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High-Intensity Load Influences Wearable Ultrasound Muscle Coordination Metrics: Implications for Injury Monitoring in Warfighters

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Disclosure

Dr. King is affiliated with a commercial enterprise, Myokinetics, INC, for wearable ultrasound technology

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Overuse Injuries & Operational Readiness

Overuse Injury Burden

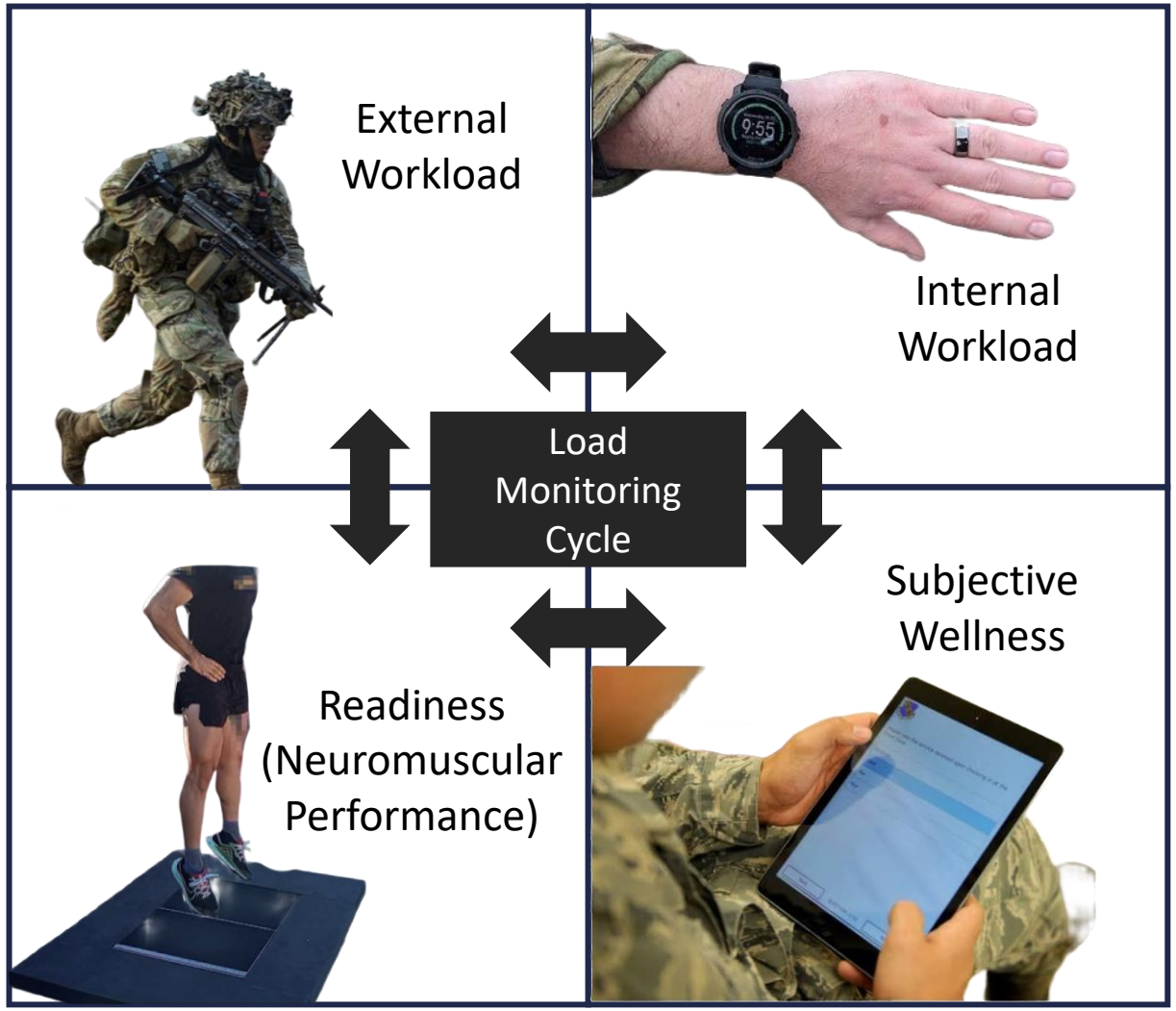
- 82% of DoD musculoskeletal injuries are overuse-related, not acute trauma
- Stress fractures affect up to 20% of women and 6% of men in initial training

Cost to Readiness

- 4M+ lost duty days DoD-wide (2019)
  - 10.7M days limited in the Army alone (2017)
- Leading cause of non-deployability (~65% of medically non-deployable soldiers)

Load monitoring flags cumulative overuse risk before it manifests as injury, enabling targeted rest or load adjustment

The Workload Monitoring Paradigm



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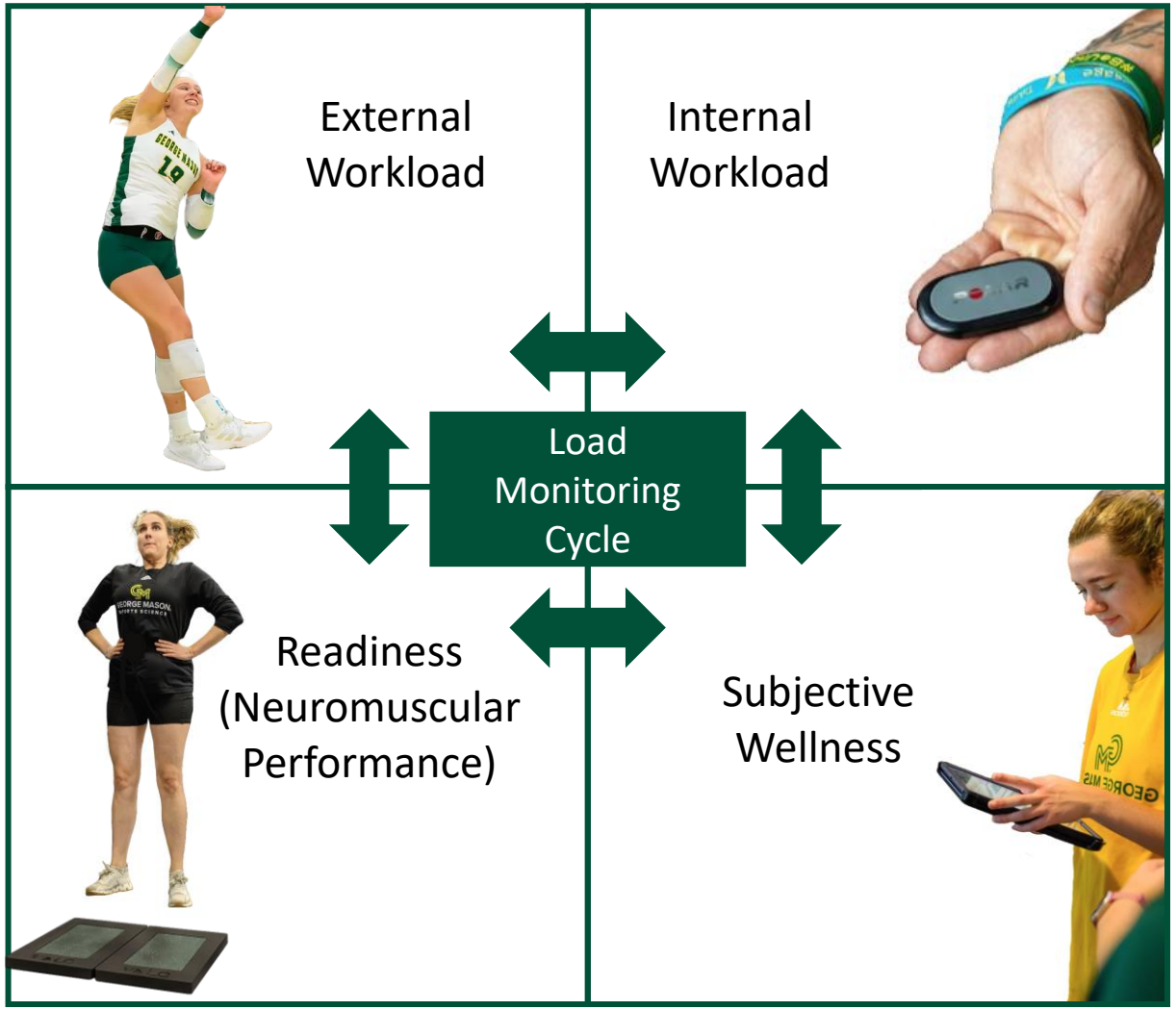

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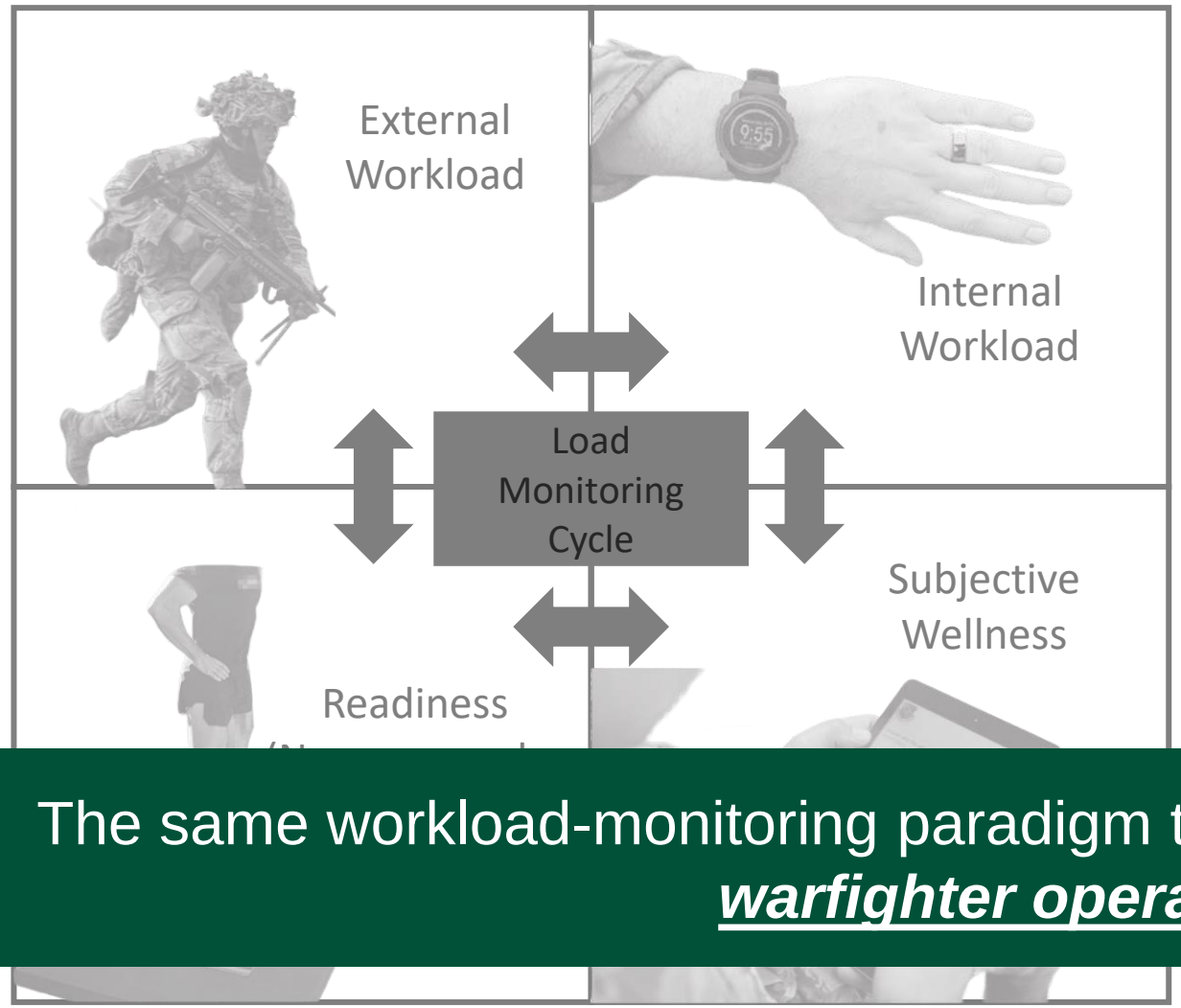
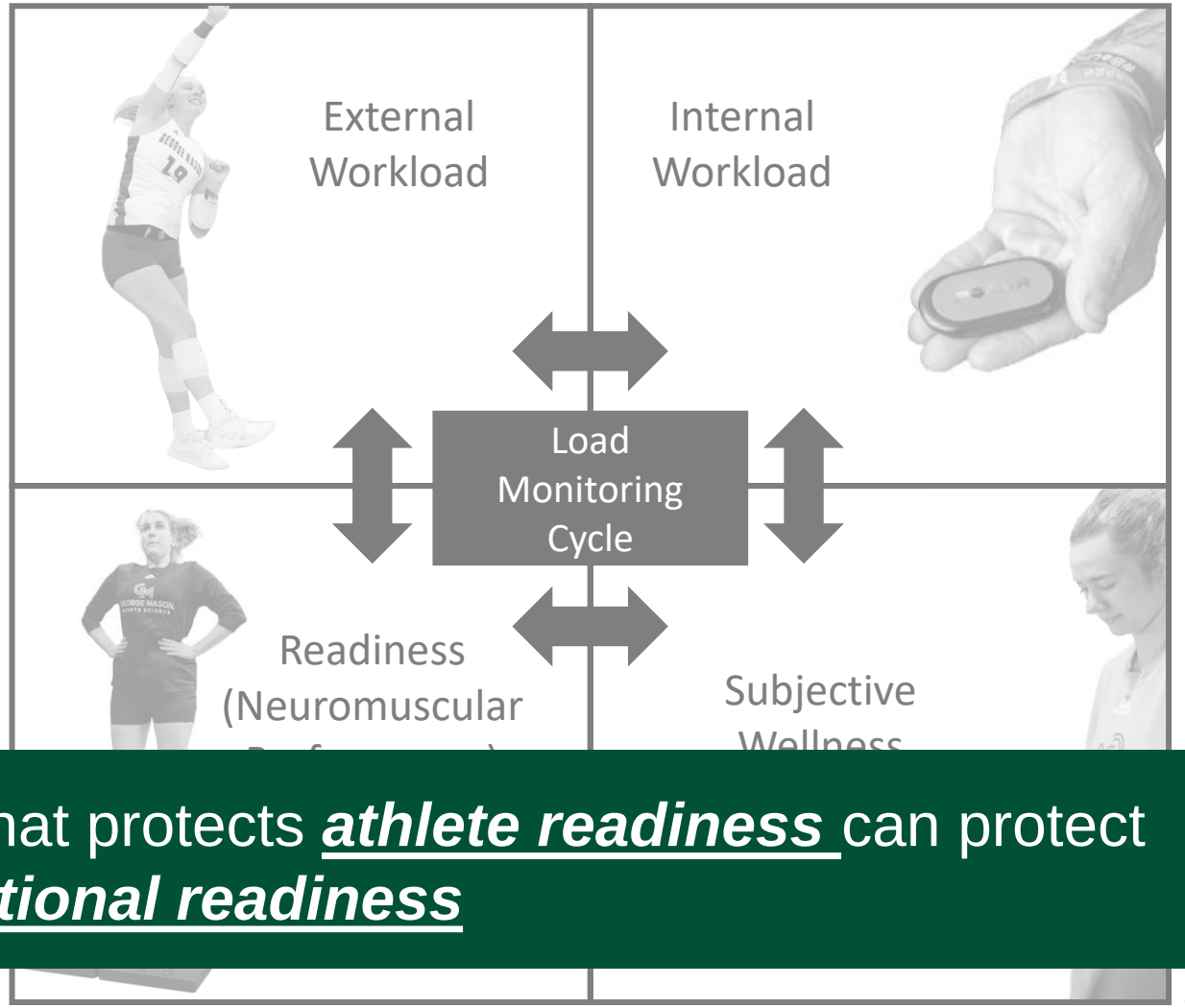




The same workload-monitoring paradigm that protects ***athlete readiness*** can protect ***warfighter operational readiness***

Collegiate Athletes as a Military-Adjacent Population

Jump & Landing Volume

- Athletes: practice/competition reps
- Warfighters: airborne ops, obstacle courses

Sustained High-Impact Training

- Athletes: 16-week competitive season
- Warfighters: sustained tactical training cycles

Injury Mechanism

- Both: repetitive-load knee & lower-extremity overuse injury

A validated proxy population for studying load-driven neuromuscular injury risk in warfighters

Injury Mechanism: Quadriceps Coordination & Knee Stability

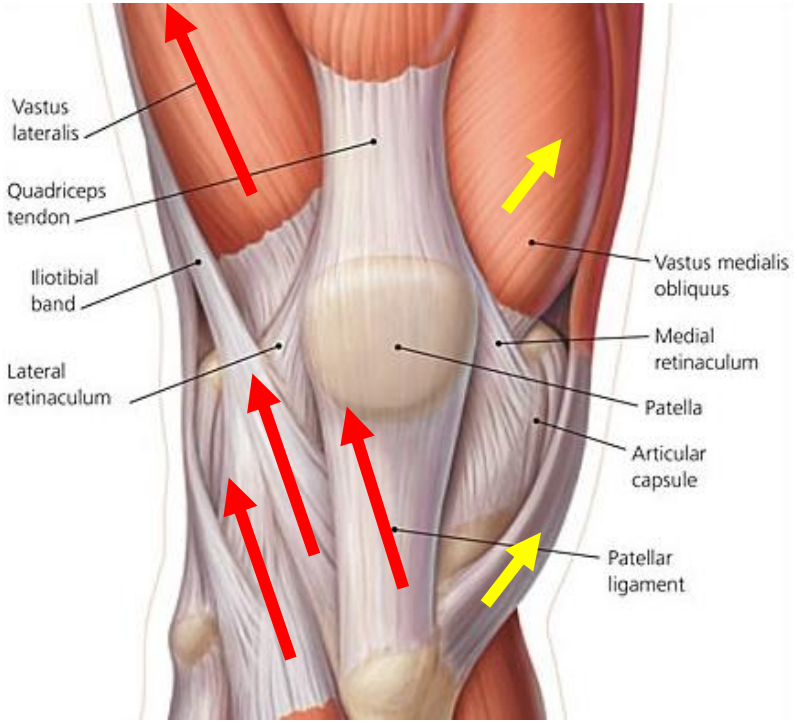
The Coordination Deficit

- Repetitive jump-landing load disrupts coordination between the vastus lateralis (VL) and vastus medialis oblique (VMO)
- VL dominance overpowers VMO, pulling the patella laterally and altering tracking

The Consequence

- Abnormal patellar tracking drives patellofemoral pain syndrome
  - One of the most common overuse knee conditions in jump-landing populations
- Left undetected, this asymmetry progresses toward broader knee instability and injury

Patella Femoral Pain Syndrome



Lateral Medial

Longitudinal Load Monitoring Study Design

External Workload

High Intensity Jumps (JC20)
Moderate Jumps (JC15)
Elevated Landings
Session Intensity

Internal Workload

BORG CR-10 Scale

0	Nothing at all	
0.3		
0.5	Extremely weak	Just noticeable
0.7		
1	Very weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	Heavy
6		
7	Very strong	
8		
9		
10	Extremely strong	"Maximal"

Session Rating of Perceived Exertion (sRPE)

Subjective Wellness

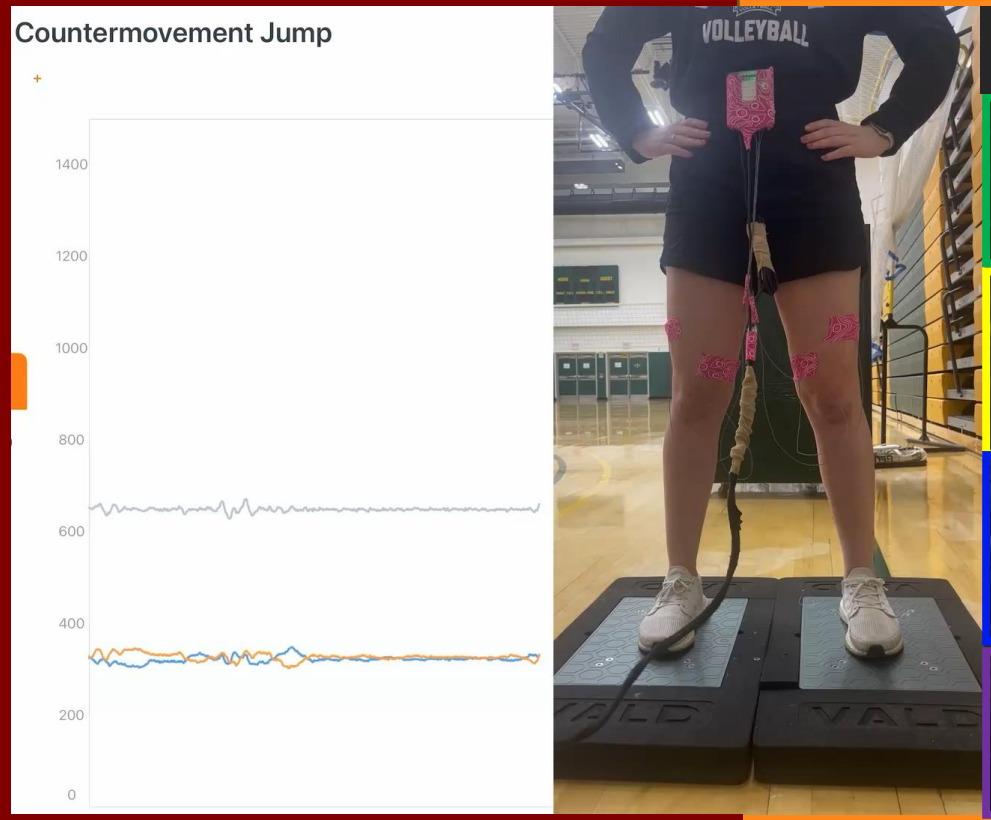
Perceived Recovery Status Scale (PRSS)	
Rating	*Description*
10	Very well recovered/Highly energetic
9	
8	Well recovered/Somewhat energetic
7	
6	Moderately recovered
5	Adequately recovered
4	Somewhat recovered
3	
2	Not well recovered/Somewhat tired
1	
0	Very poorly recovered/ Extremely tired

Overall Soreness Scale (OSS)	
Rating	*Description*
0	No soreness
1	Very light soreness
2	Moderate soreness
3	Light (weak) feeling of soreness
4	
5	Heavy (strong) feeling of soreness
6	
7	
8	Very heavy feeling of soreness
9	
10	Maximal soreness

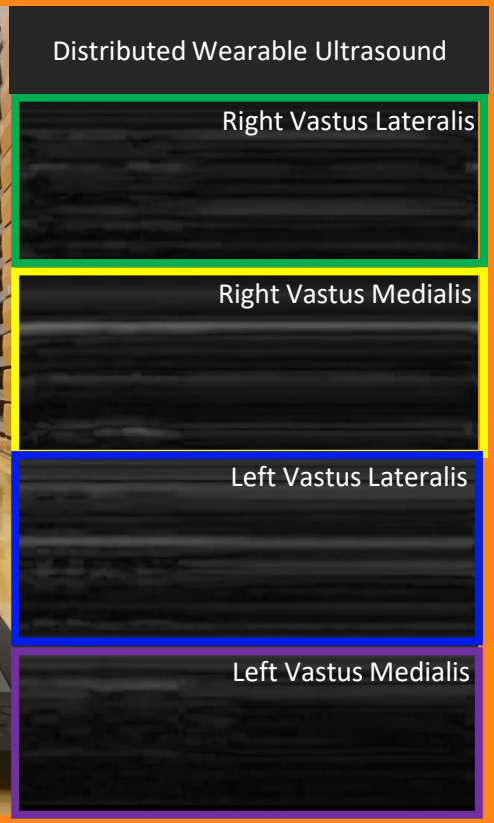
Overall Fatigue Scale (OFS)	
Rating	*Description*
0	No fatigue
1	Very light fatigue
2	Moderate fatigue
3	Light (weak) feeling of fatigue
4	
5	Heavy (strong) feeling of fatigue
6	
7	
8	Very heavy feeling of fatigue
9	
10	Maximal fatigue

Perceived Recovery (PRSS), Soreness (OSS), Fatigue (OFS)

Neuromuscular Performance Testing



Jump height (JH)
Reactive Strength Index Modified (RSImod)
Concentric Impulse (CIMPS)
Concentric Mean Force (CMFS)
Concentric Mean Force (EMFS)
Force at Peak Power (FPPS)
Take-off Peak Force (TPFS)

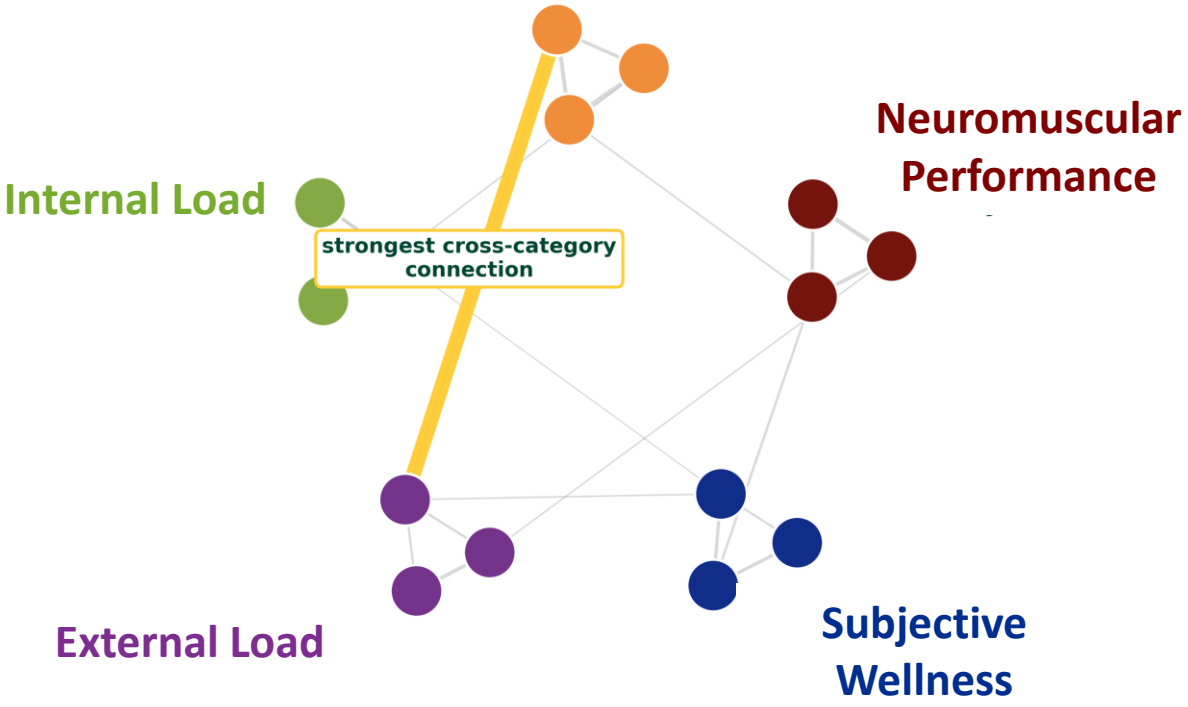


Symmetry metrics derived for timing and contraction strength were:
right VL/VMO (TSRVLVMO, CSRVLVMO)
left VL/VMO (TSLVLVMO, CSRVLVMO)
bilateral VL (TSRLVL, CSRLVL)
VMO (TSMRLVMO, CSRVLVMO)

30 players (15 male, 15 female) x 16-week competitive season

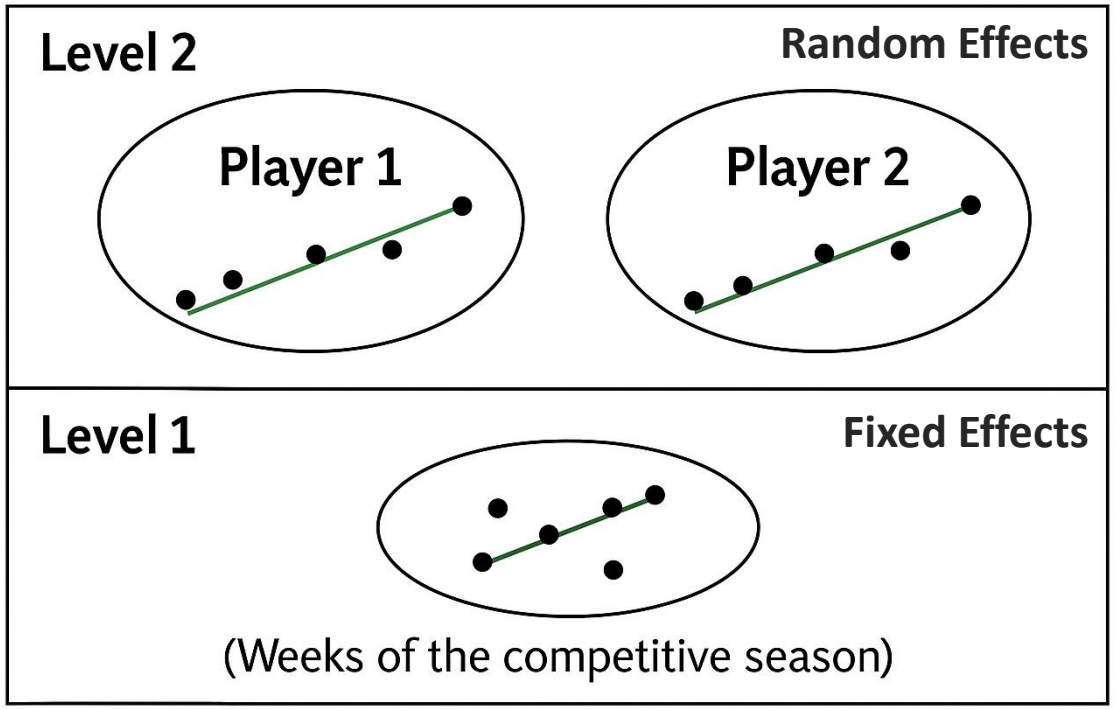
Statistical Methods – Longitudinal Analysis

Network Analysis



Shows relationships between variables

Hierarchical Linear Modeling (HLM)

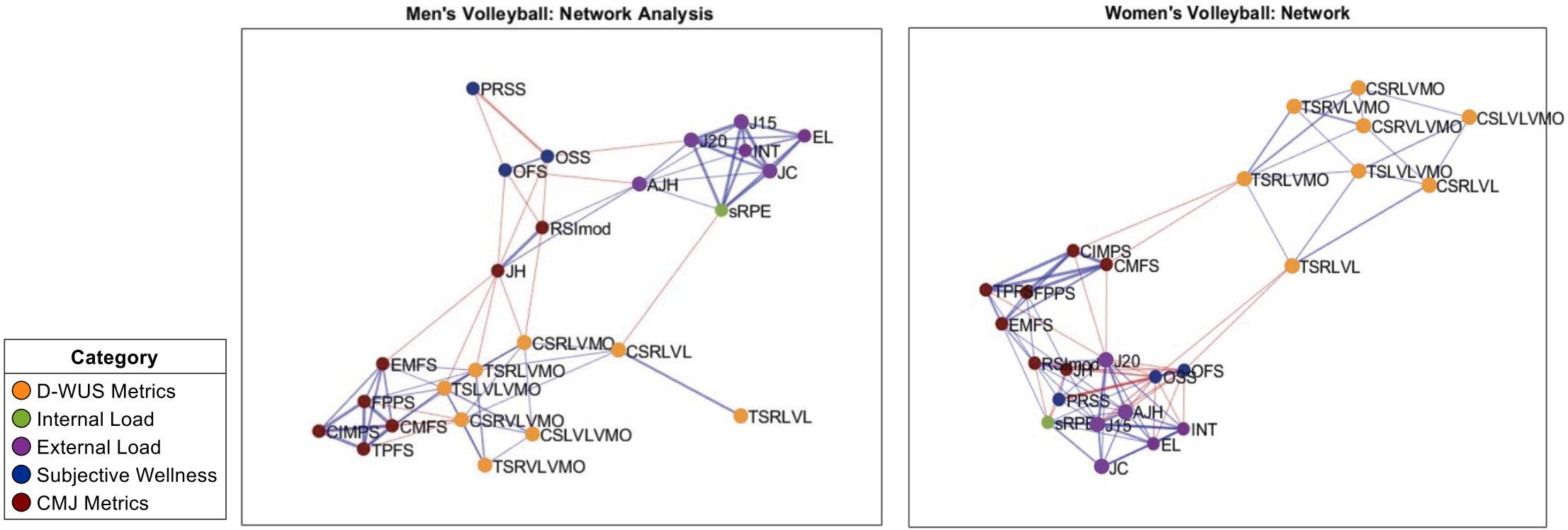


Tests whether a specific predictor significantly explains a specific outcome over time

Analysis conducted in R Studio

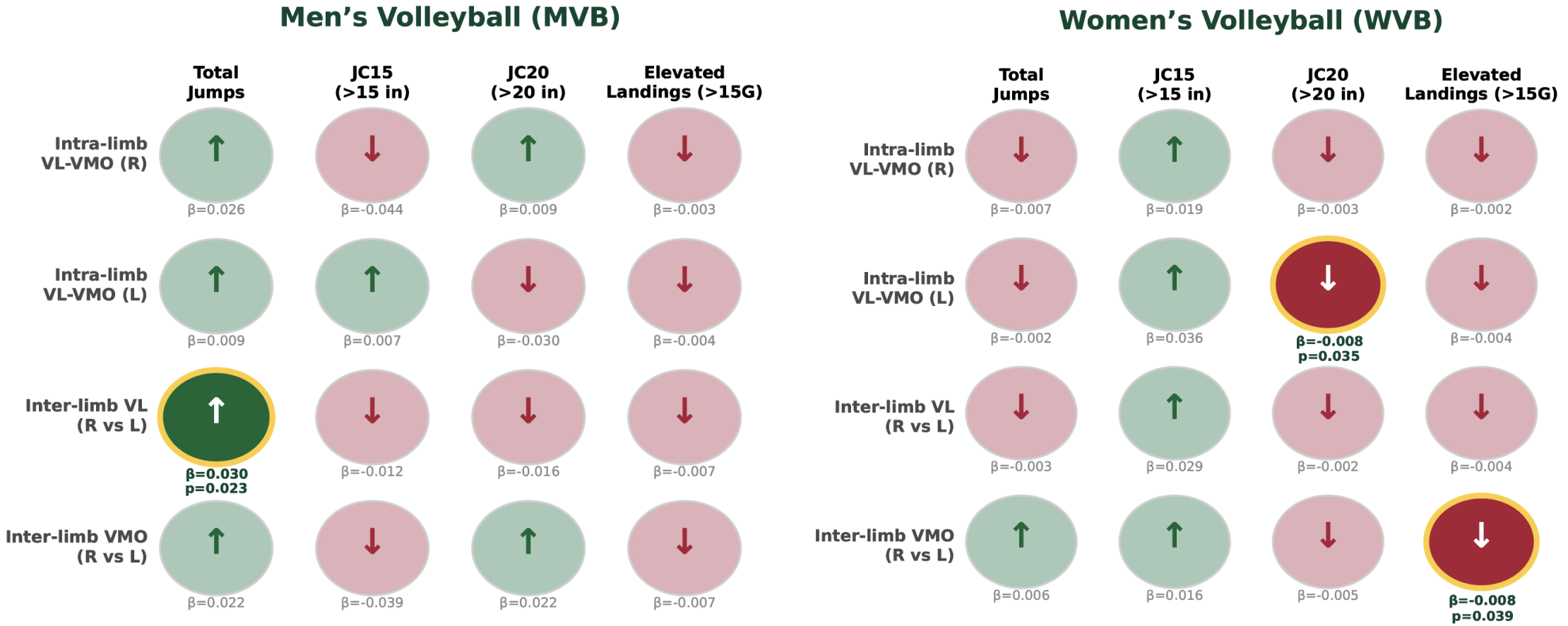
Results – Network Analysis

- Women's Volleyball: D-WUS metrics form a distinct, tightly-connected cluster
- Men's Volleyball: symmetry metrics are loosely, unevenly connected



Results: Hierarchical Linear Modeling

Does workload predict changes in wearable ultrasound symmetry?



↑ Total Jumps = ↑ inter-limb VL BSI

↑ JC20 and elevated landings = ↓ reduced BSI

Conclusion and Significance

- High-intensity load drives a sex-specific, subclinical VL-VMO coordination deficit, detectable via D-WUS before clinical injury appears
- Evidence is strongest and most consistent in women
- This sex-specific vulnerability is directly relevant to warfighter readiness, given expanding roles for women across military occupational specialties
- ***Wearable Ultrasound + load monitoring offers a fieldable, real-time platform for injury surveillance, threshold-based intervention, and return-to-duty decisions***

Thank you!

Principal Investigators

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Longitudinal Load Monitoring Study Design

30 players (15 male, 15 female) x 16-week competitive season

External Load
Jump loads measured with IMUs

Internal Load
Session RPE (sRPE)

Week 1 – Pre-Season
Week 2 – Pre-Season
Week 3 – Pre-Season
Week 4 – Regular Season
Week 5 – Regular Season
Week 6 – Regular Season
Week 7 – Regular Season
Week 8 – Regular Season
Week 9 – Regular Season
Week 10 – Regular Season
Week 11 – Regular Season
Week 12 – Regular Season
Week 13 – Regular Season
Week 14 – Regular Season
Week 15 – Regular Season
Week 15 – Regular Season
Week 16 – Regular Season

Days 1 - 7
- External Load
- Internal Load

Week 1 – Pre-Season
Week 2 – Pre-Season
Week 3 – Pre-Season
Week 4 – Regular Season
Week 5 – Regular Season
Week 6 – Regular Season
Week 7 – Regular Season
Week 8 – Regular Season
Week 9 – Regular Season
Week 10 – Regular Season
Week 11 – Regular Season
Week 12 – Regular Season
Week 13 – Regular Season
Week 14 – Regular Season
Week 15 – Regular Season
Week 15 – Regular Season
Week 16 – Regular Season

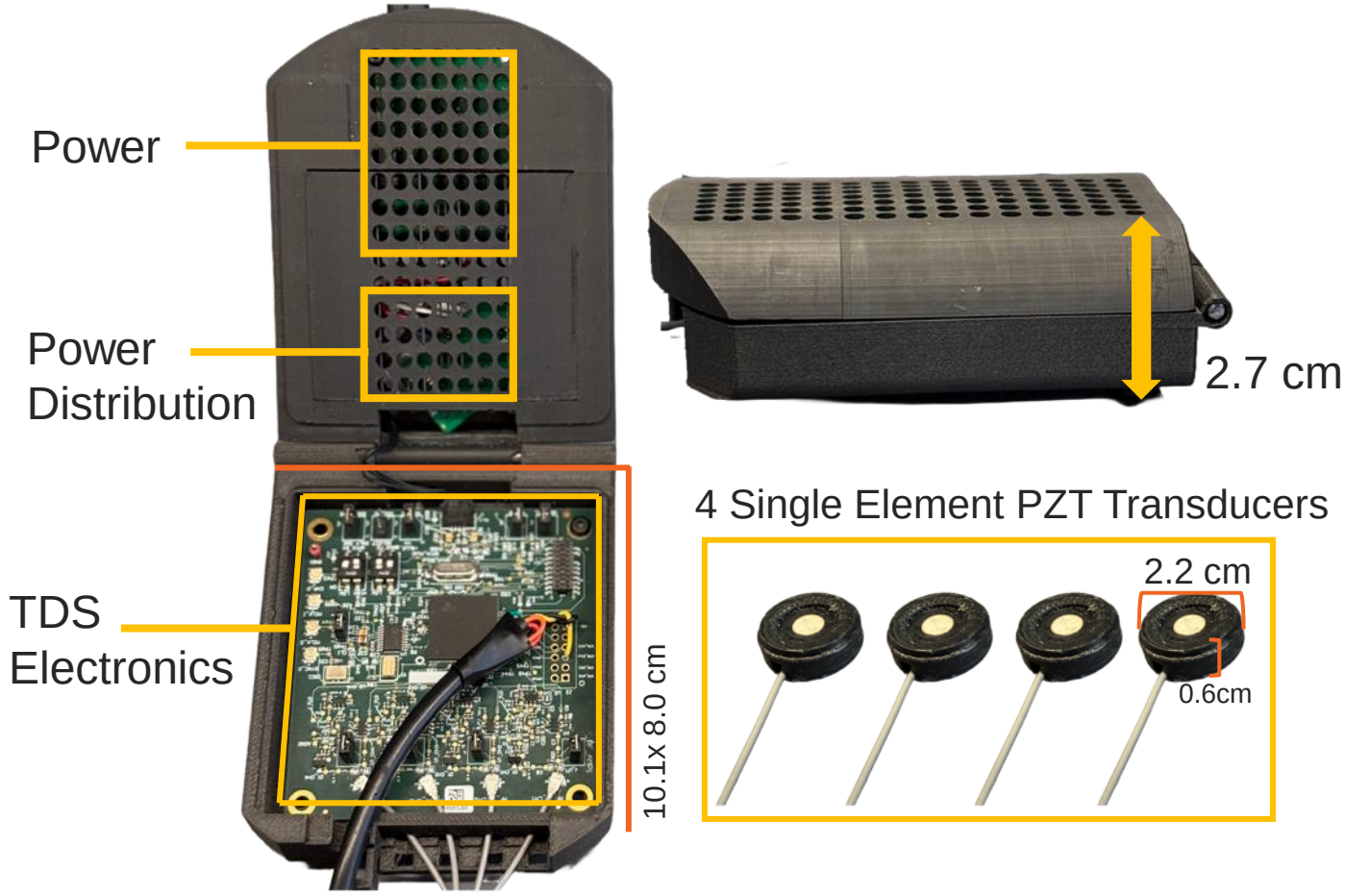
Day 7
- Neuromuscular Performance
- Self-Reported Wellness

Neuromuscular Performance
Countermovement Jumps
Wearable Ultrasound

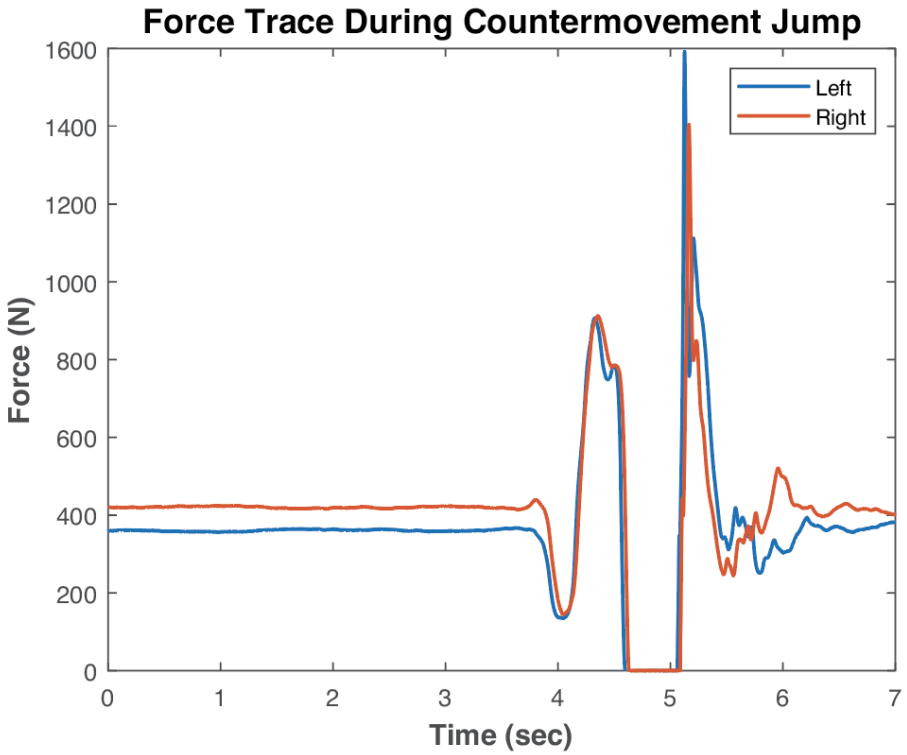
Self-Reported Wellness
Perceived Recovery
Soreness
Fatigue

Time Delay Spectrometry

- Time Delay Spectrometry
  - Low voltage, long duration transmit chirps
  - Time delay encoded in frequency
  - Signal processing to extract depth
- Benefits:
  - Lower sampling rates (kHz)
  - Simpler wearable design 4-channel M-mode design
  - ***Multi-Site Imaging during complex movements***



Neuromuscular Performance: Tissue Level Outcomes



D-WUS Image with CF-PCA Signal