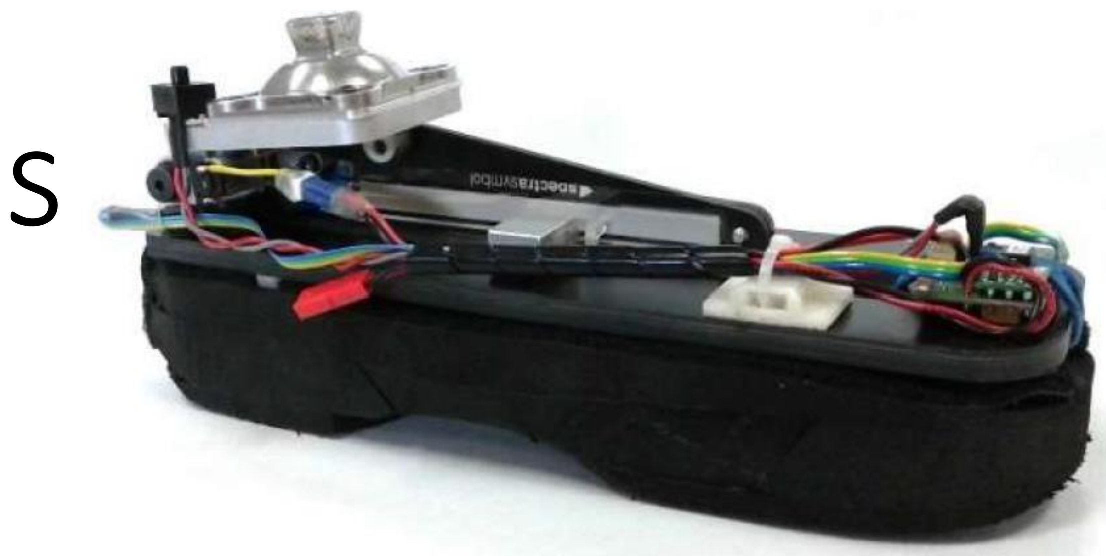
Sensitivity of Mechanical Outcomes to Various Stiffnesses of Variable Stiffness Foot



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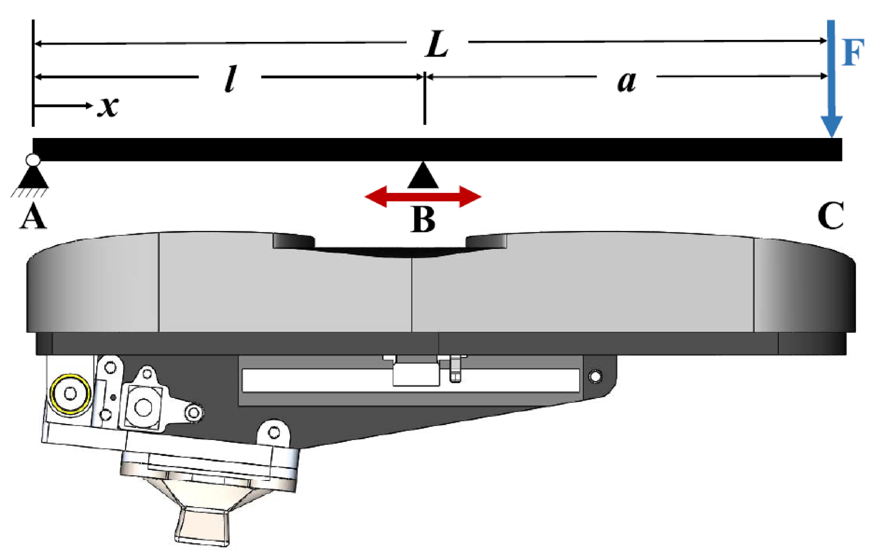
Introduction

Variable Stiffness Foot (VSF)

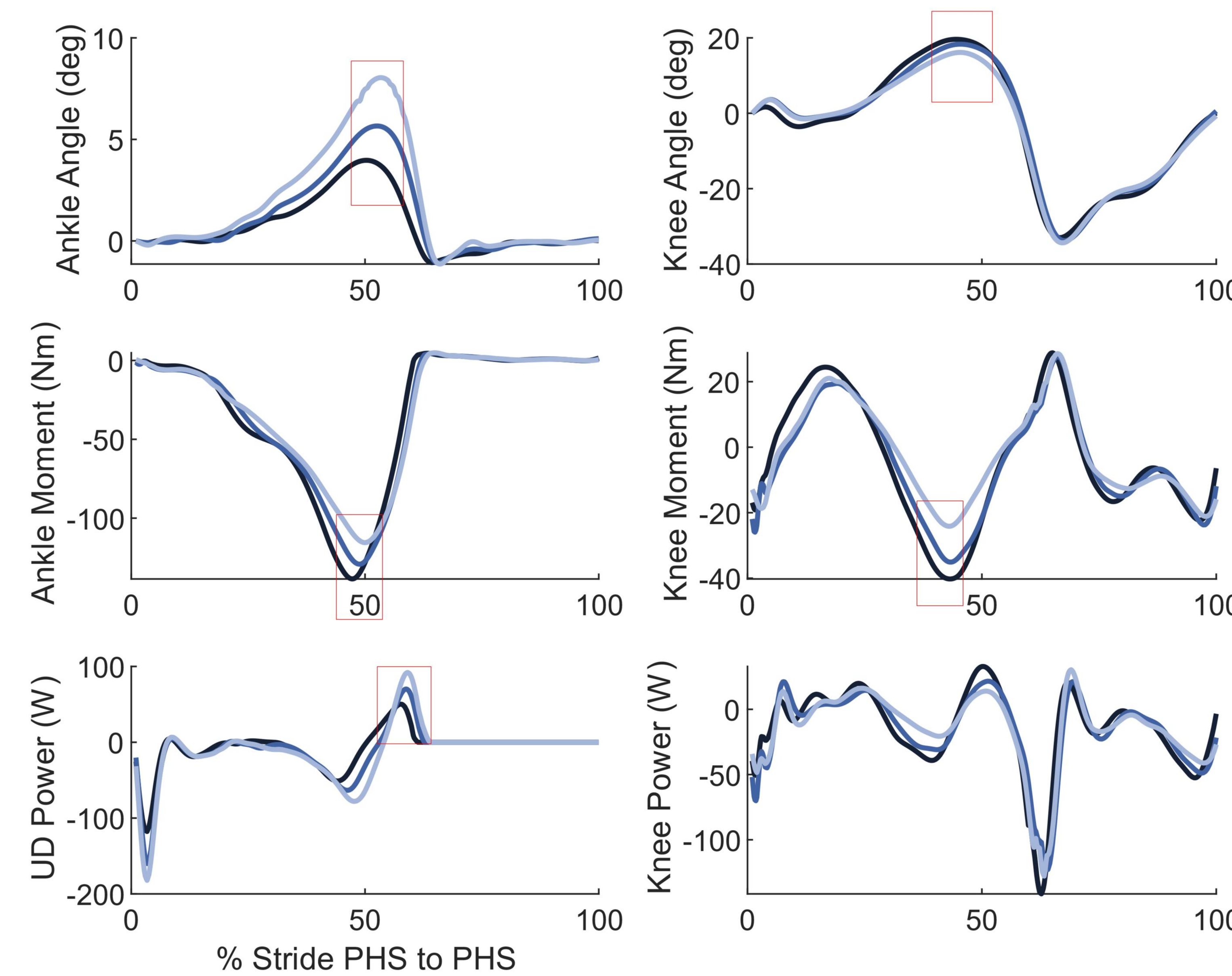
• Low Power• Lightweight
• Adaptable stiffness



Hypotheses for mechanical effects with stiffer foot:

- Decreased peak ankle dorsiflexion, increased plantarflexor moment, and decreased push off energy return
- Increased stance phase knee extension angle and decreased flexor moment

Representative mechanical outcomes

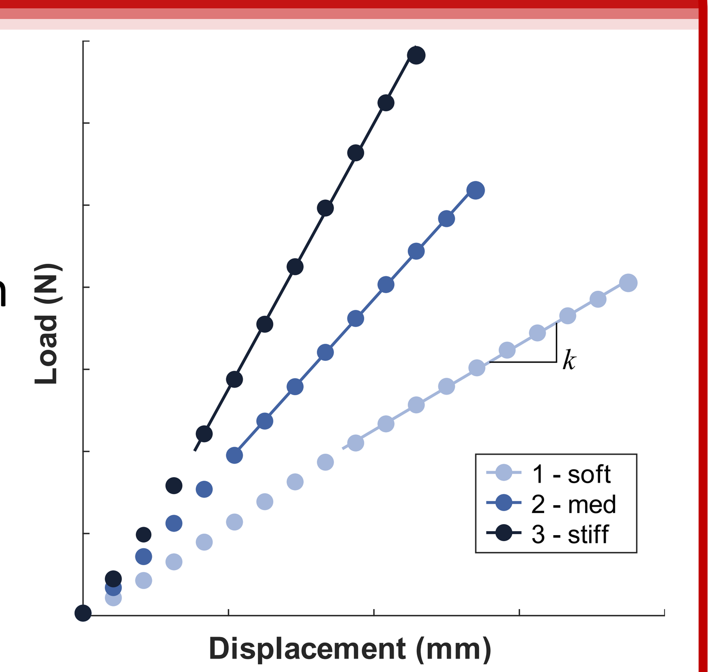


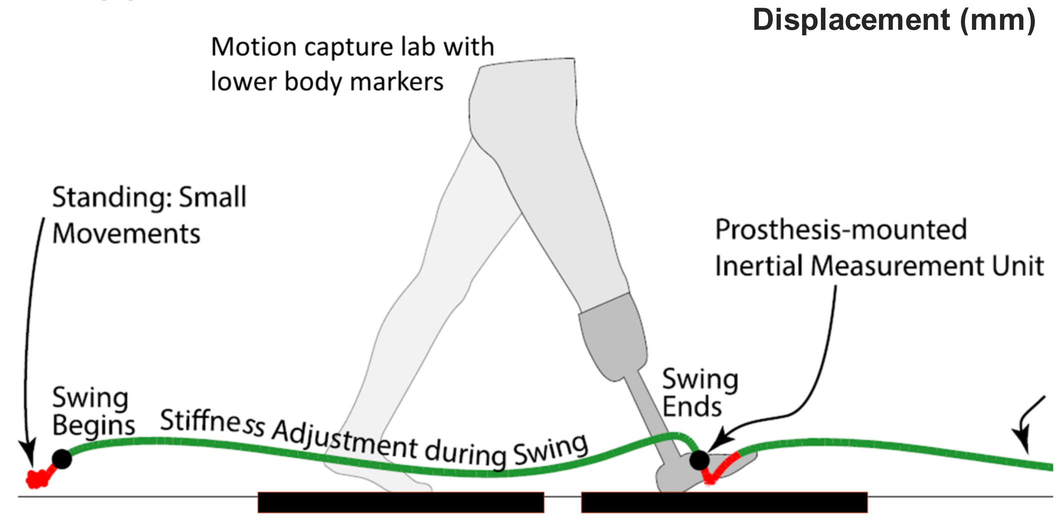
Main results

- Metrics shown on left from representative subject. PHS is prosthetic heel strike. Positive is dorsiflexion for ankle and extension for knee.
- Stiffer VSF has smaller excursion of dorsiflexion and less plantarflexor moment
- It also has more peak UD power during toe off which correlates with more push off energy. UD Power is the Unified Deformable body that specifies the power flow through the prosthesis.
- More extended knee angle is associated with increased flexor knee moment and ankle plantarflexor moment
- No distinctive features of Knee Power

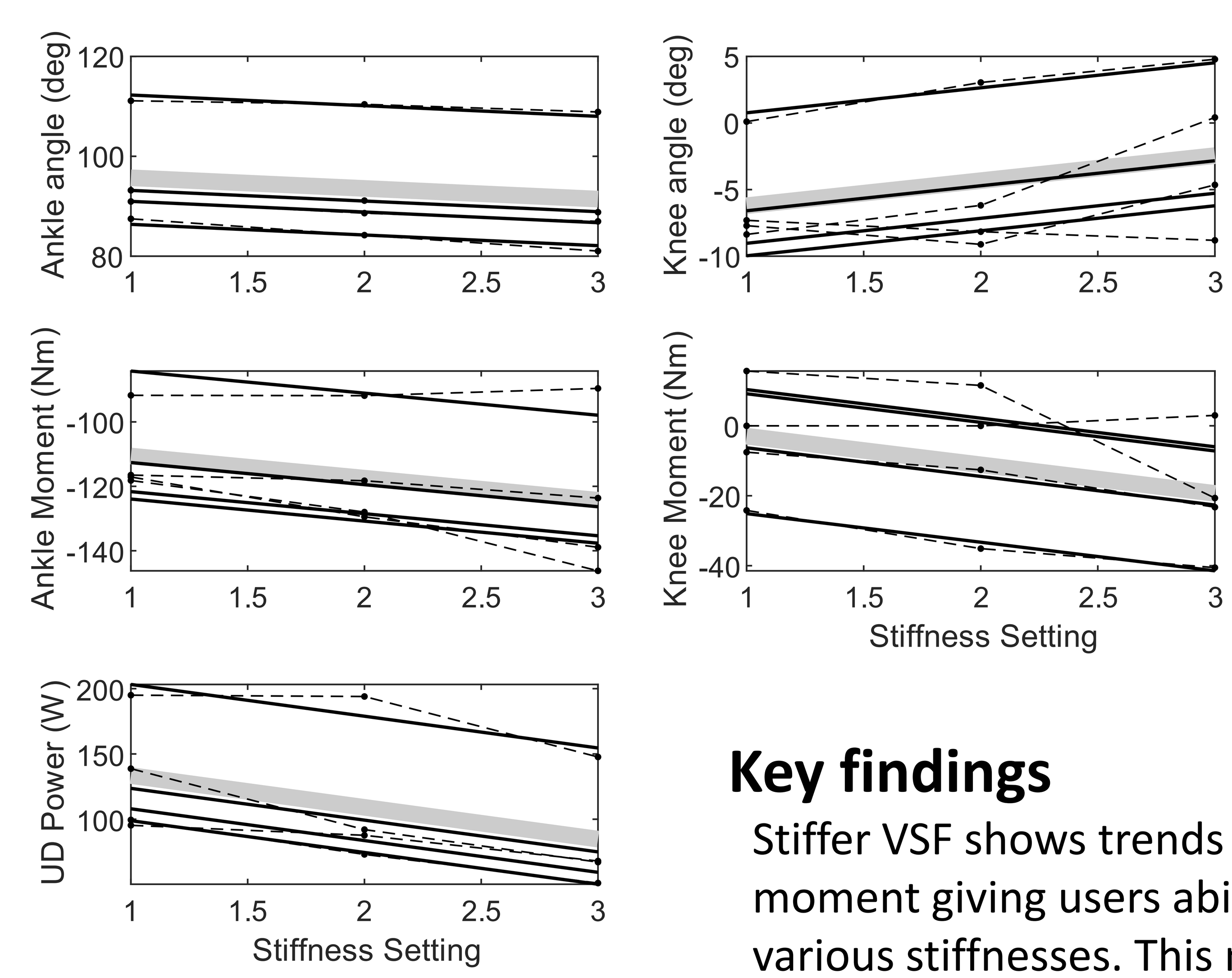
Method

- N=4 with transtibial amputation
- Three different stiffness for 3 walking trials each at 1.1 m/s
- Calculated outcomes of angle, moment, and power for ankle and knee





Summative results



Discussion

- General linear trends with increasing stiffness:
  - Decreased peak plantarflexion ankle angle,
  - More negative (plantarflexion) peak ankle moment
  - Decreased UD power
  - Increased knee extension angle
  - Decreased knee flexor moment
- Data analysis for 2-4 other subjects and appropriate statistics need to be completed

Key findings

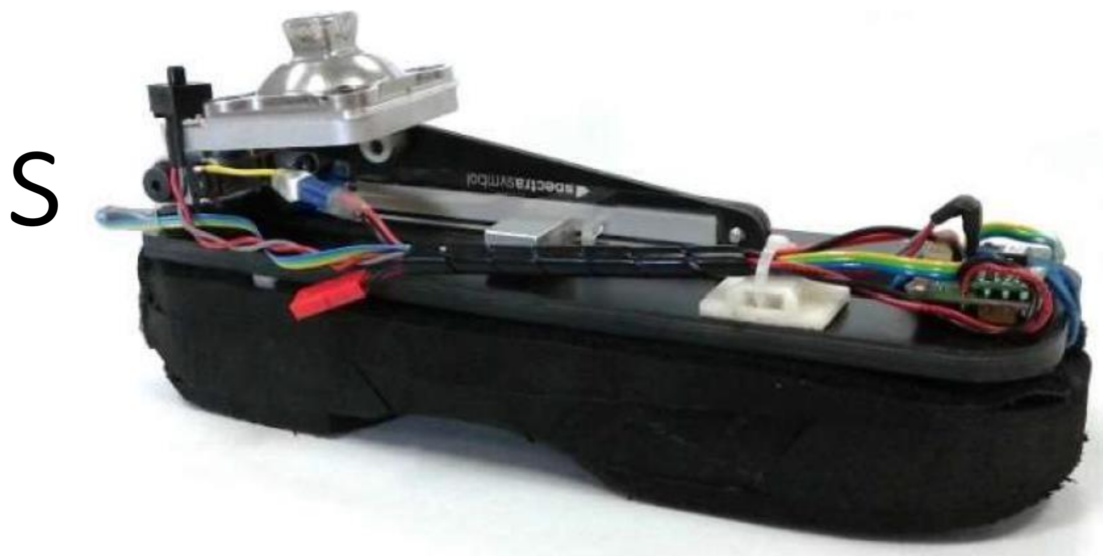
Stiffer VSF shows trends of increased knee extension, knee moment, and ankle moment giving users ability to modulate various mechanical outcomes based on various stiffnesses. This modulation will hopefully aid in their gait across level and sloped surfaces, and stairs.

UW BADGER Lab
Biomechatronics, Assistive Devices, Gait Engineering, & Rehabilitation

ACKNOWLEDGMENTS: This work was supported by NIH HD074424 and institutional funds from the University of Wisconsin – Madison.

REFERNCES:
[1] Glanzer et. al, IEEE TNSRE 26.12, 2351- 2359, 2018.
[2] Adamczyk et al, IEEE TNSRE, 23, 776-785, 2015.
[3] Torburn et al. Clinical Orthopaedics, 303 185-192, 1994
[4] Hansen et al. Gait & posture 32.2 181-184, 2010

Sensitivity of Mechanical Outcomes to Various Stiffnesses of Variable Stiffness Foot



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Introduction

Variable Stiffness Foot (VSF)

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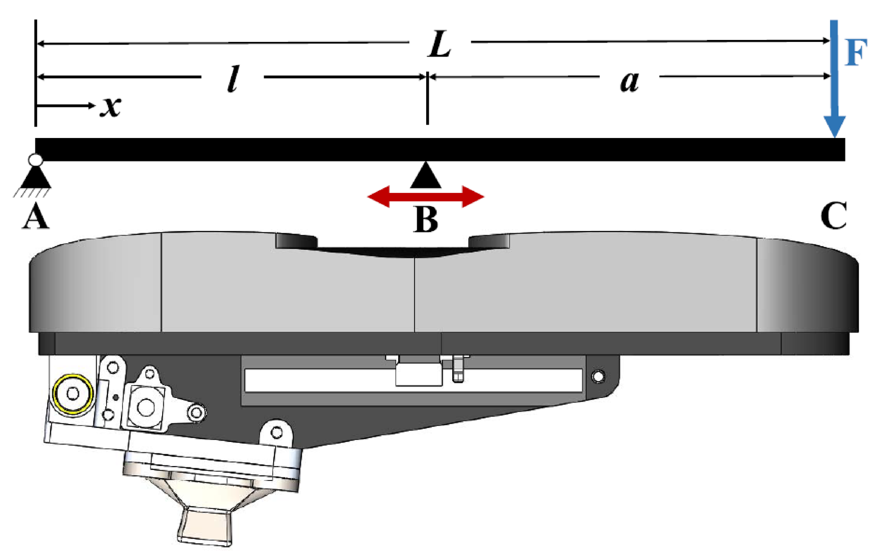
• Adaptable stiffness

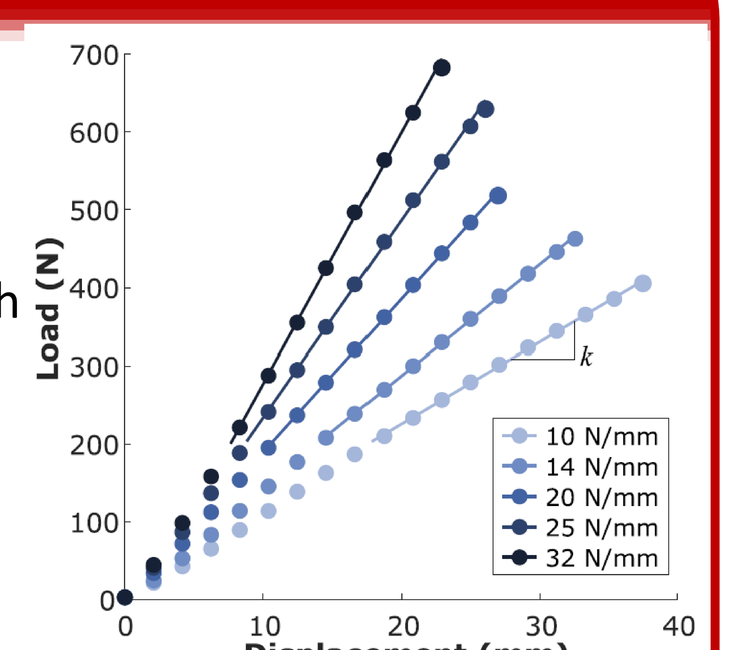


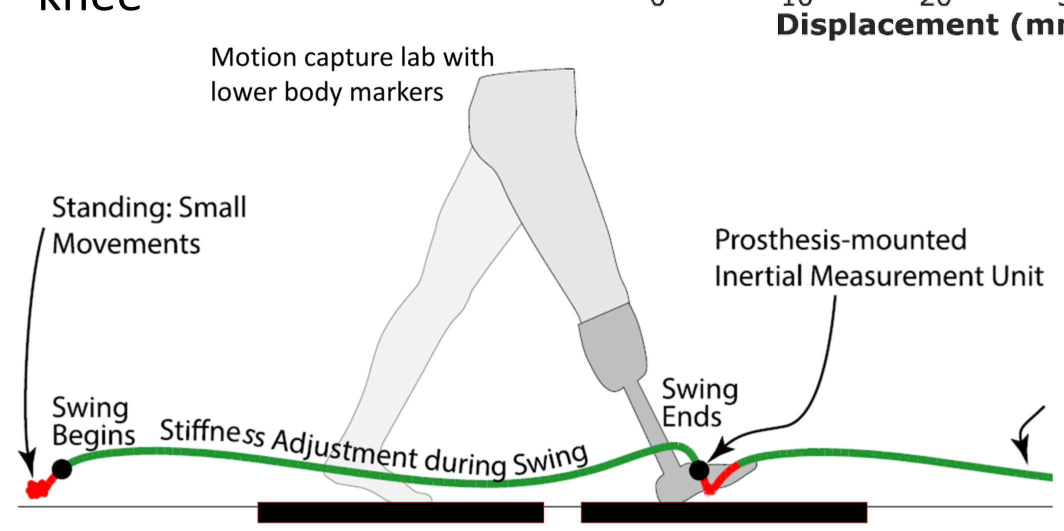
Hypotheses for mechanical effects with more compliant foot:

- Increased peak ankle dorsiflexion, decreased plantarflexor moment, and increased push off energy
- Decreased stance phase knee angle, flexor moment, and energy

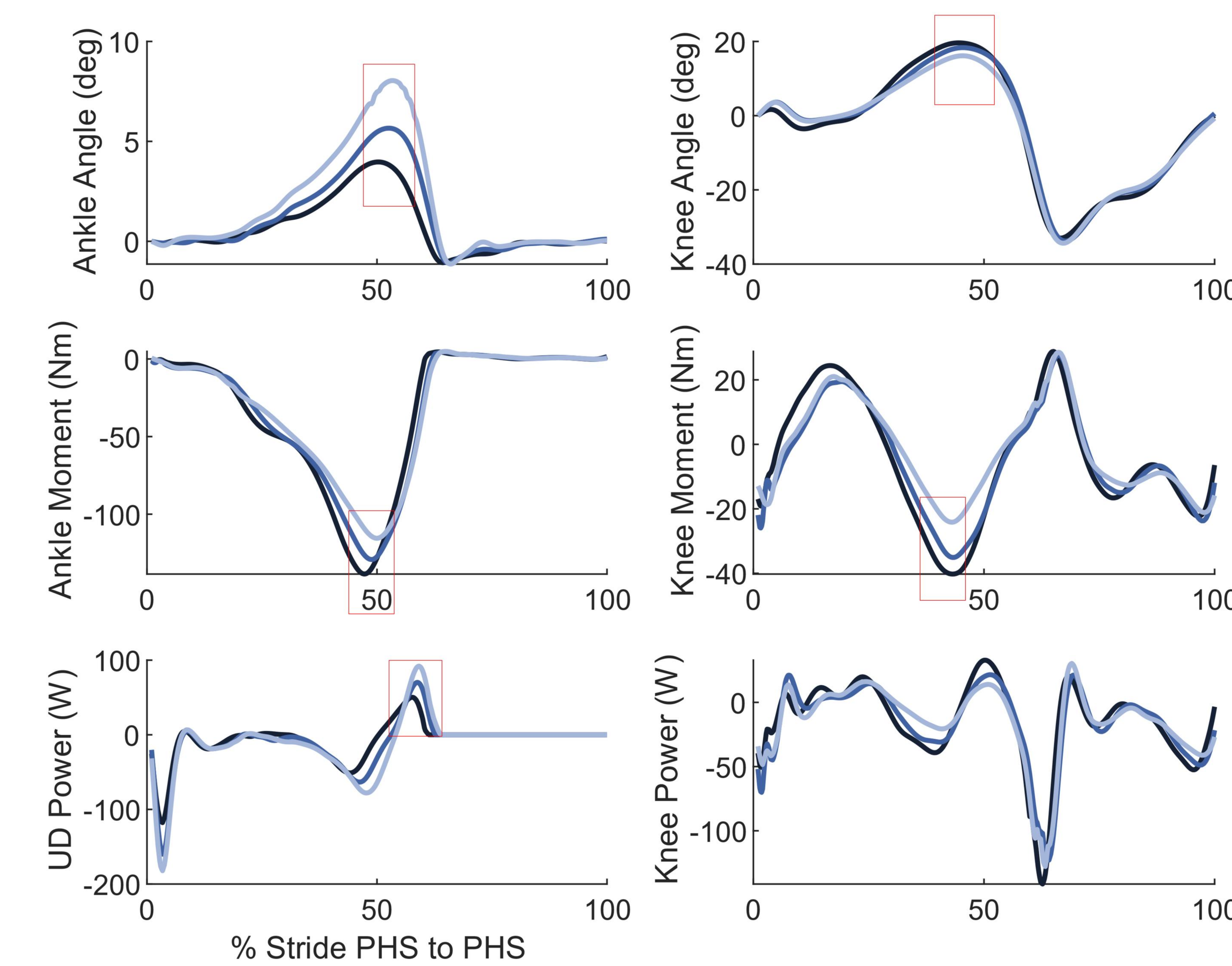
Method

- N=4 with transtibial amputation
- Three different stiffness for 3 walking trials each at 1.1 m/s
- Calculated outcomes of angle, moment, and power for ankle and knee





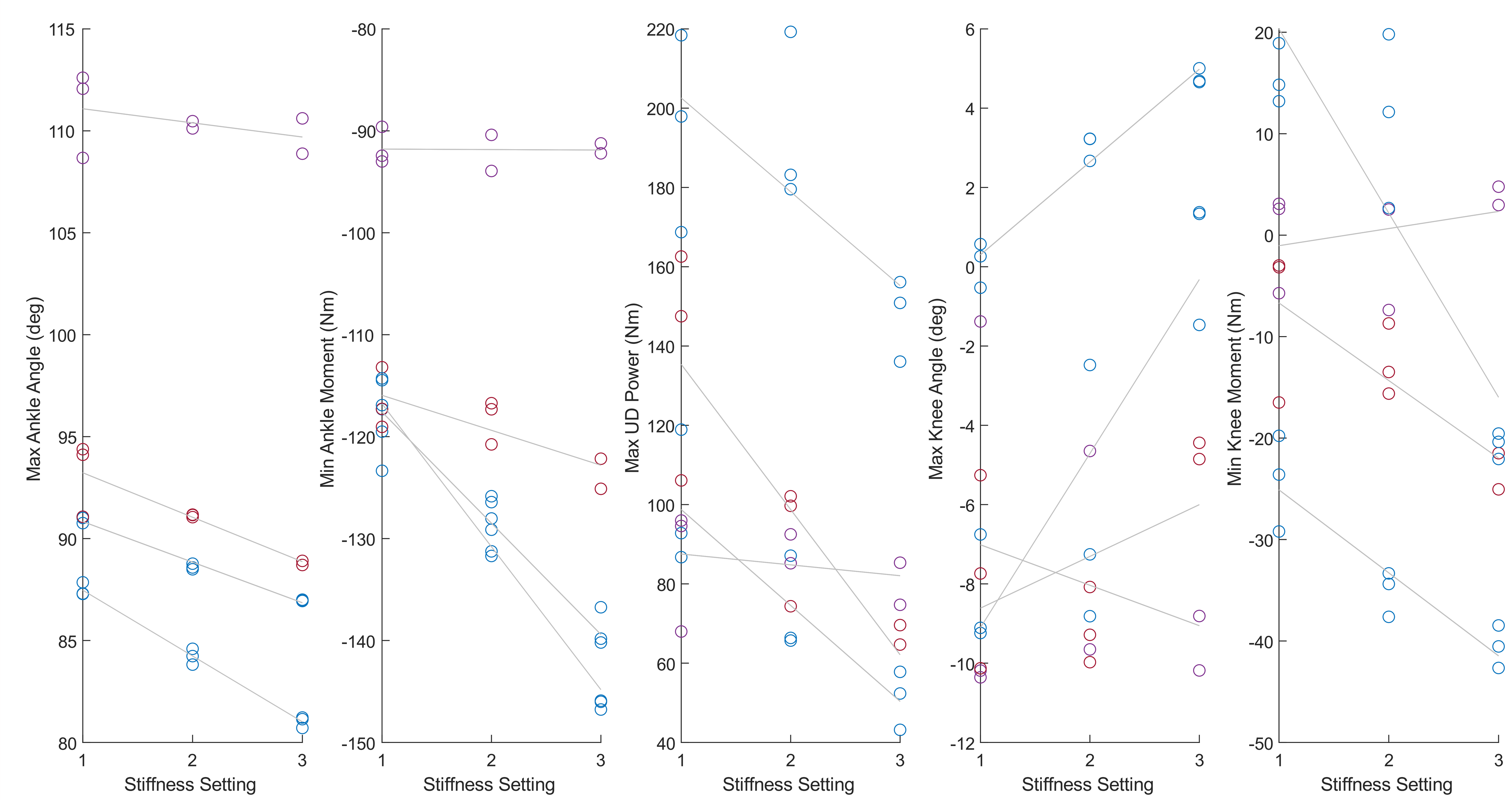
Results from single representative subject



Main results

- More compliant VSF has a larger excursion of dorsiflexion and less plantarflexor moment
- It also has more peak UD power during toe off which correlates with more push off energy
- Less extended knee angle is associated with decreased flexor knee moment and ankle plantarflexor moment
- No consistent feature of knee power across subjects

Summative results



Discussion

- General linear trends for decreased peak ankle angle, more negative (plantarflexion) peak, decreased UD power, and increase in knee angle with increasing stiffness
- Data analysis for 2-4 other subjects to be completed

Key findings

- More compliant VSF shows trends of decreased knee extension, knee moment, and ankle moment

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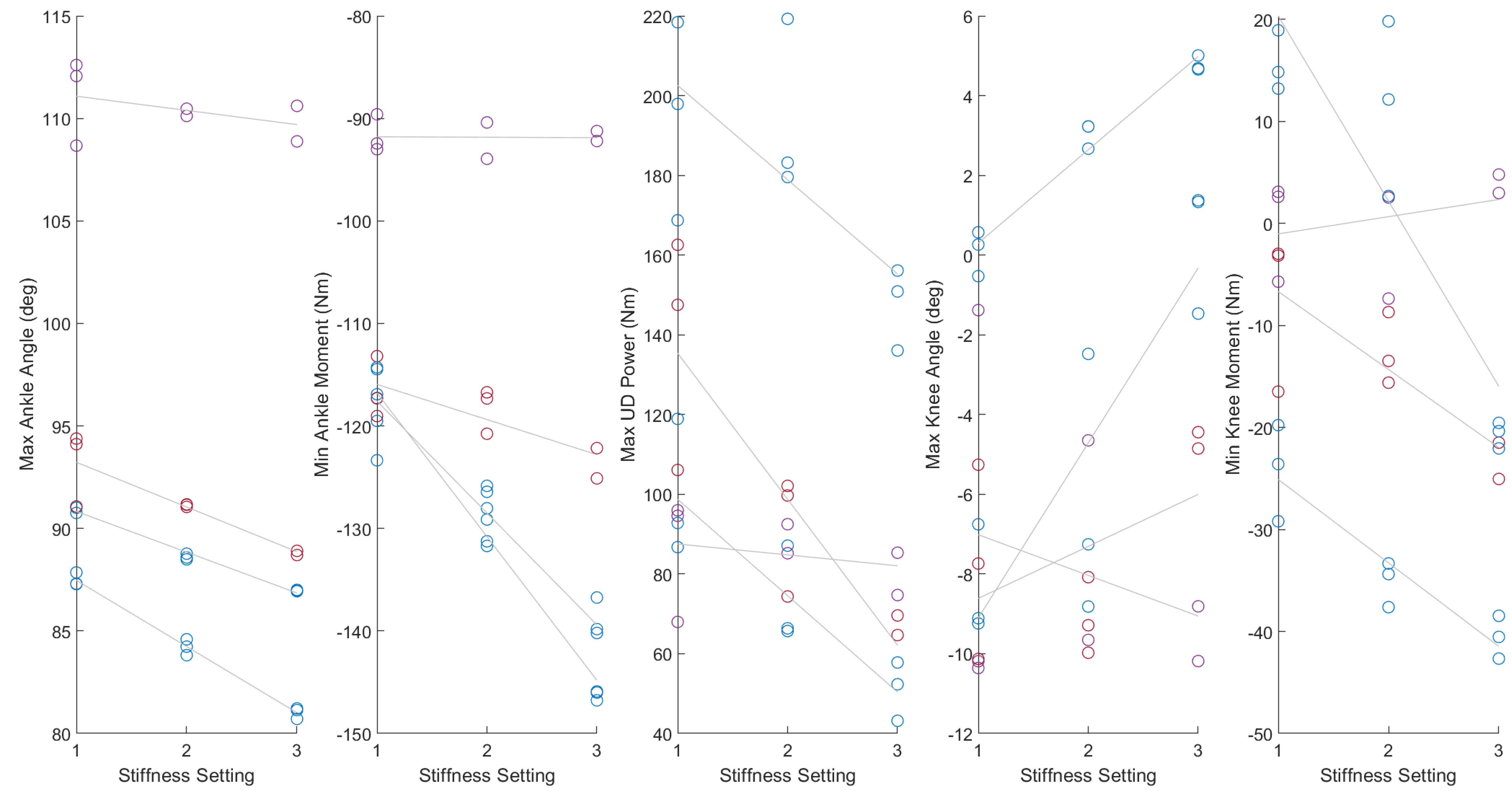
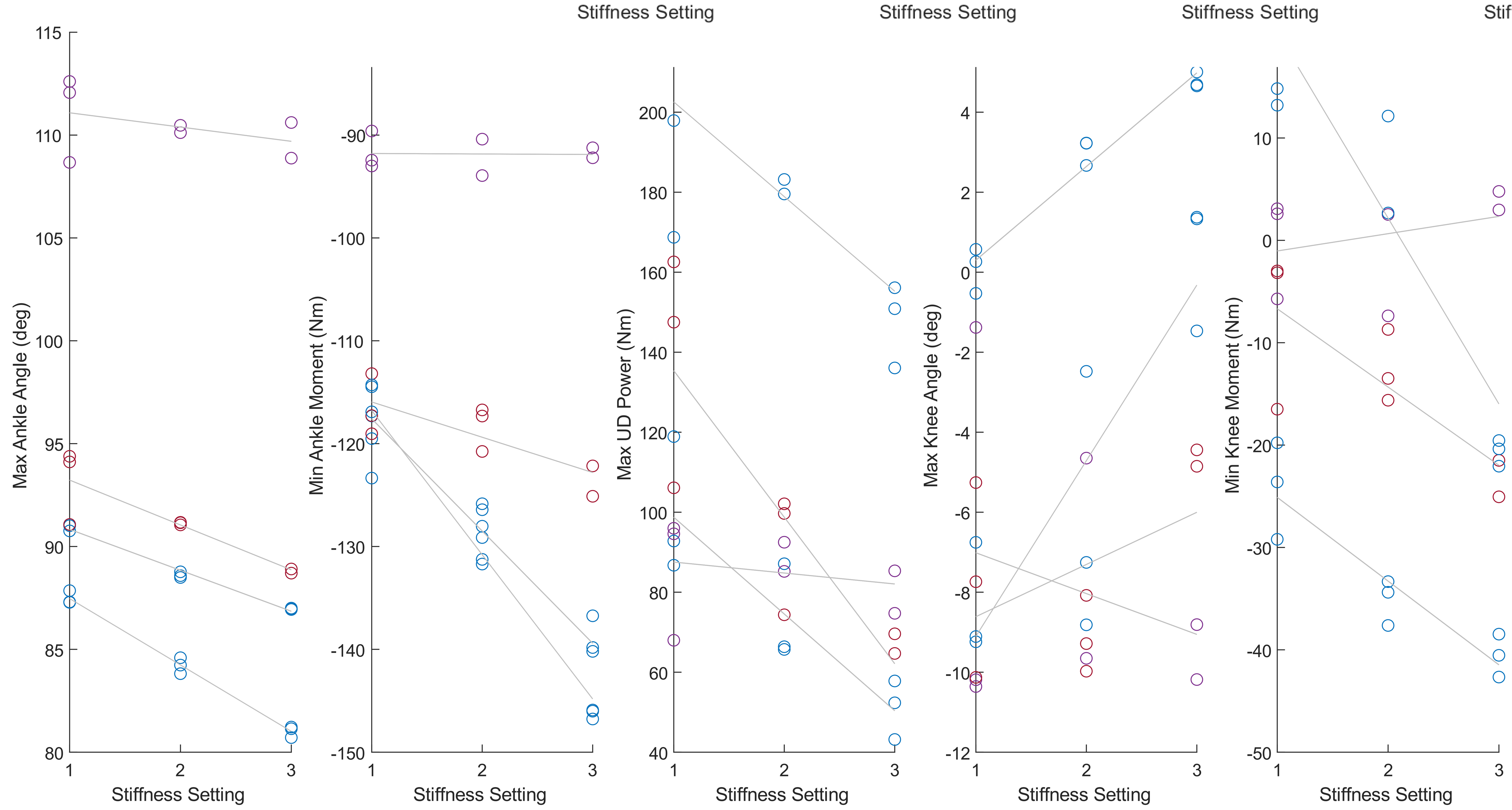
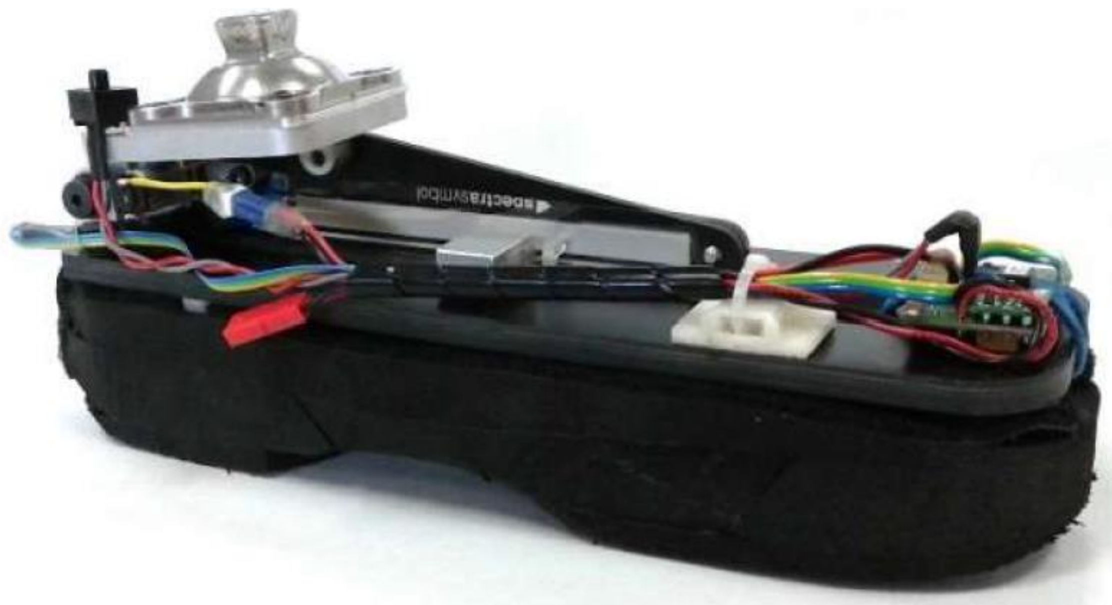

Max Ankle Angle (deg)
Min Ankle Moment (Nm)
Max UD Power (Nm)
Max Knee Angle (deg)
Min Knee Moment (Nm)
Stiffness Setting


Max Ankle Angle (deg)
Min Ankle Moment (Nm)
Max UD Power (Nm)
Max Knee Angle (deg)
Min Knee Moment (Nm)
Stiffness Setting

Sensitivity of Mechanical Outcomes to Various Stiffnesses of Variable Stiffness Foot (VSF)



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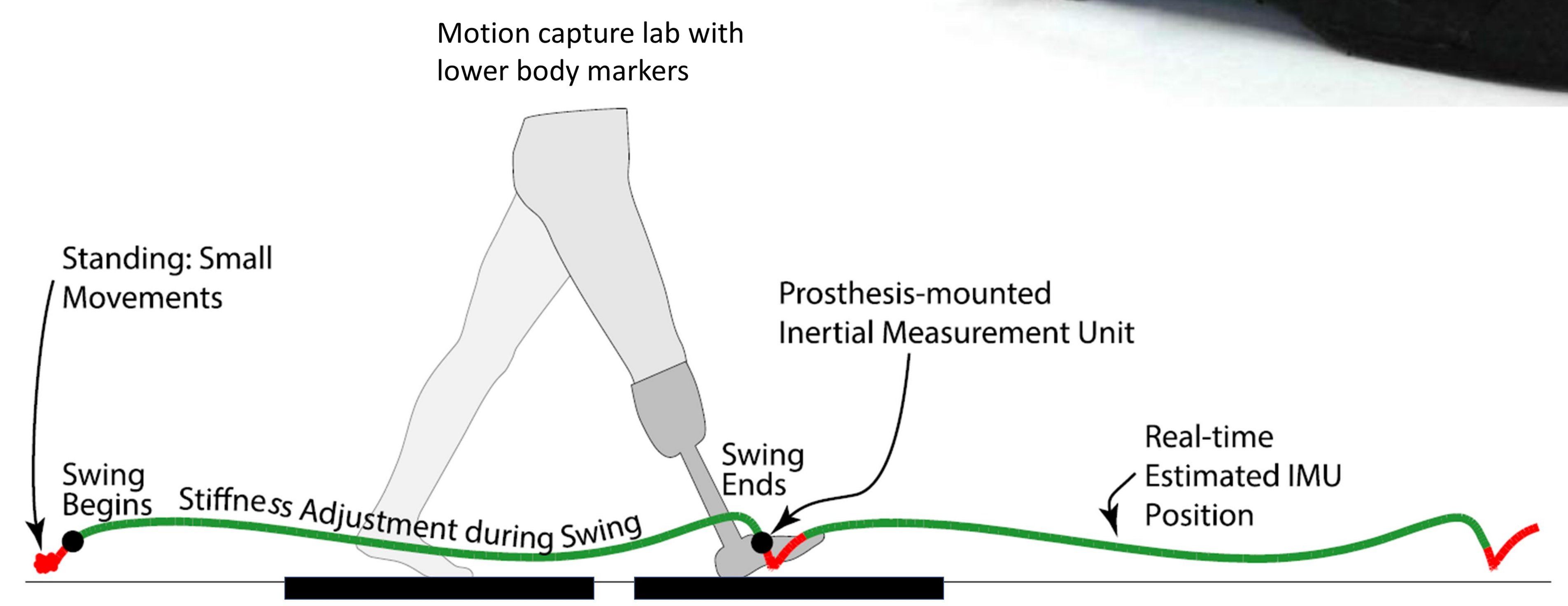
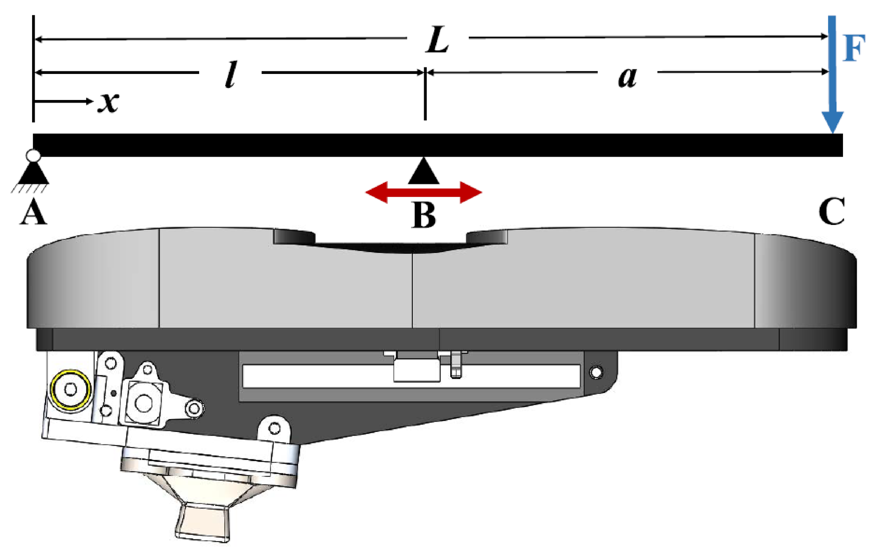


Introduction

The VSF (Figure 1) prototype has a rigid ankle and a compliant forefoot keel whose effective stiffness is modulated by a support fulcrum moved by a motor and belt system.

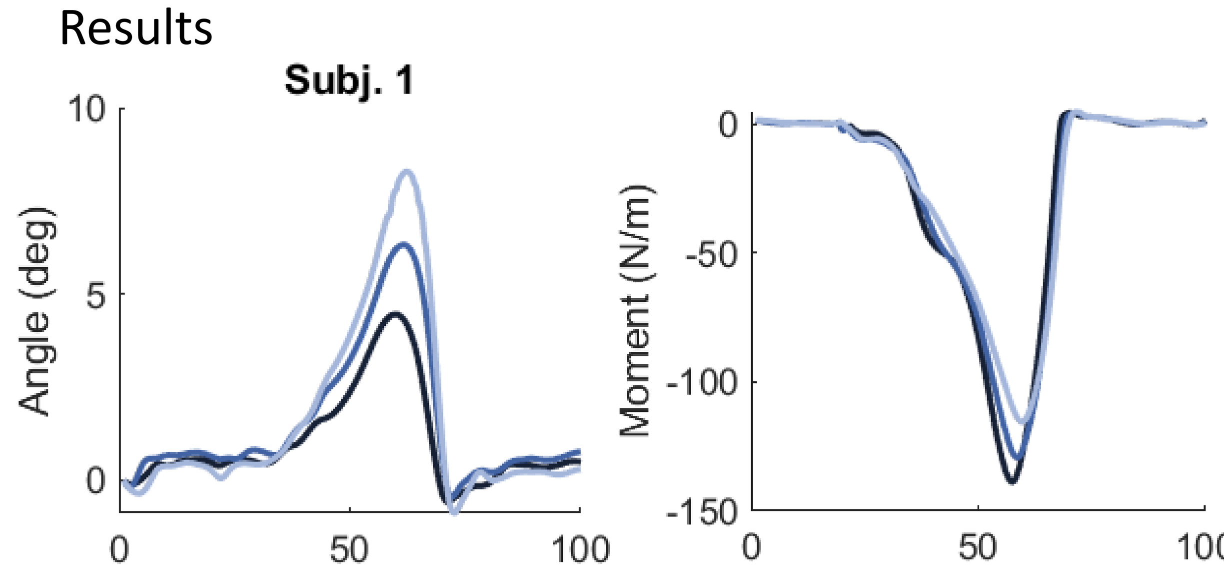


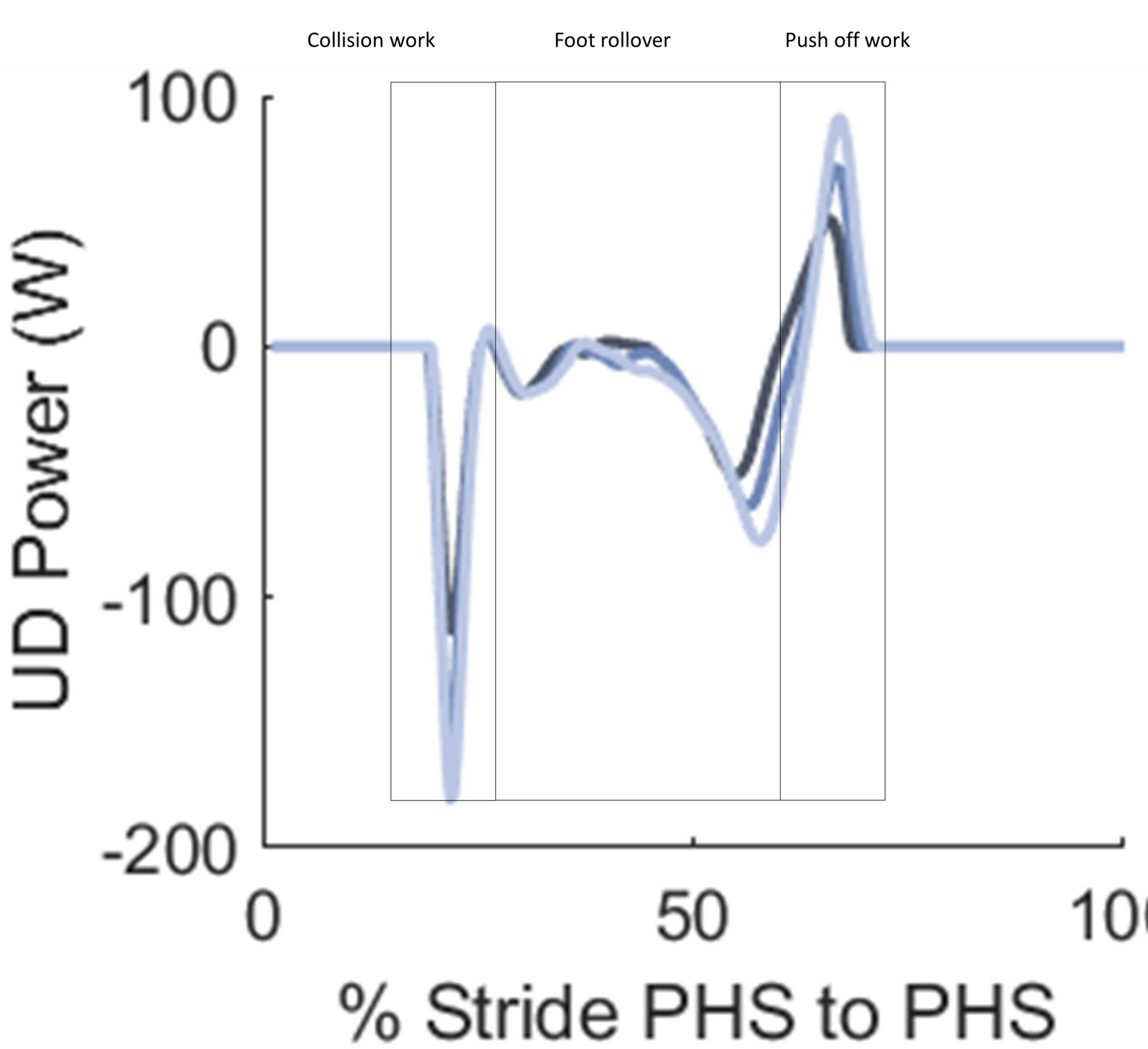
Methods

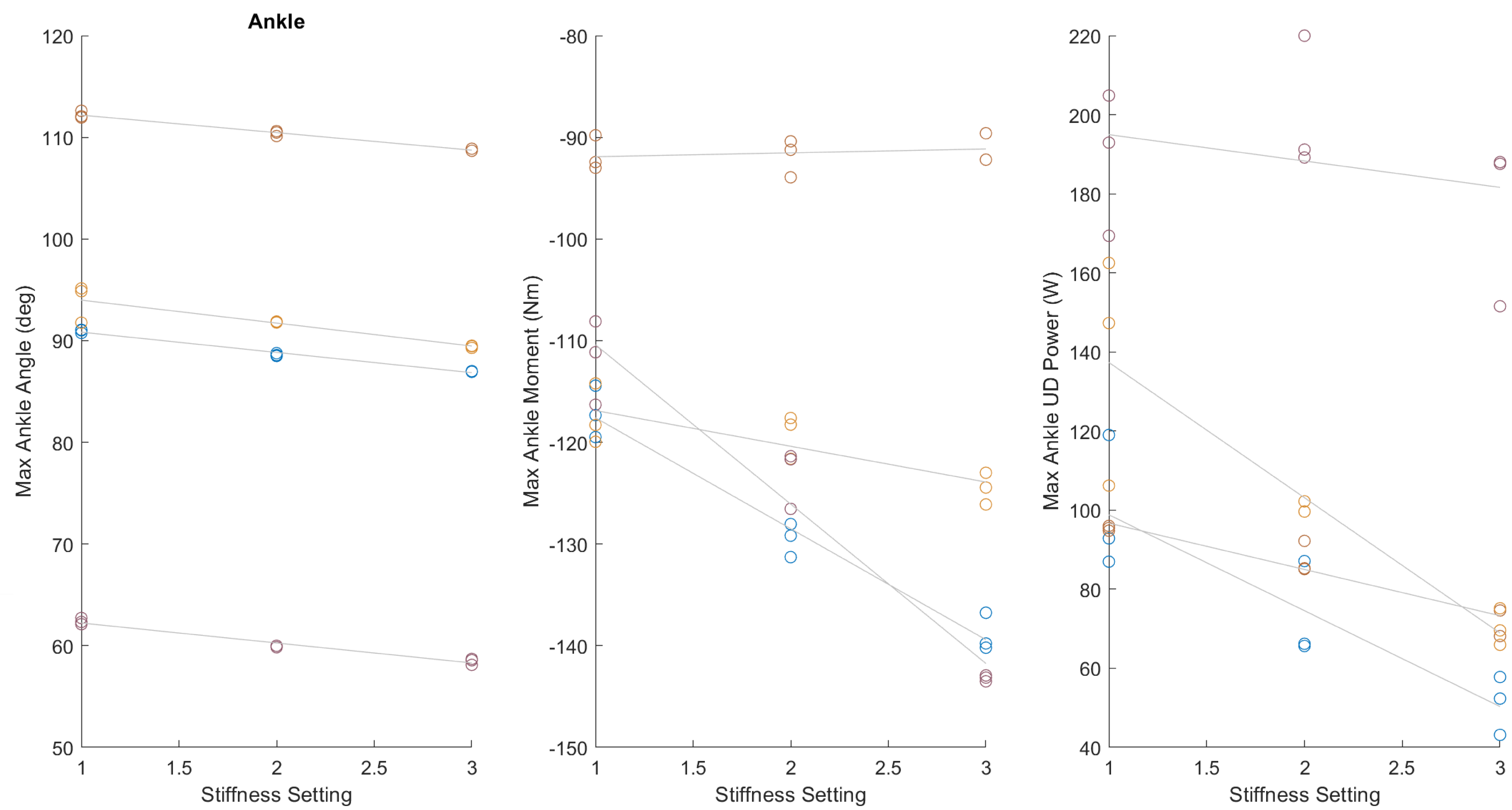
Five persons with trans-tibial amputation were included in this experiment

The participants walked with three different VSF stiffness settings for 3 trials at 1.1m/s.

Results







Results and Discussion

Conclusion

Acknowledgments
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References
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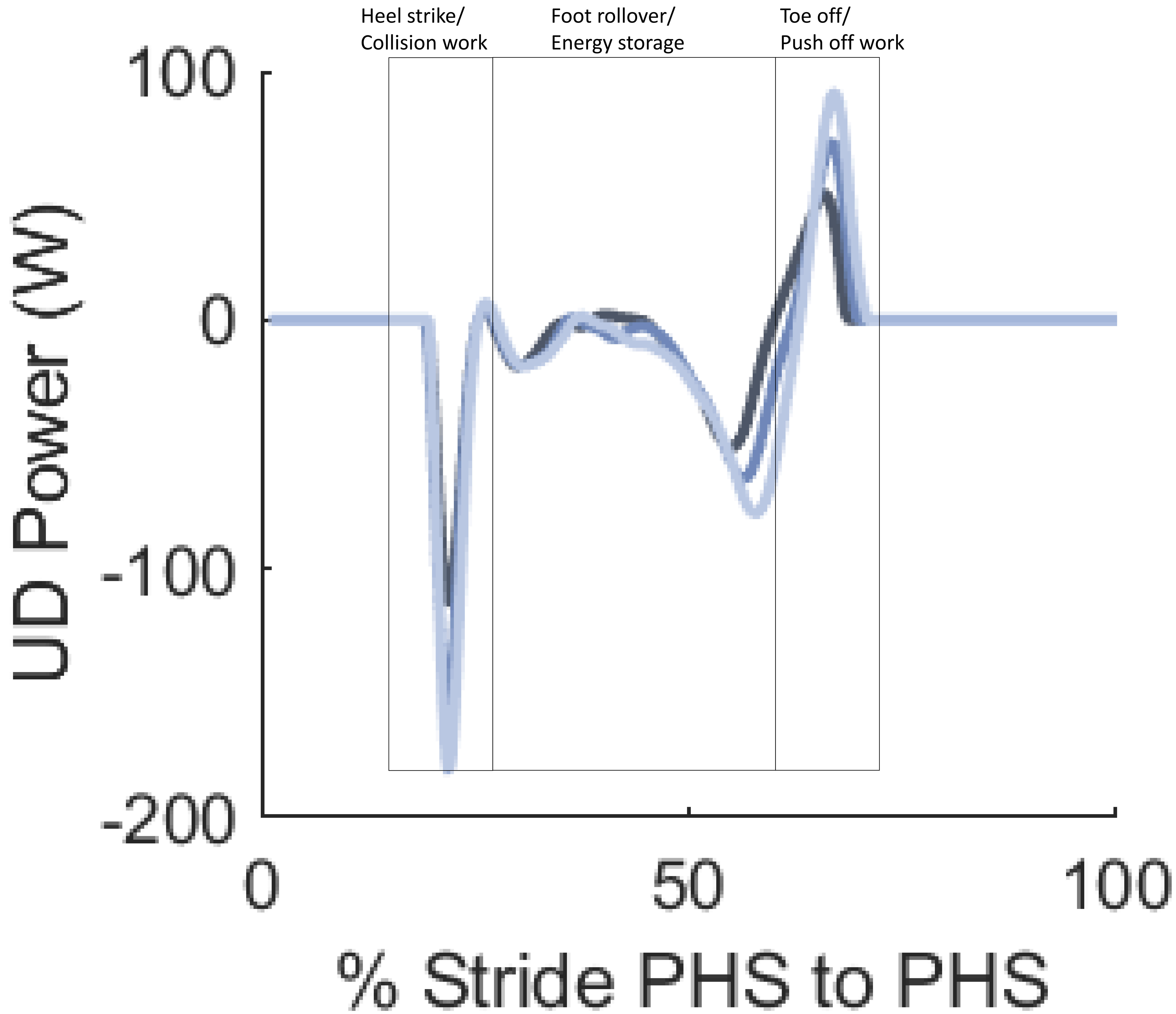
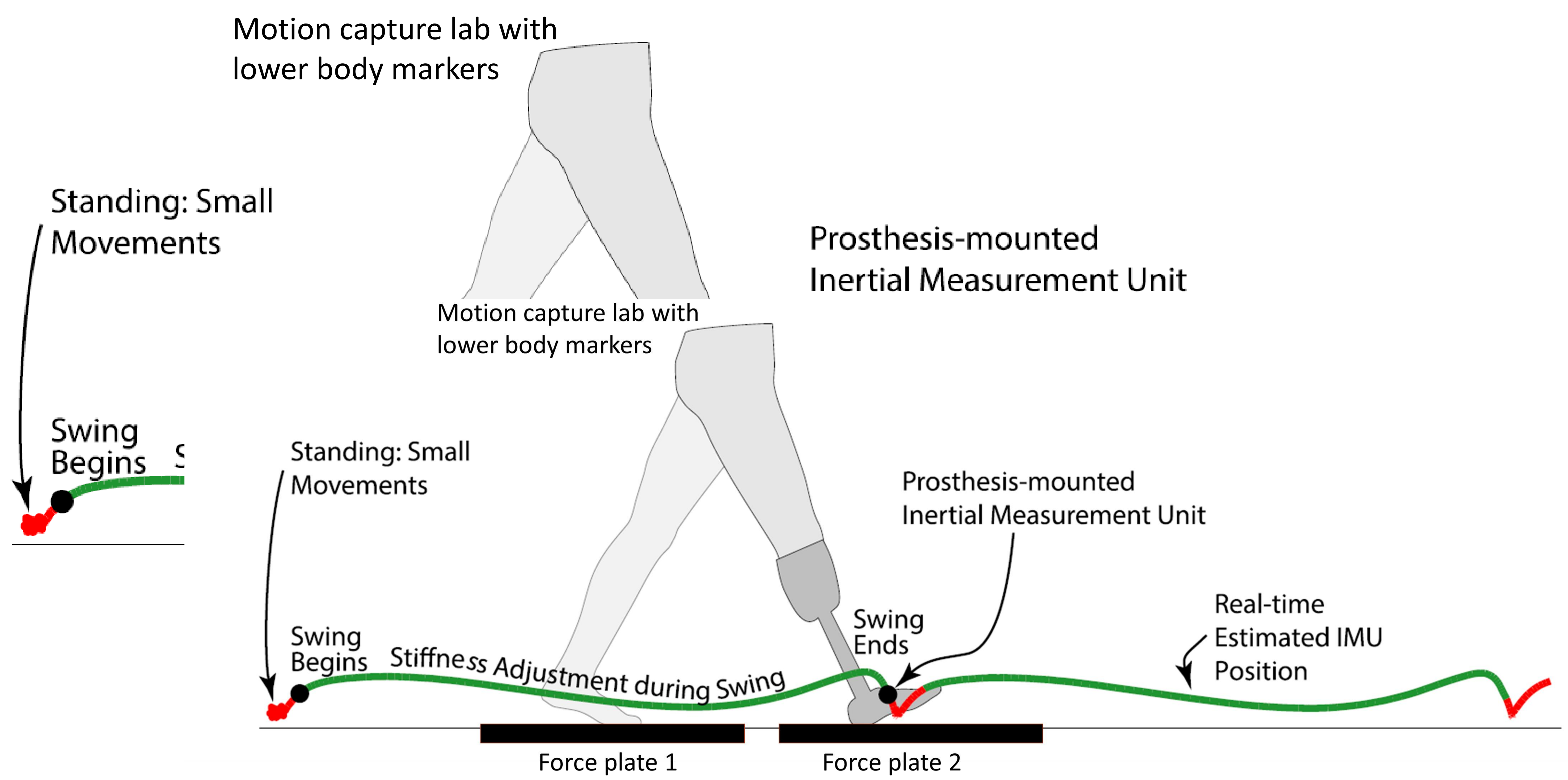
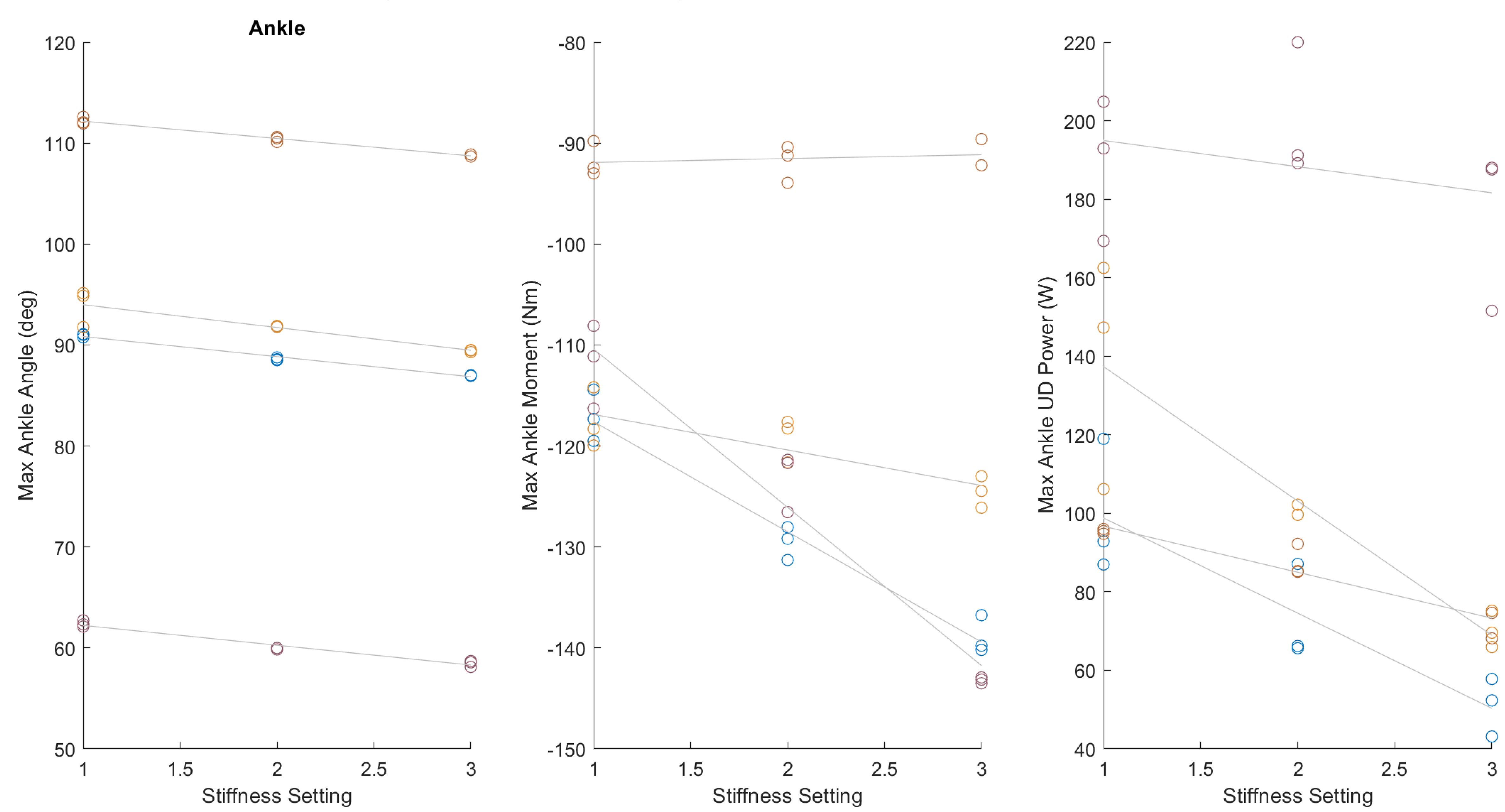
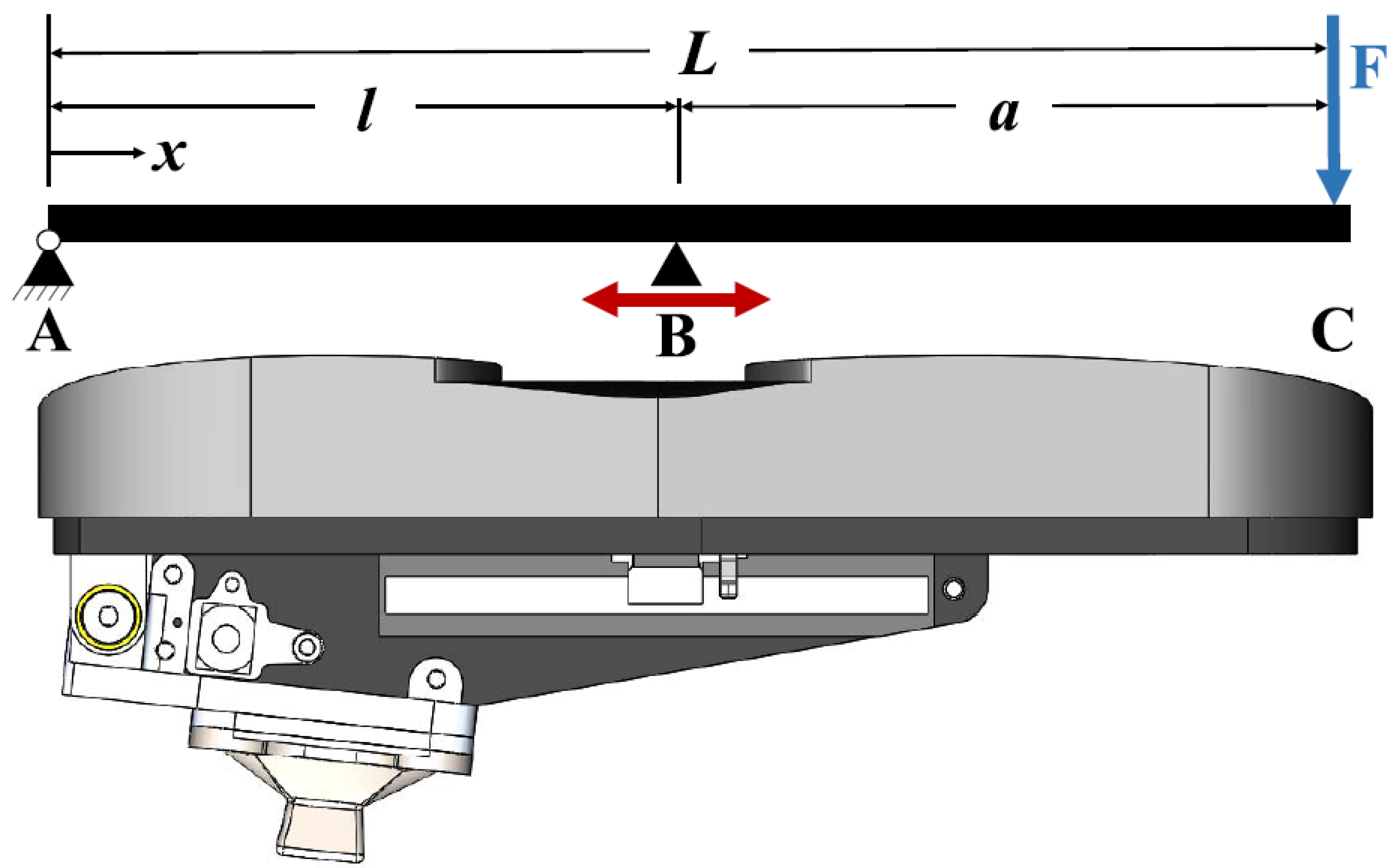
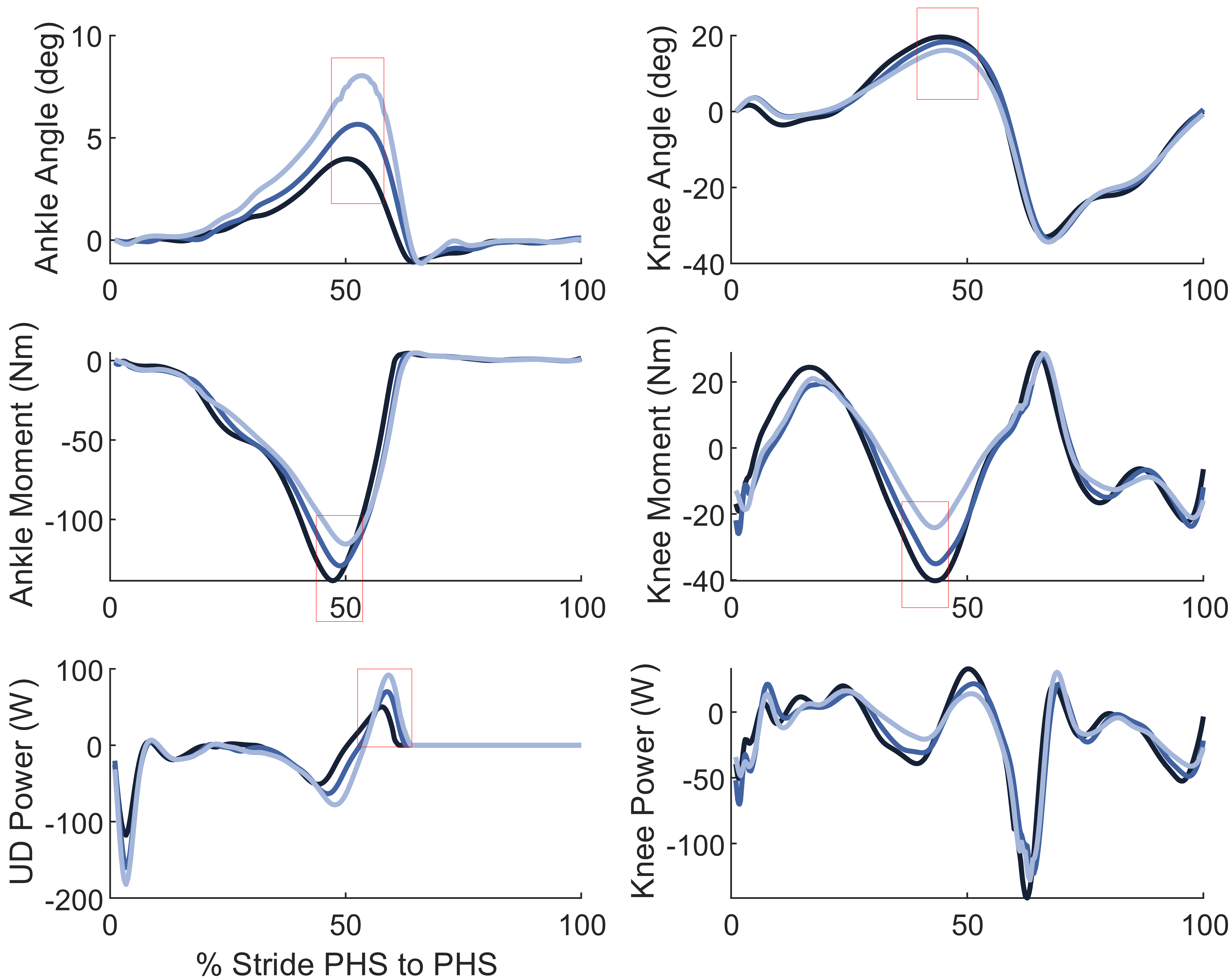

Heel strike/
Collision work
Foot rollover/
Energy storage
Toe off/
Push off work
100
0
-100
-200
UD Power (W)
0
50
100
% Stride PHS to PHS


Motion capture lab with lower body markers
Standing: Small Movements
Prosthesis-mounted Inertial Measurement Unit
Swing Begins
Motion capture lab with lower body markers
Standing: Small Movements
Prosthesis-mounted Inertial Measurement Unit
Swing Begins
Stiffness Adjustment during Swing
Swing Ends
Real-time Estimated IMU Position
Force plate 1
Force plate 2


Ankle
Max Ankle Angle (deg)
Stiffness Setting
Max Ankle Moment (Nm)
Stiffness Setting
Max Ankle UD Power (W)
Stiffness Setting

Motion capture lab with lower body markers




Ankle Angle (deg)
Knee Angle (deg)
Ankle Moment (Nm)
Knee Moment (Nm)
UD Power (W)
Knee Power (W)
% Stride PHS to PHS