UW BADGER Lab

Biomechatronics, Assistive Devices, Gait Engineering, & Rehabilitation

Effect of prosthetic forefoot stiffnesses on the dynamic mean ankle moment arm (DMAMA) across different ambulation modes

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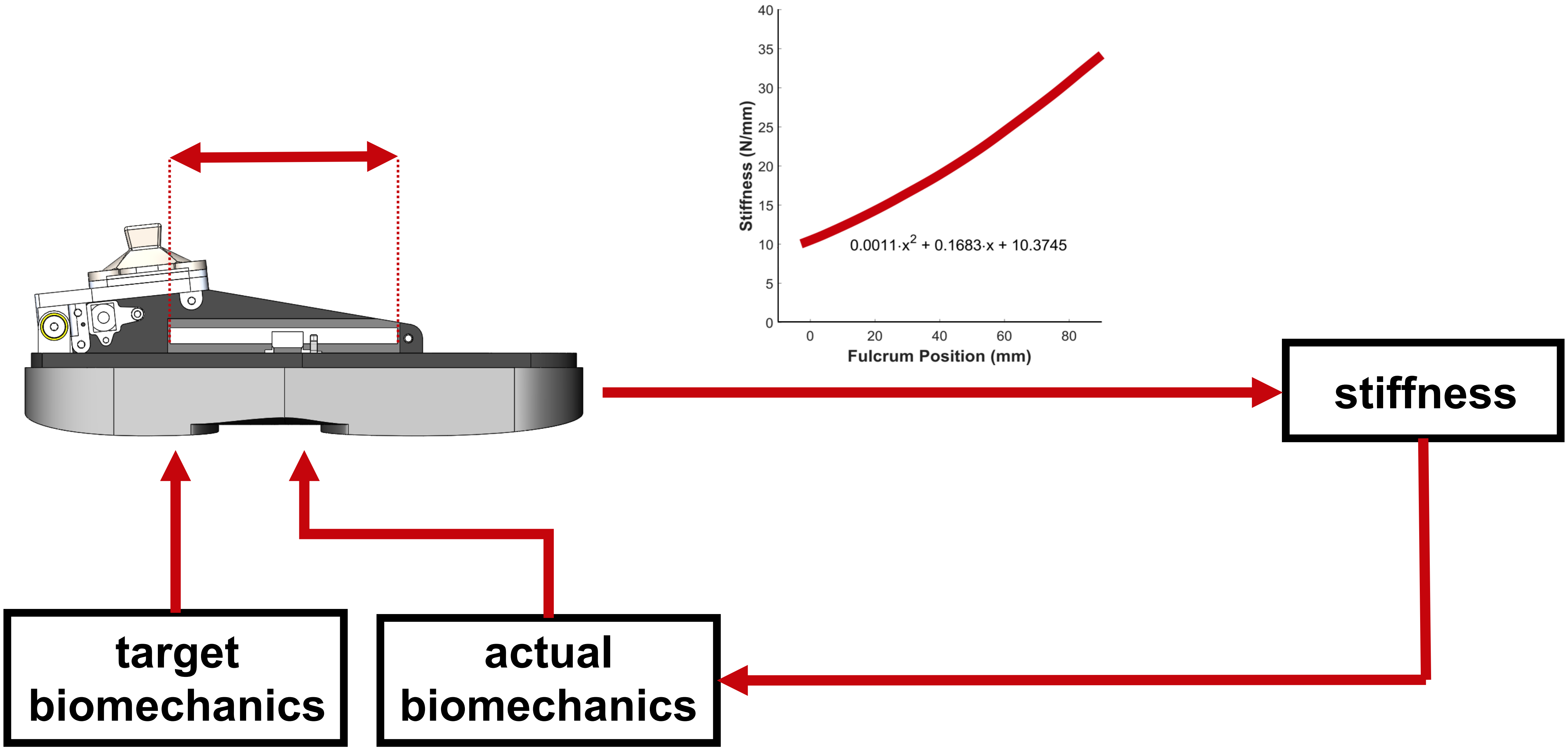
Progress towards biomimetic prostheses

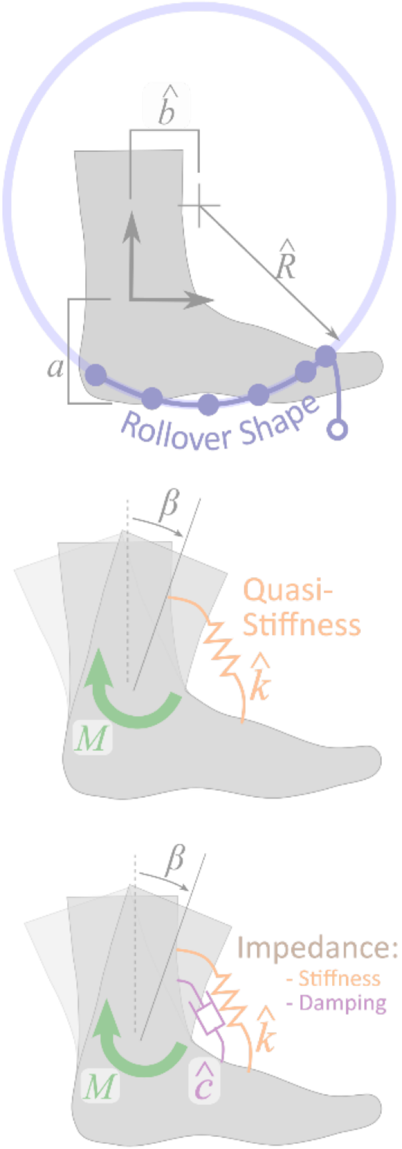
biomechanical data

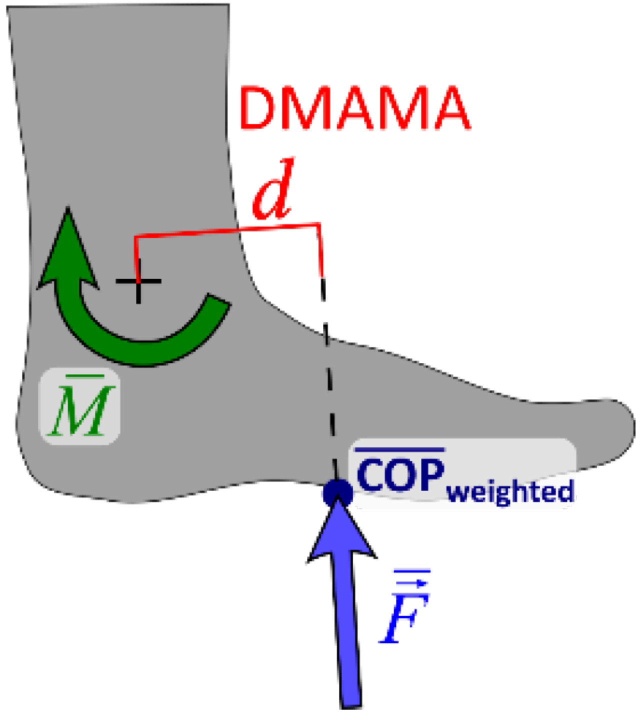
prosthetic foot stiffness

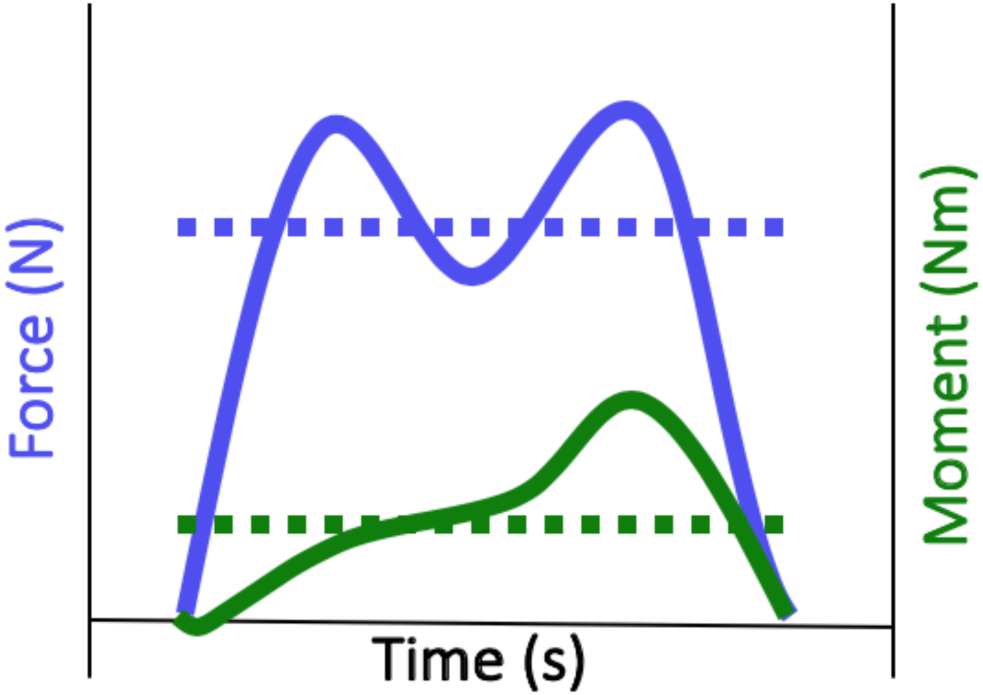
Our variable stiffness foot (VSF)



Dynamic mean ankle moment arm (DMAMA)



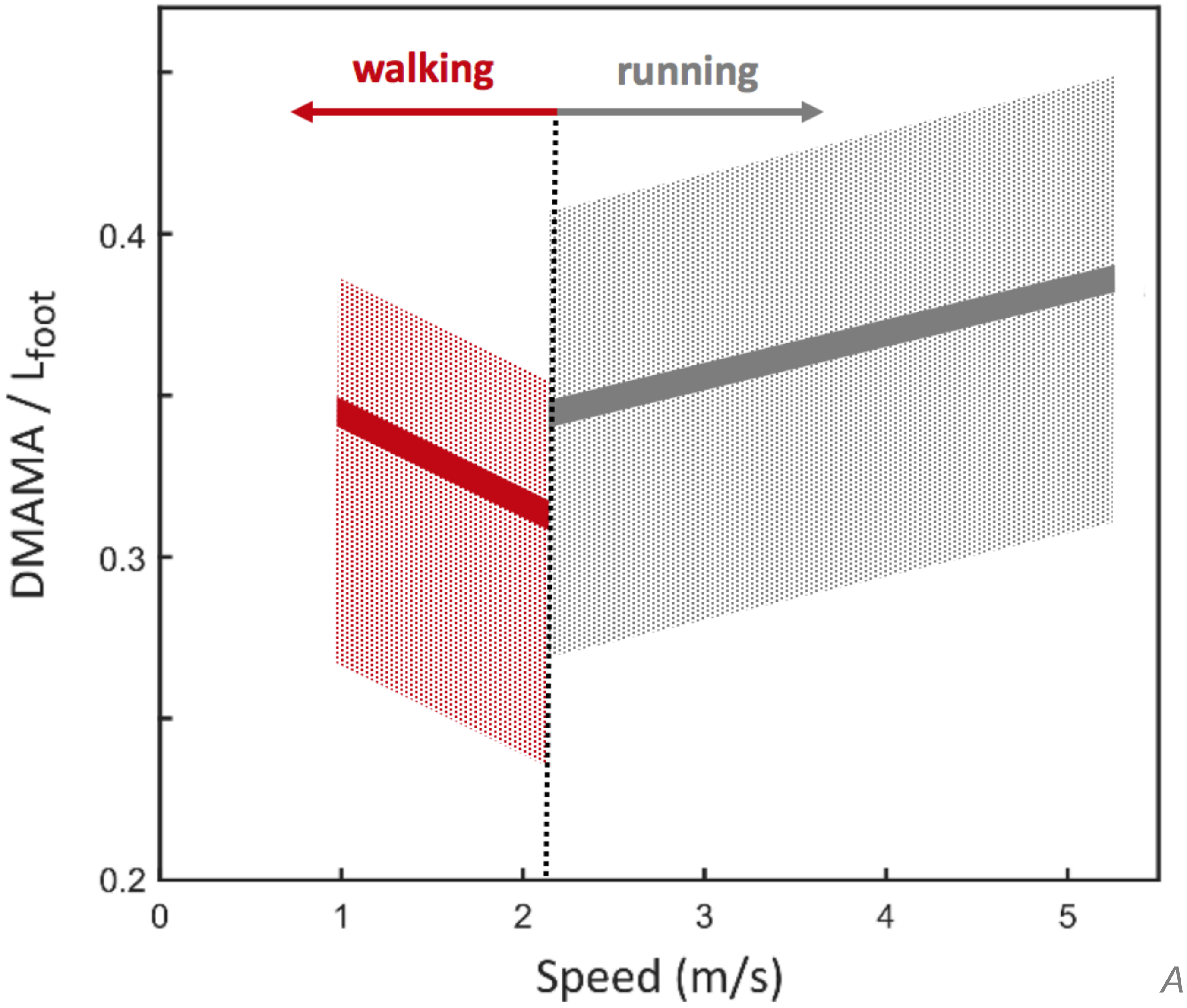




$$\text{DMAMA:} \quad d = \frac{J}{I} = \frac{\int_{\text{HS}}^{\text{TO}} M\,dt}{\left\| \int_{\text{HS}}^{\text{TO}} \vec{F}\,dt \right\|} = \frac{\bar{M}}{\bar{F}}$$

Adamczyk (in revision), JBME
Hansen 2004, Clin. Biomech.
Lee 2016, IEEE JTEHM
Shamaei 2013, PLoS

Effects of Speed on DMAMA



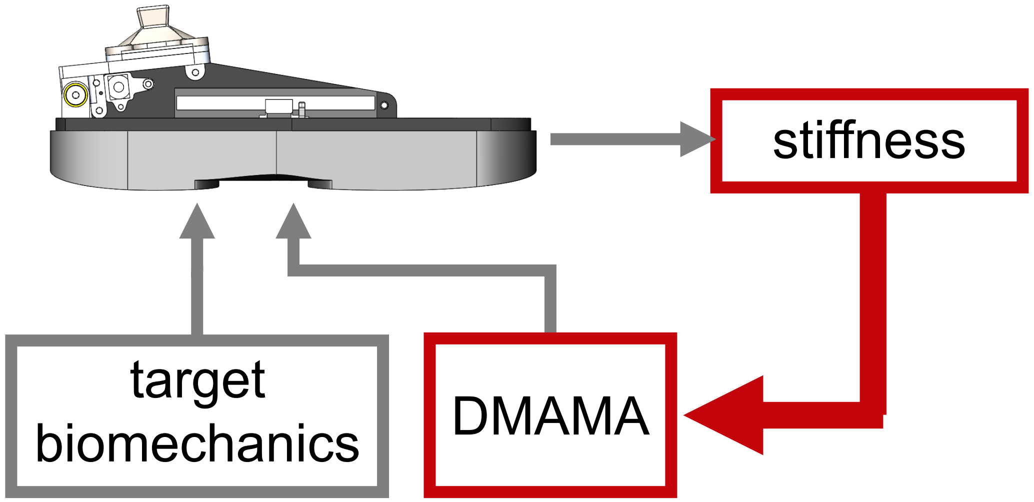
Adamczyk (in revision), JBME

Our Study

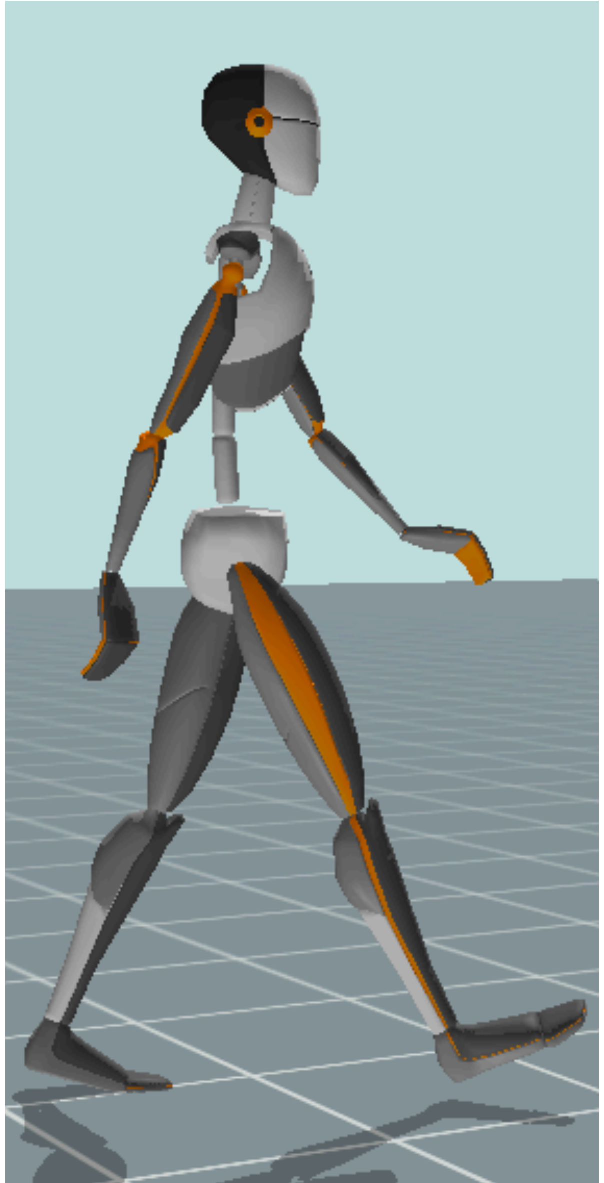
Can DMAMA reflect biomechanical changes caused by stiffness?

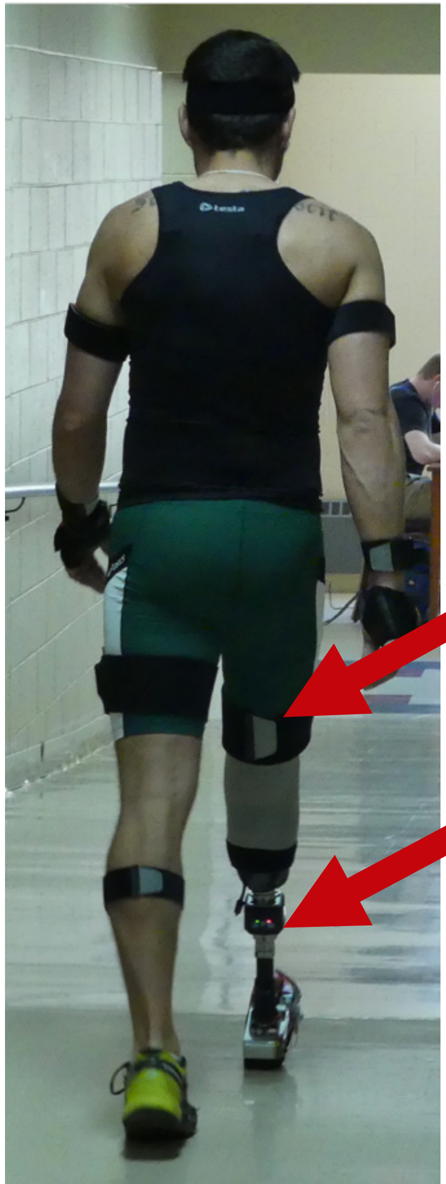
DMAMA will change with stiffness across all ambulation modes

Control stiffness in a biomimetic way



Moving data collection outside of the lab

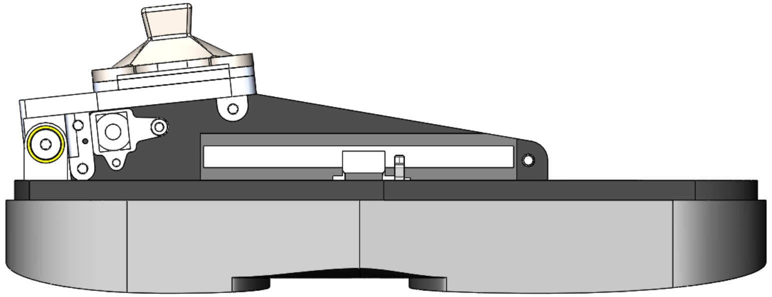


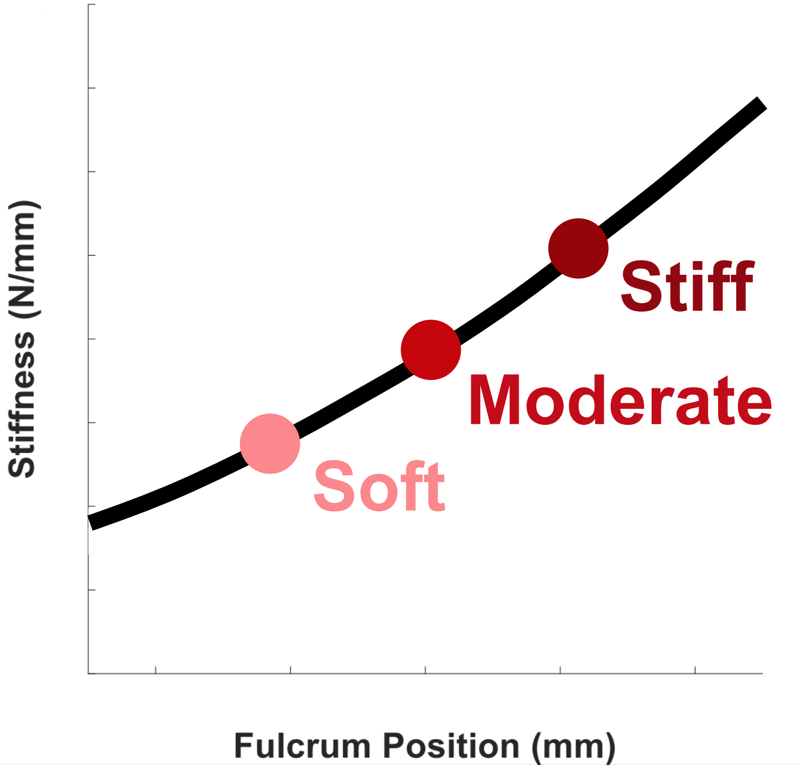


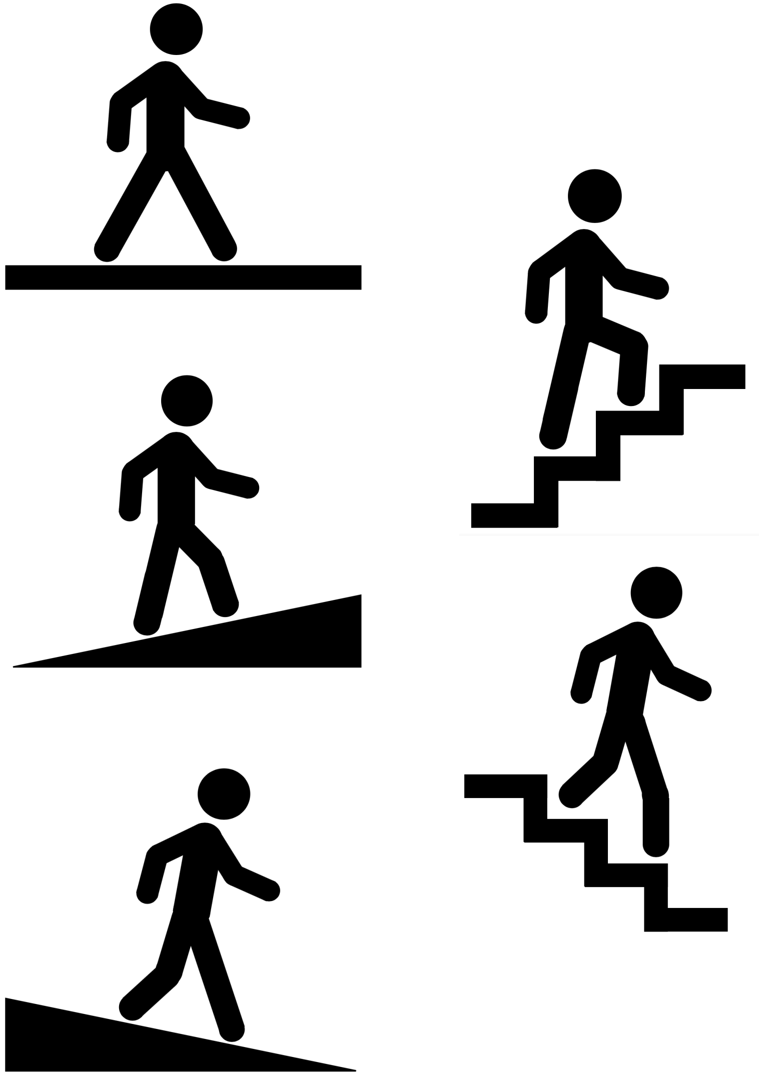
IMU suit

Pylon-embedded load cell

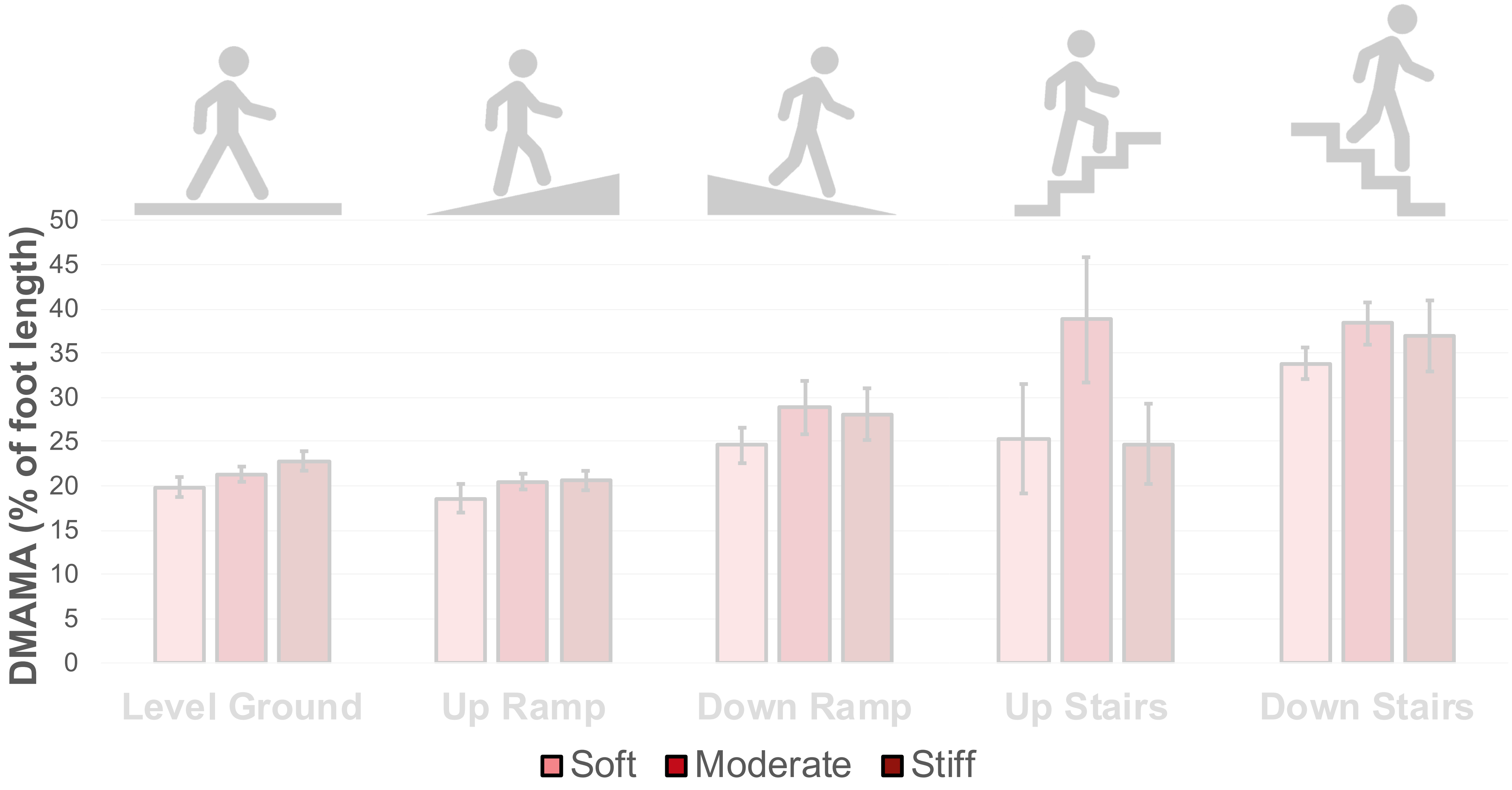
Testing Conditions



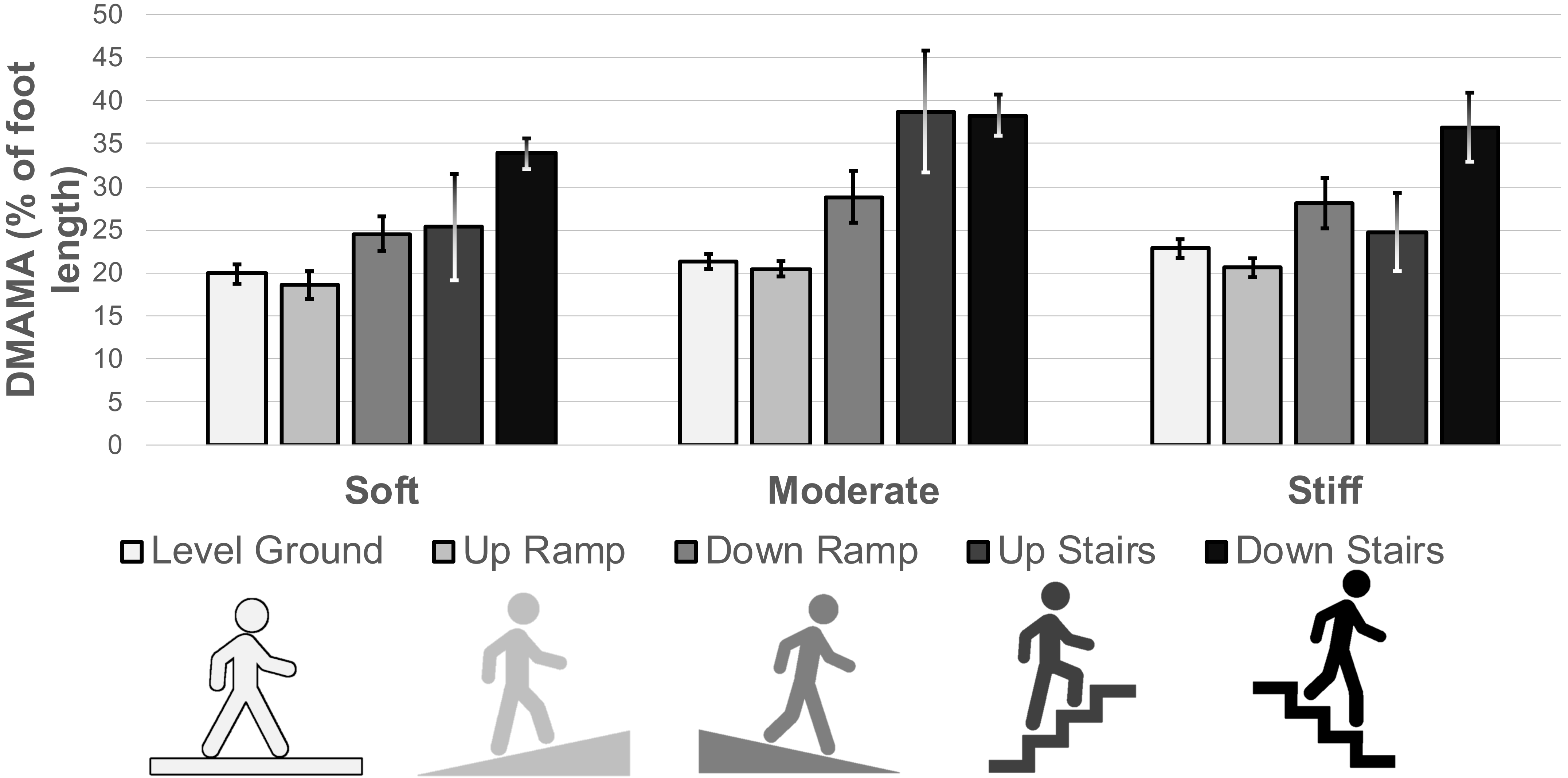




Effect of **stiffness** on DMAMA

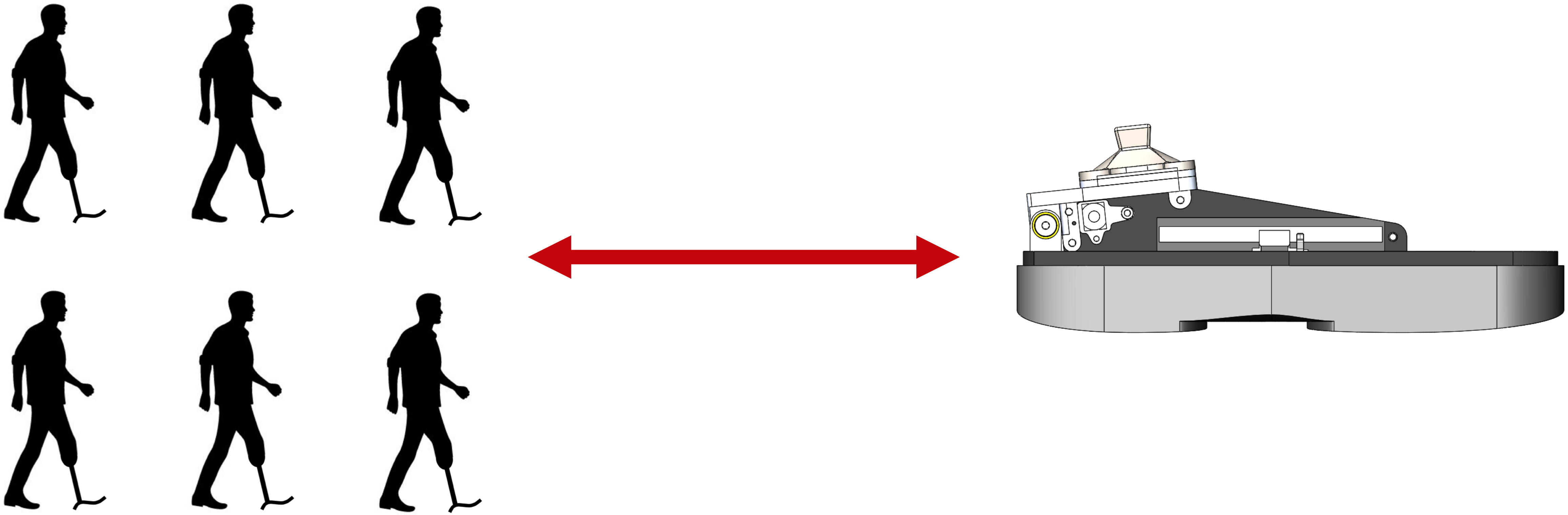


Effect of **ambulation mode** on DMAMA



Conclusion

DMAMA may be able to quantify **biomechanical changes** caused by changes in **stiffness** and **ambulation mode**



Thank you!

Acknowledgements

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References

A. H. Hansen, D. S. Childress, and E. H. Knox, “Roll-over shapes of human locomotor systems: effects of walking speed,” *Clin. Biomech. Bristol Avon*, vol. 19, no. 4, pp. 407–414, May 2004.

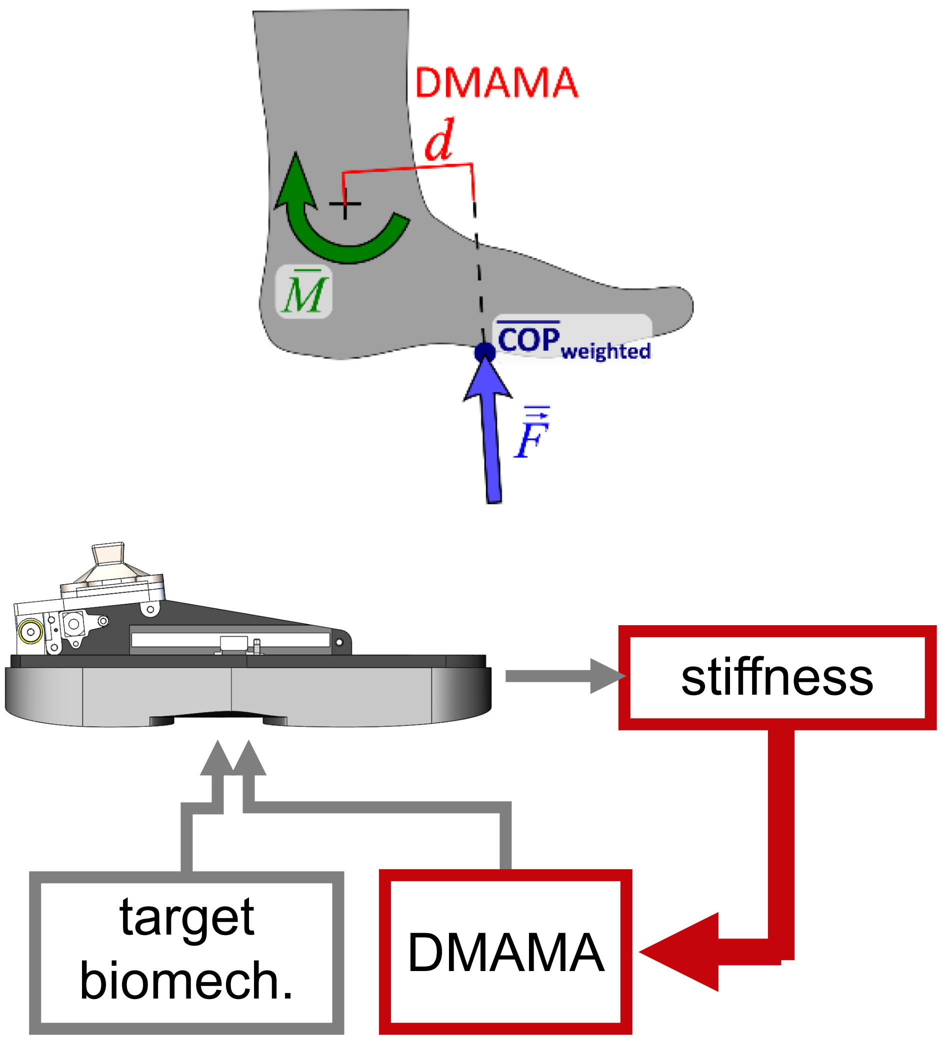
E. M. Glanzer and P. G. Adamczyk, “Design and validation of a semi-active variable stiffness foot prosthesis,” *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 26, no. 12, pp. 2351-2359, Dec. 2018.

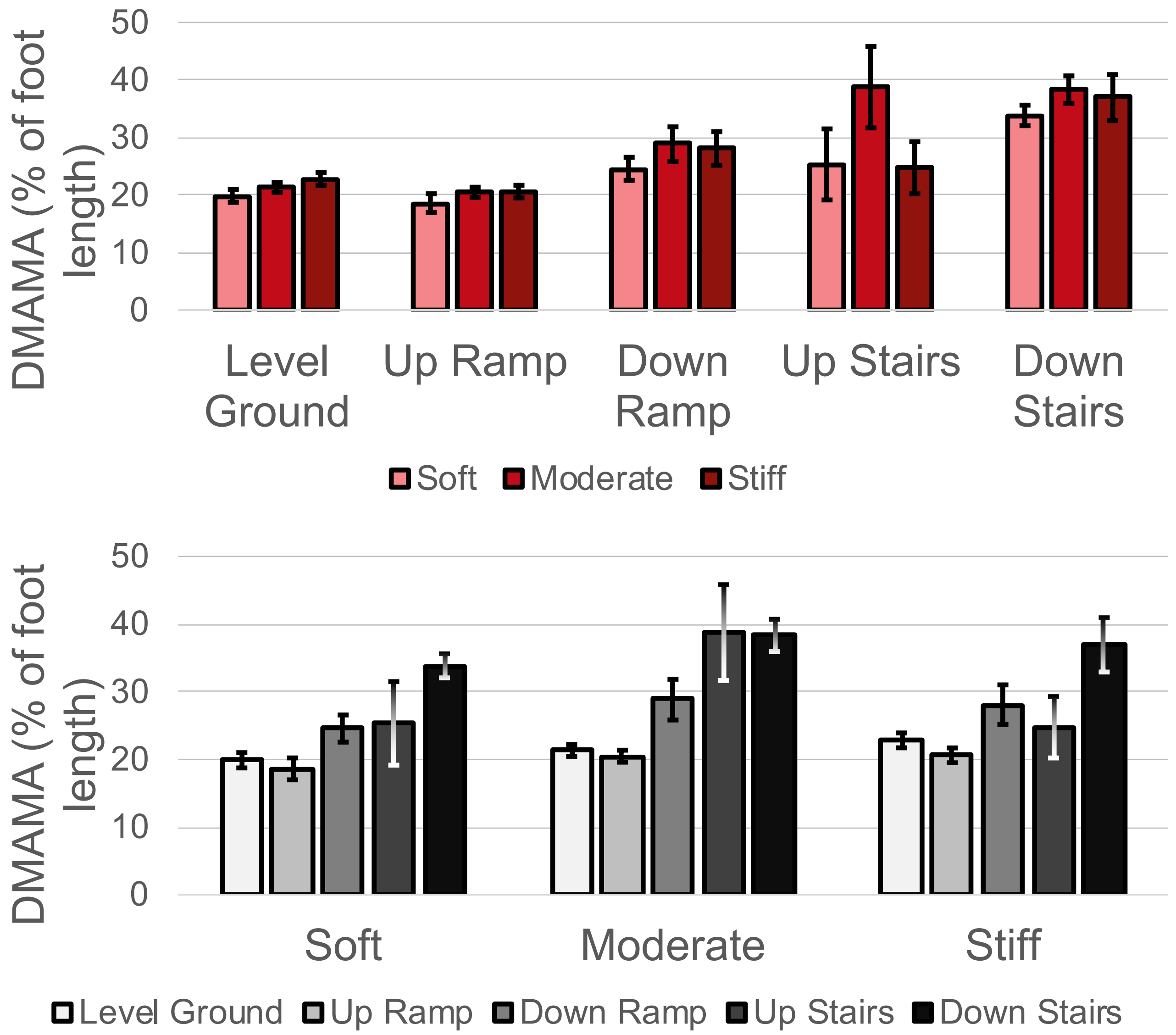
H. Lee, E. J. Rouse, and H. I. Krebs, “Summary of Human Ankle Mechanical Impedance During Walking,” *IEEE J. Transl. Eng. Health Med.*, vol. 4, pp. 1–7, 2016.

K. Shamaei, G. S. Sawicki, and A. M. Dollar, “Estimation of Quasi-Stiffness and Propulsive Work of the Human Ankle in the Stance Phase of Walking,” *PLoS ONE*, vol. 8, no. 3, p. e59935, Mar. 2013.

P. G. Adamczyk, “Ankle control in walking and running: speed- and gait-related changes in dynamic mean ankle moment arm (DMAMA),” *J. Biomech. Eng.*, in revision.

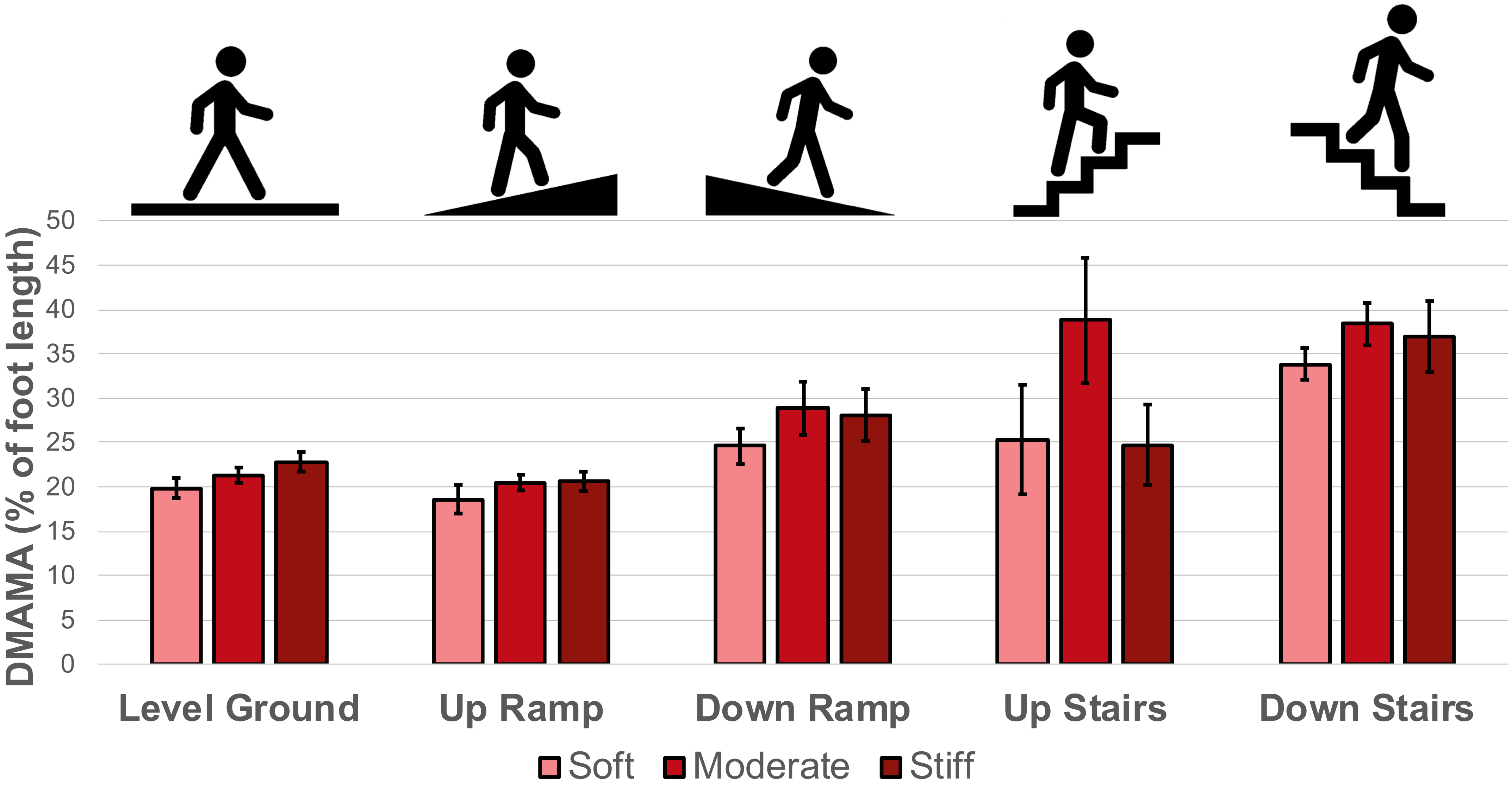
Questions?


DMAMA
d
M
COP weighted
F
stiffness
target biomech.
DMAMA

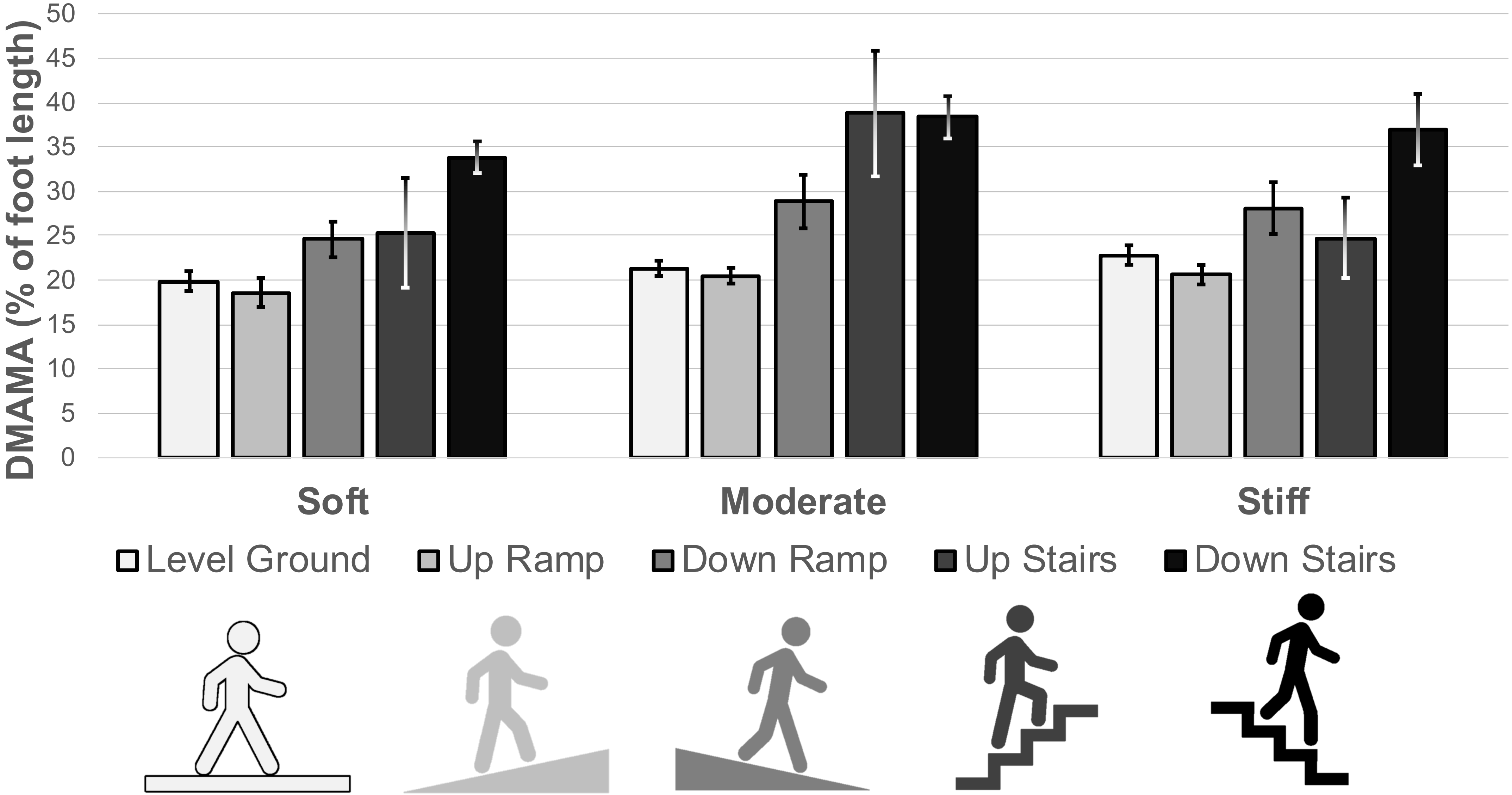

DMAMA (% of foot length)
50
40
30
20
10
0
Level Ground
Up Ramp
Down Ramp
Up Stairs
Down Stairs
Soft
Moderate
Stiff
DMAMA (% of foot length)
50
40
30
20
10
0
Soft
Moderate
Stiff
Level Ground
Up Ramp
Down Ramp
Up Stairs
Down Stairs

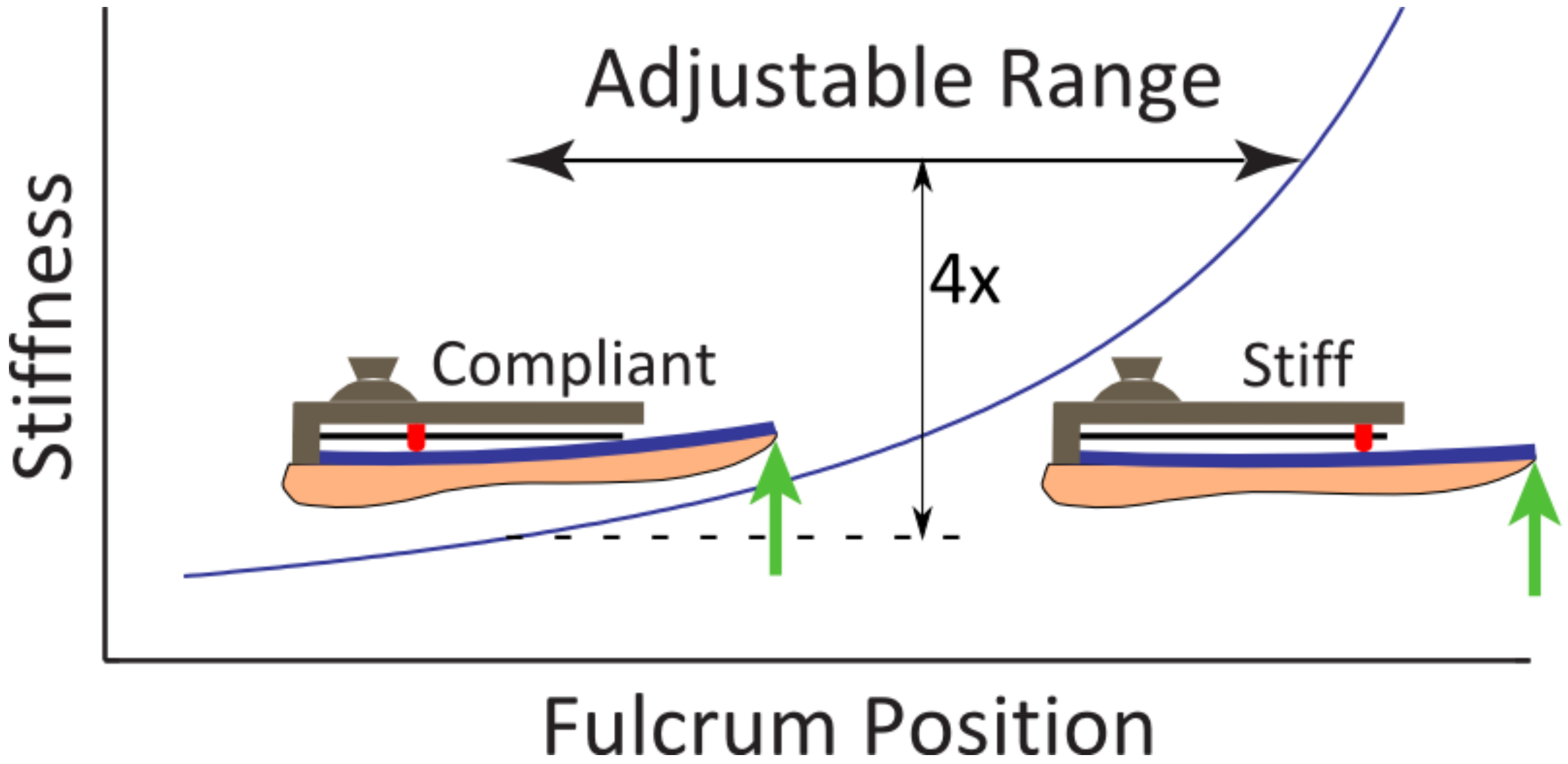
Extra Slides

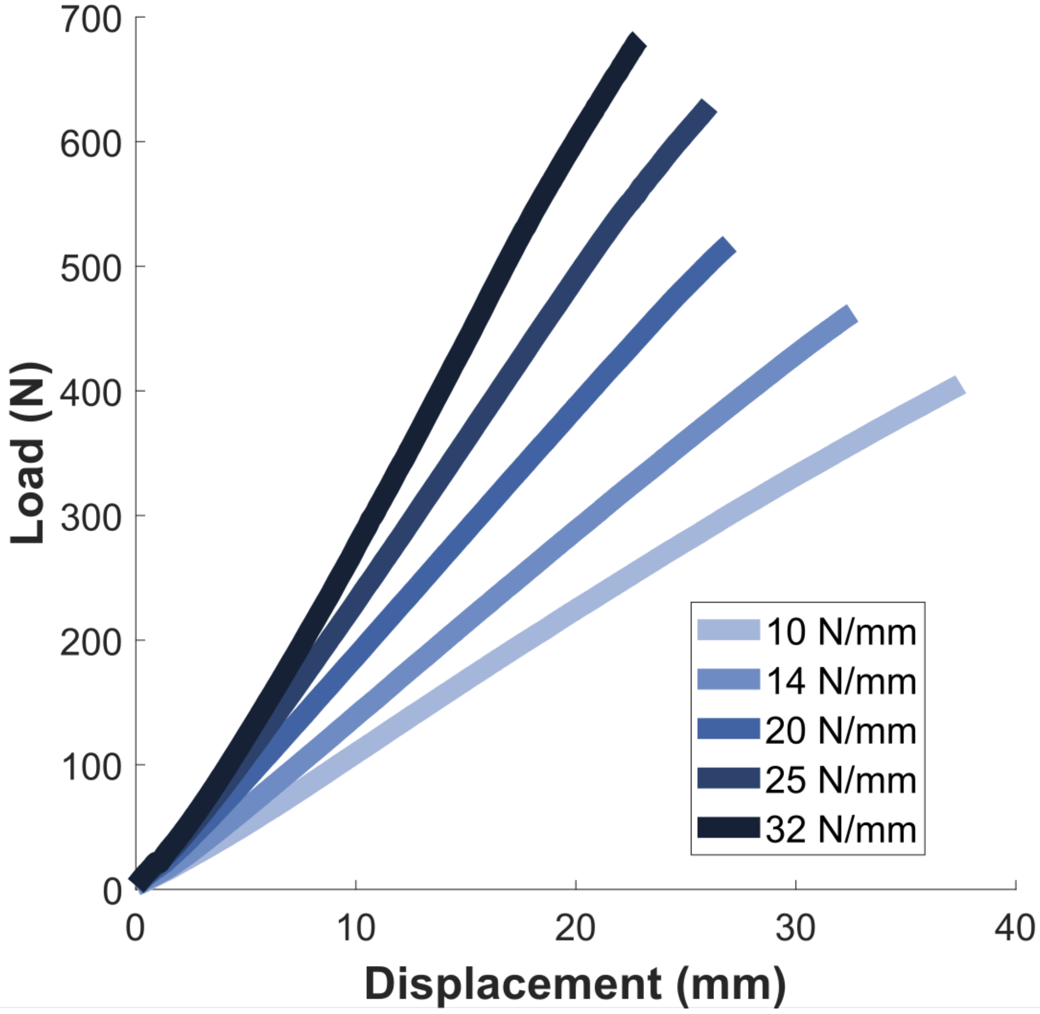
Effect of Stiffness on DMAMA

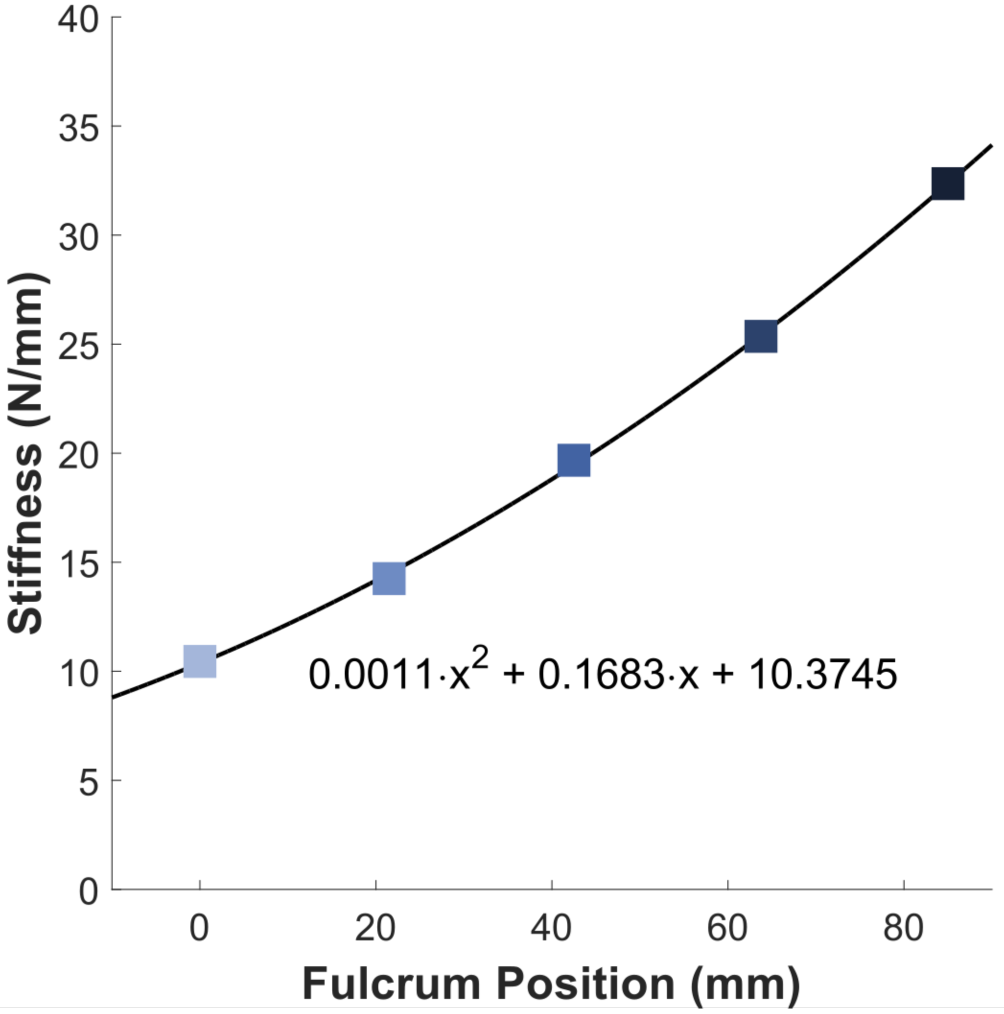


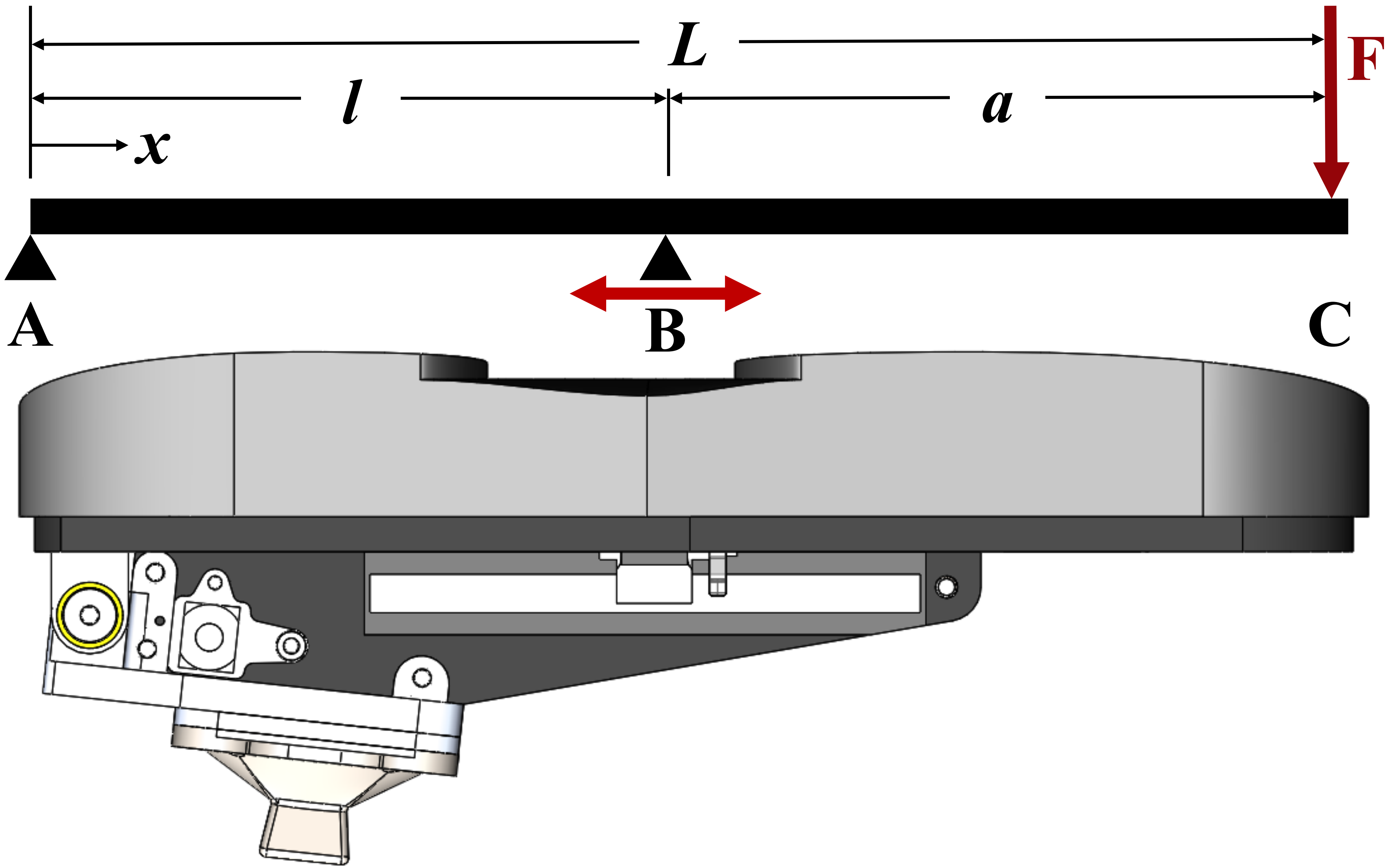
Effect of Ambulation Mode on DMAMA



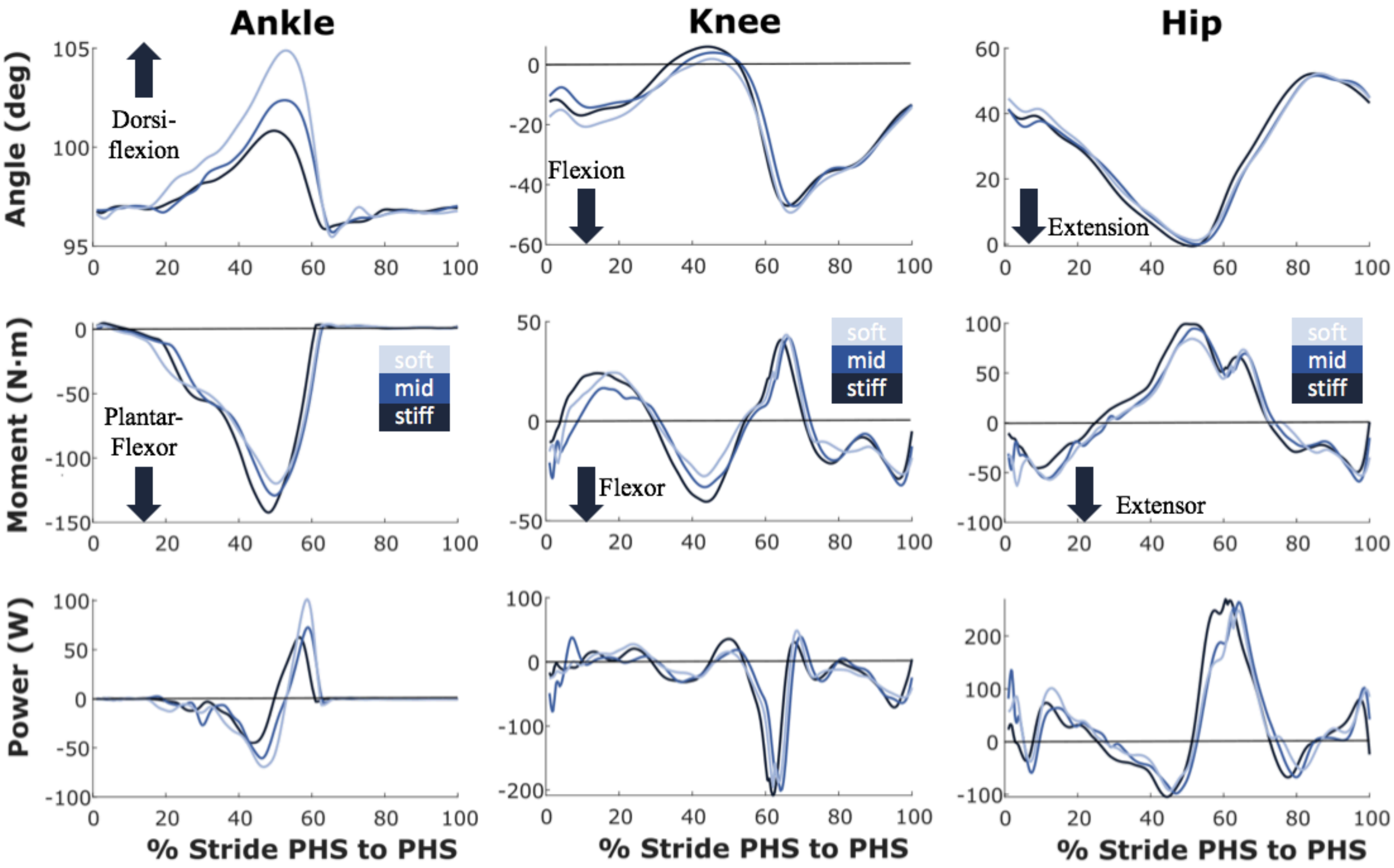

Adjustable Range
4x
Compliant
Stiff
Stiffness
Fulcrum Position


Load (N)
Displacement (mm)
10 N/mm
14 N/mm
20 N/mm
25 N/mm
32 N/mm

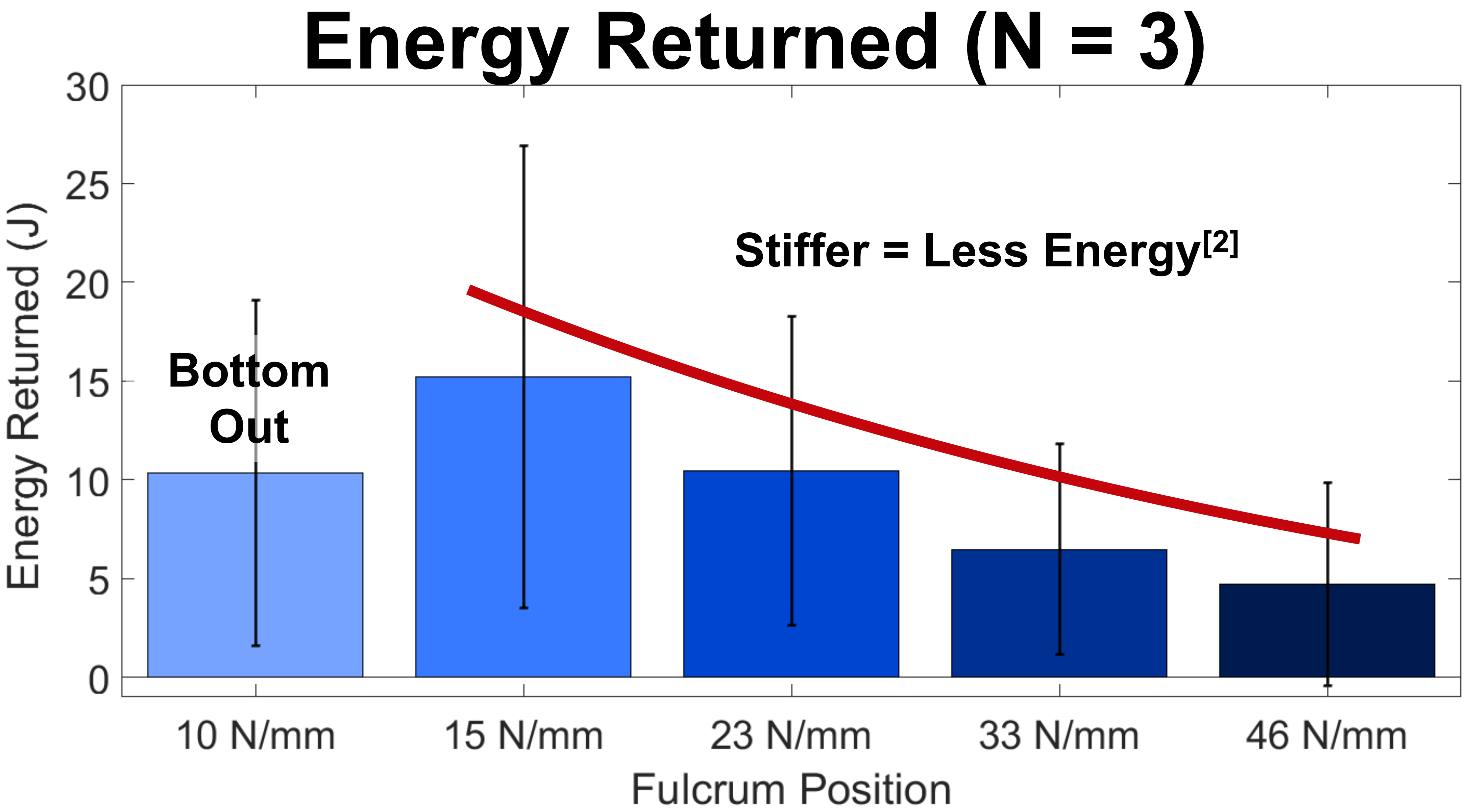

Stiffness (N/mm)
Fulcrum Position (mm)
0.0011·x^2 + 0.1683·x + 10.3745



L
F
l
a
x
A
B
C



Ankle
Knee
Hip
Angle (deg)
Moment (N·m)
Power (W)
Dorsi-
flexion
Flexion
Extension
Plantar-
Flexor
Flexor
Extensor
soft
mid
stiff
% Stride PHS to PHS


Energy Returned (N = 3)
Energy Returned (J)
30
25
20
15
10
5
0
Bottom Out
Stiffer = Less Energy[2]
10 N/mm
15 N/mm
23 N/mm
33 N/mm
46 N/mm
Fulcrum Position