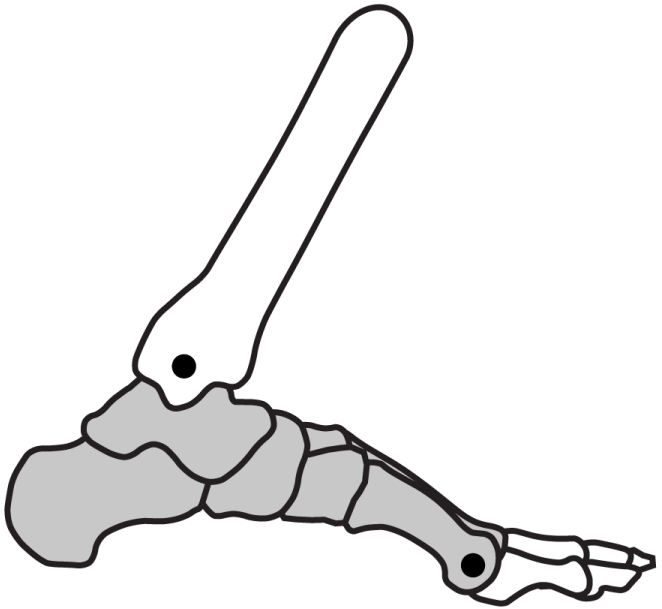
what we think we know

bleeding edge of science



what we don't know

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



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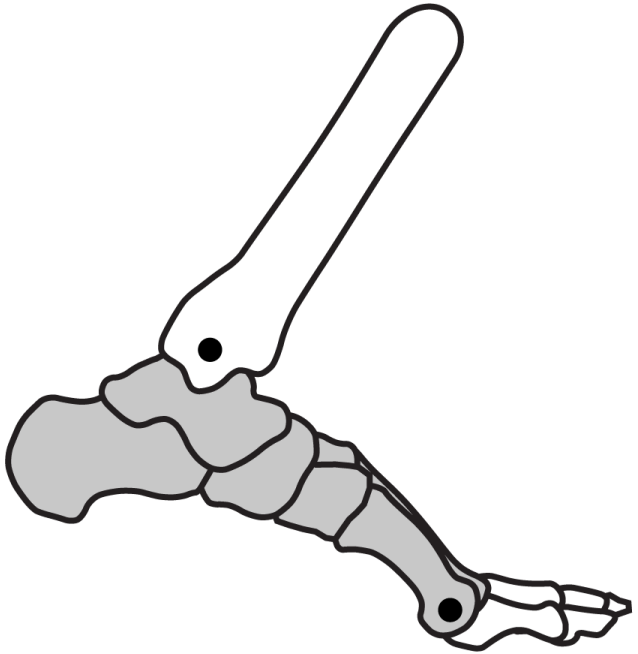

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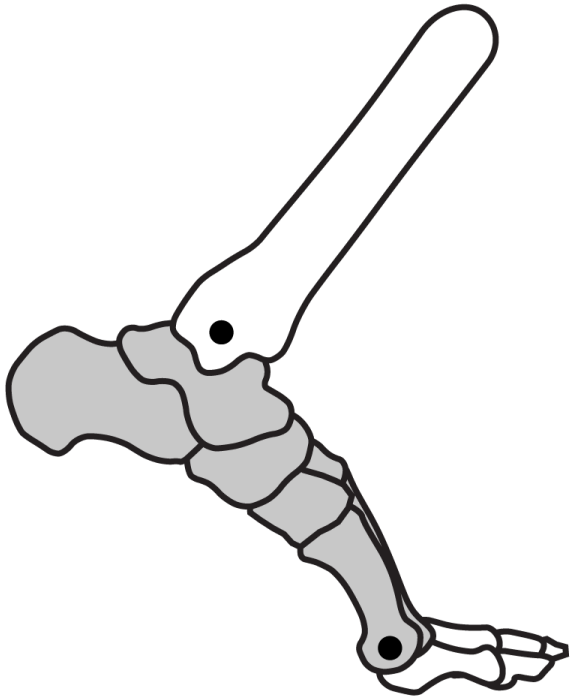

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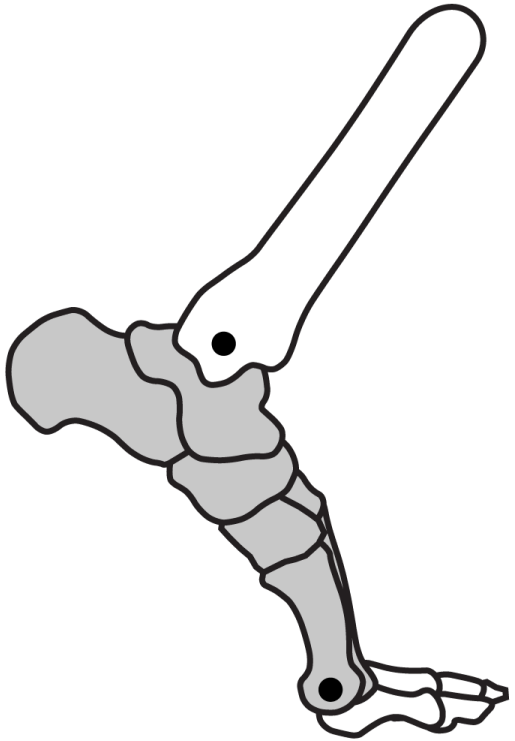
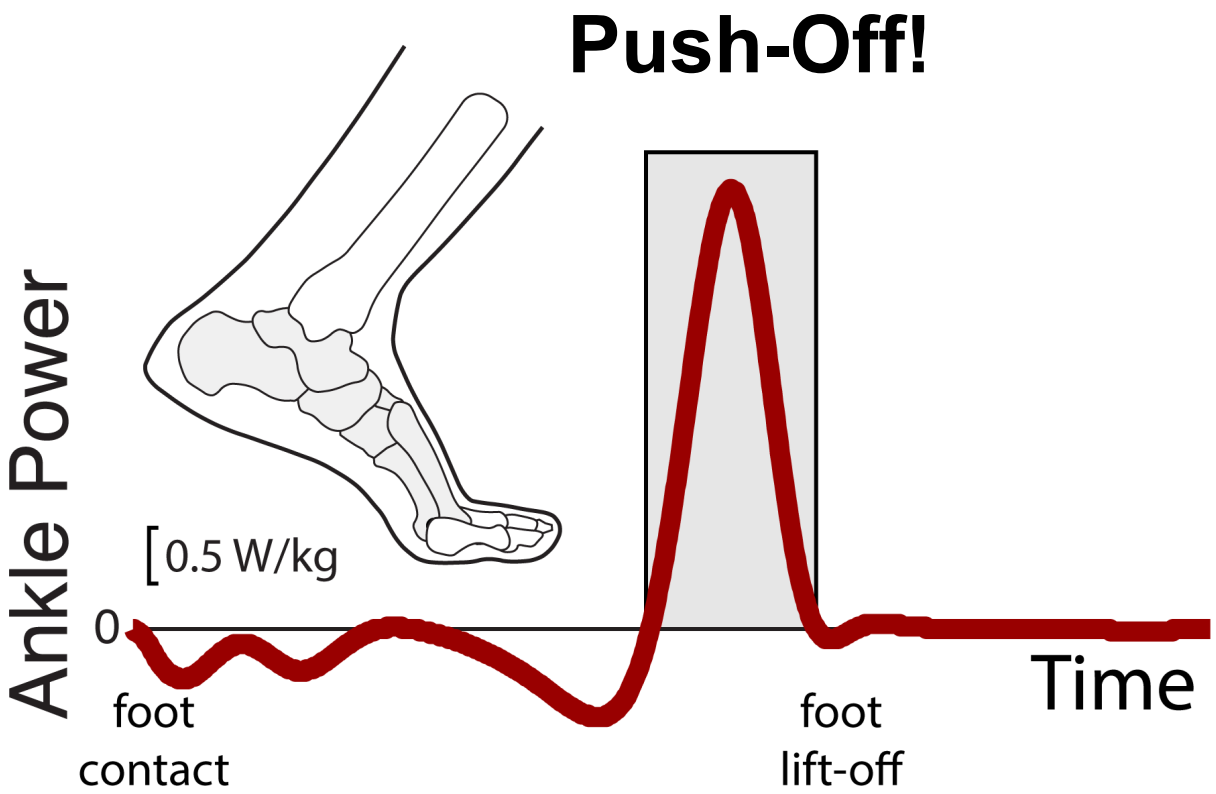


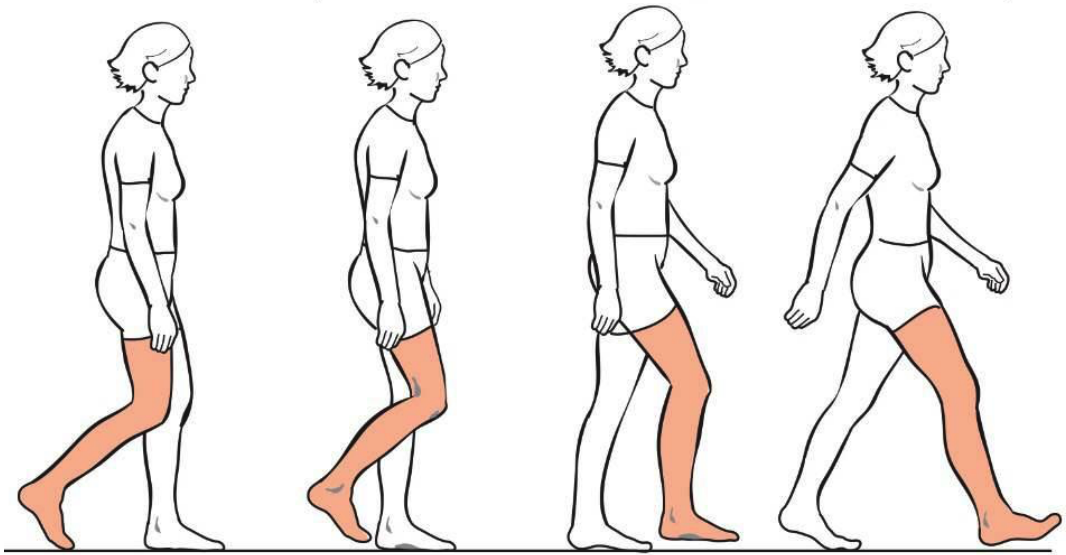
Ankle Push-off (burst of power) or Roll-off (restrain falling)?



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

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

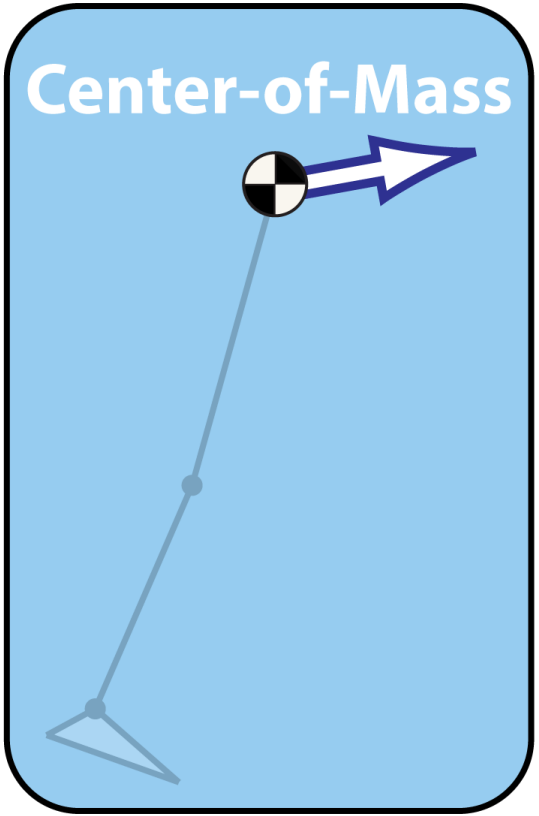
Swing Leg!

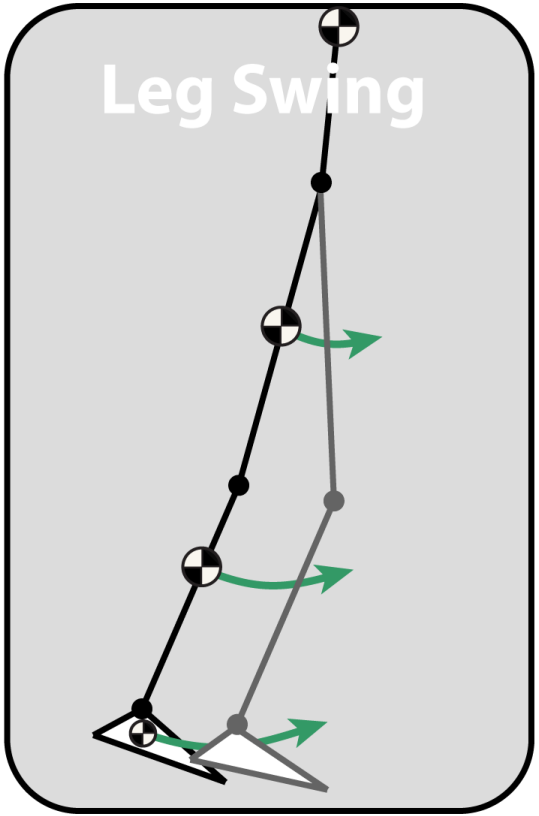


Winter & Robertson 1978, Meinders et al. 1998, Neptune et al. 2001, etc.

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

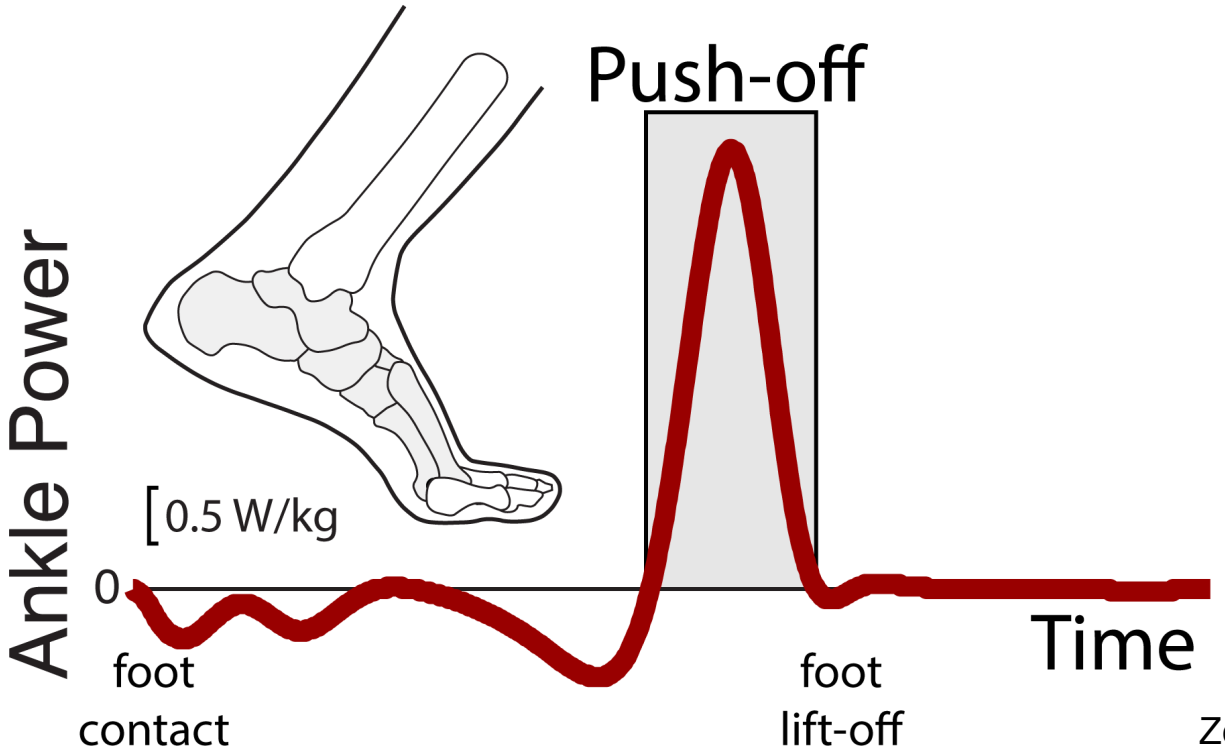
COM = Center-of-Mass





Peter Adamczyk
(Wisconsin)

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



Zelik & Adamczyk 2016 (JEB)

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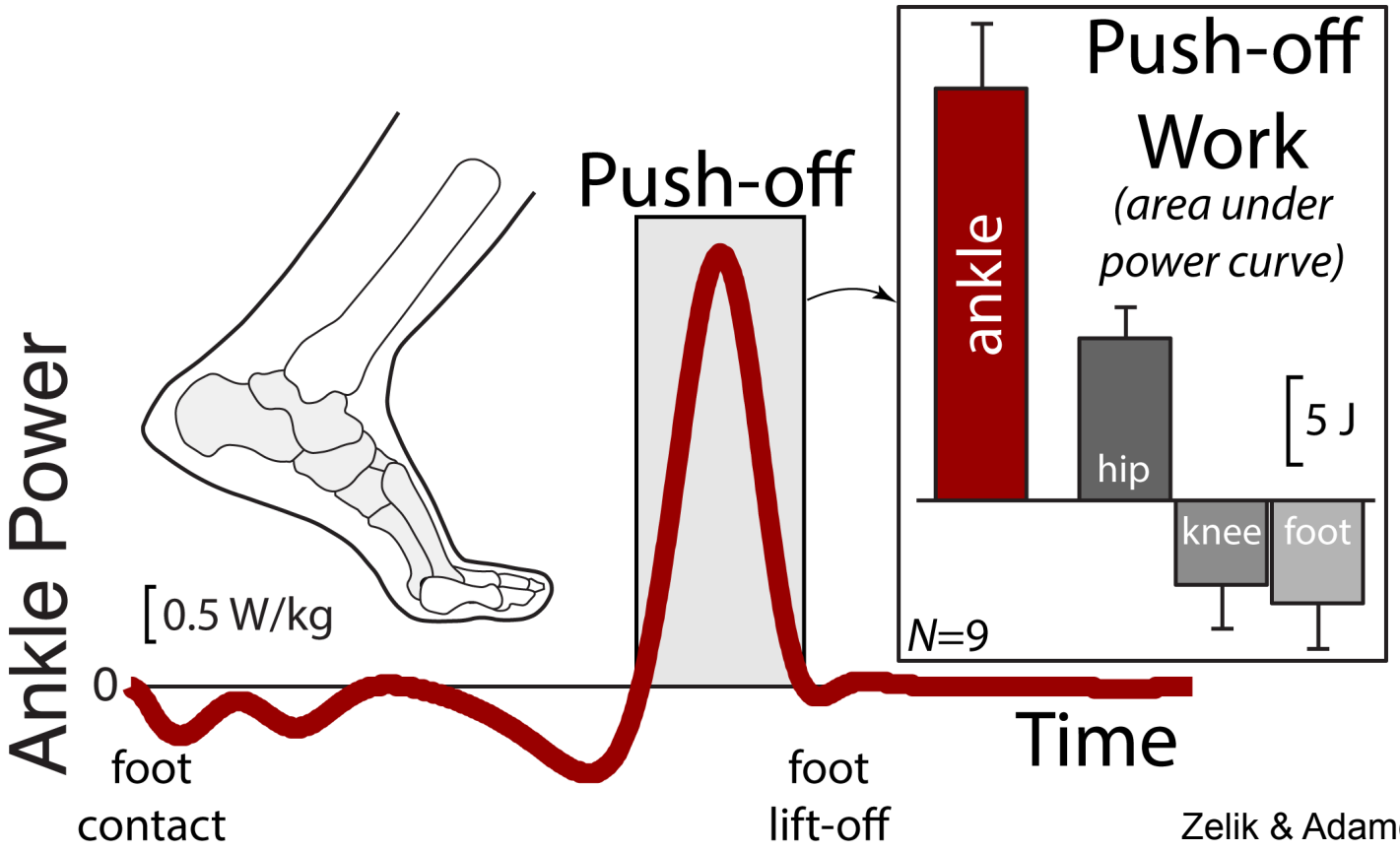
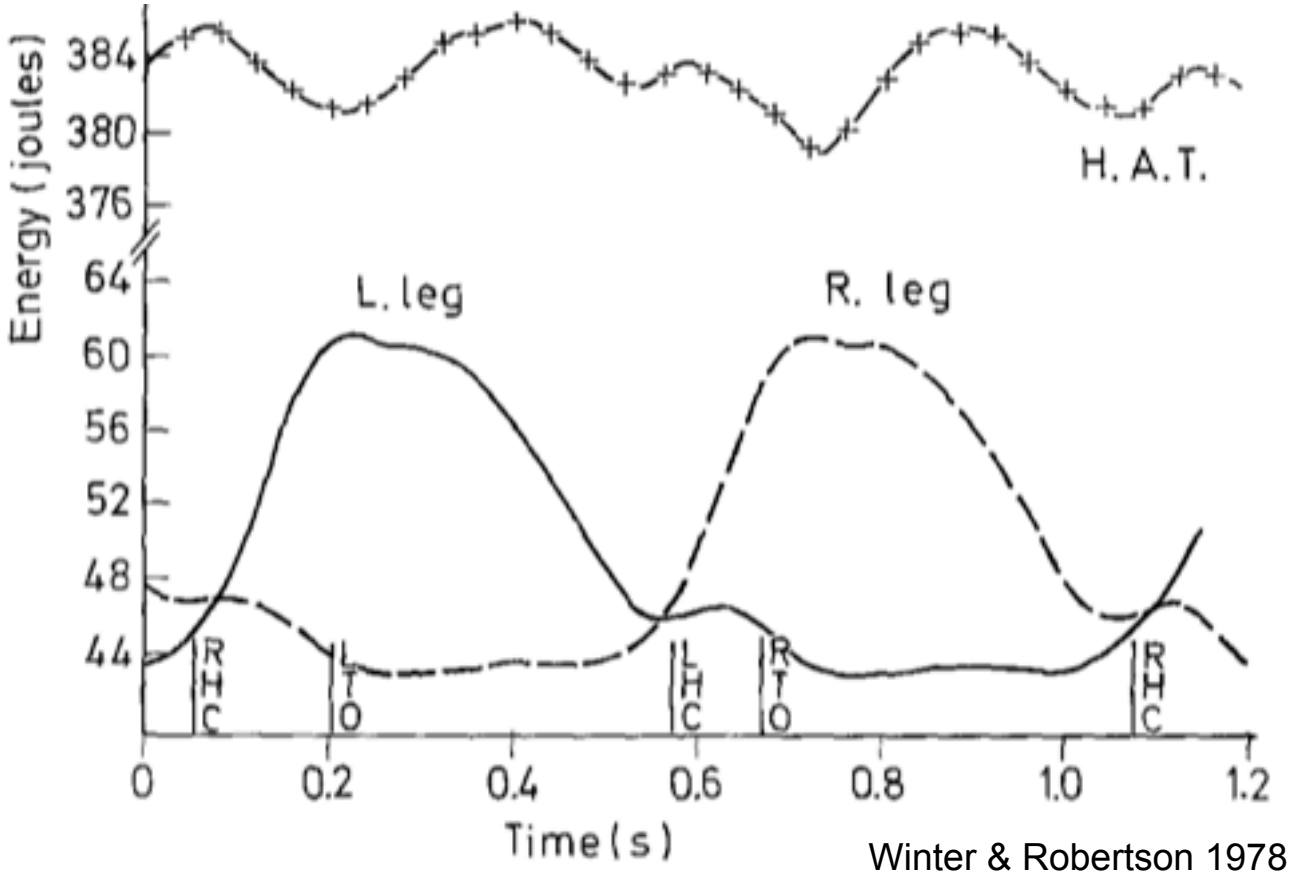


Zelik & Adamczyk 2016 (JEB)

Push-off accelerates limb segments; little trunk energy change



Winter & Robertson 1978

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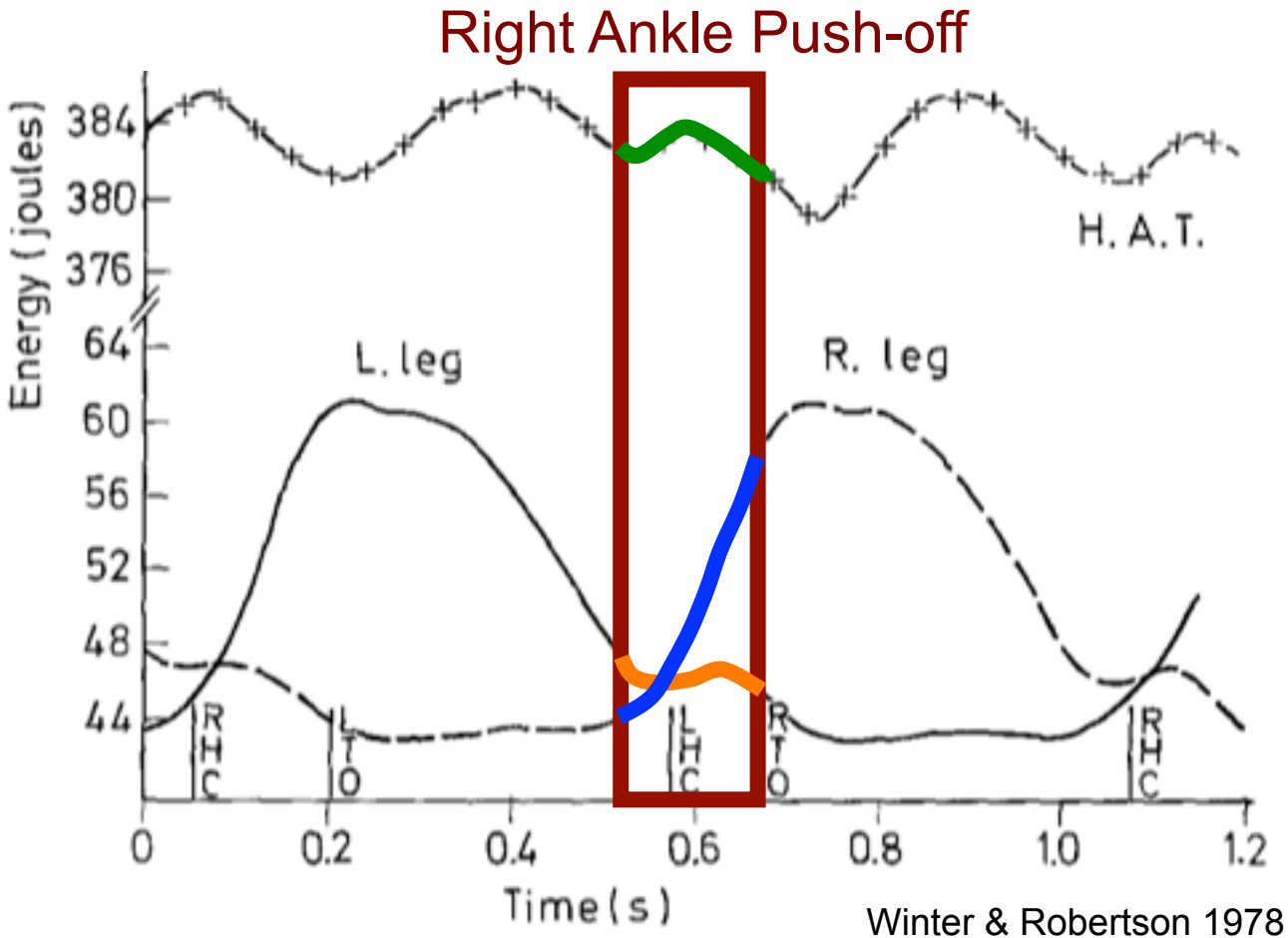

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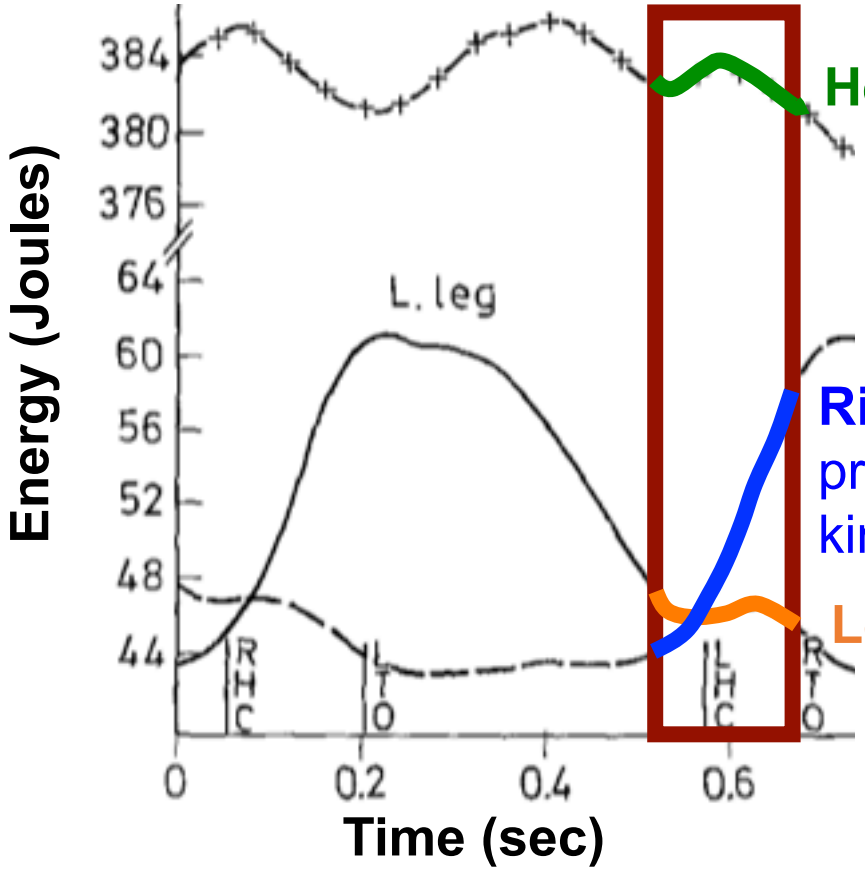
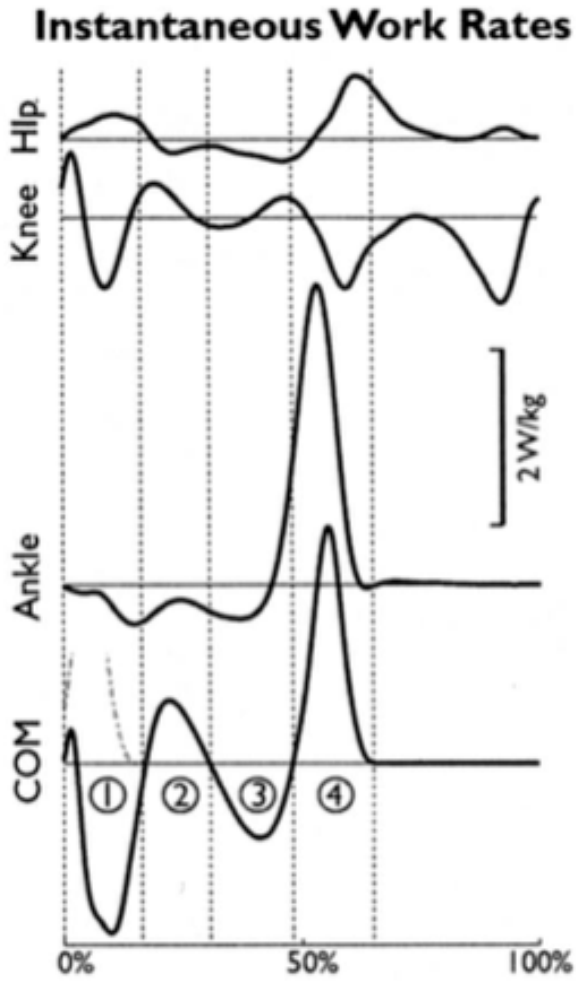


Winter & Robertson 1978

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

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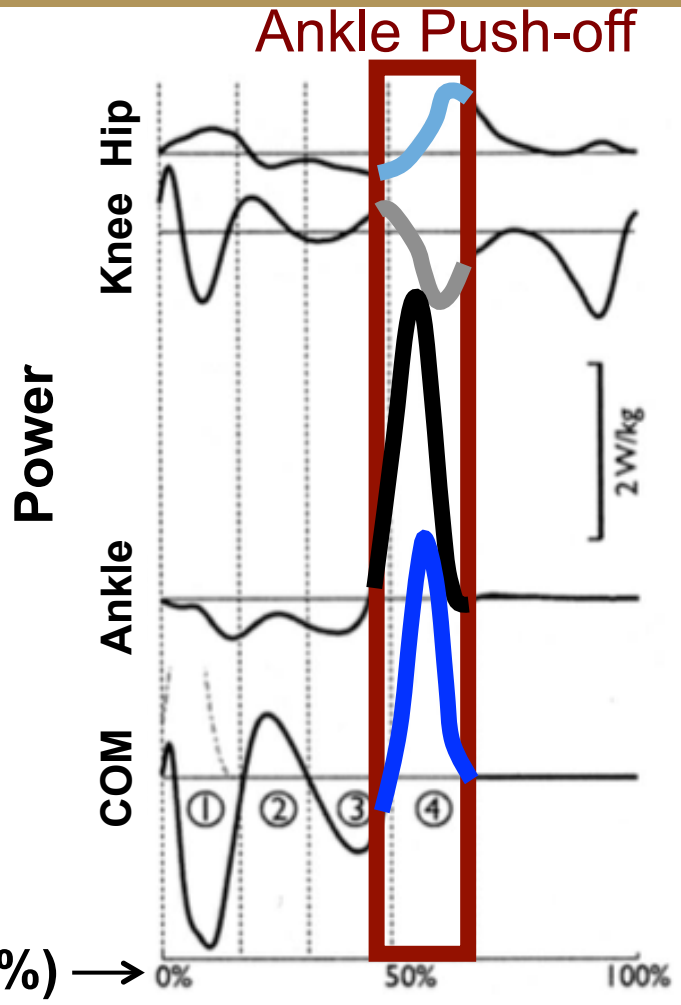
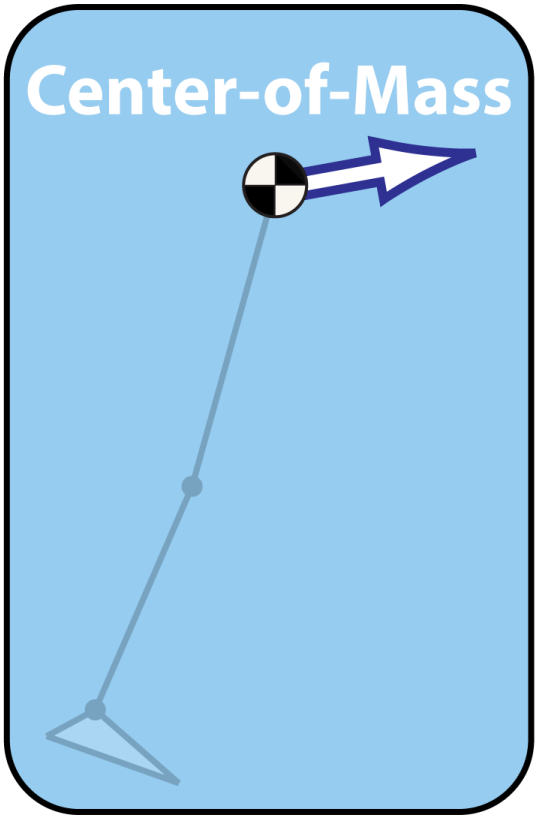


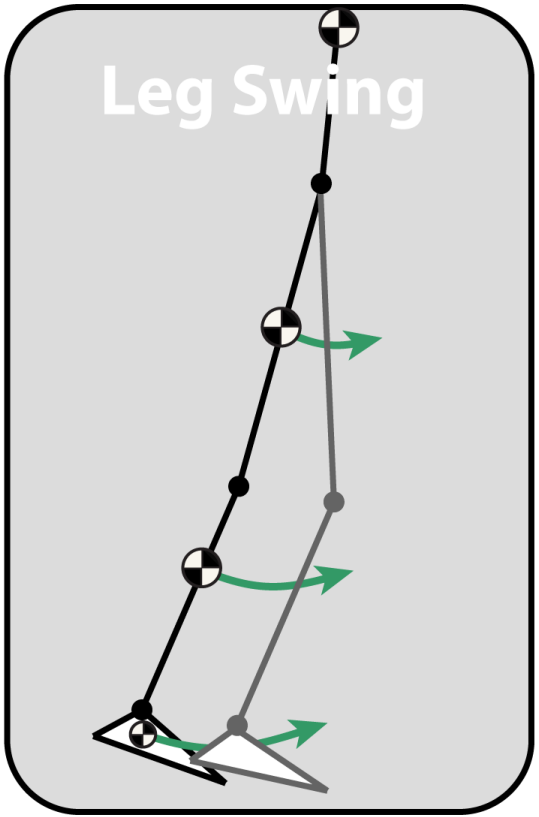
Kuo, Donelan & Ruina 2005

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

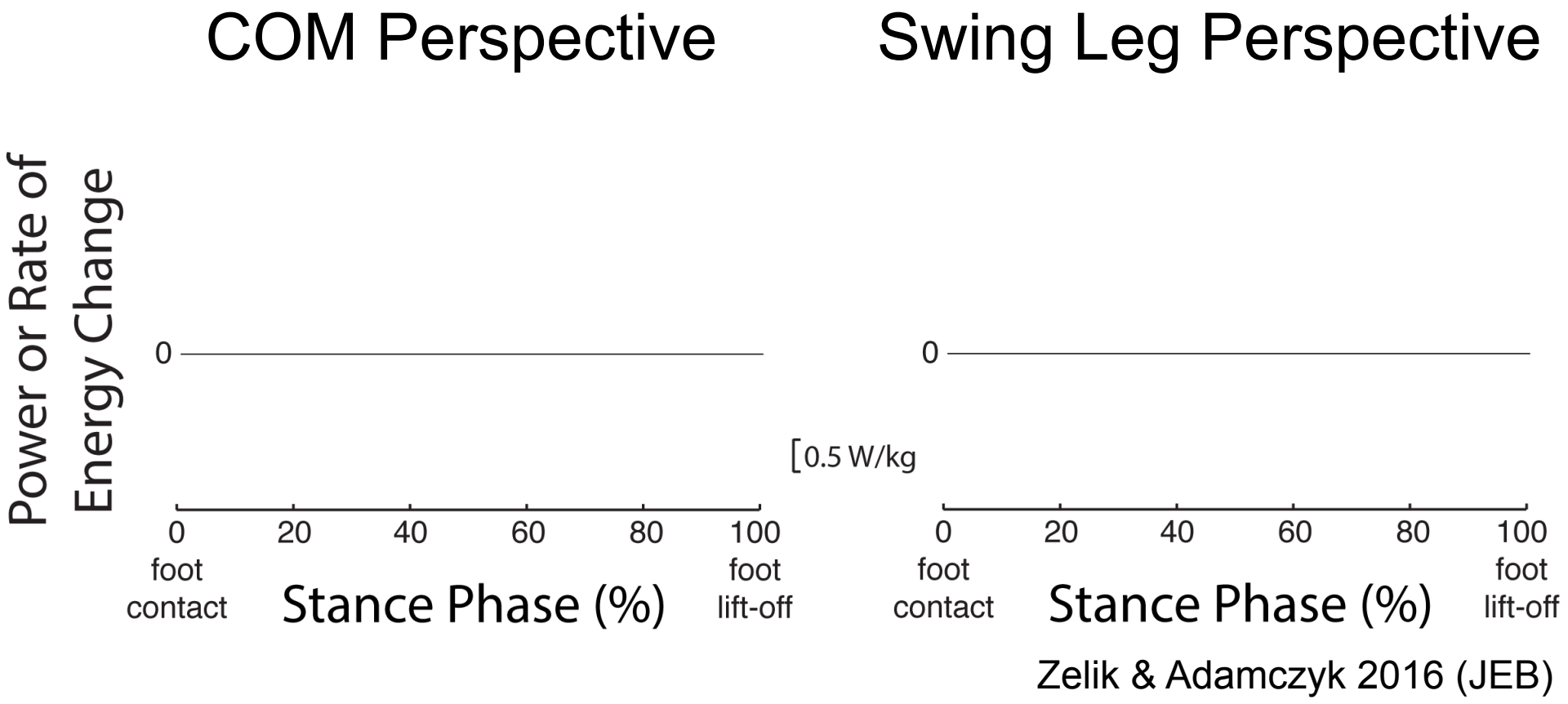
Study	Takeaway
Donelan et al. 2002 **Zelik & Kuo 2010**	Ankle & COM Push-off work increase together with gait speed
Houdijk et al. 2009 **Caputo & Collins 2014**	Ankle & COM Push-off work are both reduced for prosthetic users
Huang et al. 2015	Restrictive orthosis: COM work decreased linearly with ankle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

Two perspectives. Each with evidence. Conflicting conclusions





Combining work & energy estimates to coalesce perspectives

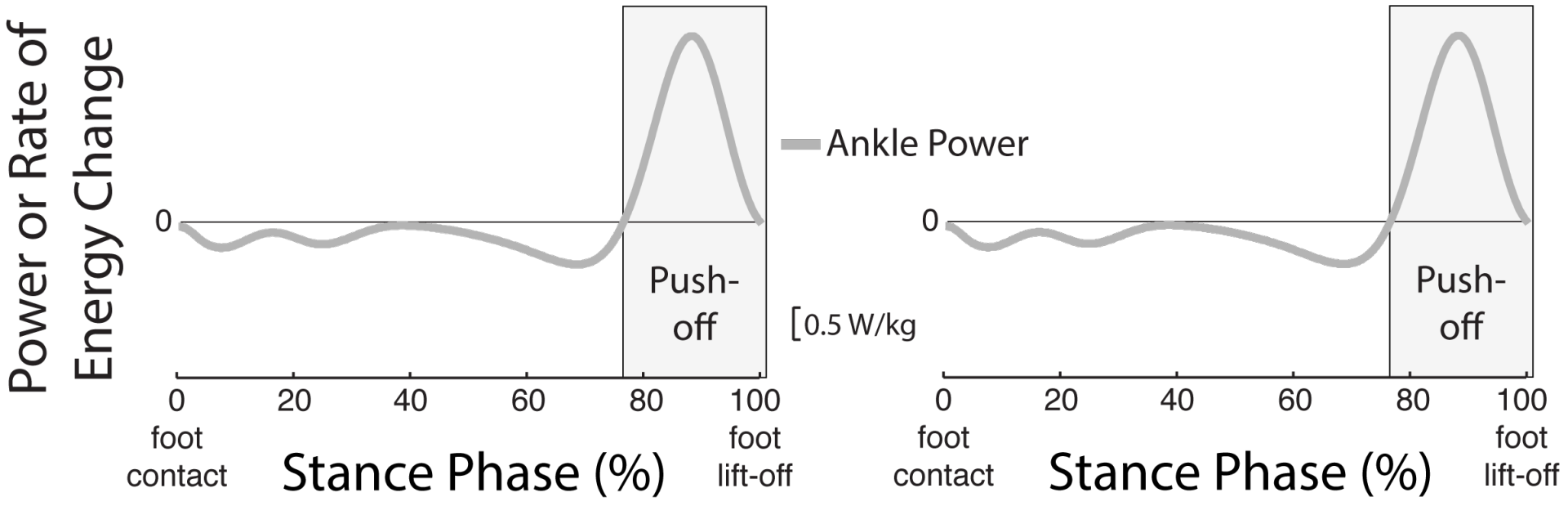


Zelik & Adamczyk 2016 (JEB)

Combining work & energy estimates to coalesce perspectives

COM Perspective

Swing Leg Perspective



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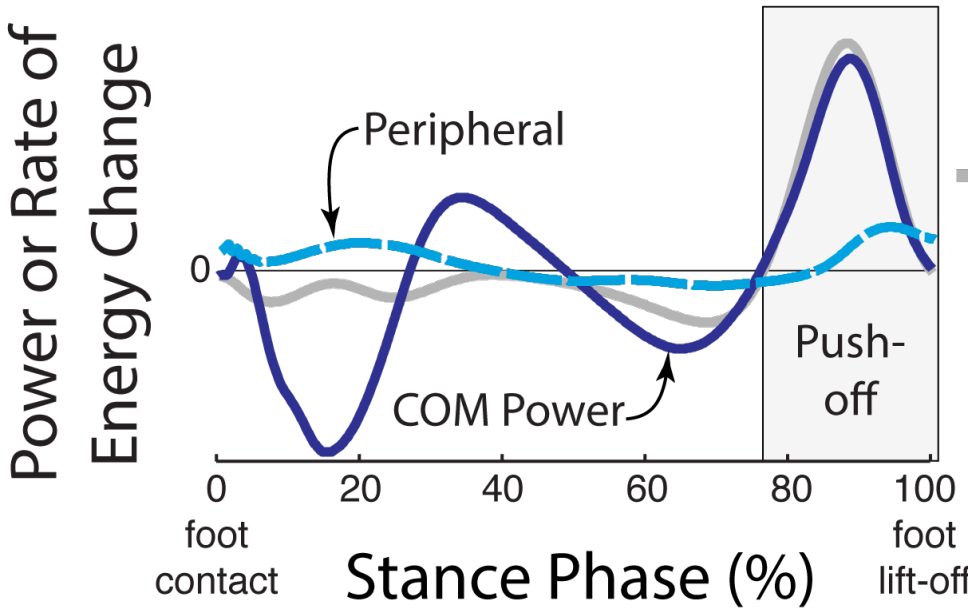

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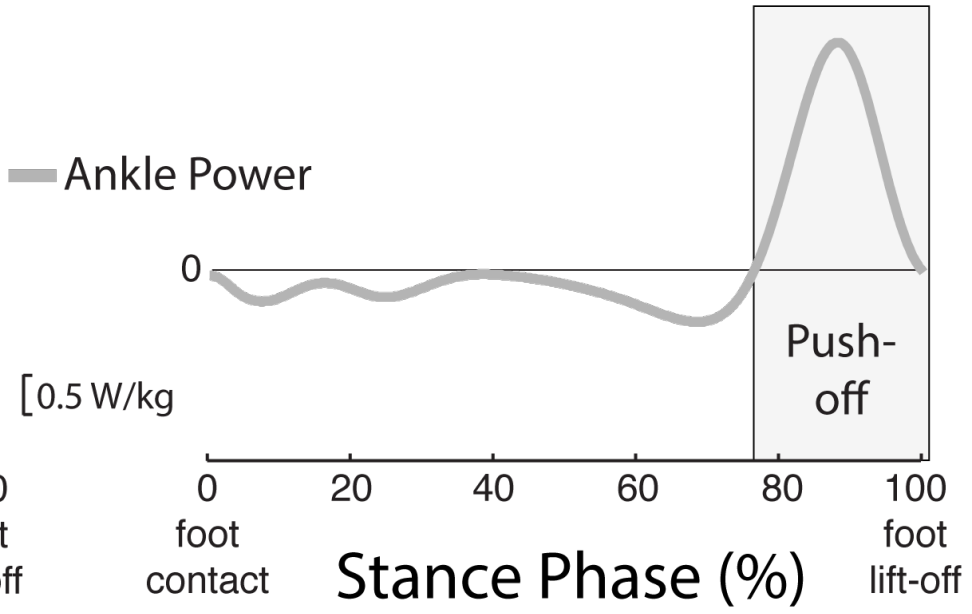

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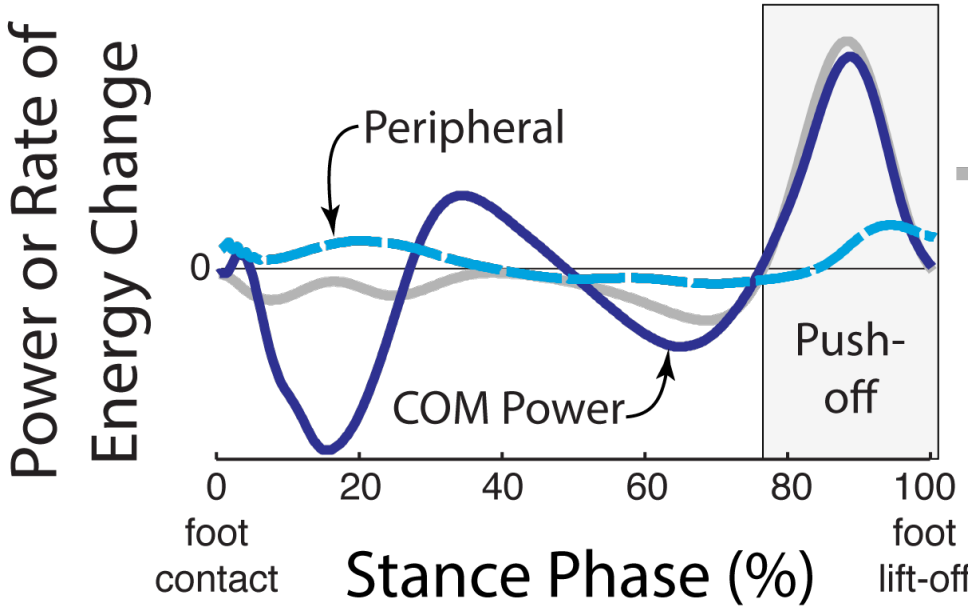

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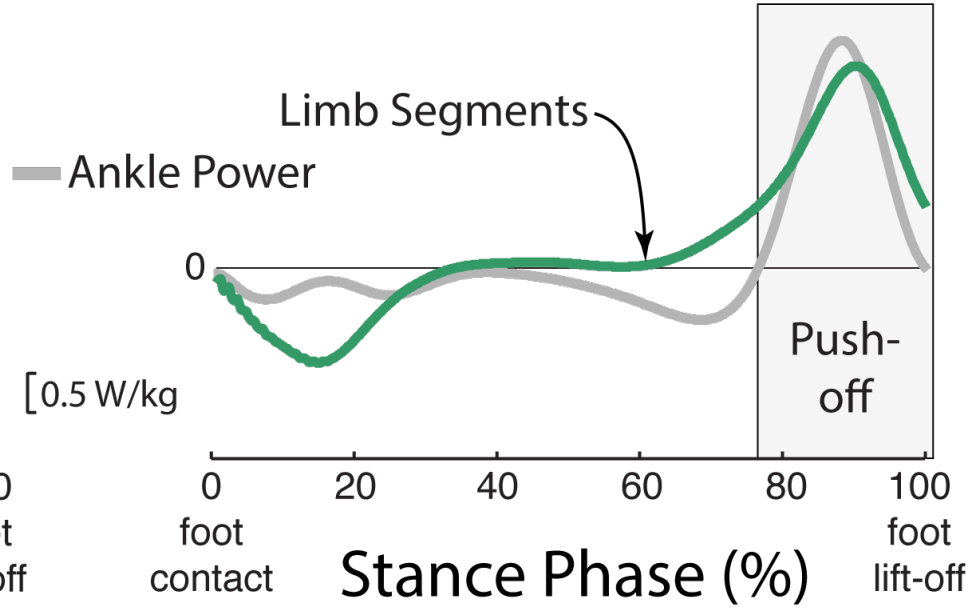

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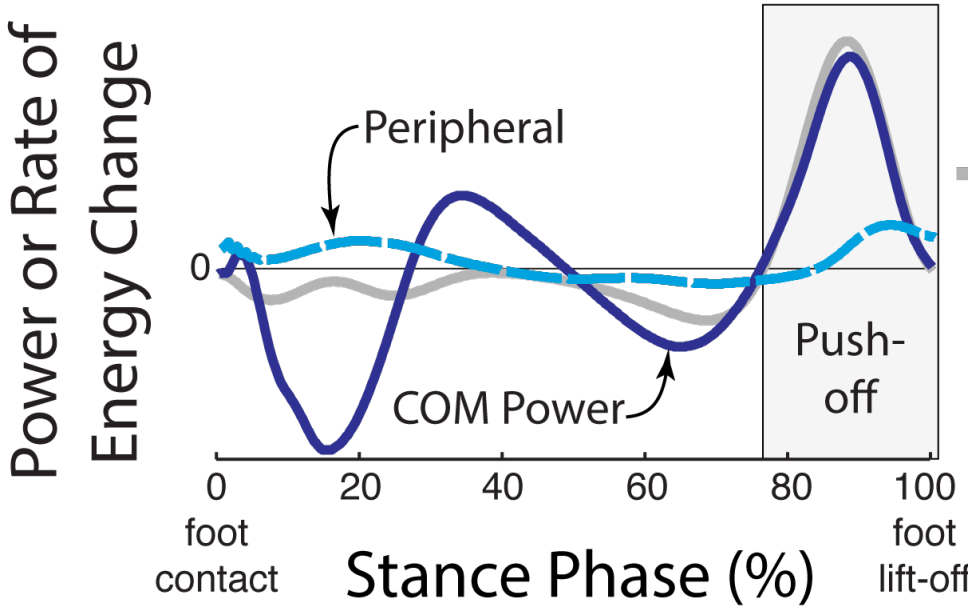

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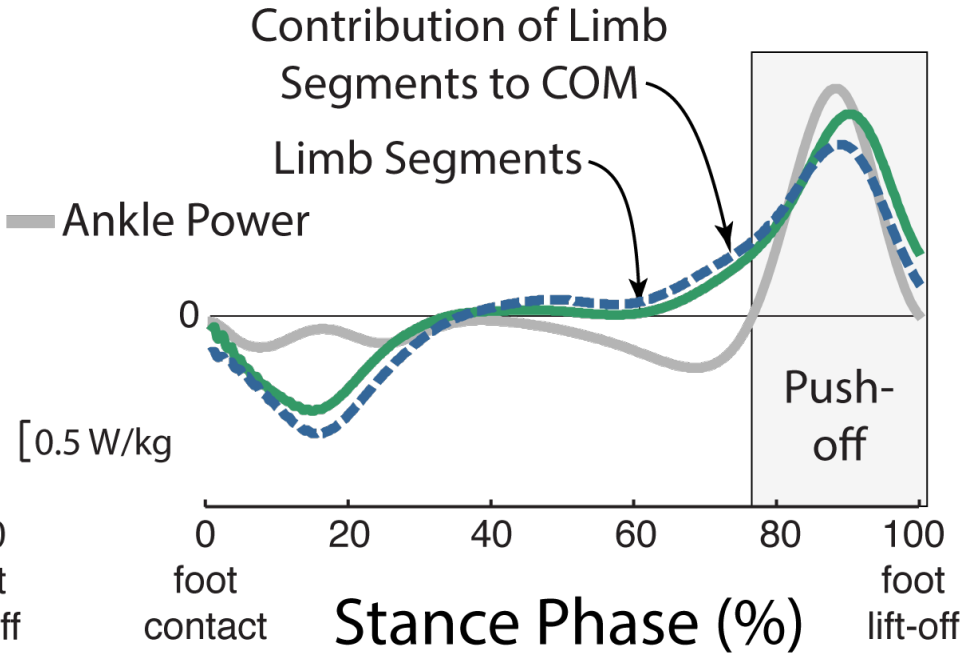

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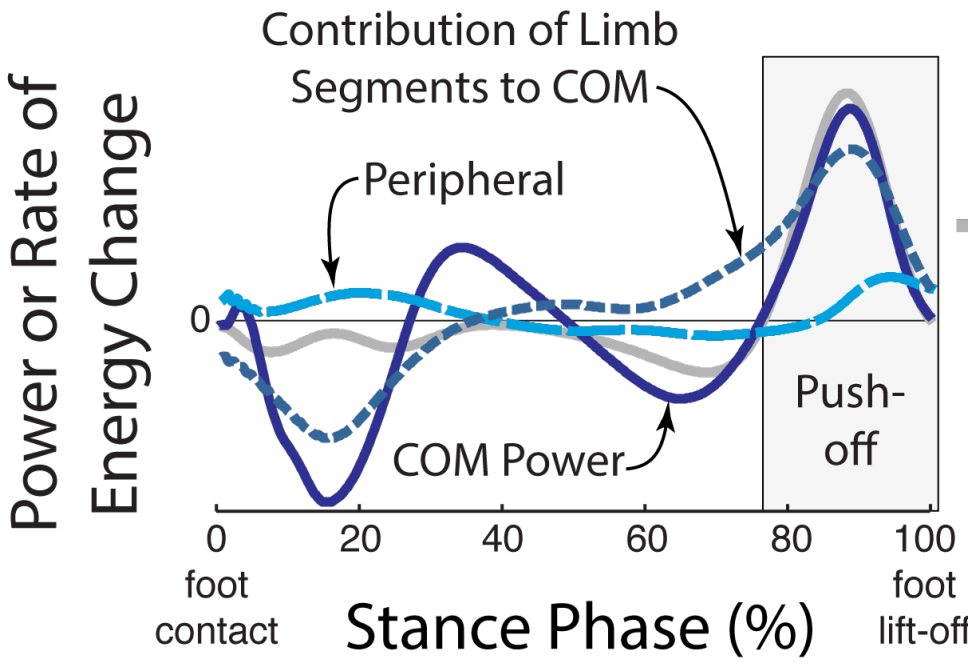

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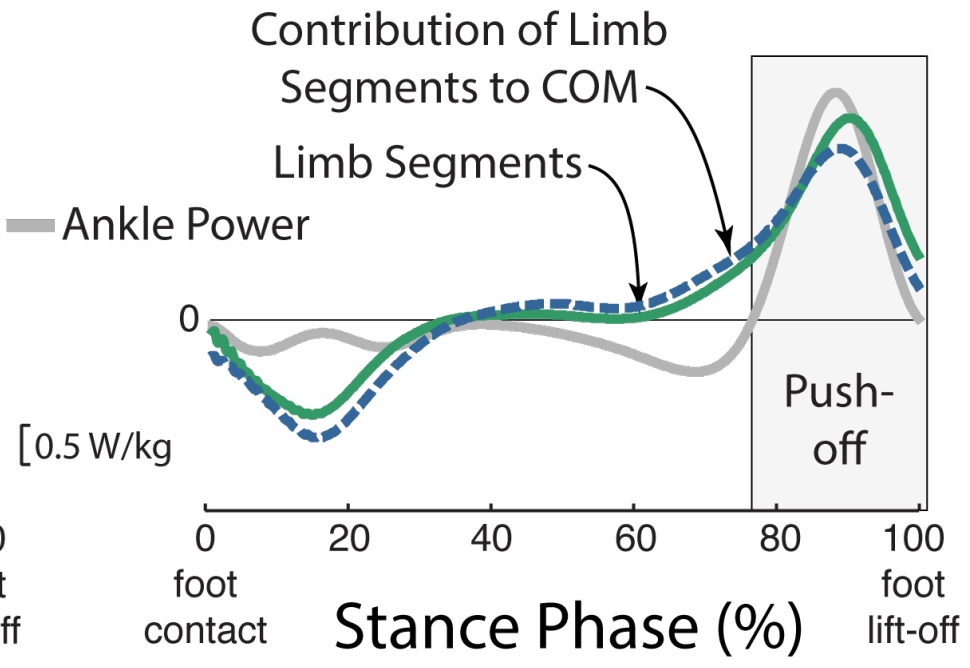

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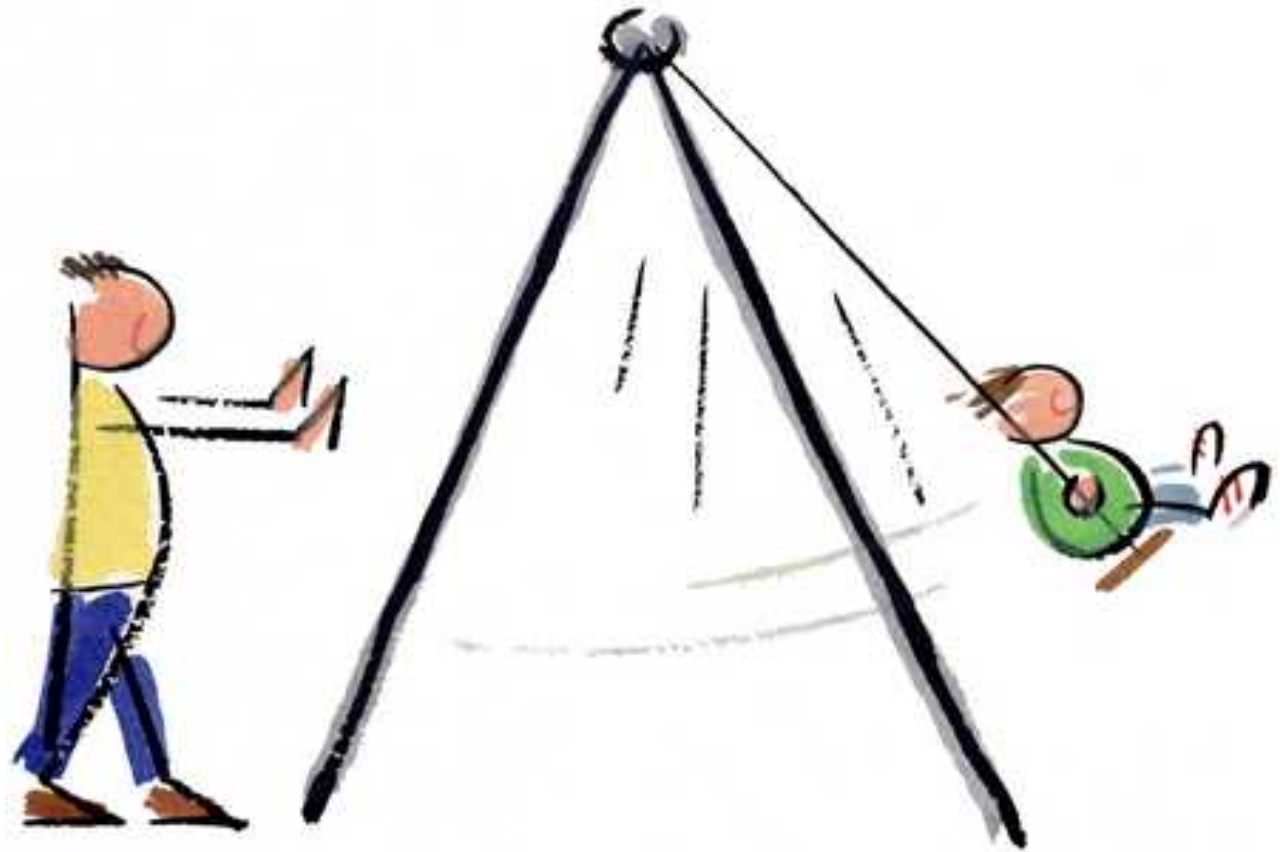

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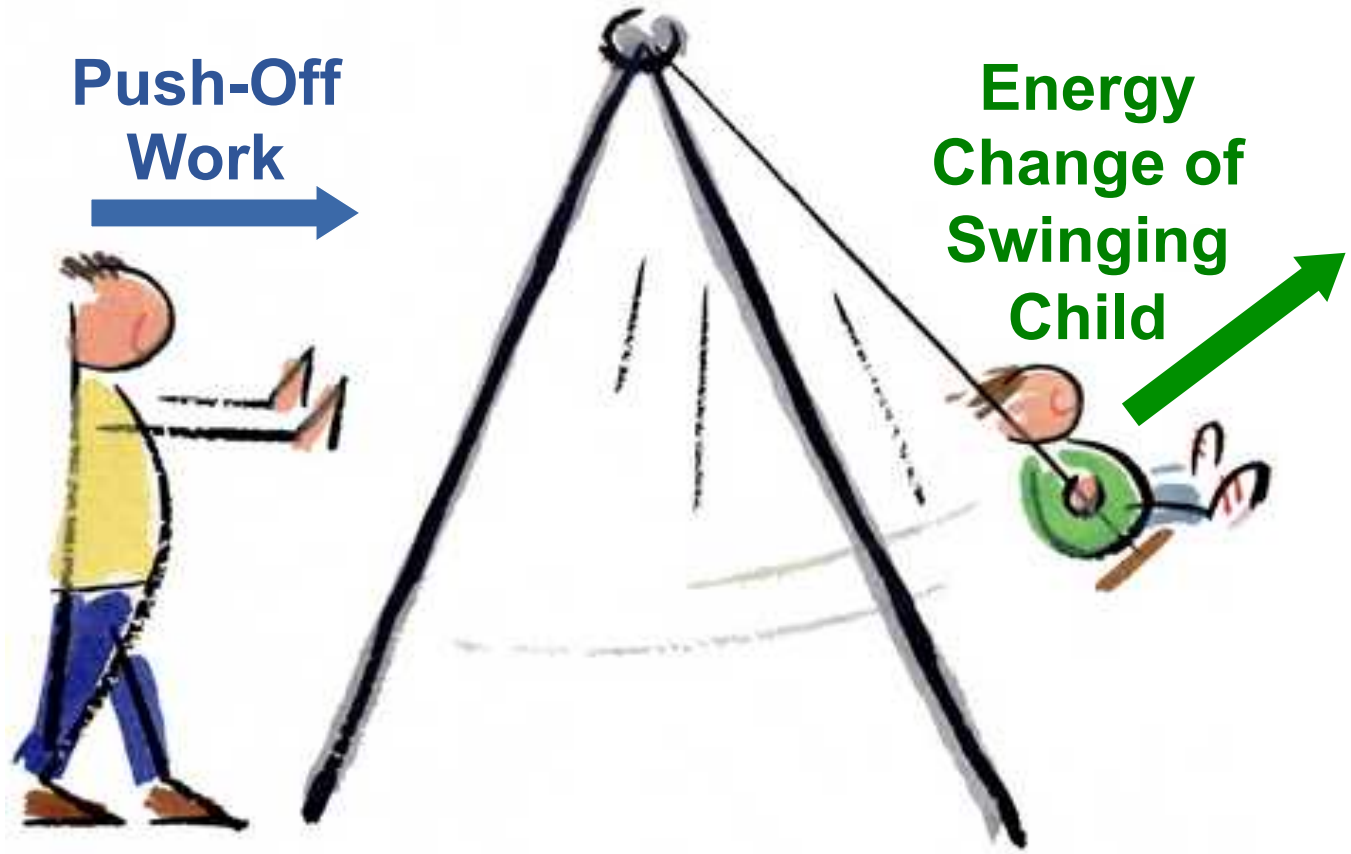

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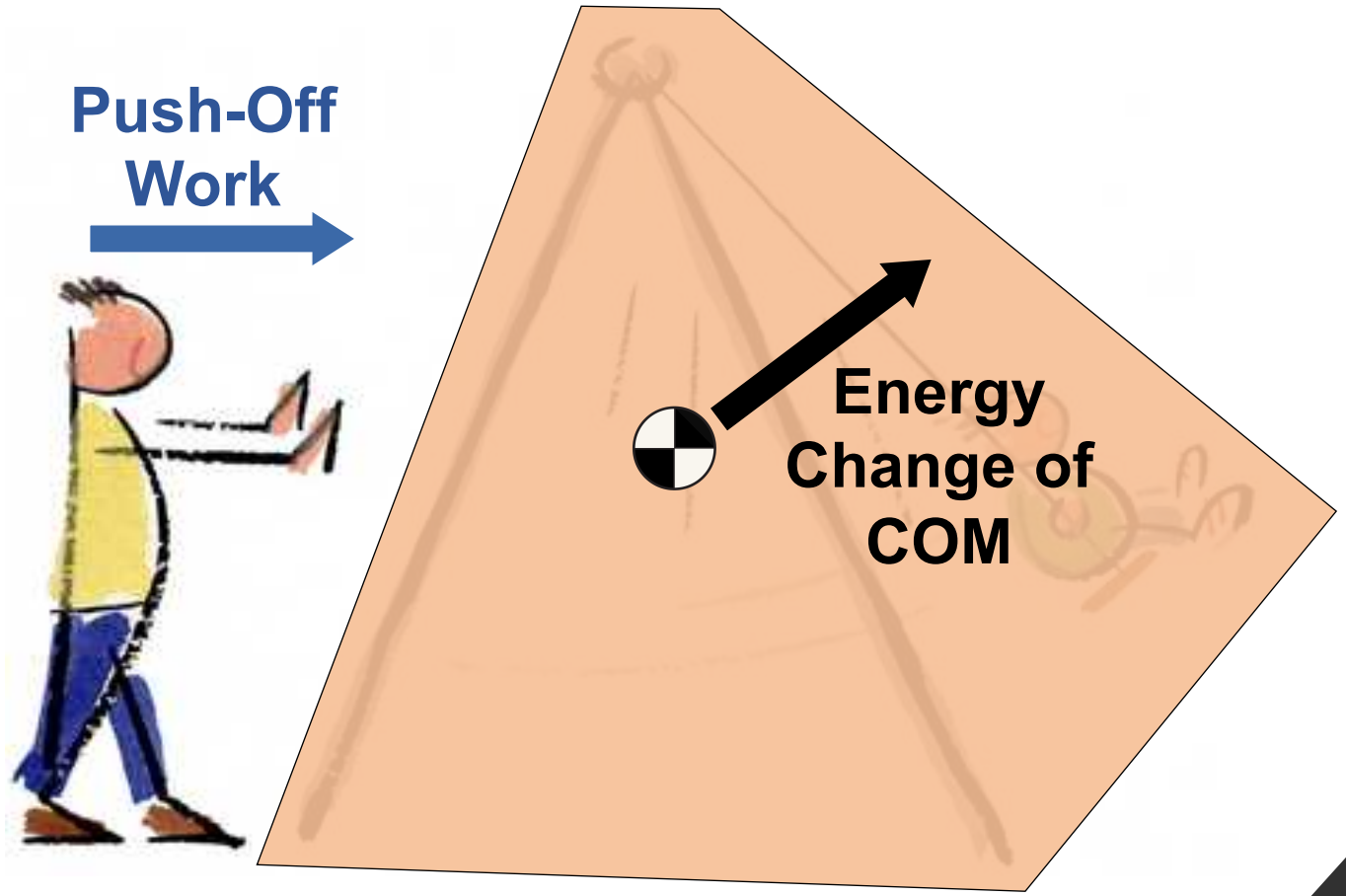


Combining work & energy estimates to coalesce perspectives

The debate whether Push-off from ankles powers leg swing or COM rankles.

But a unified view

indicates both are true:

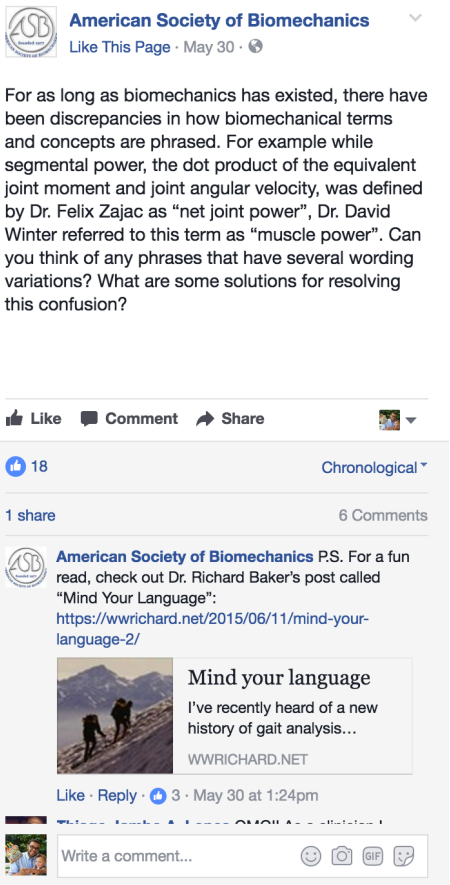
Two effects inextricably tangled.

Zelik & Adamczyk 2016 (JEB)

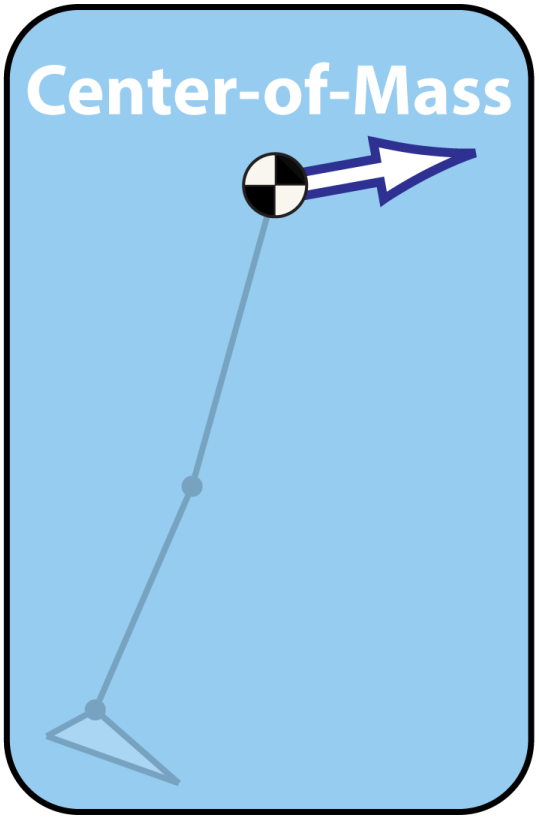
rankle – to continue to cause irritation or annoyance

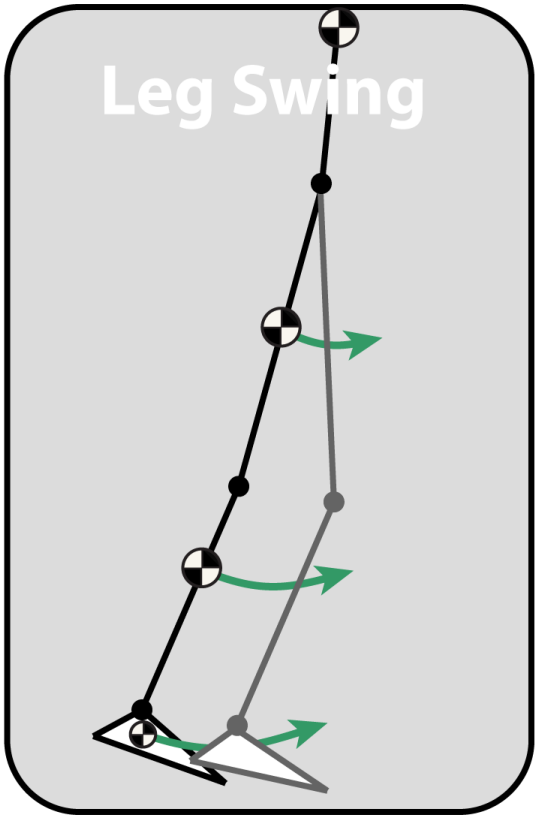
Speaking the same language… a non-trivial problem

COMMUNITY DISCUSSION



Definition of “leg swing”?





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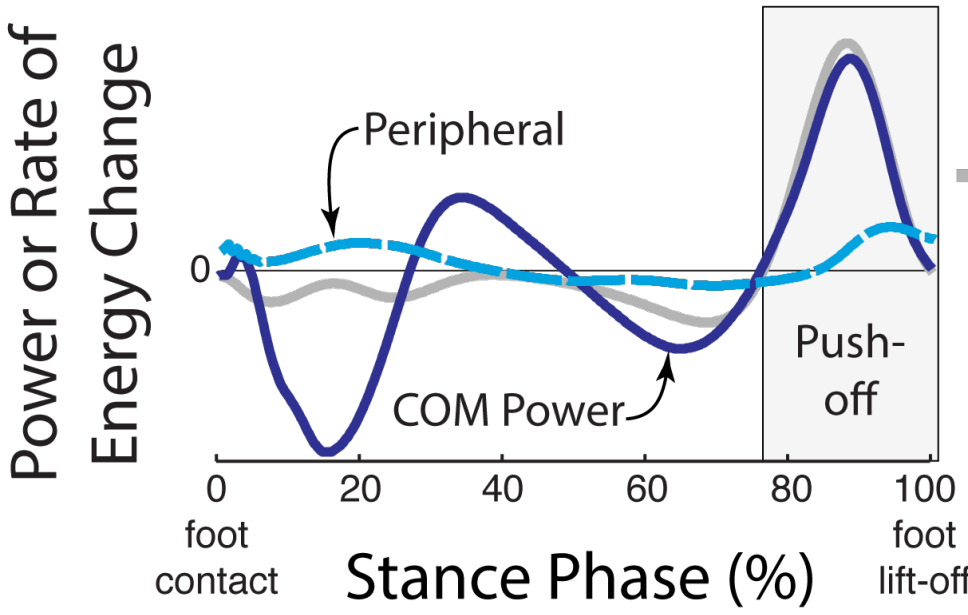
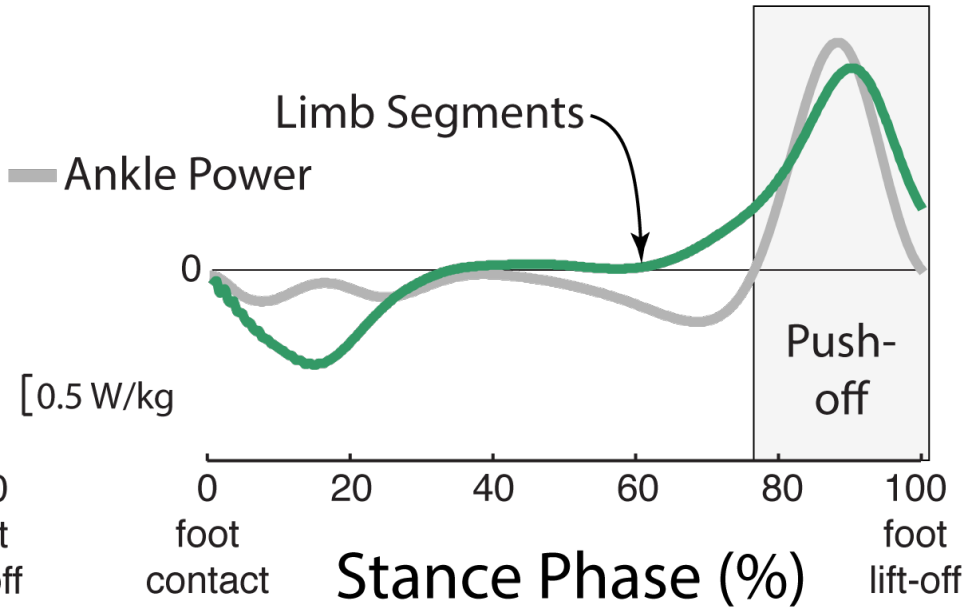


Swing Leg Perspective



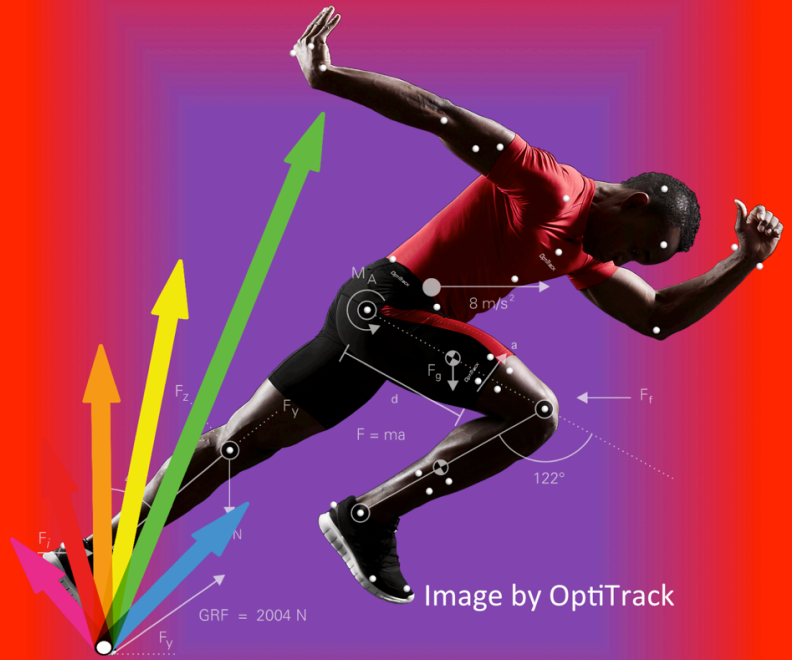
Unification in biomechanics

"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)*

Unification in biomechanics

Celebrating the 21st century's breakthrough science

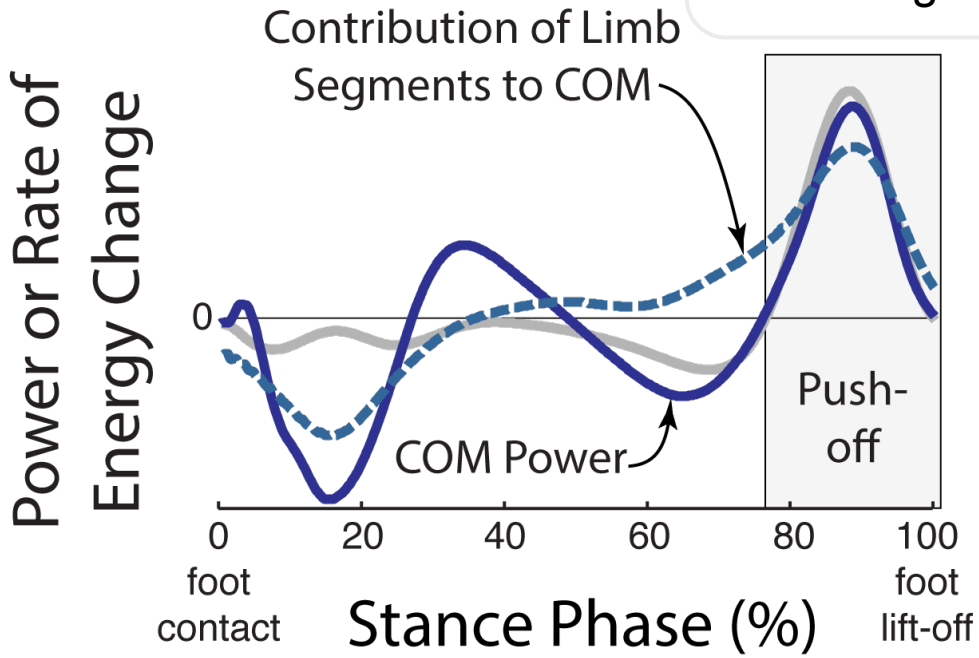


National Biomechanics Day

PS. Participate in NBD, an exciting & <u>unifying</u> outreach event!!!

Acknowledgements

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



Funding: NIH, Vanderbilt University