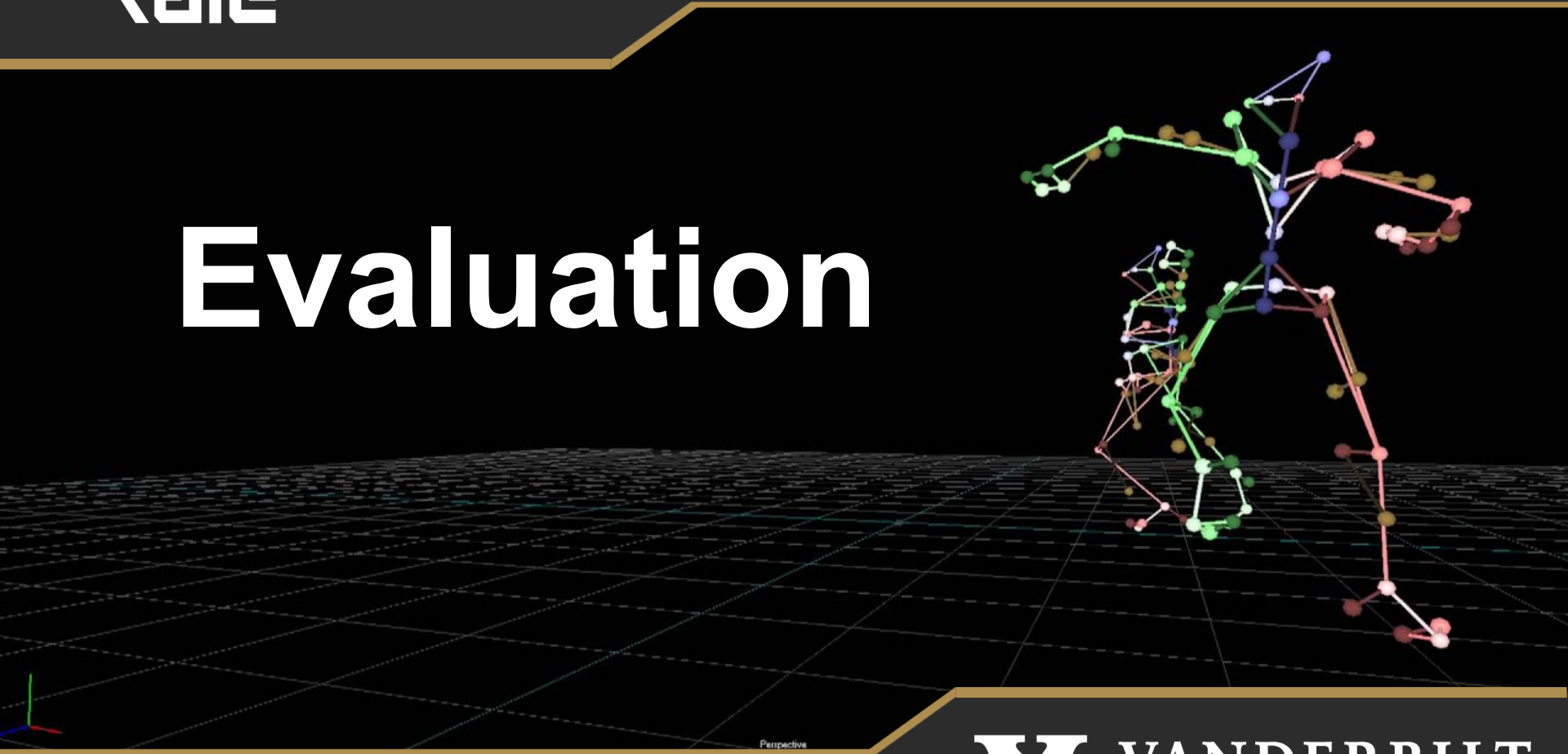
Evaluation



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REHABILITATION ENGINEERING
+ ASSISTIVE TECHNOLOGY

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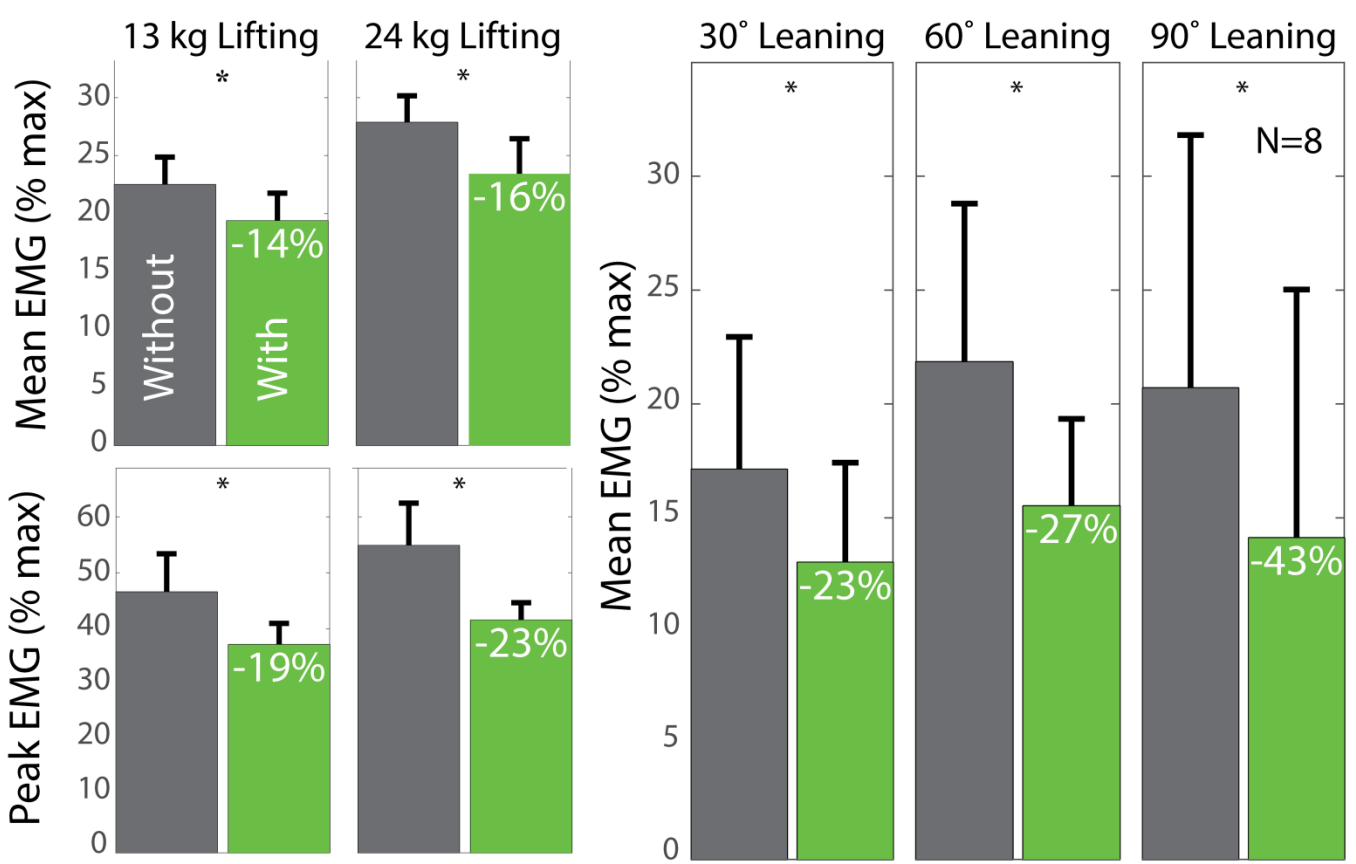
Mechanized clothing reduced lumbar loading



Lamers et al. 2018. IEEE TNSRE

Question 1: Can mechanized clothing reduce muscle fatigue?

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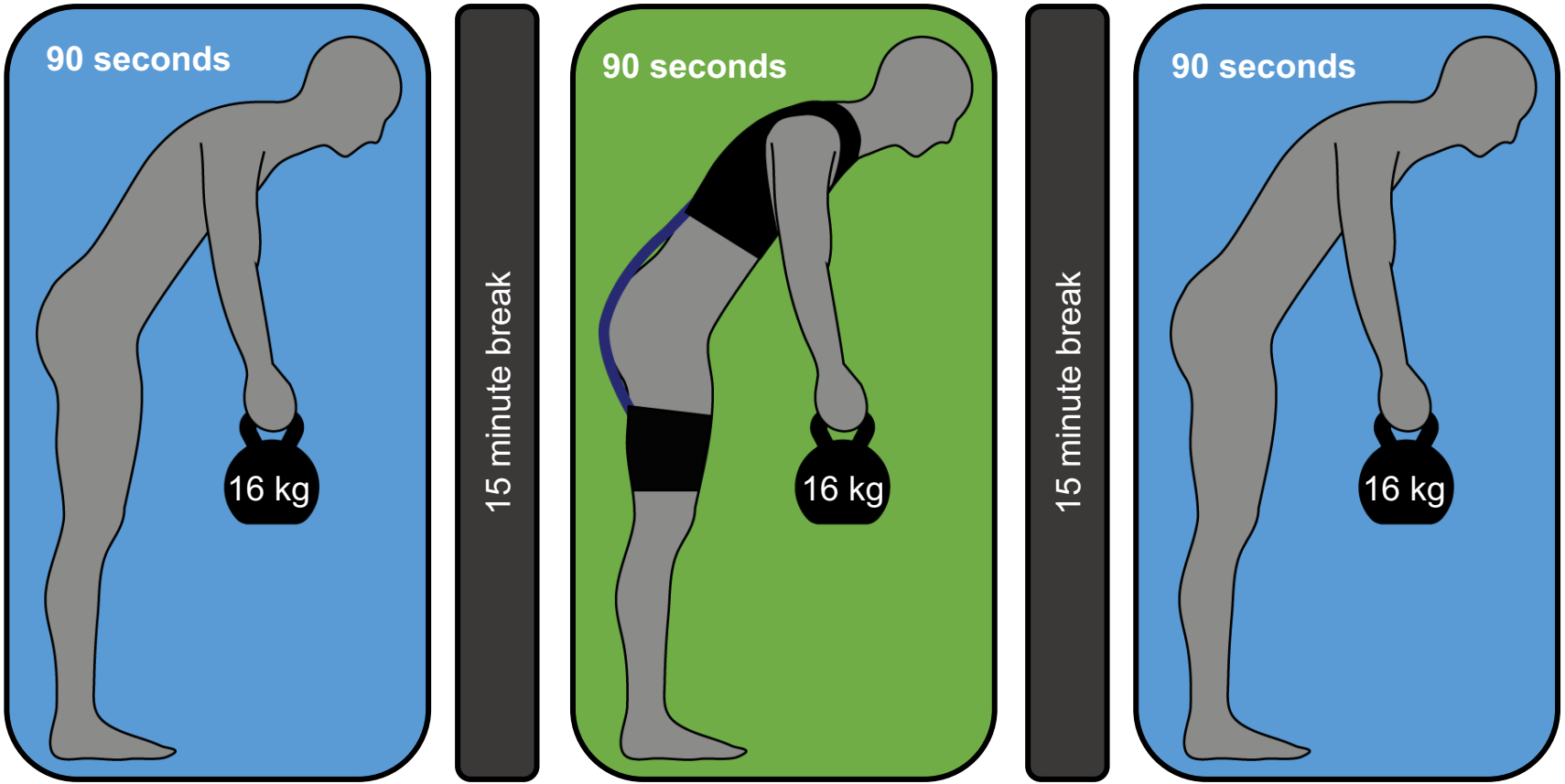
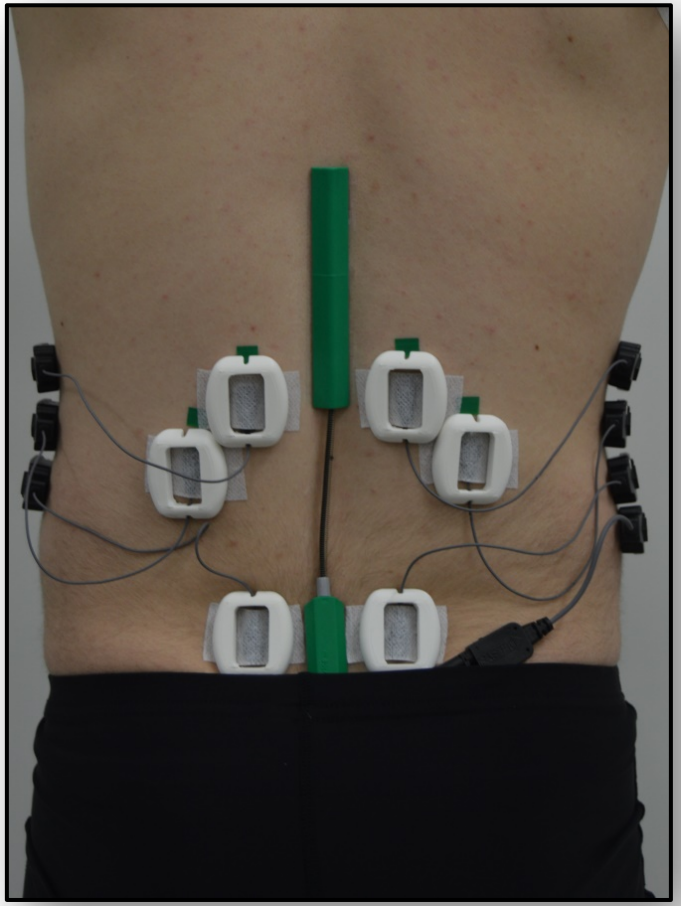
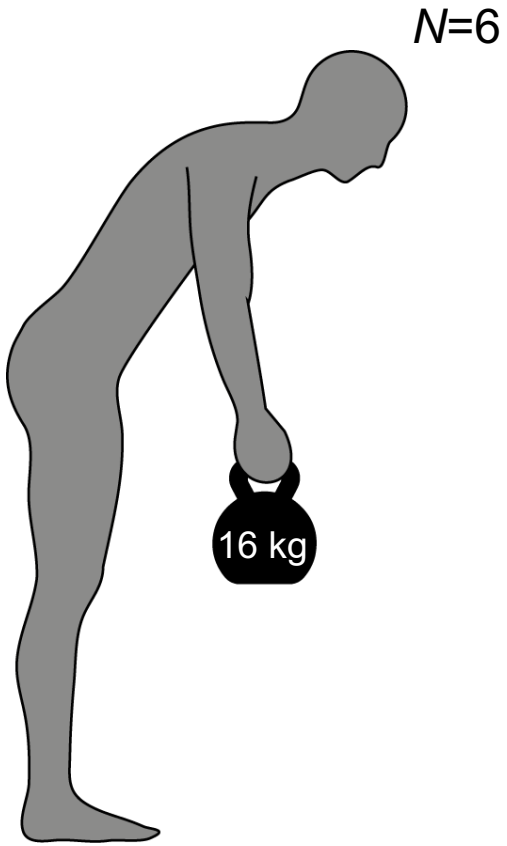
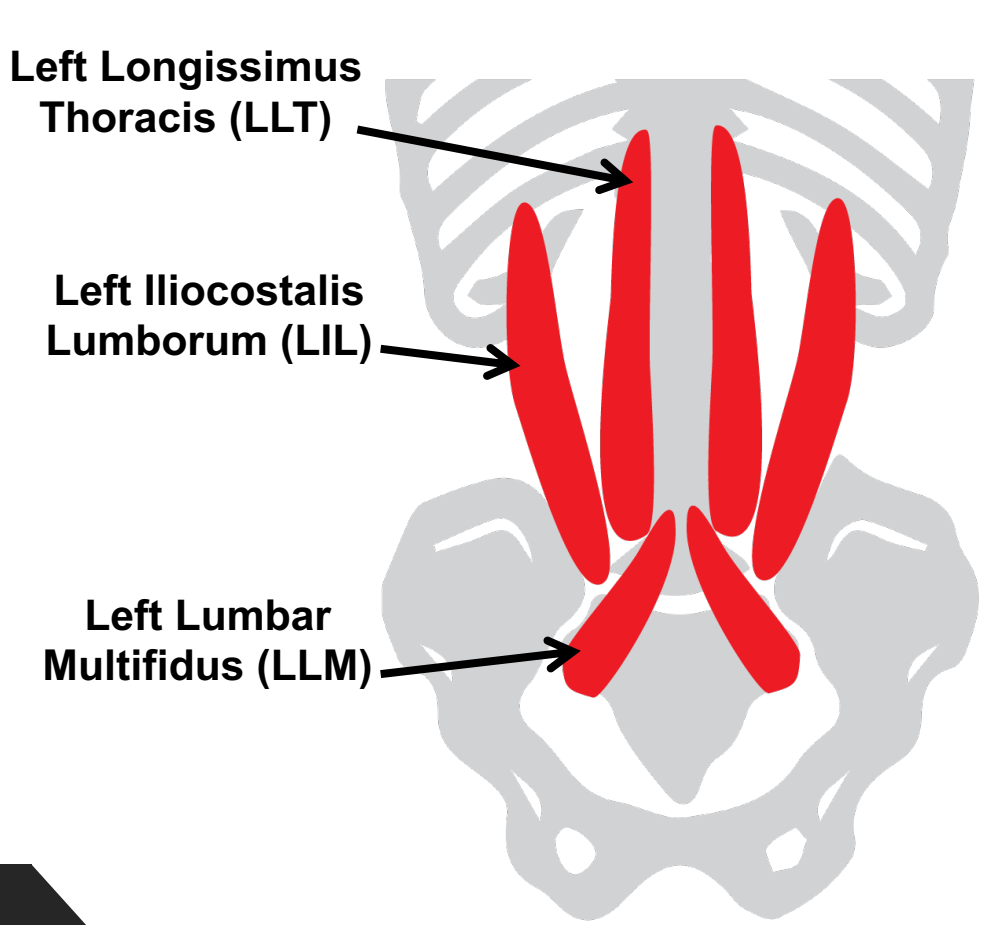


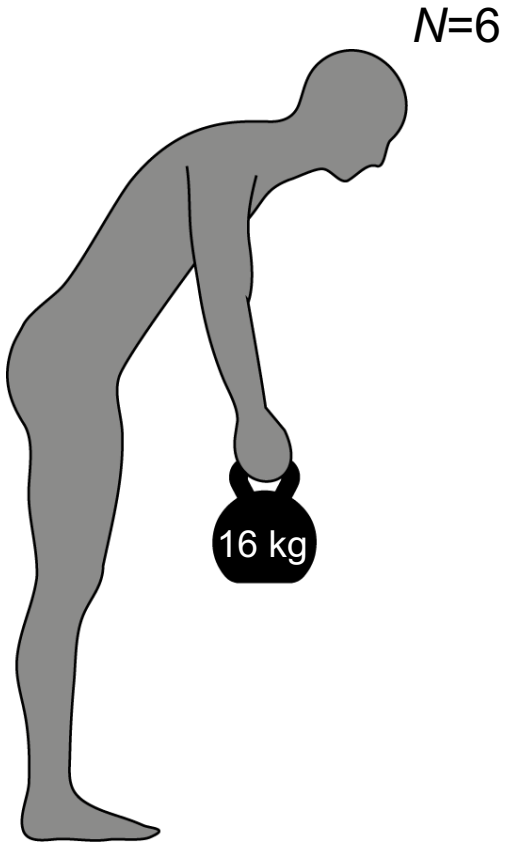
Question 2: Are changes in fatigue consistent across muscles & users?





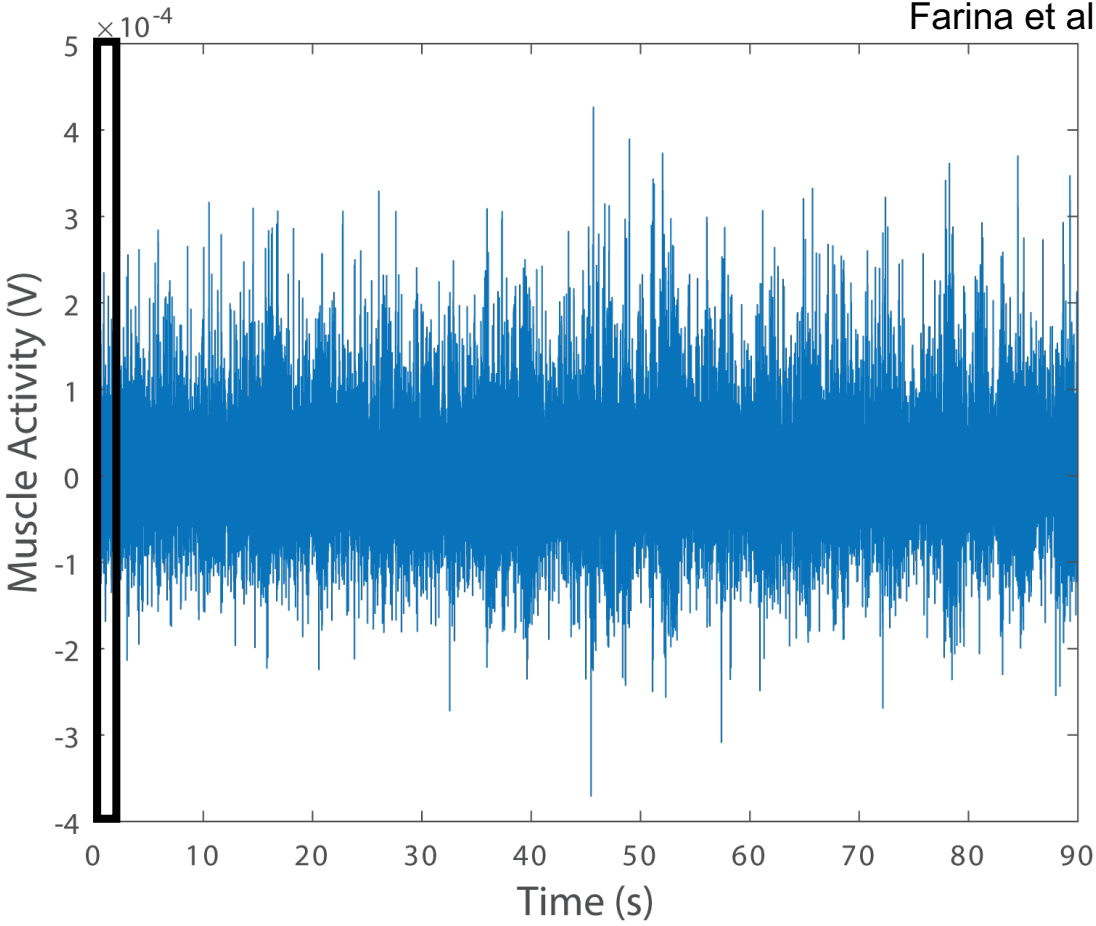
Question 2: Are changes in fatigue consistent across muscles & users?





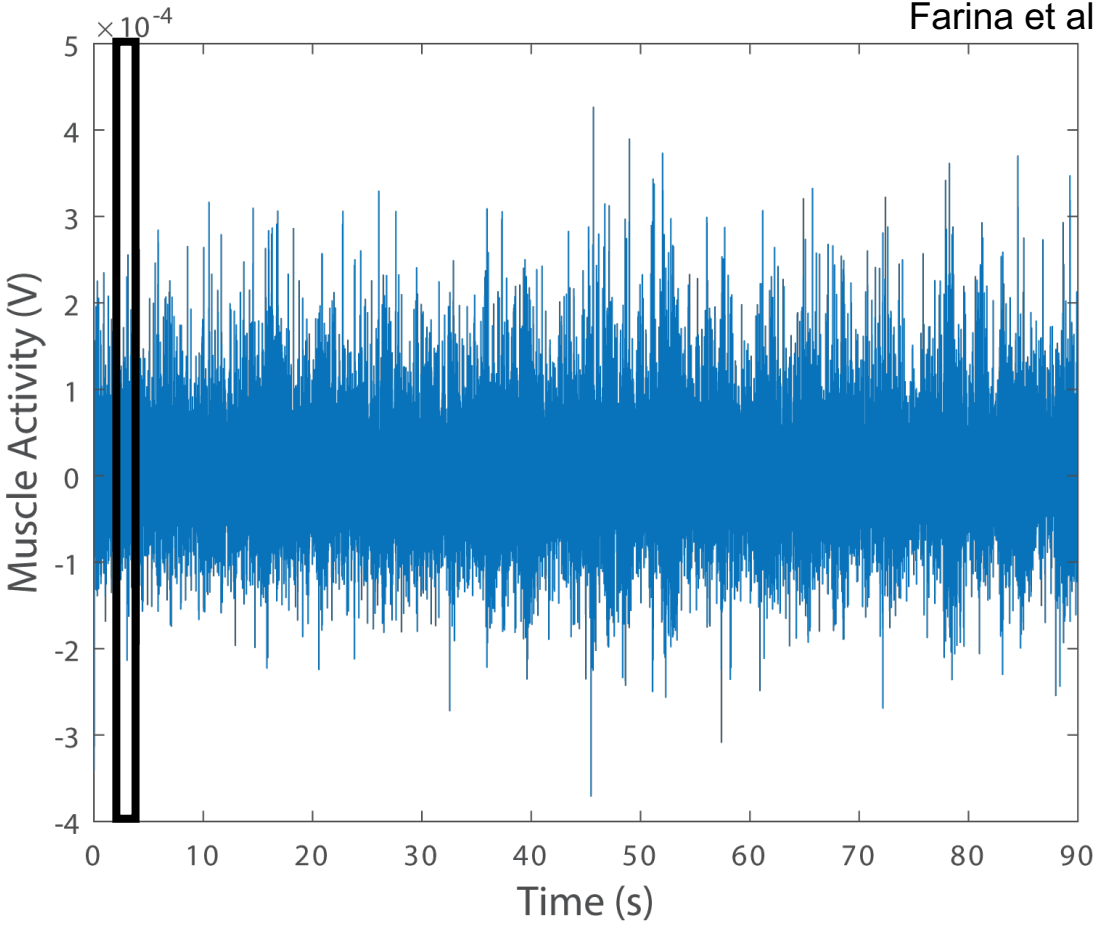
Median frequency provides objective indicator of muscle fatigue

Farina et al. 2003, Merletti et al. 1990



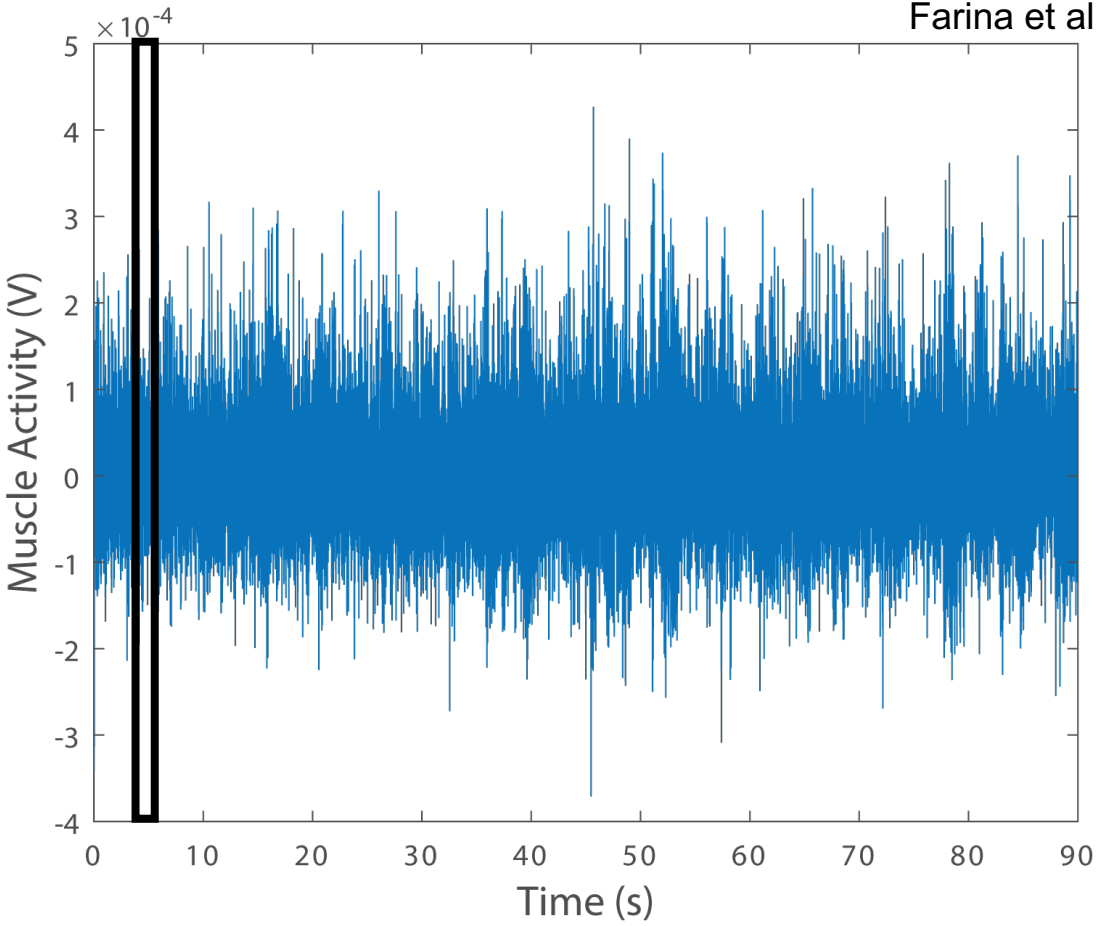
Median frequency provides objective indicator of muscle fatigue

Farina et al. 2003, Merletti et al. 1990

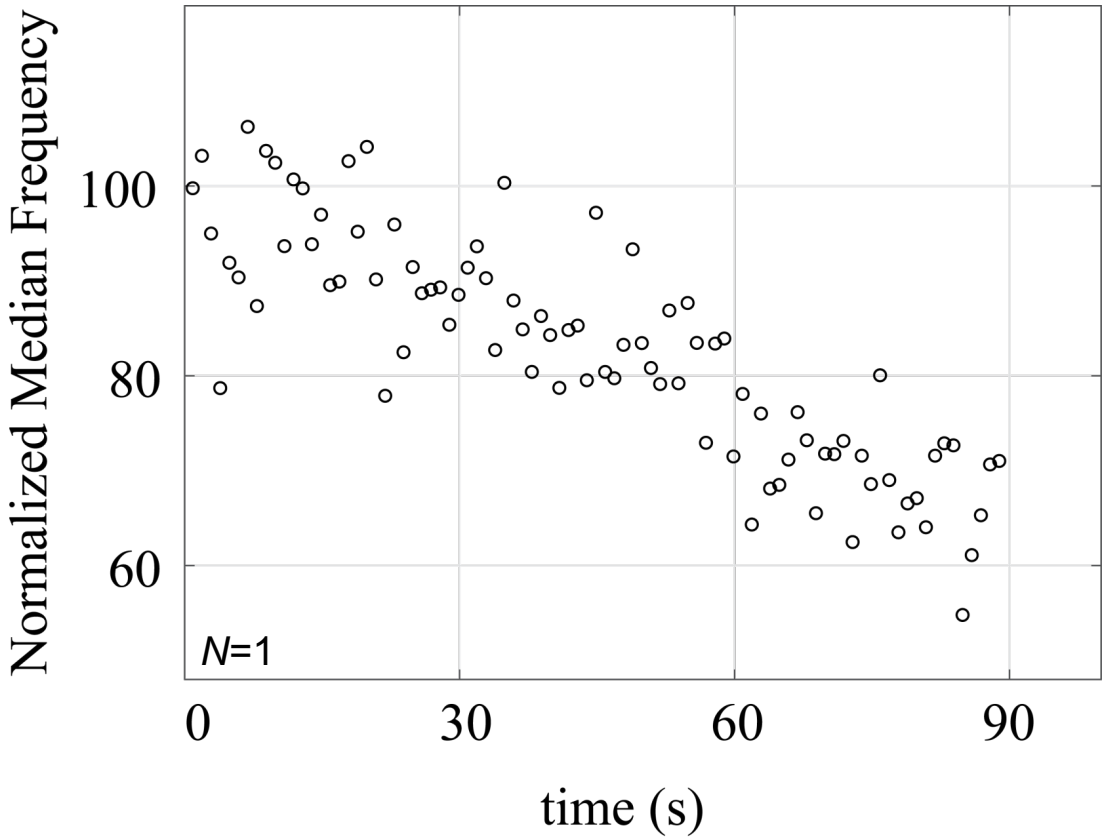


Median frequency provides objective indicator of muscle fatigue

Farina et al. 2003, Merletti et al. 1990



Slope of median frequency vs. time = muscle fatigue rate



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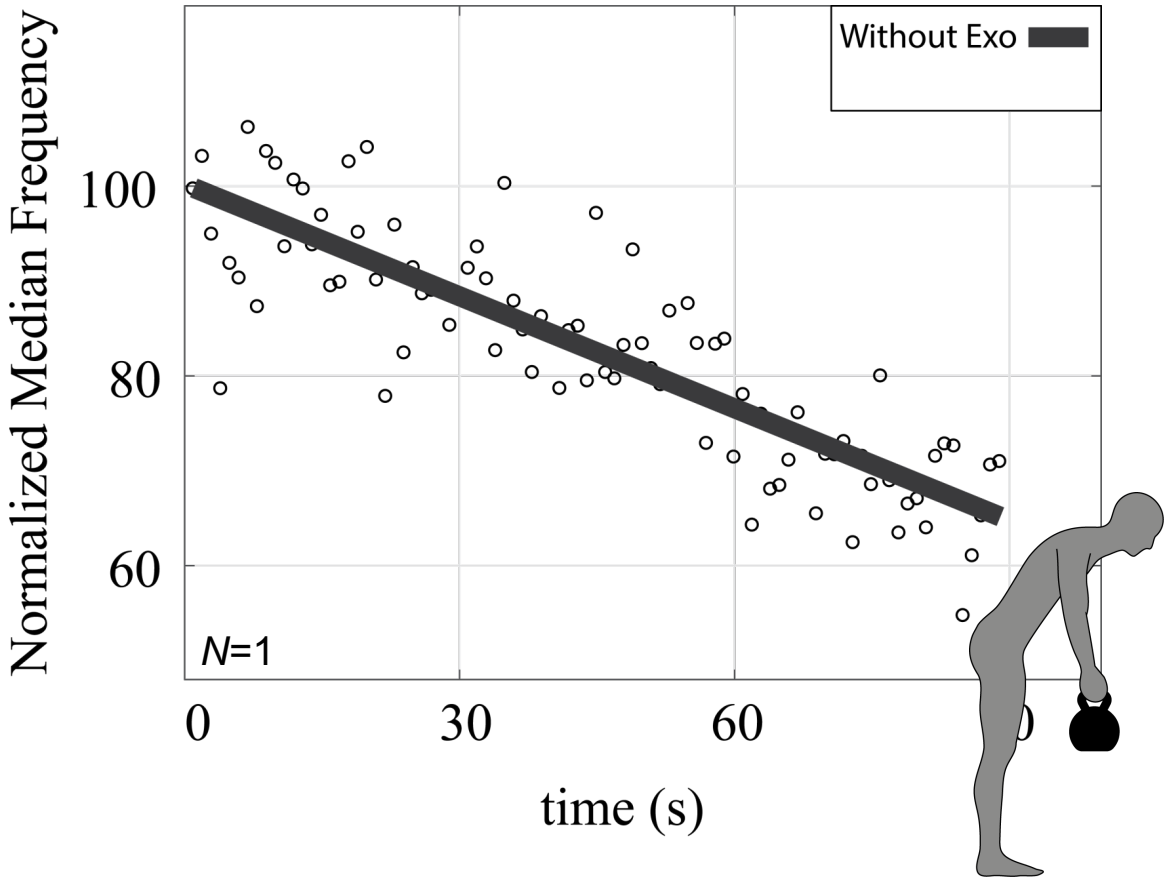

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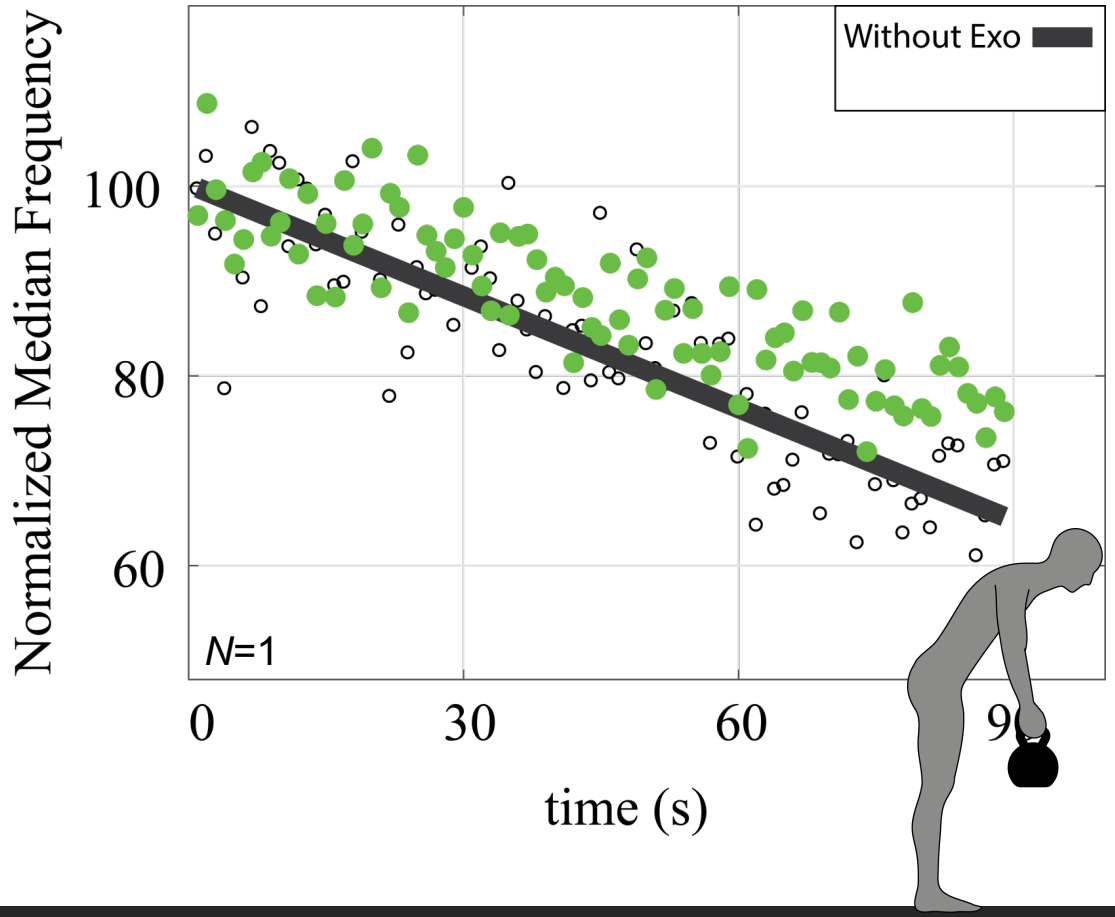
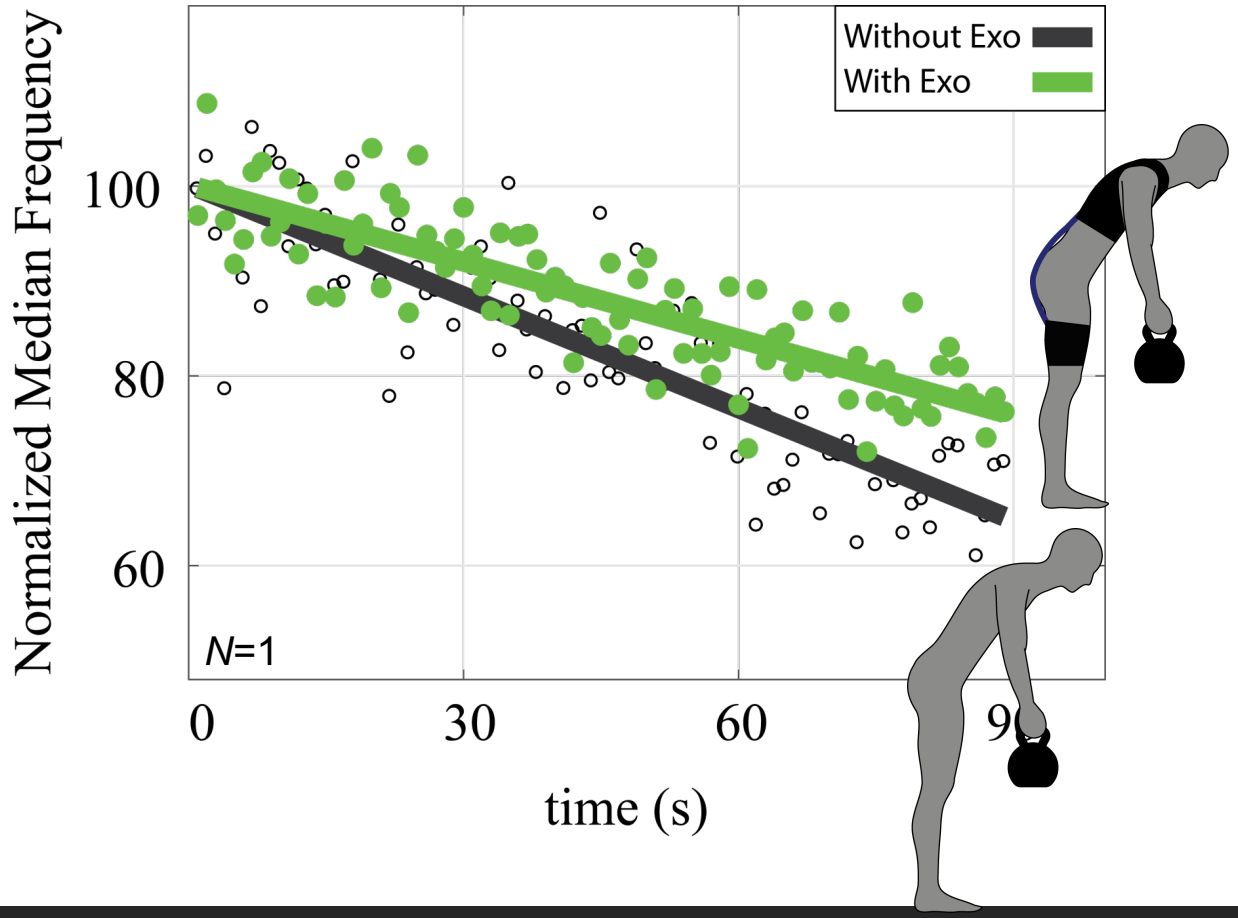
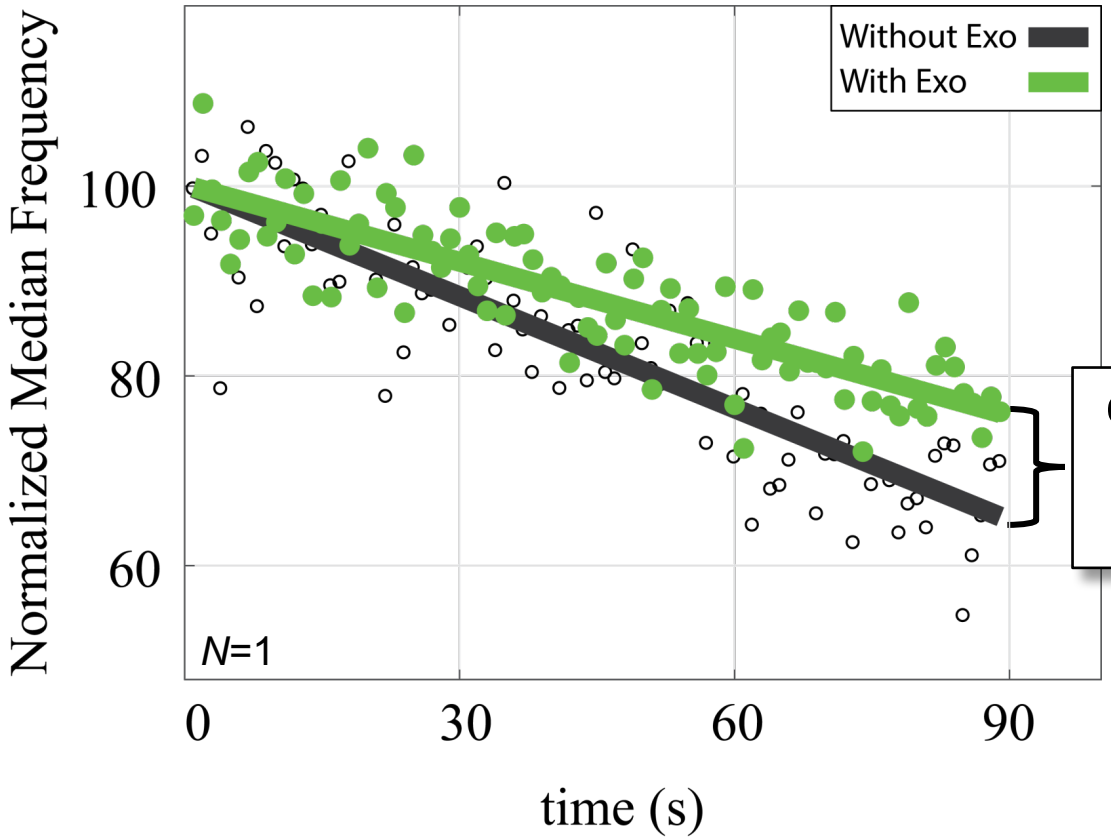


Less steep slope = slower rate of muscle fatigue



Key outcome metrics: % change in slope with vs. without exo



% change in slope

analysis of covariance

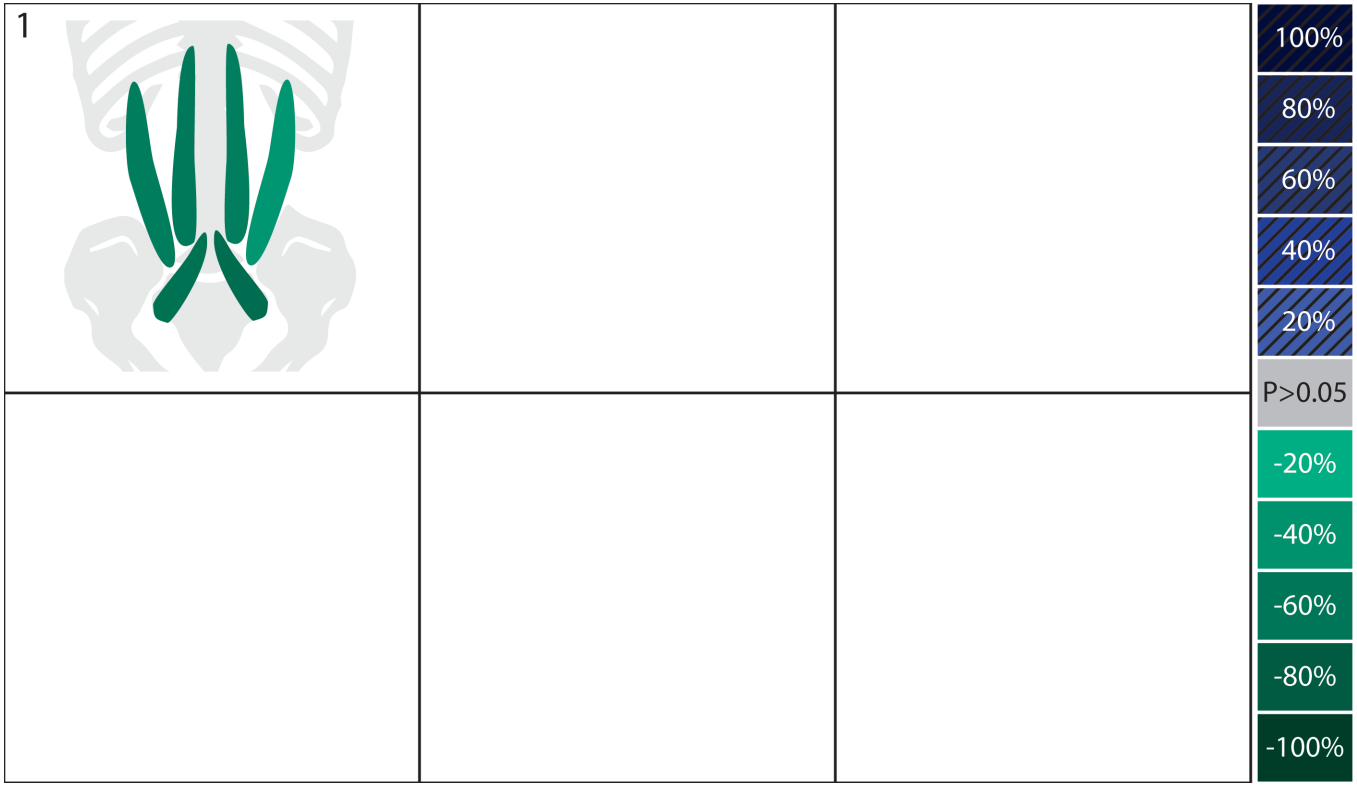
Q1: Can mechanized clothing reduce muscle fatigue?

Fatigue rate increased when wearing exo

Fatigue rate decreased when wearing exo

Lamers et al. In Review

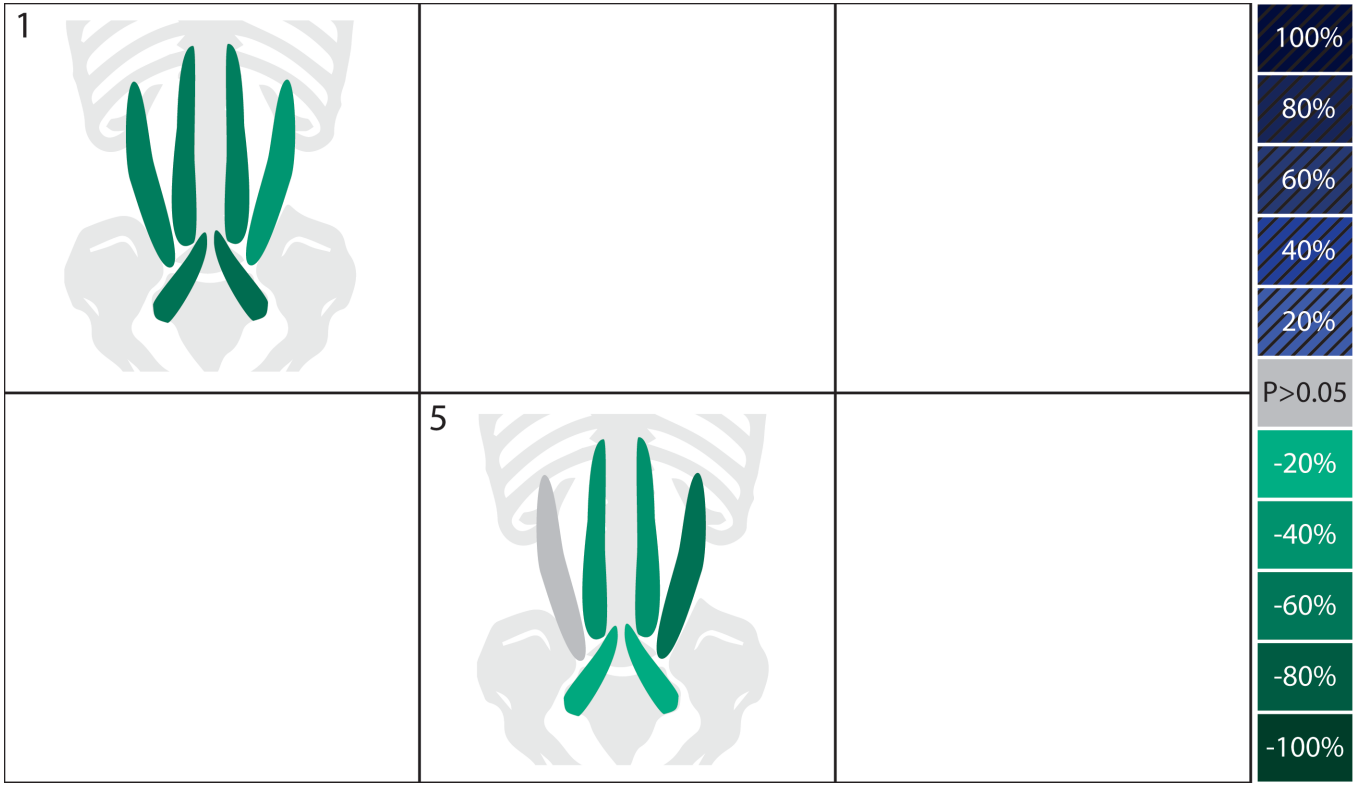
Q1: Can mechanized clothing reduce muscle fatigue? **YES!**



Fatigue rate increased when wearing exo

Fatigue rate decreased when wearing exo

Q1: Can mechanized clothing reduce muscle fatigue? **YES!**



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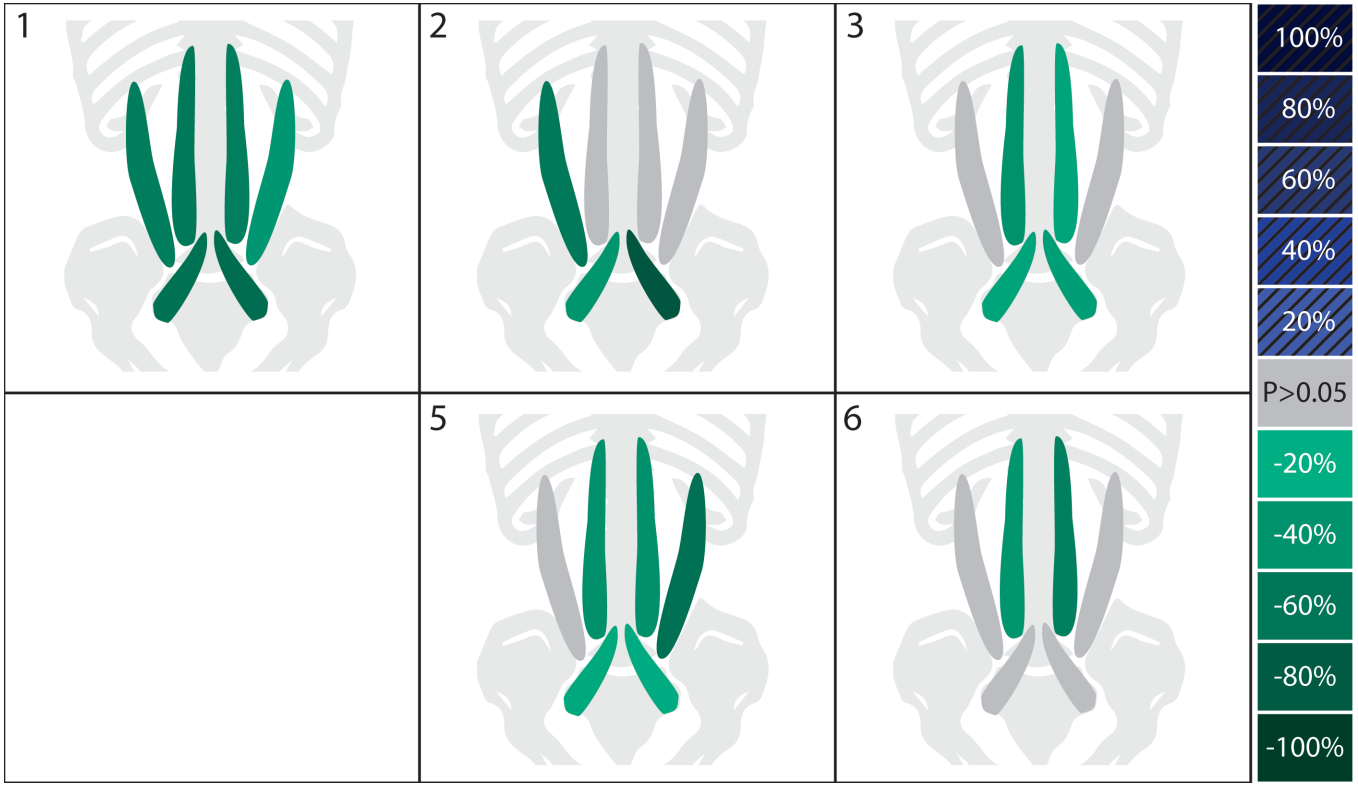

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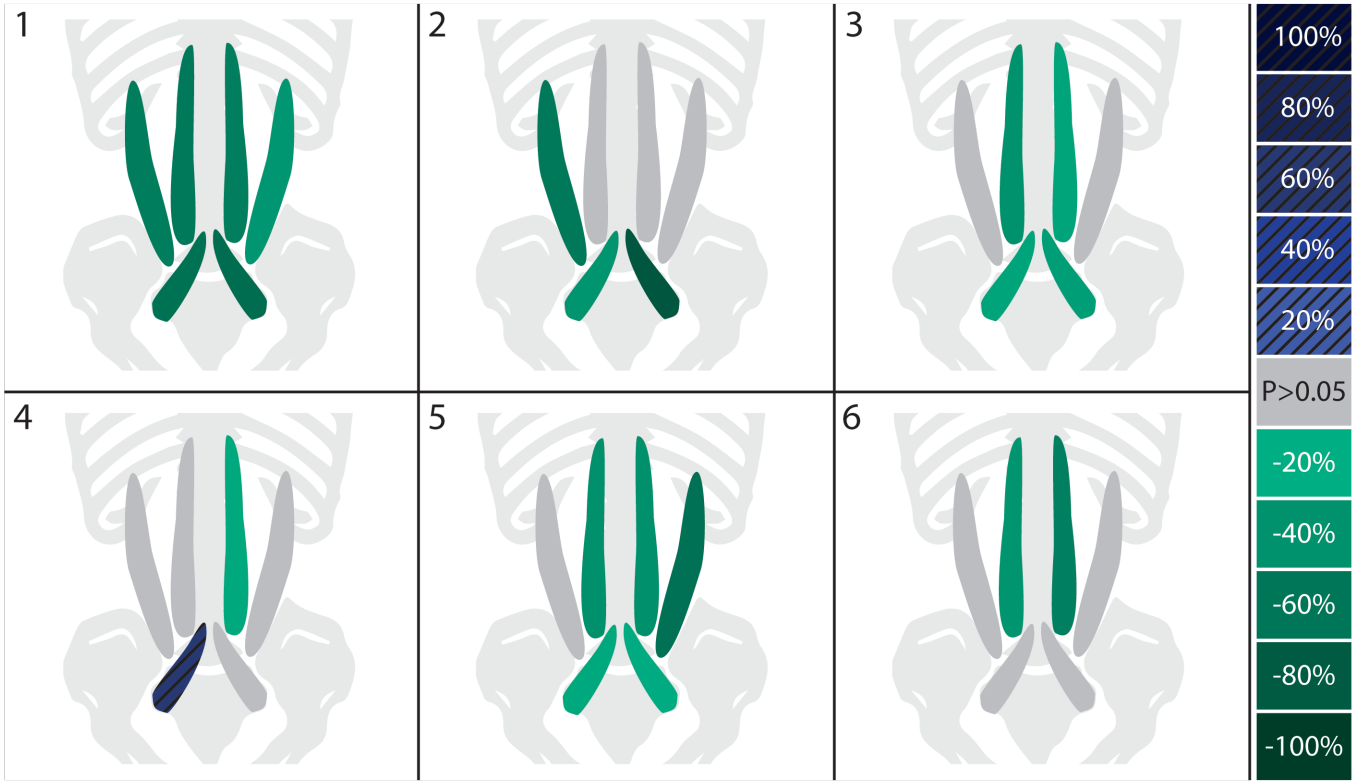
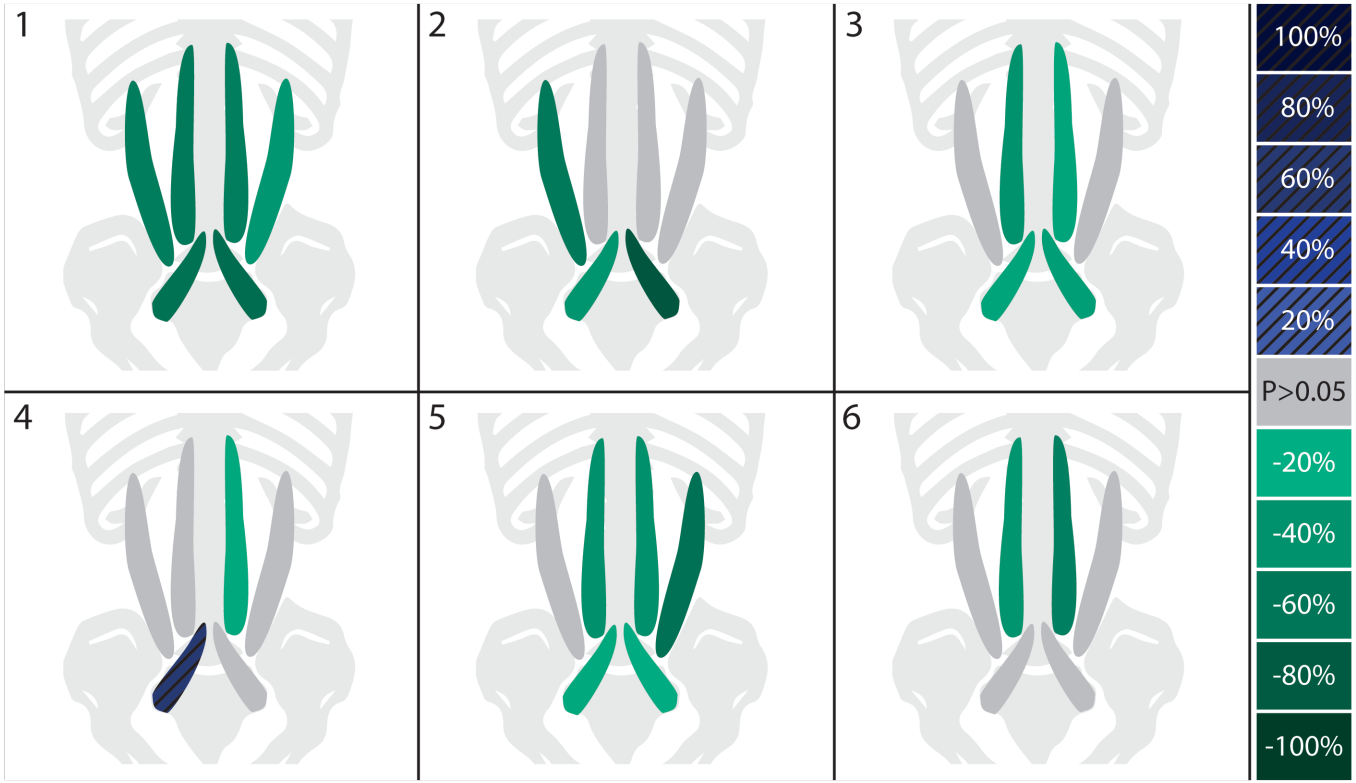


Fatigue rate increased when wearing exo

Fatigue rate decreased when wearing exo

Q2: Are changes consistent across muscles & users? **NO!**



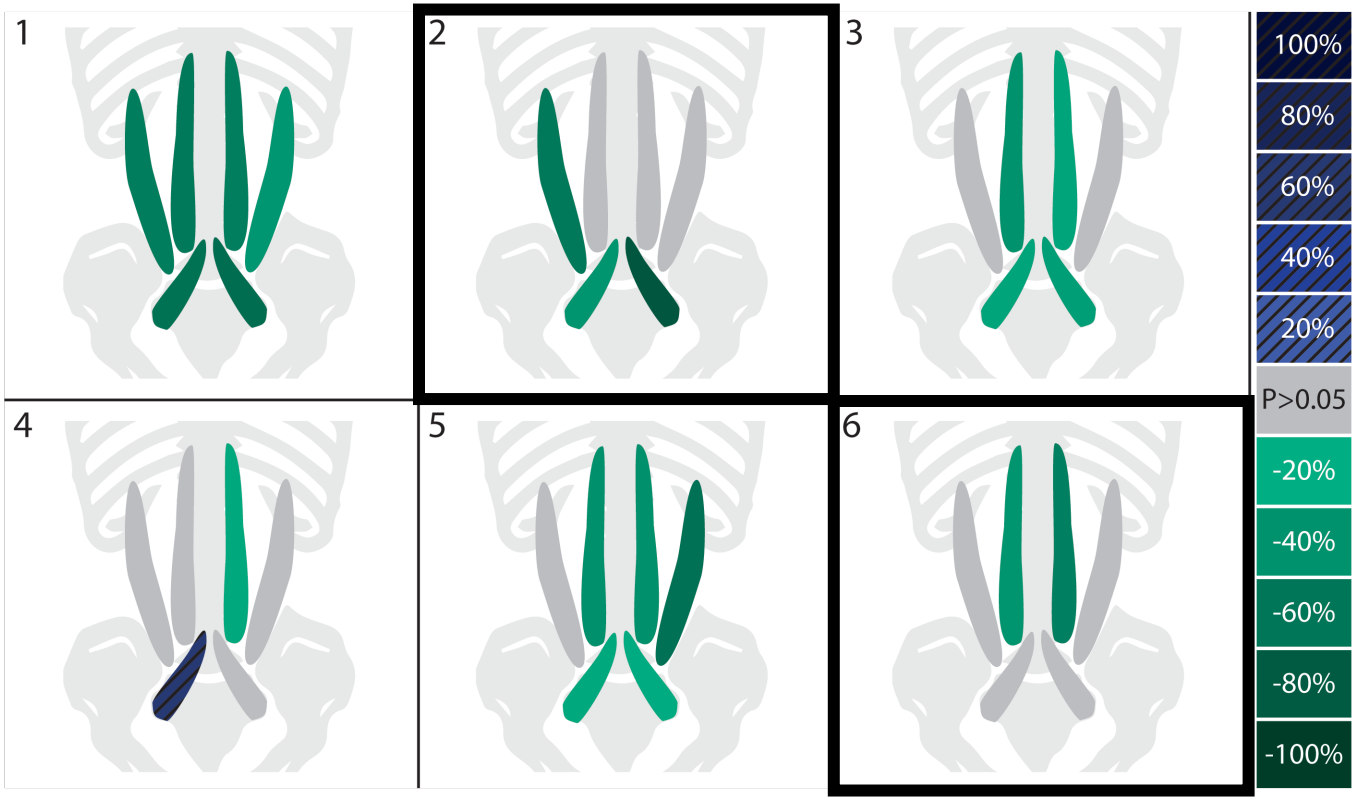
2 subjects:
5-6 muscles

3 subjects:
2-4 muscles

1 subject:
1 muscle*

Lamers et al. In Review

For exo evaluation standards which muscles should we test?



Lamers et al. In Review

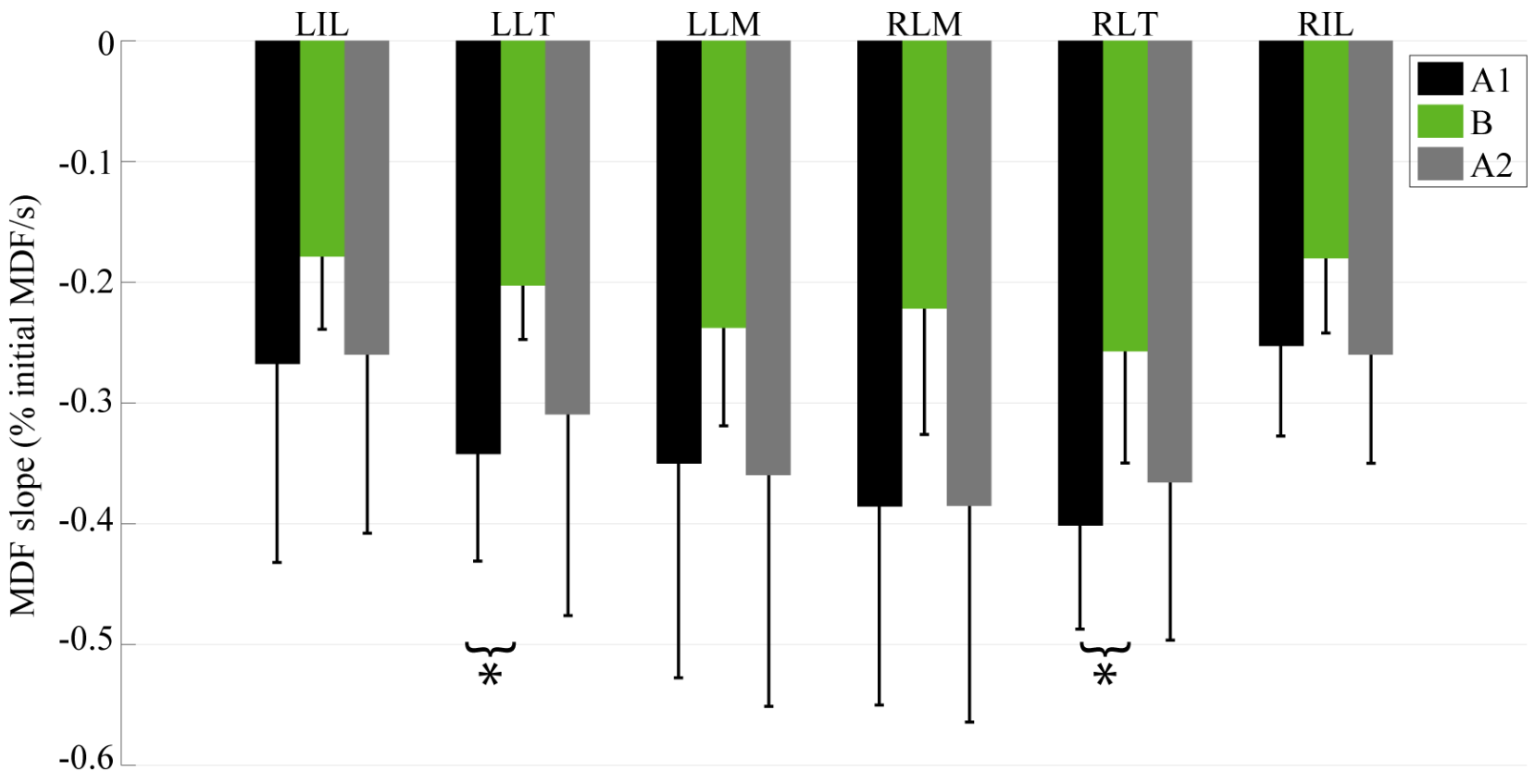
Pros & cons to group-level (inter-subject mean) results

N=6

Lamers et al. In Review

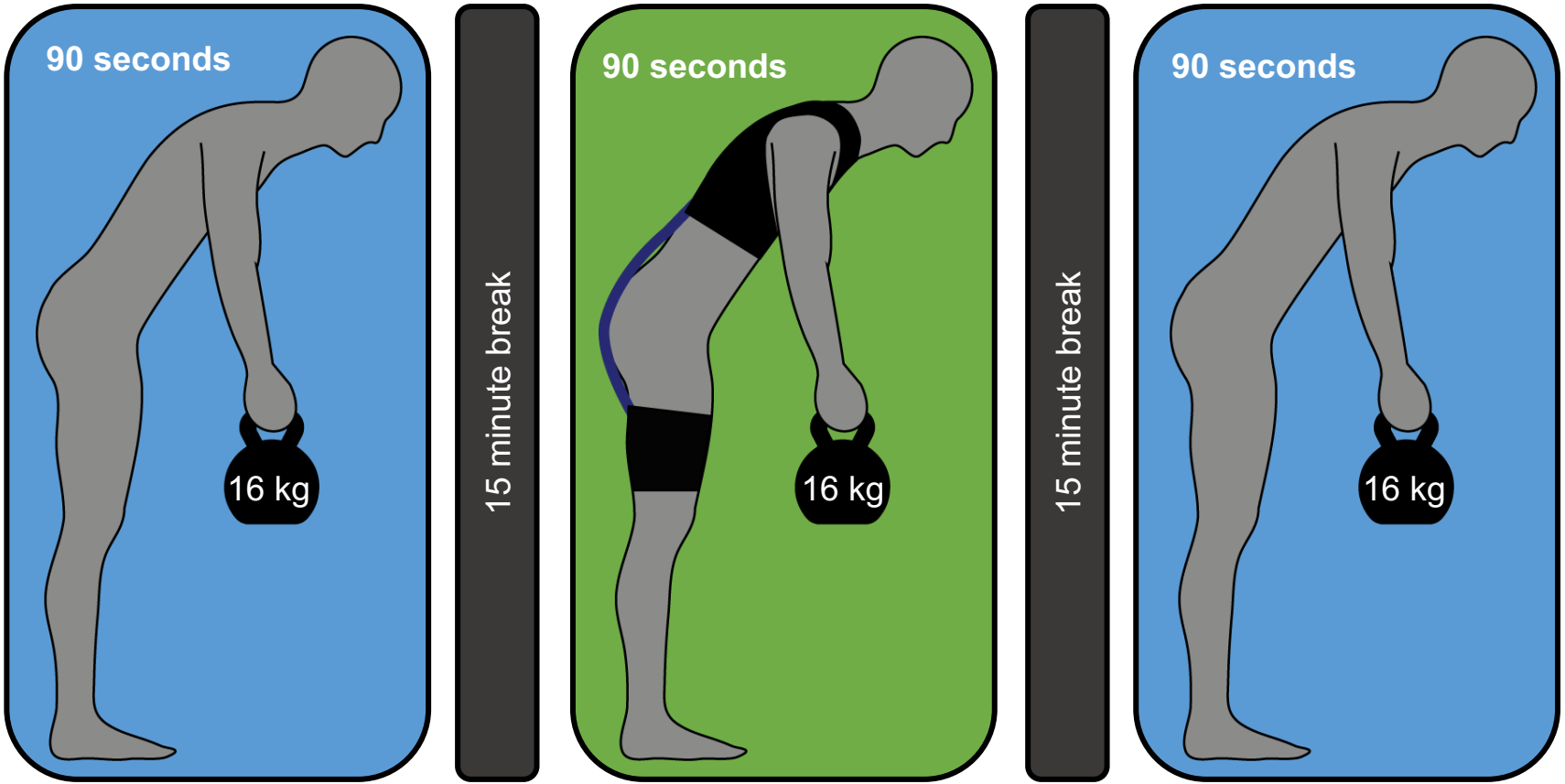
Pros & cons to group-level (inter-subject mean) results

N=6



Lamers et al. In Review

Measuring muscle fatigue (especially back) can be very difficult



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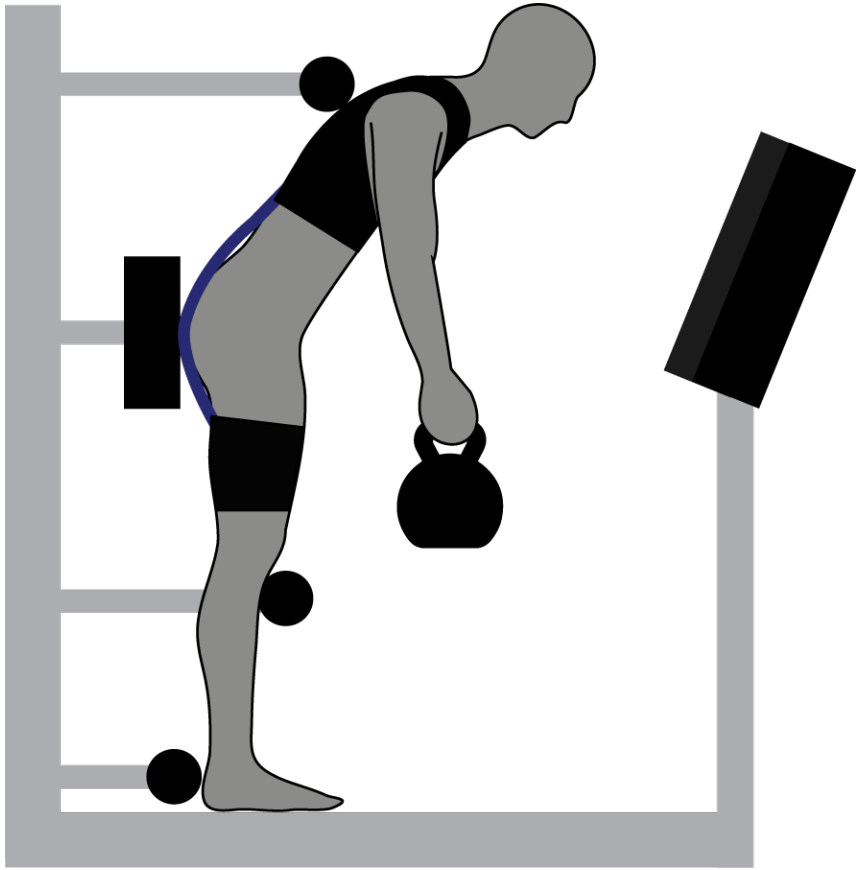
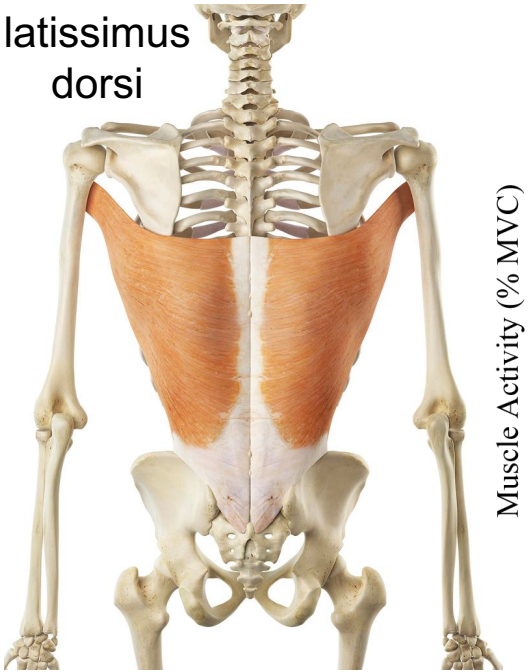
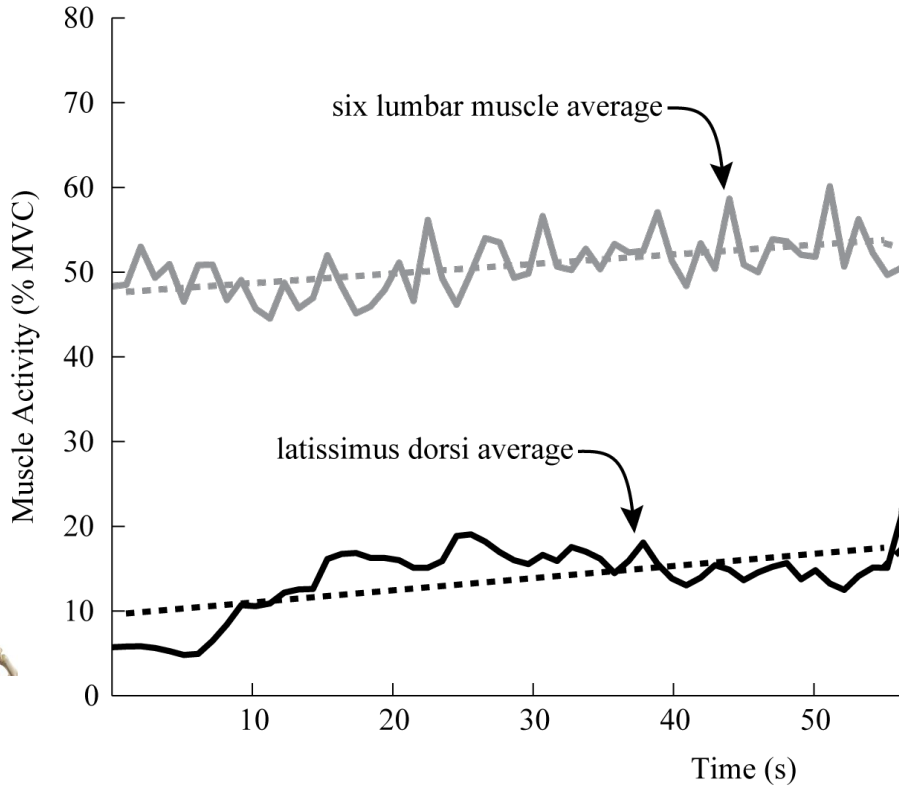


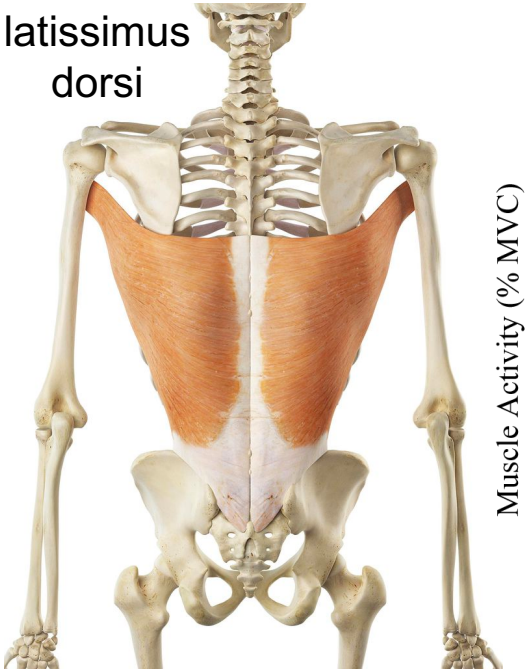
Unexpected adaptations: latissumus dorsi

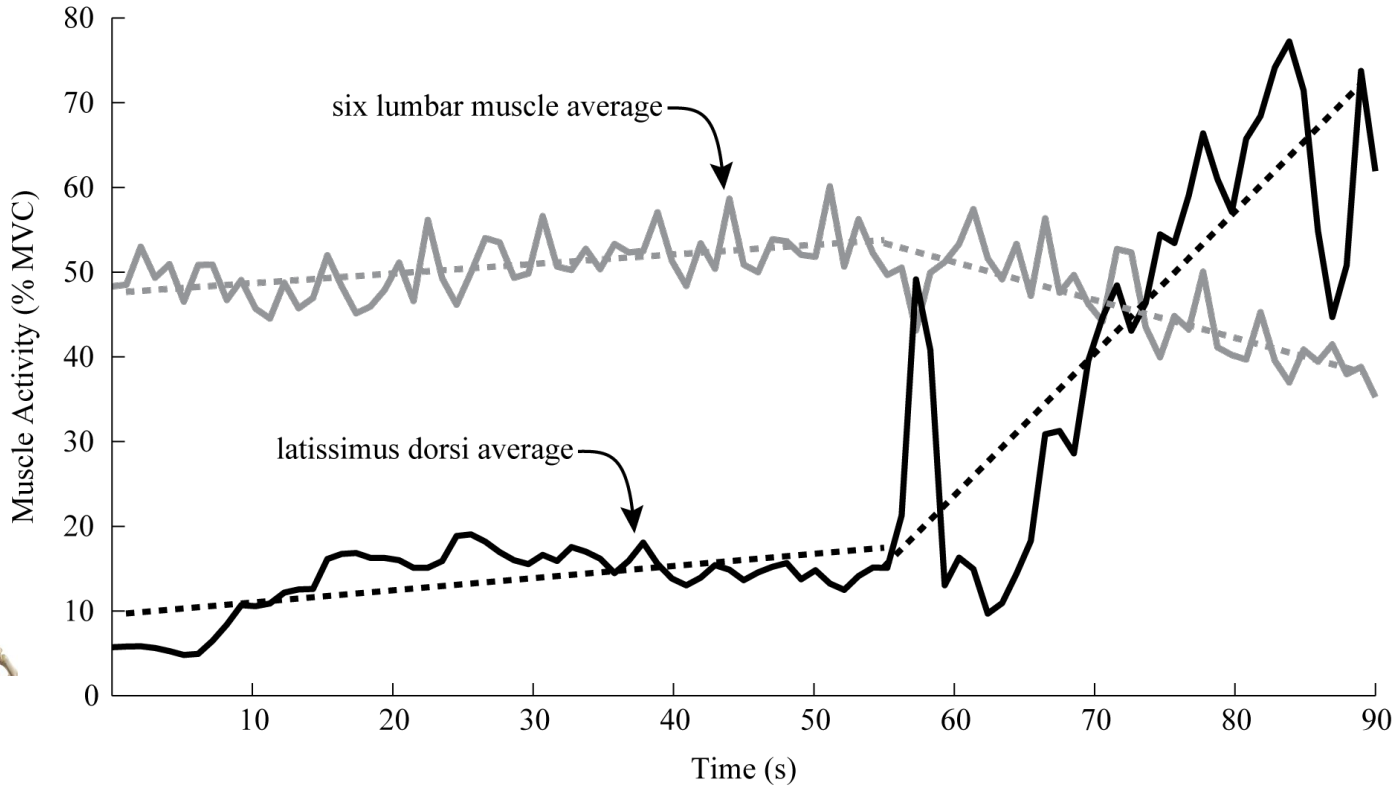




Lamers et al. In Review

Unexpected adaptations: latissumus dorsi kicked into high gear





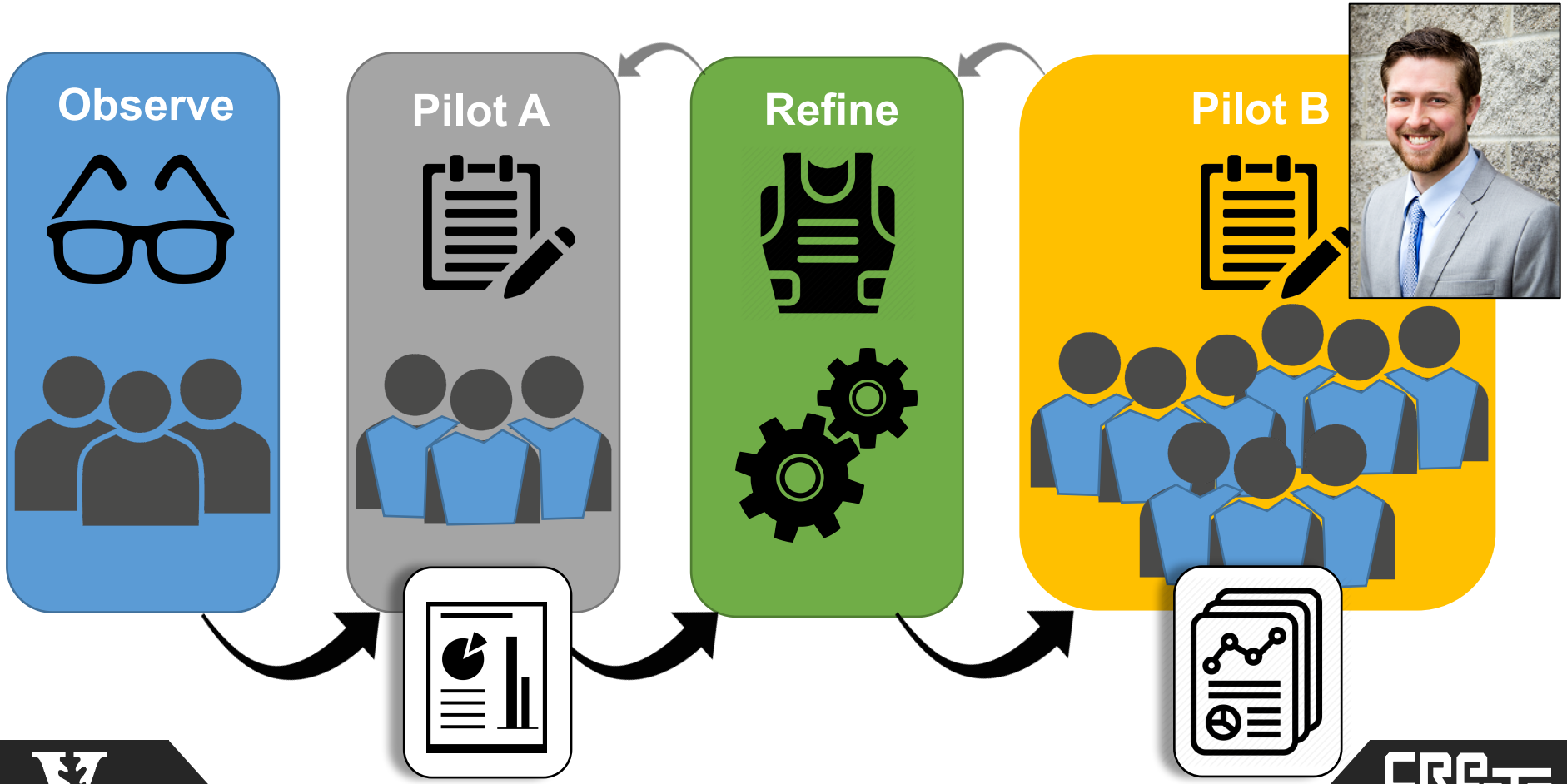
Lamers et al. In Review

To improve fit & comfort for males & females, different sizes

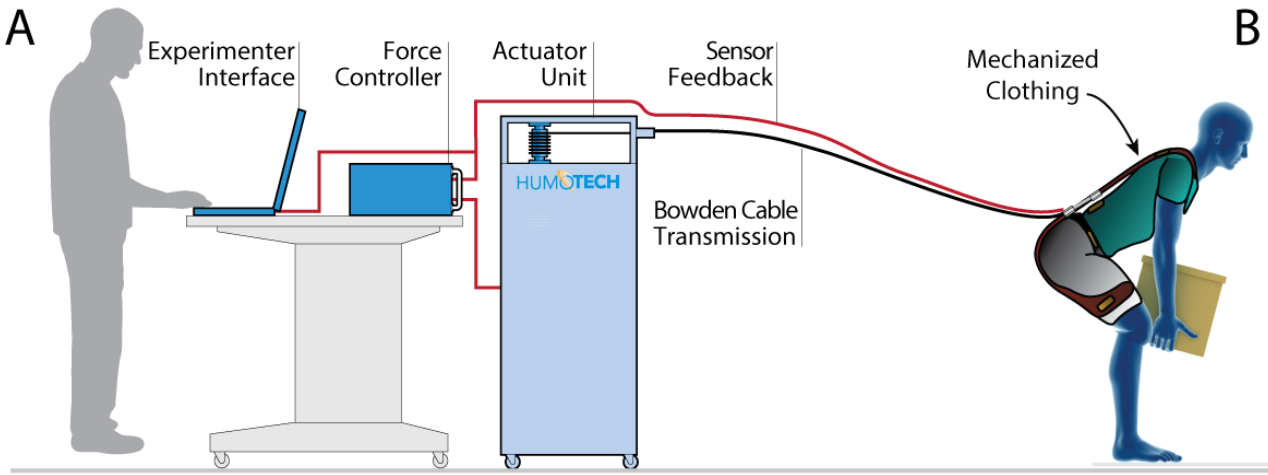
To fit comfortably under uniforms

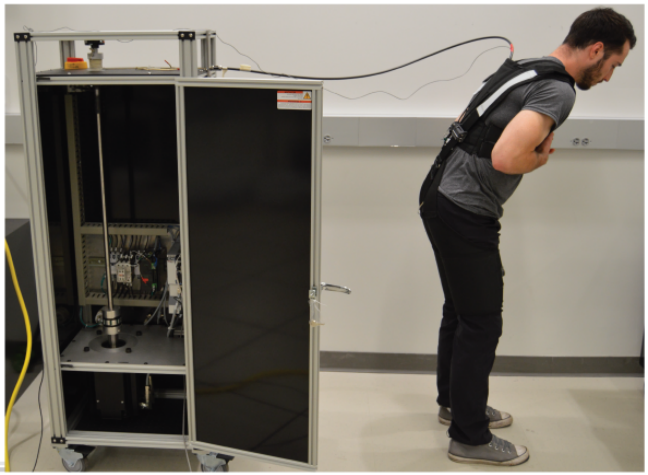
Logistics, Manufacturing, Retail, Nursing, Construction, Military

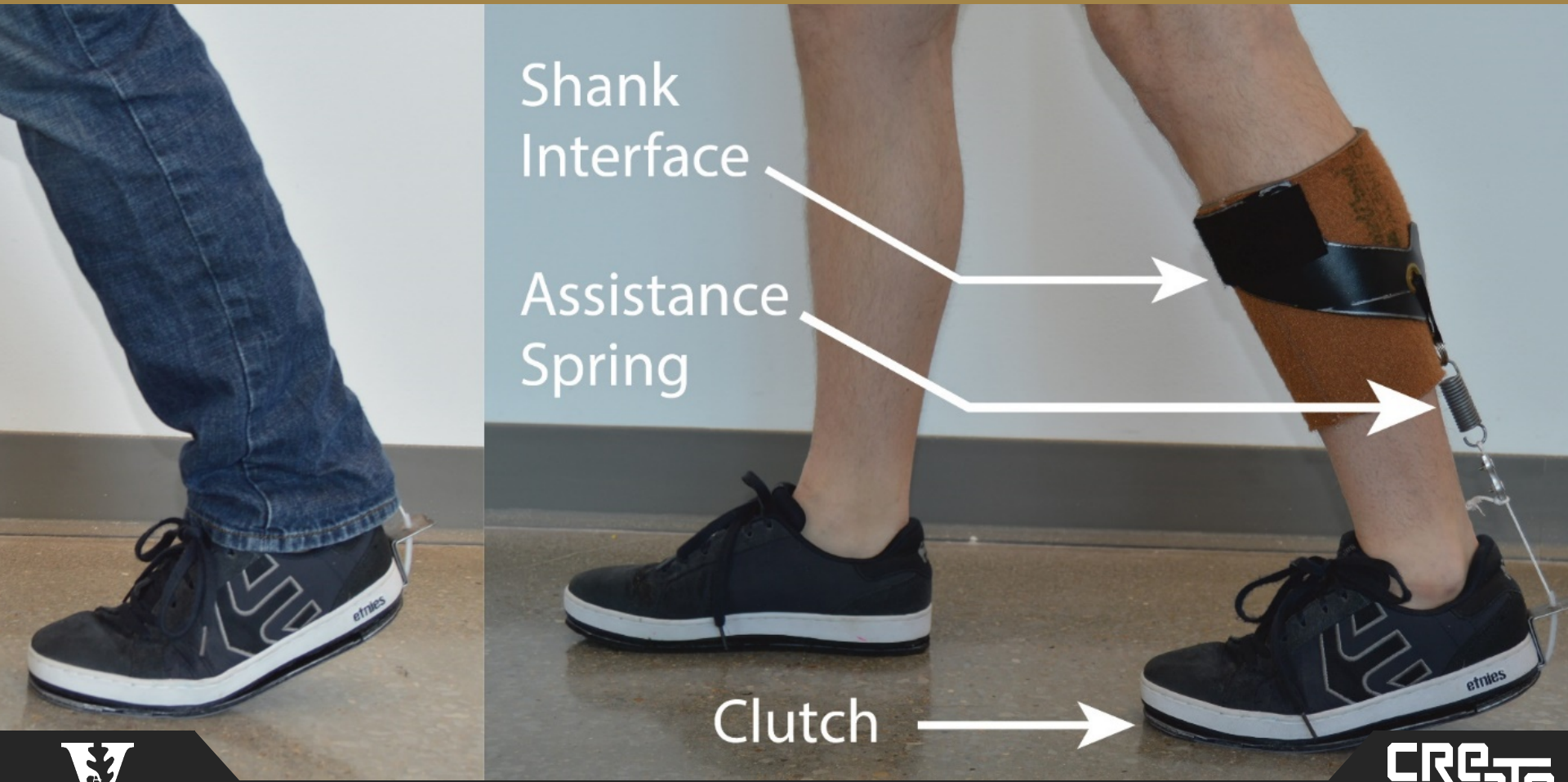
Working with industry partners to design tests (spring/summer 2019)



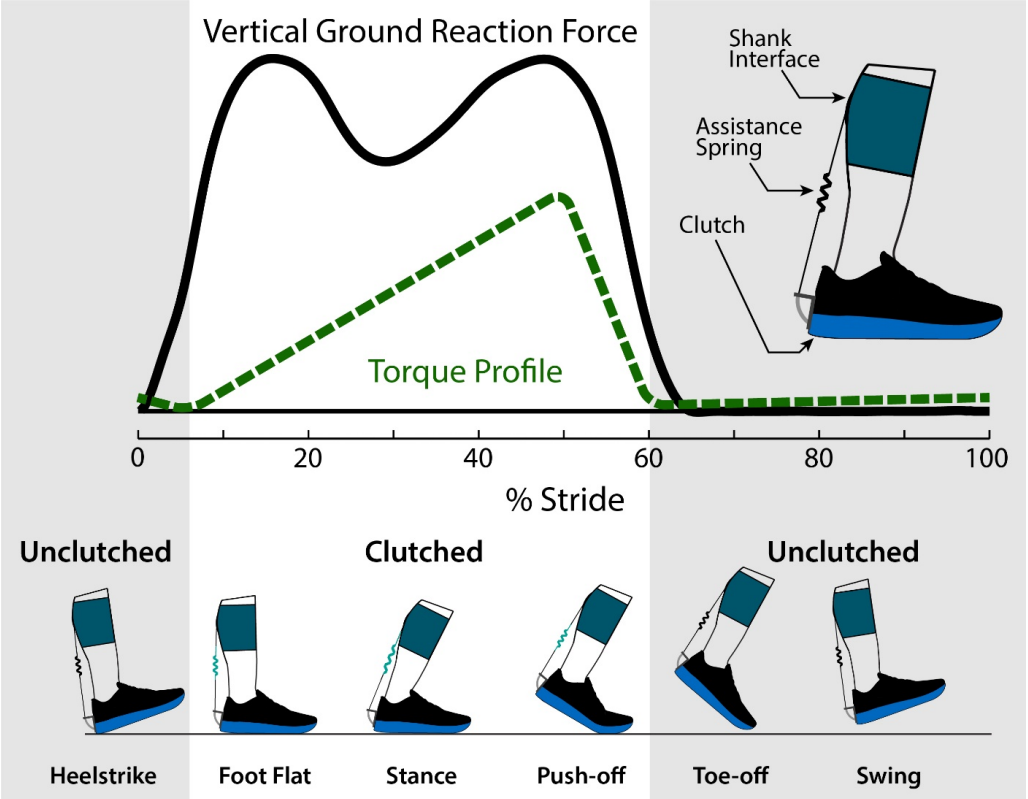
Human-in-the-loop optimization of assistive stiffness





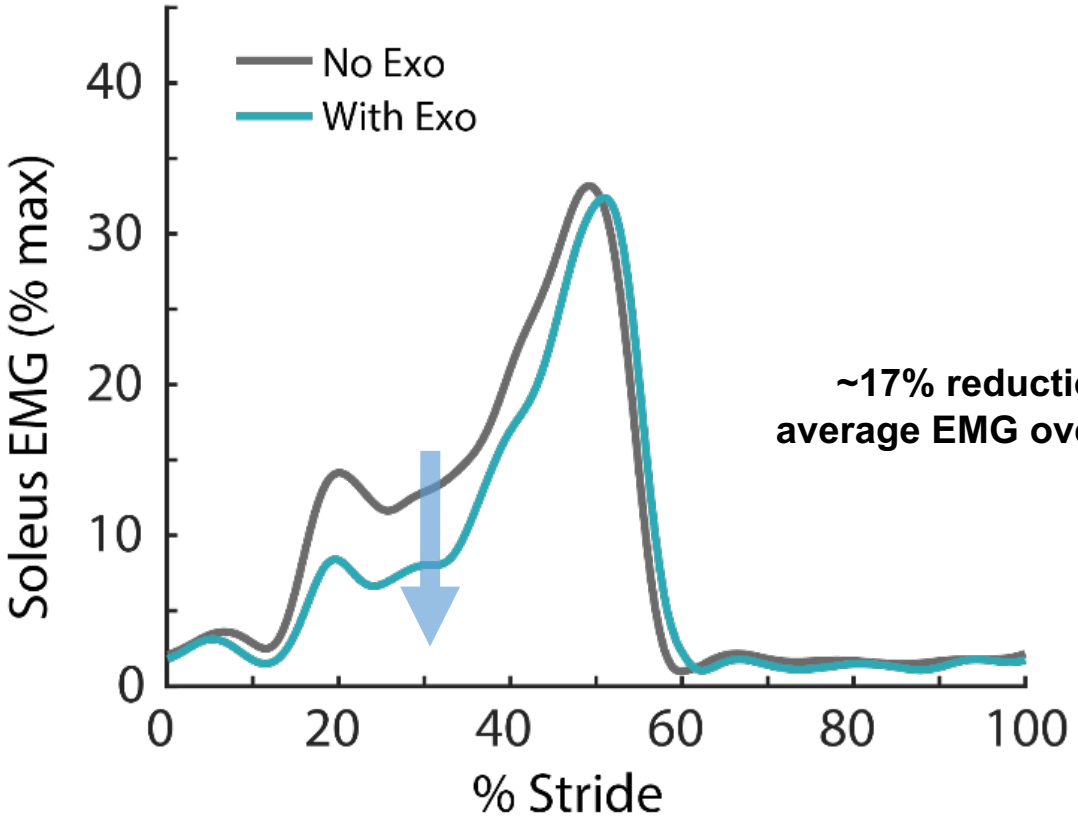

Shank
Interface
Assistance
Spring
Clutch

Ankle assistance



Yandell, Tacca & Zelik 2019 IEEE TNSRE

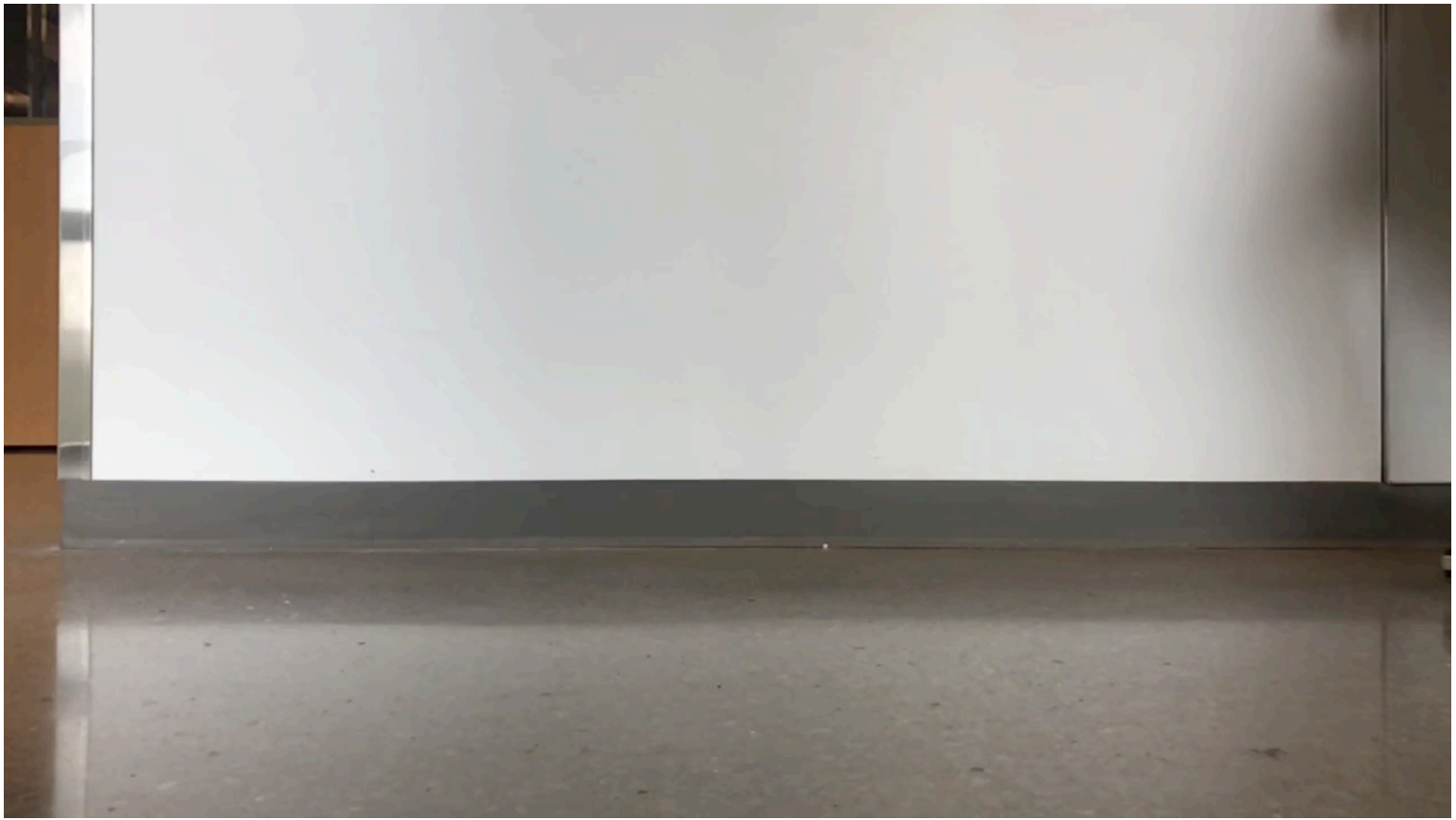
Reduced calf muscle activity during walking



$N = 1$
1.25 m/s

Yandell, Tacca & Zelik 2019 IEEE TNSRE

Ankle assistance



Conclusions & key takeaways

Science

- small reductions in tissue load = big reductions in tissue damage

Design

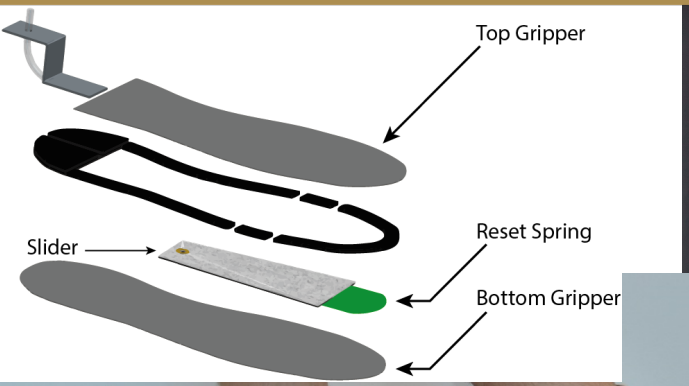
- clutchable springs enable full range-of-motion + assistance on demand

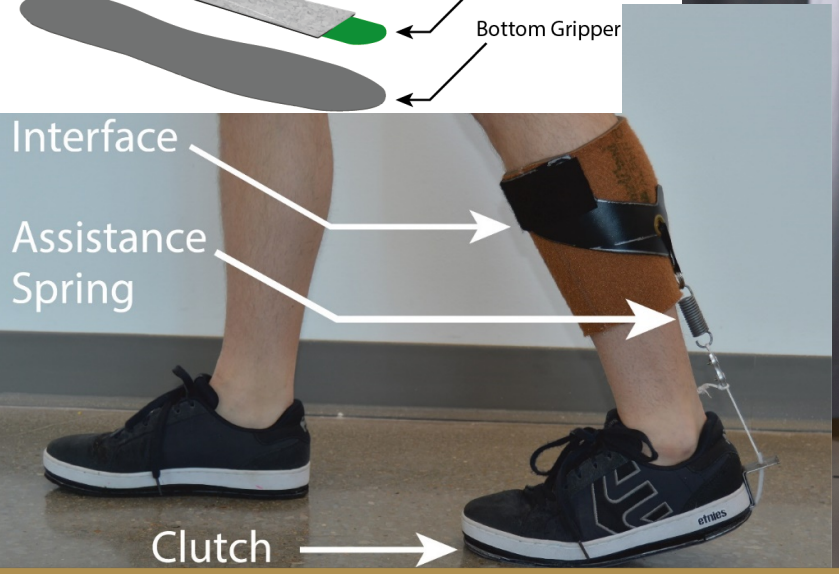
Evaluation

- spring-powered exosuits can reduce muscle loading & fatigue
- inter-subject & inter-muscle variability: challenges for evaluation standards

(for all exoskeletons)

“Where is my supersuit?!?!” - Frozone





Acknowledgements: Vanderbilt University & NIH

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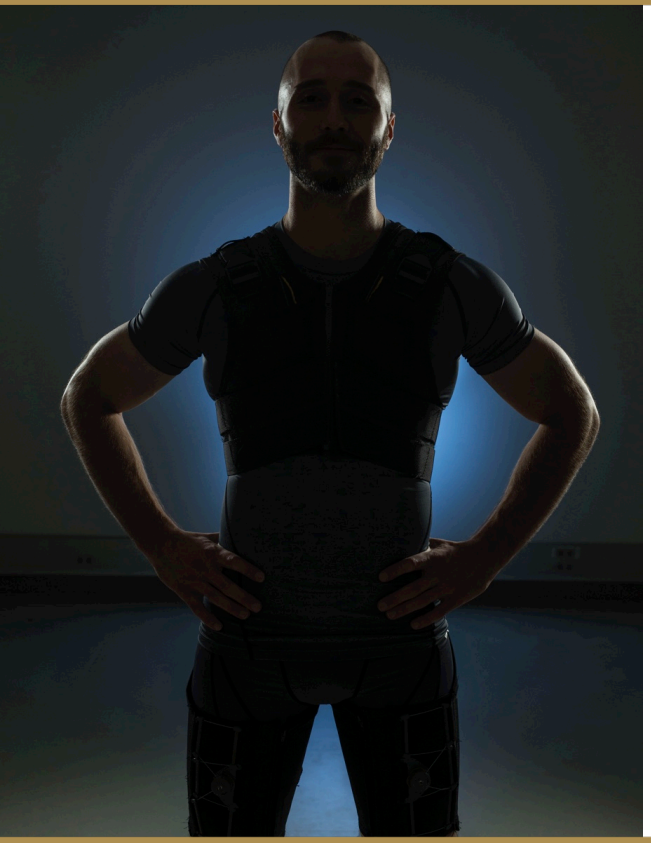
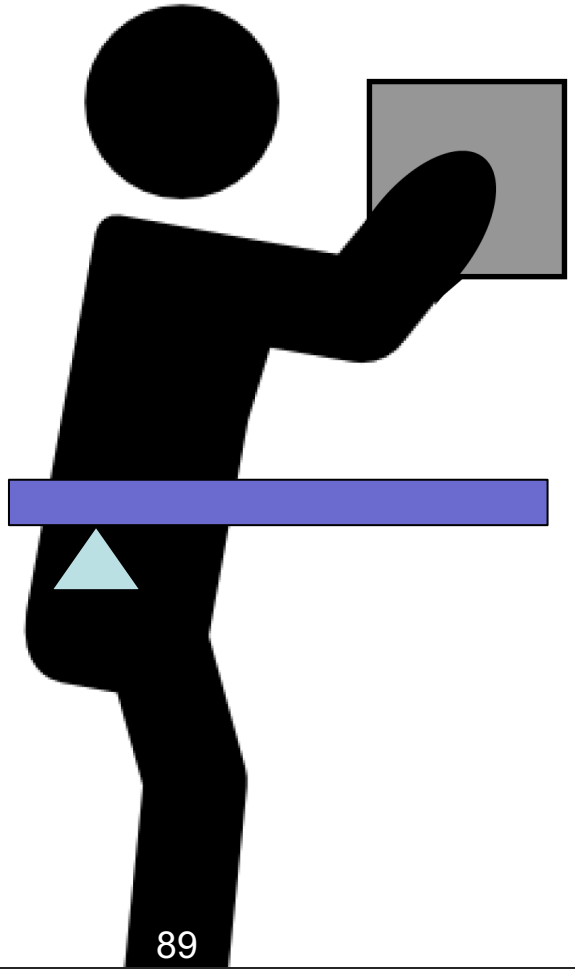


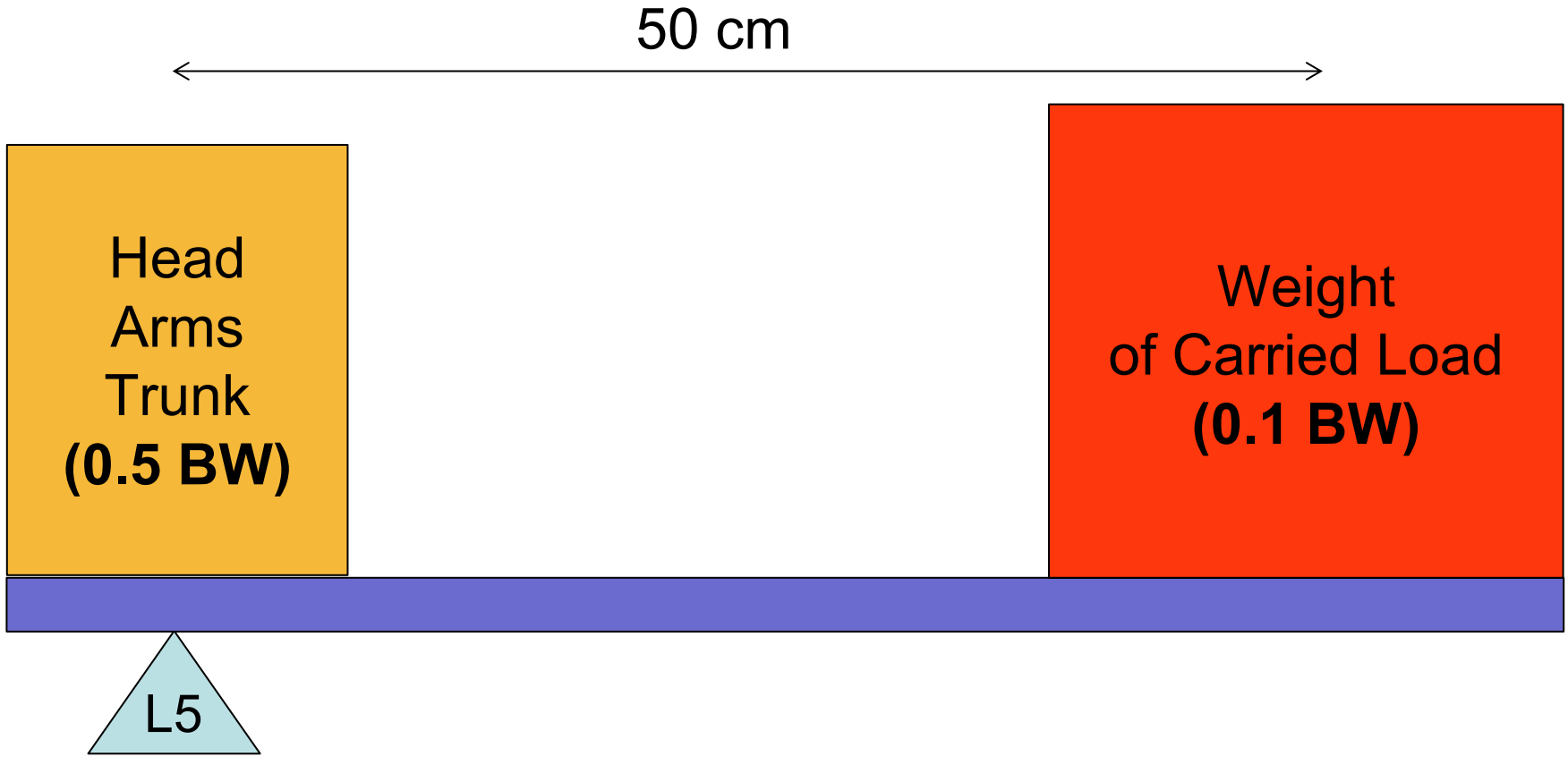
APPENDIX

Why lumbar forces are primarily from muscles → lever system




L5
Lumbar spine

BW = body weight (e.g., 0.5 BW = 50% of body weight)



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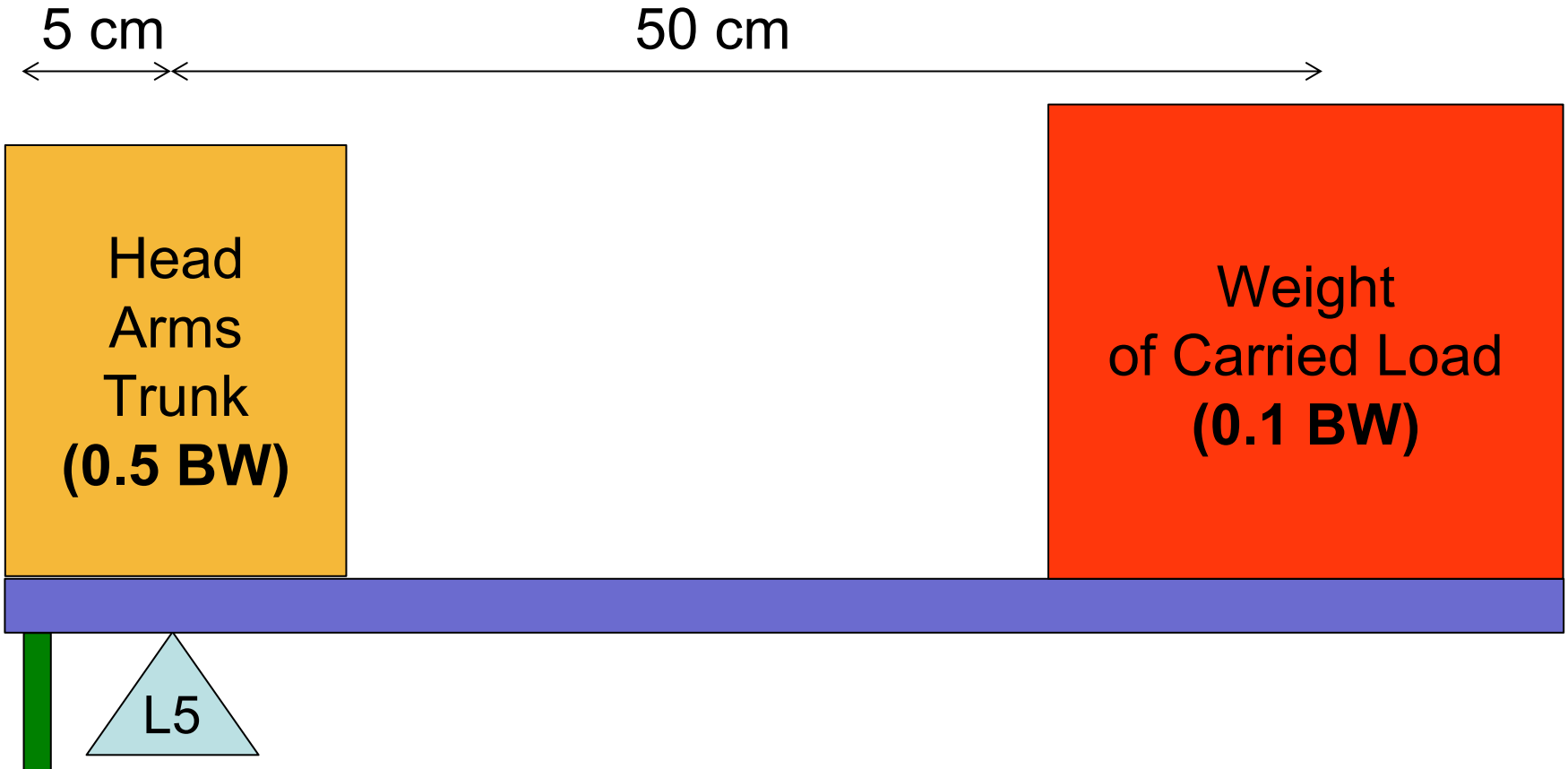
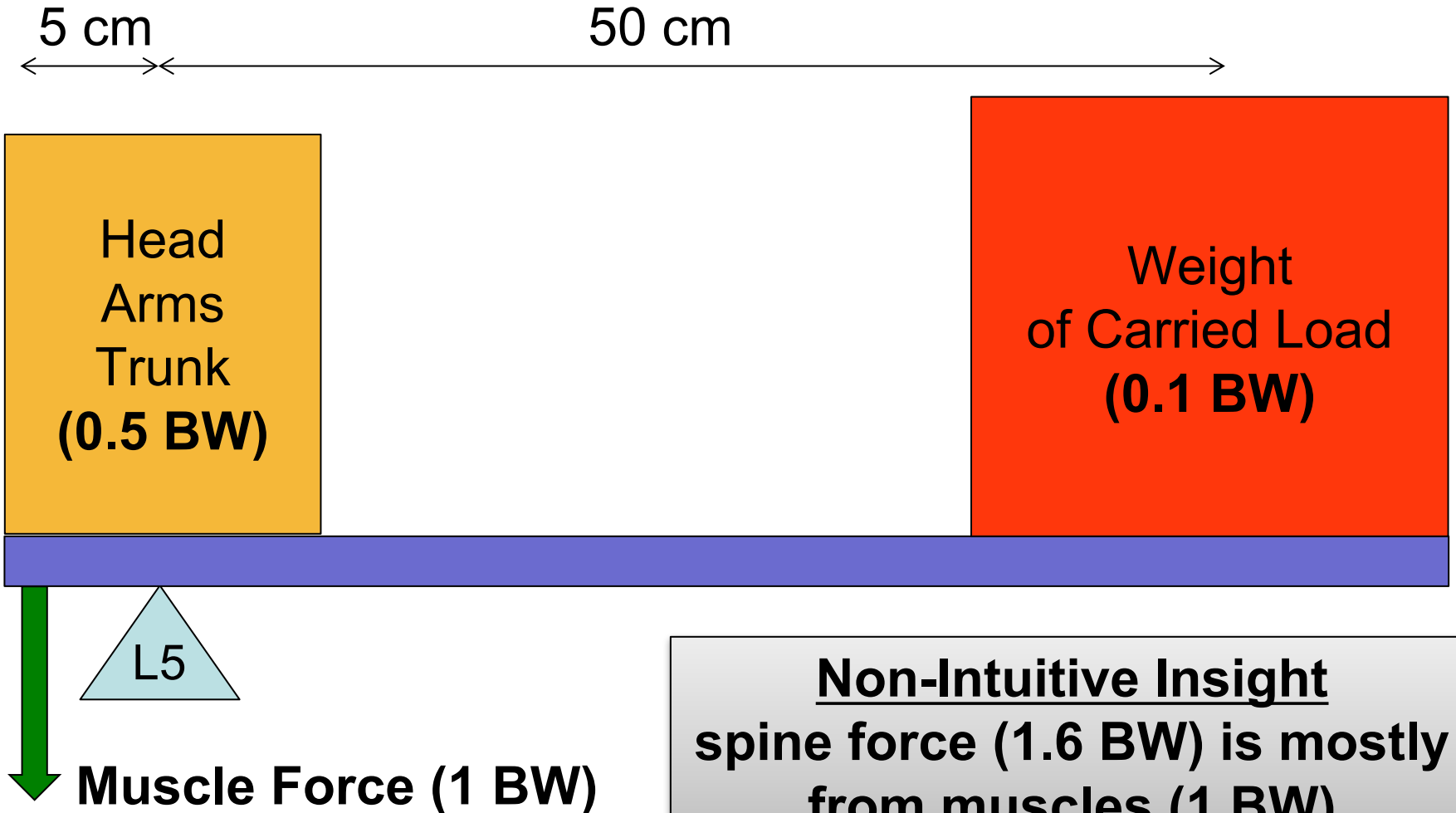


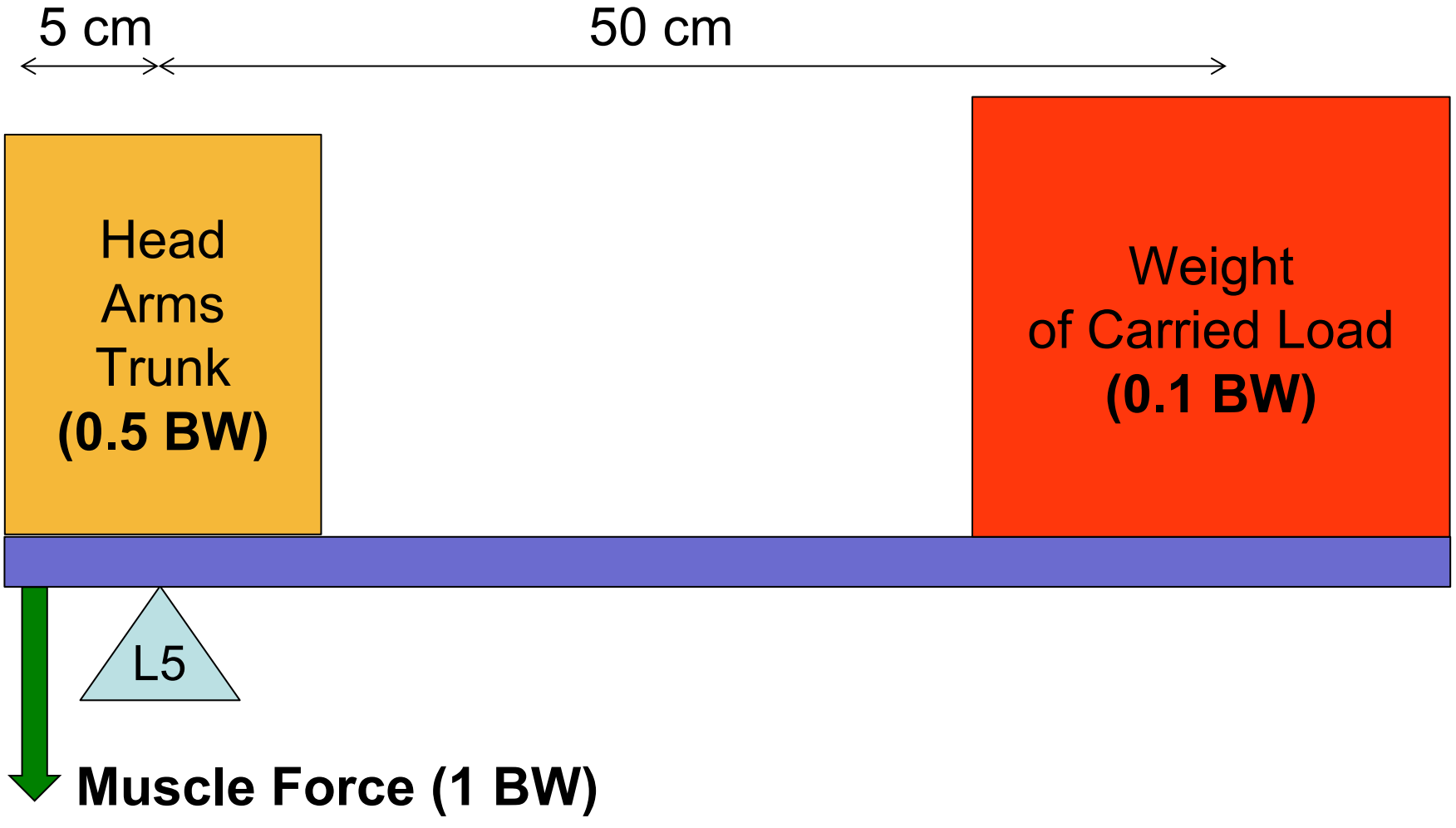
Muscle Force = 0.1 BW * 50 cm / 5 cm = 1 BW

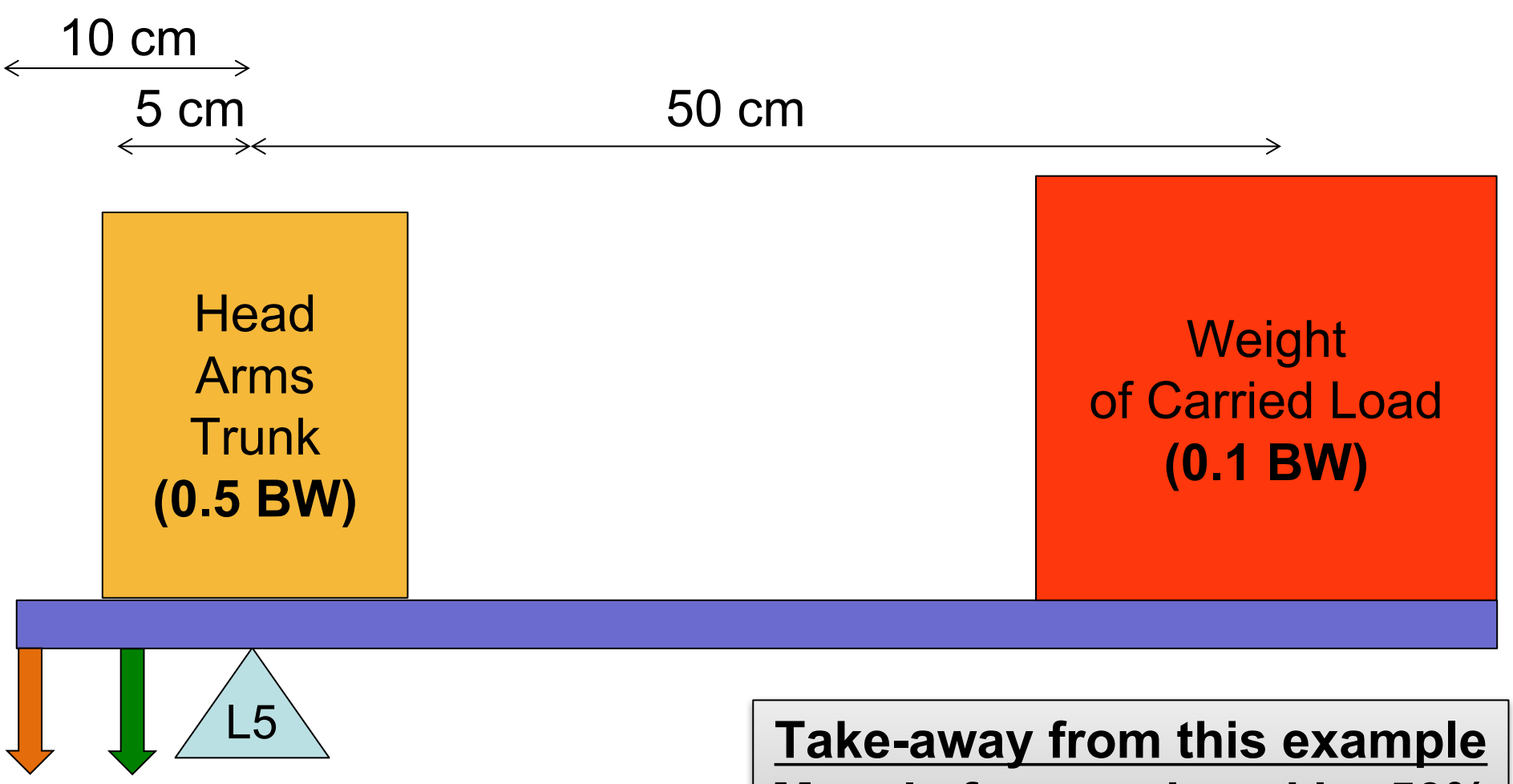
(provides torque to prevent tipping over due to carried load)



Non-Intuitive Insight

spine force (1.6 BW) is mostly from muscles (1 BW)


5 cm
50 cm
Head
Arms
Trunk
(0.5 BW)
Weight
of Carried Load
(0.1 BW)
L5
Muscle Force (1 BW)



Take-away from this example

Muscle force reduced by 50%

Spine force reduced by 15%

Contact Info

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Twitter: @KarlZelik