Biomechanics of recumbent handcycling during high and moderate intensity exercise

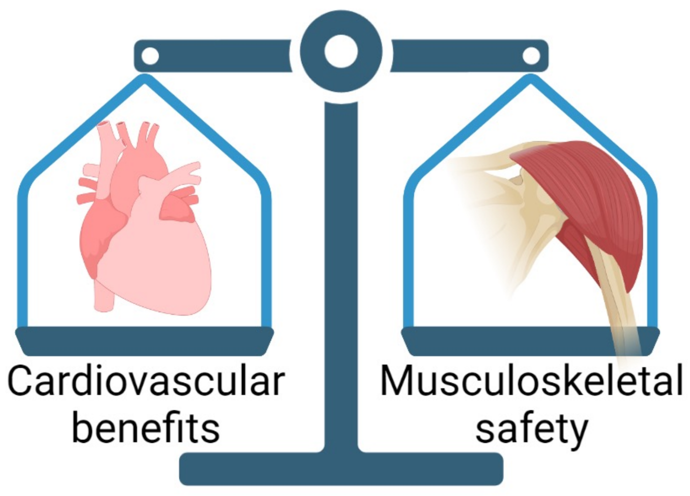
Kellie M. Halloran[1], Joseph Peters[2,3], Michael Focht[1], Ian Rice[4], Mariana E. Kersh[1,3,5]

[1]Dept. of Mechanical Science and Engineering, [2]Disability Resources and Educational Services,
[3]Beckman Institute for Advanced Science and Technology,
[4]Dept. of Kinesiology and Community Health, [5]Carle Illinois College of Medicine,
University of Illinois at Urbana-Champaign, Urbana IL

TISSUE BIOMECHANICS LABORATORY

1. Clinical motivation

- People with spinal cord injuries (PwSCI) are at high risk for cardiovascular disease (CVD)[1], and exercise is recommended to reduce CVD risk
- Up to 68% of PwSCI experience shoulder pain which is aggravated with exercise[2,3]



- High Intensity Interval Training (HIIT) could be an exercise solution to prevent CVD[4]
- Lower shoulder loading during handcycling could prevent shoulder injuries[5]

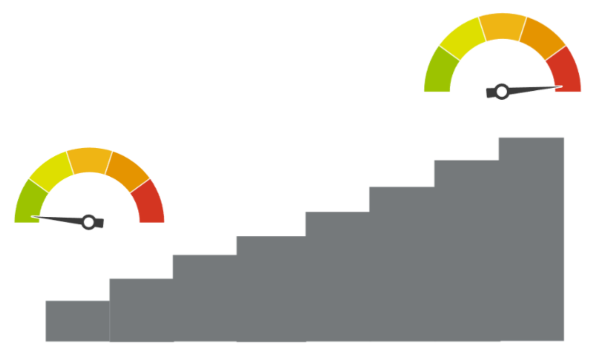
What is the impact of handcycling HIIT on shoulder injury risk?

- Joint angles and torques can provide insight into shoulder loading during exercise

2. Exercise Protocols

Session 1: Incremental Test

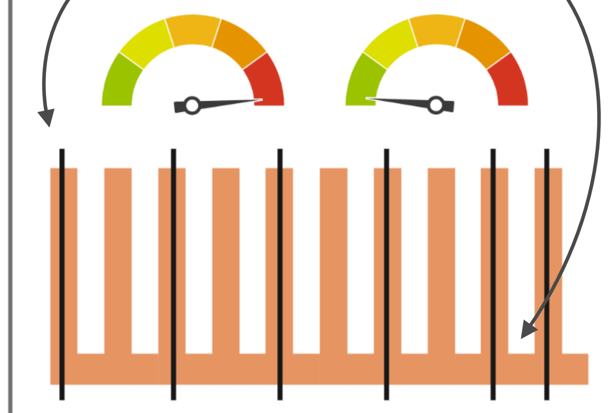
Increase by 10 W every min until exhaustion



Calculate peak power output (PPO)

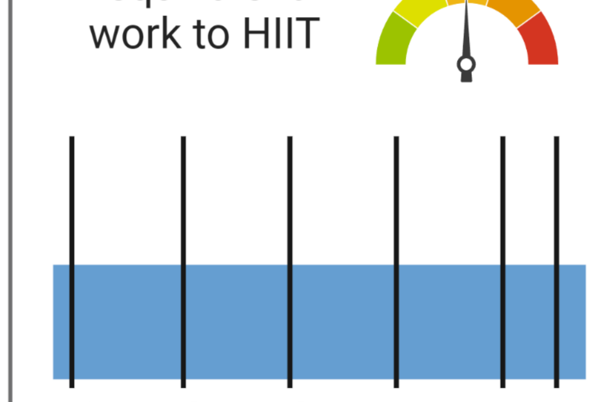
Session 2: High Intensity Interval Training (HIIT)

1 min 90% PPO — 1 min 10% PPO

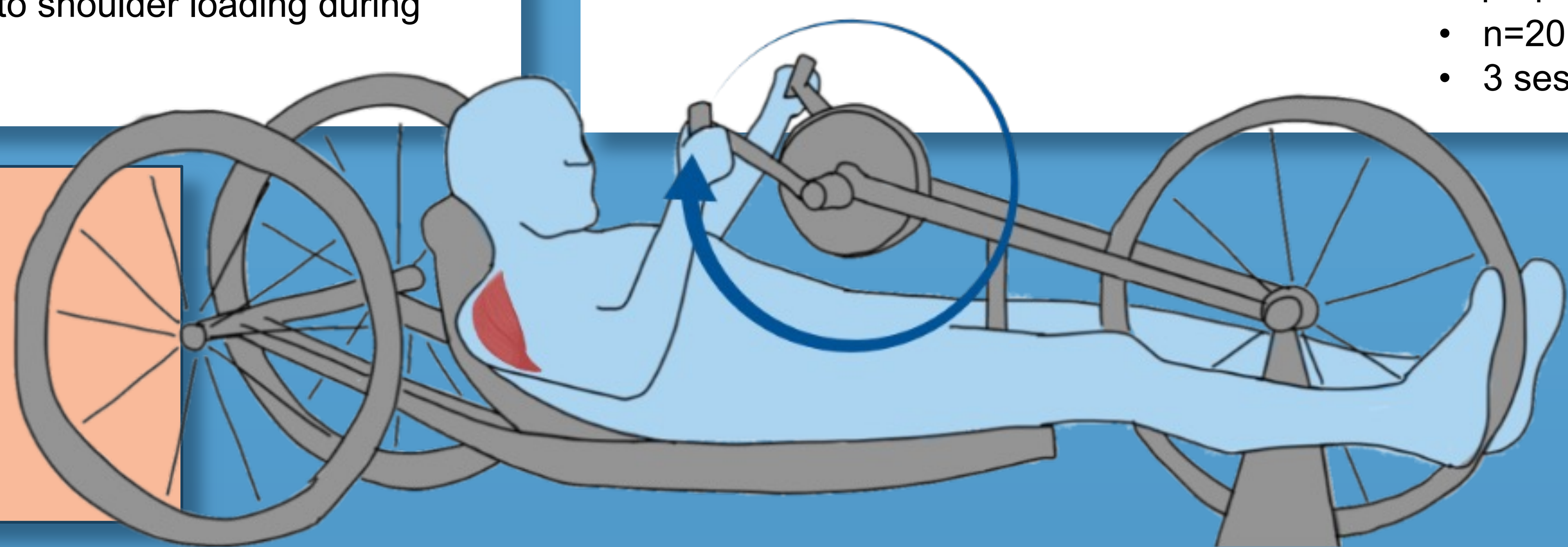


Session 3: Moderate Intensity Continuous Training (MICT)

Exercise until equivalent work to HIIT — 45% PPO



- Data was collected for 10 propulsion cycles at 6 timepoints
  - n=20 wheelchair athletes (9 female)
  - 3 sessions spaced 2-10 days apart

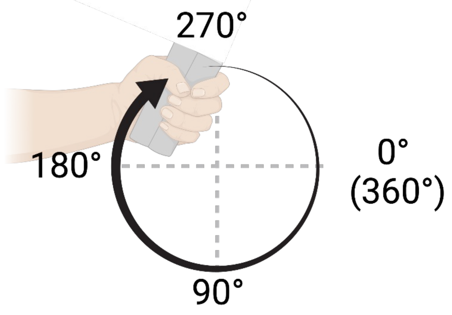


Objective

Examine the shoulder biomechanics (joint angles and joint torques) during handcycling HIIT and MICT

Exercise videos:

3. Methods

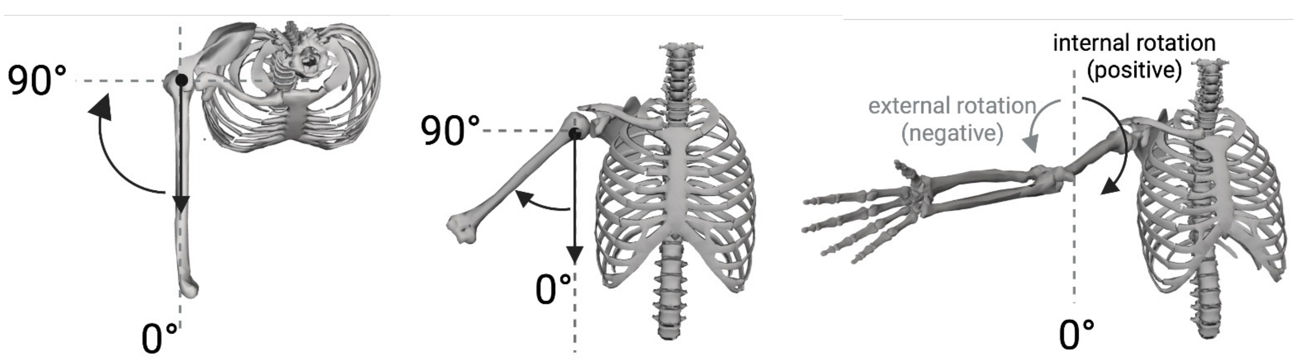


Data collection:

- Segment kinematics recorded with motion capture (10 camera, Vicon)
- Acromion marker cluster used for scapular kinematics[6,7]
- Handle instrumented with load cell used to collect kinetics

Musculoskeletal modeling:

- Wu shoulder model[8] scaled to each participant (OpenSim)
- Calculated joint angles (inverse kinematics) and torques (inverse dynamics)

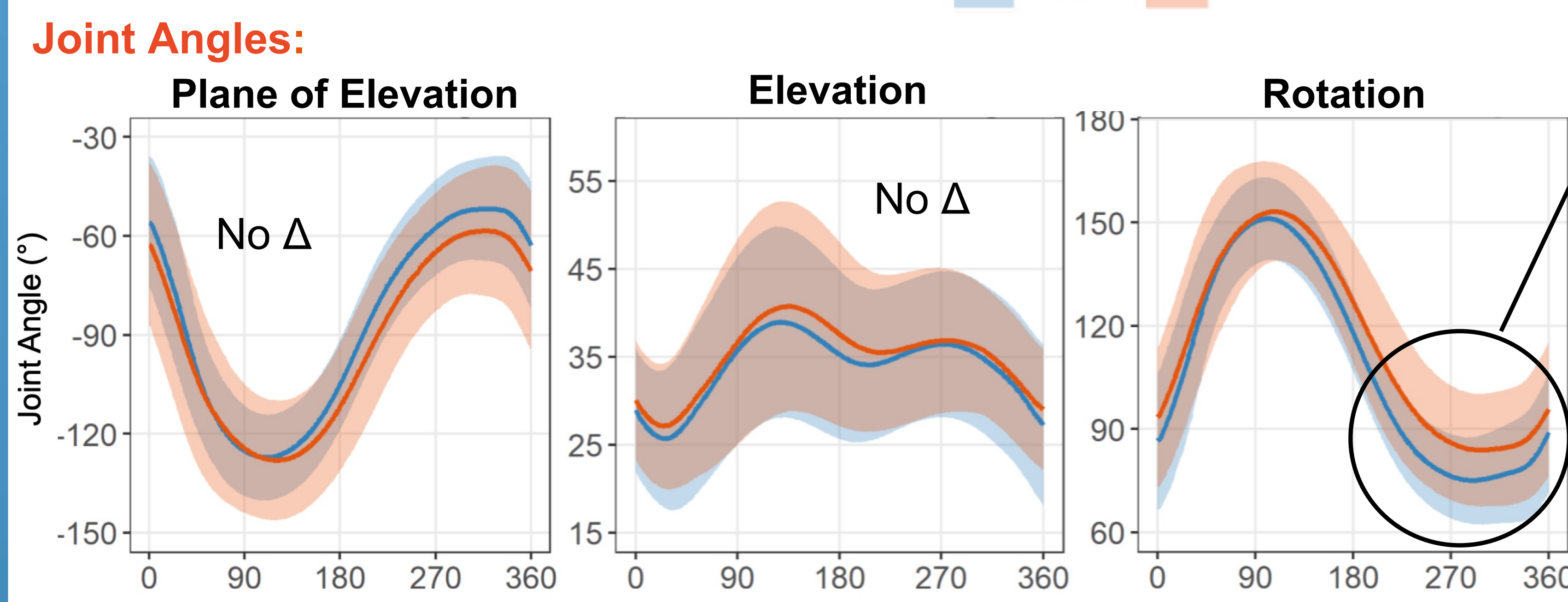


Data reduction and analysis:

- Kinematics: smoothed (moving average, window size = 0.25*n) and filtered (Butterworth, ω_n = 10 Hz)
- Kinetics: filtered (Butterworth, ω_n = 8 Hz)
- Minimum and maximum joint angles, mean joint torques compared between and during exercise
- If normally distributed: paired t-test. Otherwise, Wilcoxon signed-ranks test (α = 0.05)

4. Key findings

Joint Angles:

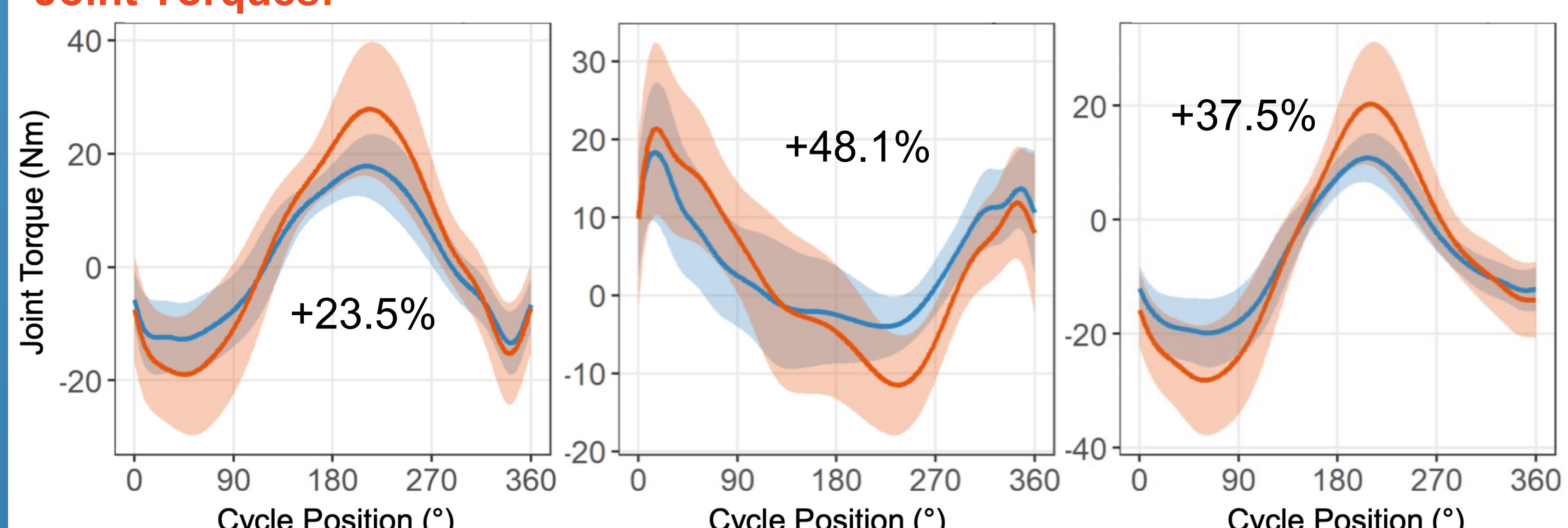


Minimum rotation was higher in HIIT than MICT at TPs 1, 4, 5, 6 ($p < 0.05$)

Compared rotation angle to TP1:

	2	3	4	5	6	Δ_{max}
MICT min	***	**	**	***	**	4.6°
HIIT min			*	*	**	1.7°
MICT max		*	**	**	*	3.1°

Joint Torques:



- Higher in HIIT compared to MICT
- Largest increase found in elevation torque
- Mean plane and rotation increased during MICT
- Mean elevation increased during HIIT

Compared to TP1:

Plane of Elevation:

	2	3	4	5	6	Δ_{max}
MICT					***	1.2 Nm
HIIT						

Elevation:

	2	3	4	5	6	Δ_{max}
MICT						
HIIT			*	*	**	1.9 Nm

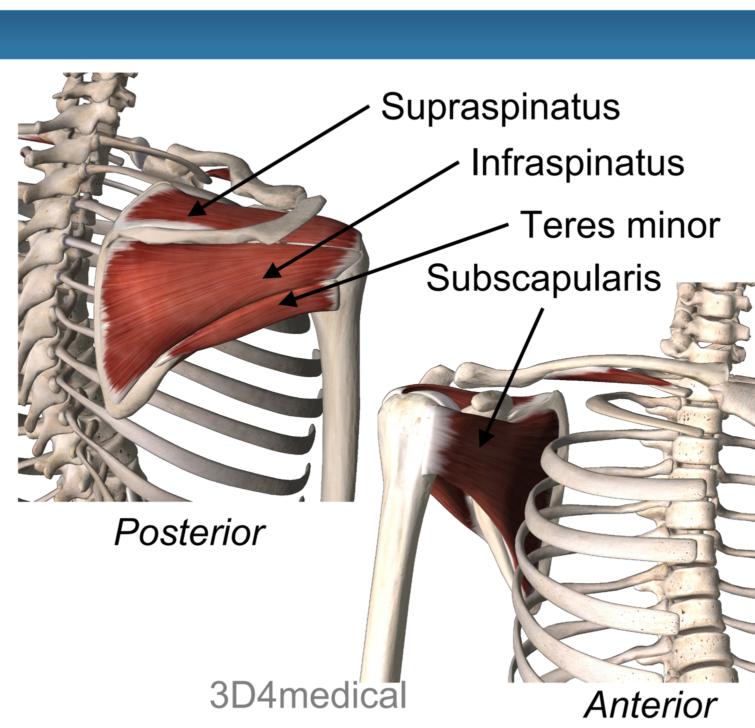
Rotation:

	2	3	4	5	6	Δ_{max}
MICT				*	**	0.74 Nm
HIIT						

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

5. Conclusions

- Different rotation kinematics in HIIT could be driving torque differences
- Higher torques in HIIT suggest higher rotator cuff strain, especially in the supraspinatus (shoulder elevator)
- Changes within exercise protocols indicate different fatigue states (MICT: changes in plane and rotation torques, HIIT: changes in elevation torque), although minimal
- Need to quantify individual soft tissue loads more thoroughly to understand rotator cuff injury risk



Limitations: Athletic population may not reflect general SCI population
Future study: Examine muscle forces using collected EMG data and static optimization of musculoskeletal model

References

[1] Nash+, 2007, *Arch Phys Med Rehab* [2] Subbarao+, 1995, *J Spinal Cord Med* [3] Jahanian+, 2020, *J Spinal Cord Med* [4] Nightingale+, 2017, *Arch Phys Med Rehab* [5] Arnet+, 2012, *J Rehab Med* [6] Warner+, 2012, *Hum Mov Sci* [7] Bourne+, 2009, *J Biomech Engr* [8] Wu+, 2016, *J Biomech.* Some figures created with BioRender.com

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TBL website, additional data