Sensorimotor Countermeasures (SMC) Head Down Bed Rest (HDBR) Study

Countermeasures for Mitigation of Sensorimotor Decrements Following Head-Down Bed Rest

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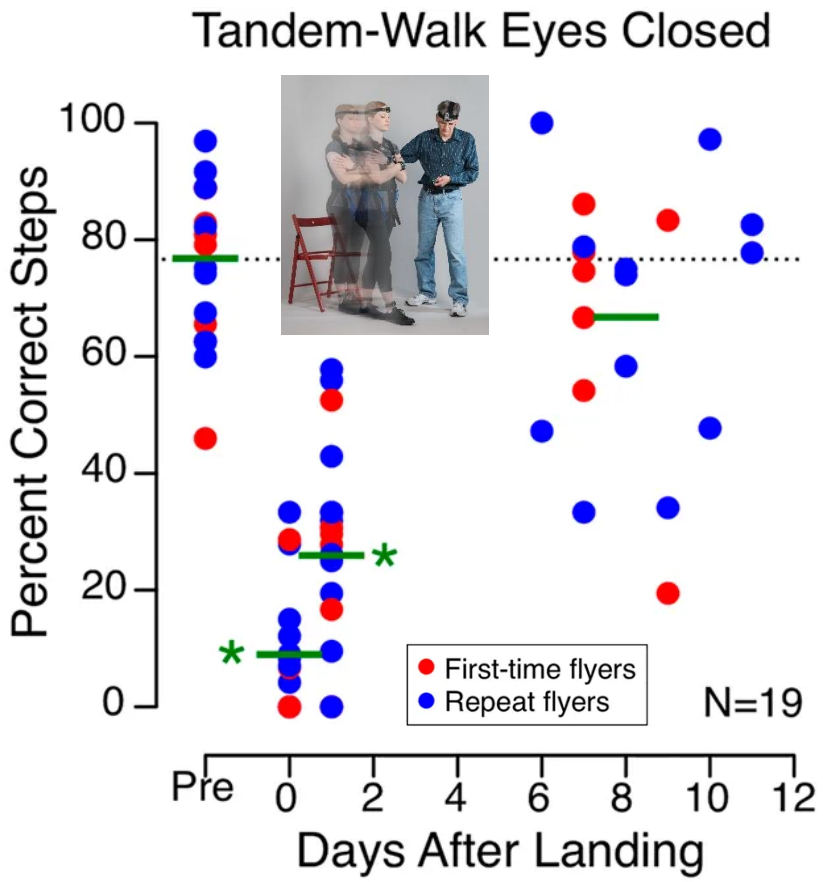
L. R. Bent[3], F. J. Valero-Cuevas[4], L. Oddsson[5,6], E. L. Lawrence[4], N. Strock[7], M. Young[1], J. J. Bloomberg[1], M. Mortreux[2], M. L. Bouxsein[2], A. Beheshti[8,9], T. Abitante[10], D. Newman[10], K. Dunlap[2], G. Cenci[2], A. Sawyer[11], S. J. Wood[1], B. T. Peters[7]

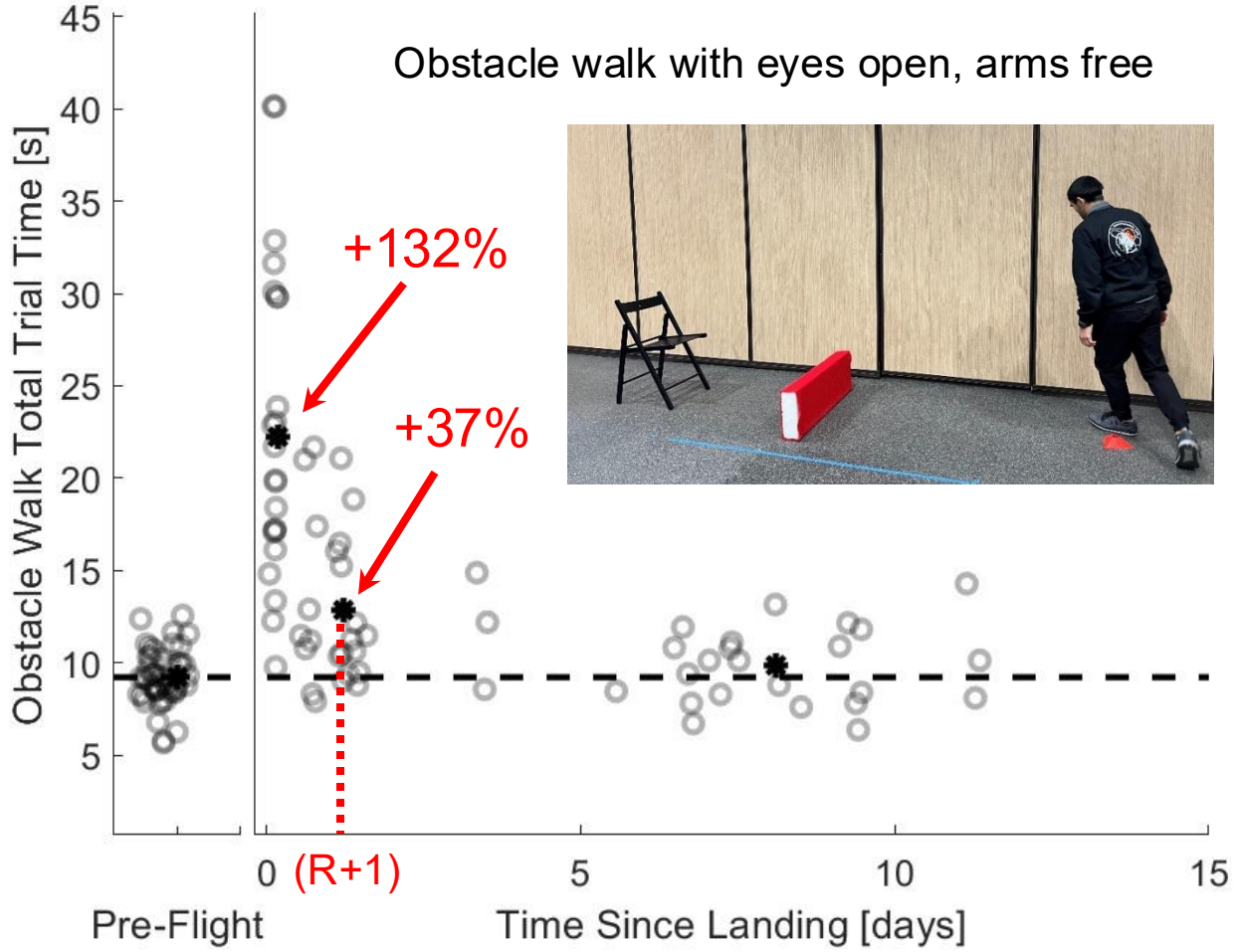
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[3]University of Guelph, Guelph, Ontario, [4]Neuromuscular Dynamics LLC, Glendale, CA, [5]University of Minnesota, Minneapolis, MN, [6]RxFunction Inc., Eden Prairie, MN, [7]KBR, Houston, TX, [8]KBR, Moffett Field, CA, [9]Broad Institute of MIT and Harvard, Cambridge, MA, [10]Massachusetts Institute of Technology, Cambridge, MA, [11]University of California at San Francisco, San Francisco, CA,

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Background

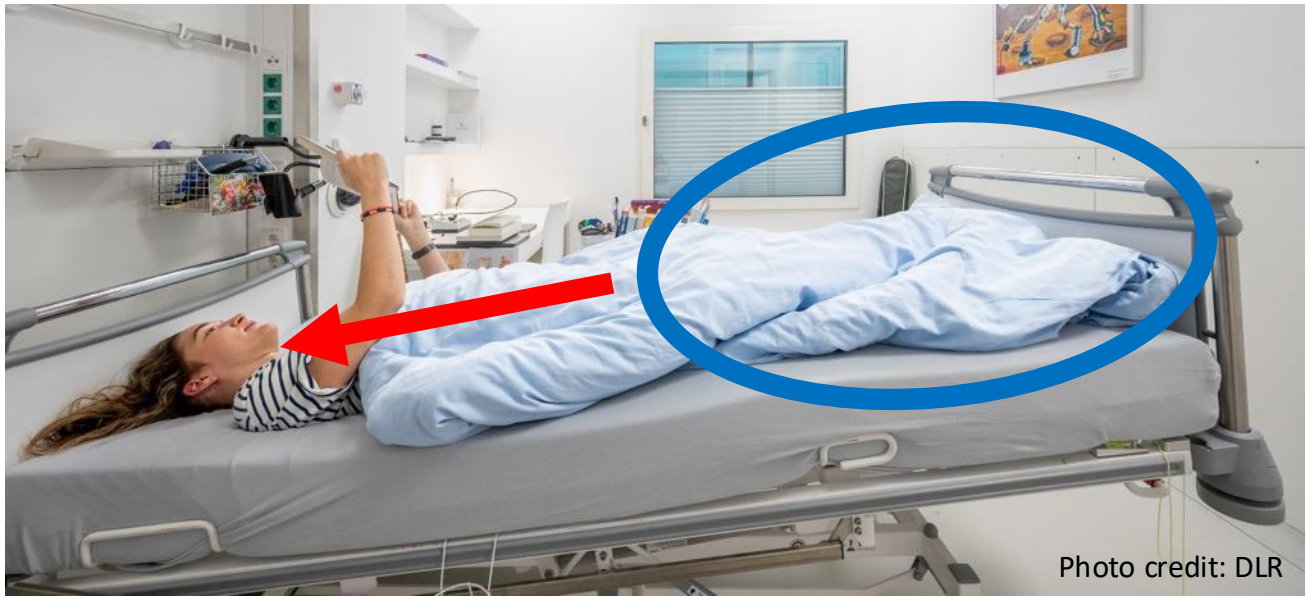
- Current in-flight exercise countermeasures do not fully protect post-flight balance control (Clement et al., 2022), and exploration spaceflight will lack key exercise capabilities (e.g., treadmill).
- Risk to crew health/safety and risk to mission objectives.





Background

- Body unloading-induced sensorimotor deconditioning during spaceflight plays a significant role in post-flight balance impairments[1].
- Head down bed rest (HDBR) is an established analog for spaceflight unloading



1. Mulavara et al., MSSE, 2018

Objectives and Aims

- Objectives: 1) Test the efficacy of in-bed sensorimotor countermeasures for maintaining operationally relevant functional performance and sensorimotor function following 60 days of 6° HDBR.

  2) Explore the factors that contribute to efficacy to refine countermeasures for spaceflight operations.

- Four groups based on countermeasure usage (in four 12-subject campaigns):

1. Control (CON)
2. Electrical Muscle Stimulation (EMS)
3. Proprioception Training (PT)
4. Exercise plus Proprioception Training (EPT)

EMS

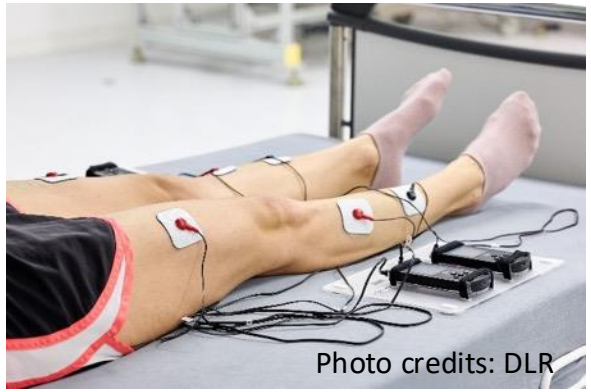


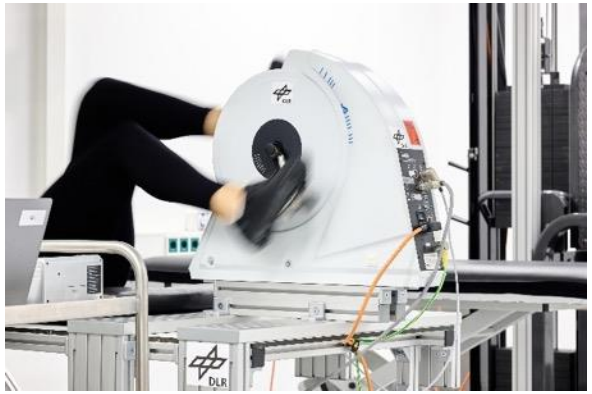
Photo credits: DLR

Proprioception Training



3 days per week
30min per session
~16 trials lasting 60-sec each

Aerobic and Resistance Exercise



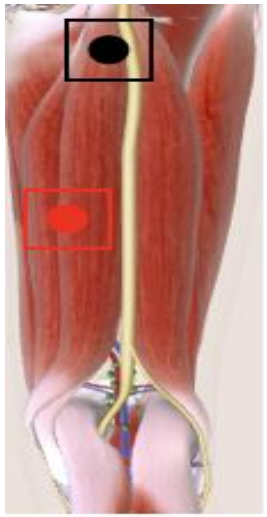
Cycling Aerobic Training (cAT)
6 days per week

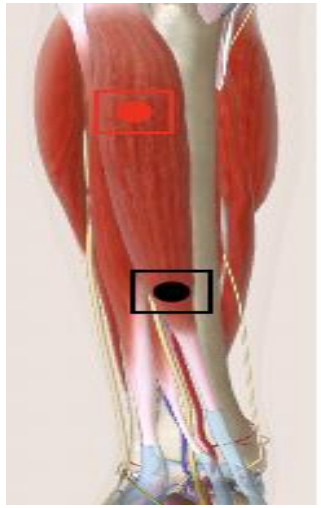


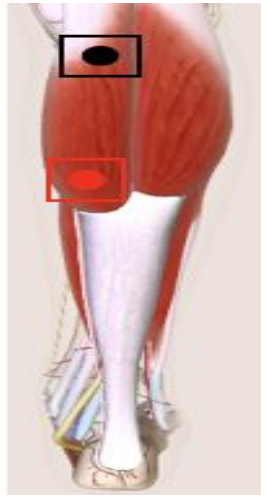
Resistance Training (RT)
3 days per week

EMS











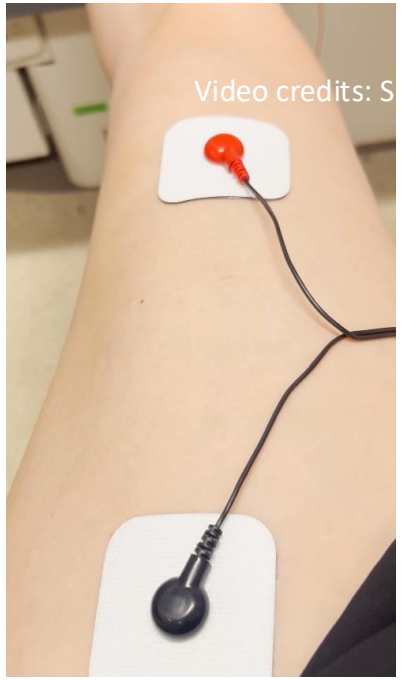
4 muscles stimulated bilaterally

✓ Rectus Femoris

✓ Biceps Femoris

✓ Tibialis Anterior

✓ Gastrocnemius



30 minutes of daily stimulation

Proprioception Training

Goal: Target the activation and control of smaller postural muscles during axial loading to enhance the proprioceptive/tactile contributions to standing balance



Photo credit: DLR

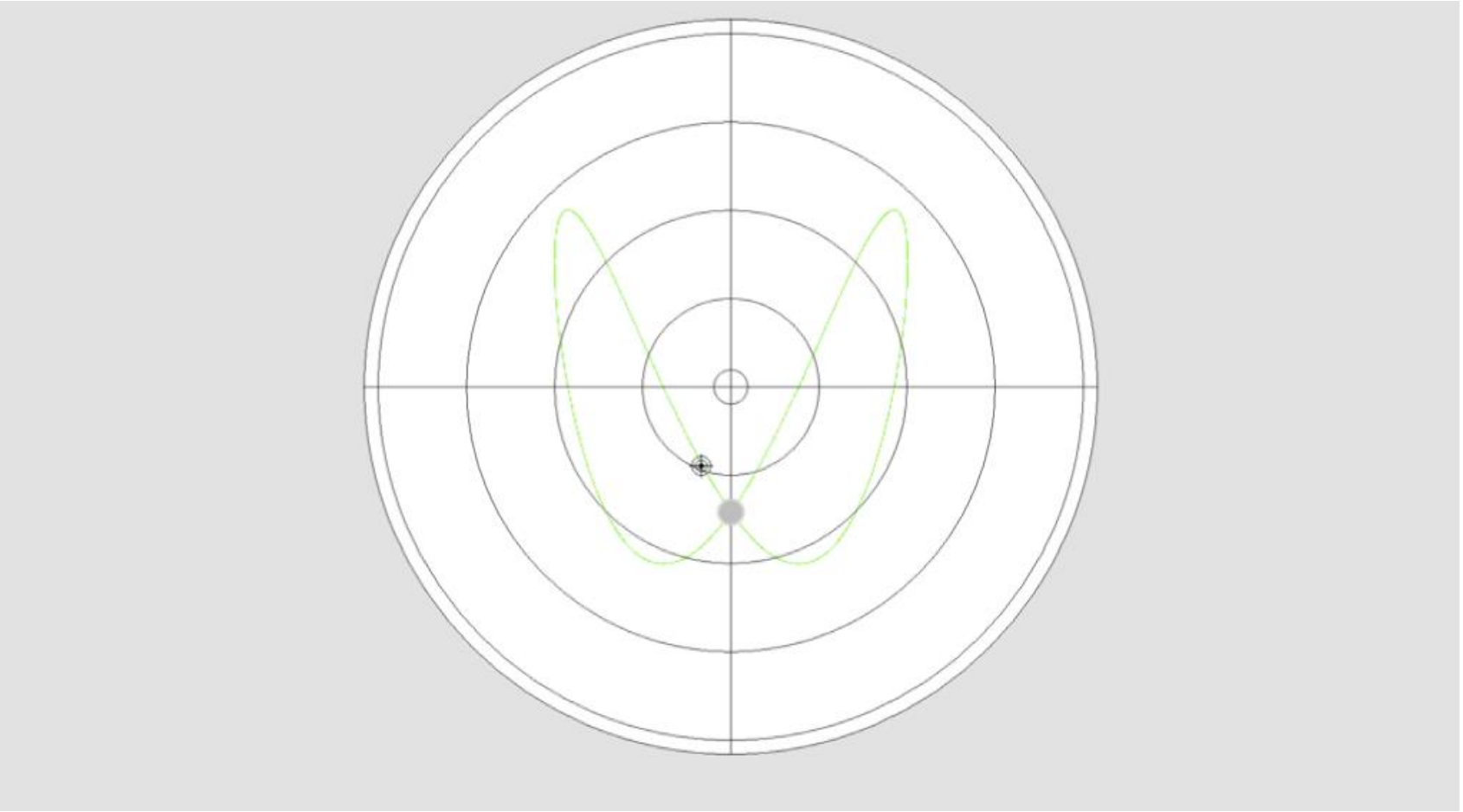


✓ Body loading
✓ Postural challenge
✓ Tactile input
✓ Visual Feedback

Training 3 days per week (26 total sessions) for 30min each session

Proprioception Training

Visual Feedback: Target Following – currently used for countermeasure sessions



Virtual training parameters:

- Tracing Shape
- Shape Size
- Target Speed
- Movement Direction
- Movement “Noise”

Physical training parameters:

- Foot Position
- Body Load

Outcome Measures Overview

*full or partial data share with HRP Standard Measures

	BDC	Throughout HDT	~HDT30	~HDT59	R+0	R+1 (or R+2)	R+4	R+8-12
Functional Performance Tests	X				X	X	X	X
Sensorimotor Tests*	X				X	X	X	X
Proprioception Testing	X		X	X		X	X	X
Foot Sole Skin Sensitivity	X	X				X	X	X
Muscle MRI	X		X	X				
Muscle Ultrasound	X	X						X
Electrical Impedance Myography	X	X						X
Bone Ultrasound	X		X	X				X
Blood Draws (miRNA)	X (CON, EMS)			X (CON, EMS)				X (CON, EMS)
Blood Draws (Markers)*	X		X	X				X
Muscular Function Tests*	X					X		X
Cardiovascular Tests*	X				X			

Campaigns 1 and 2 (out of 4)

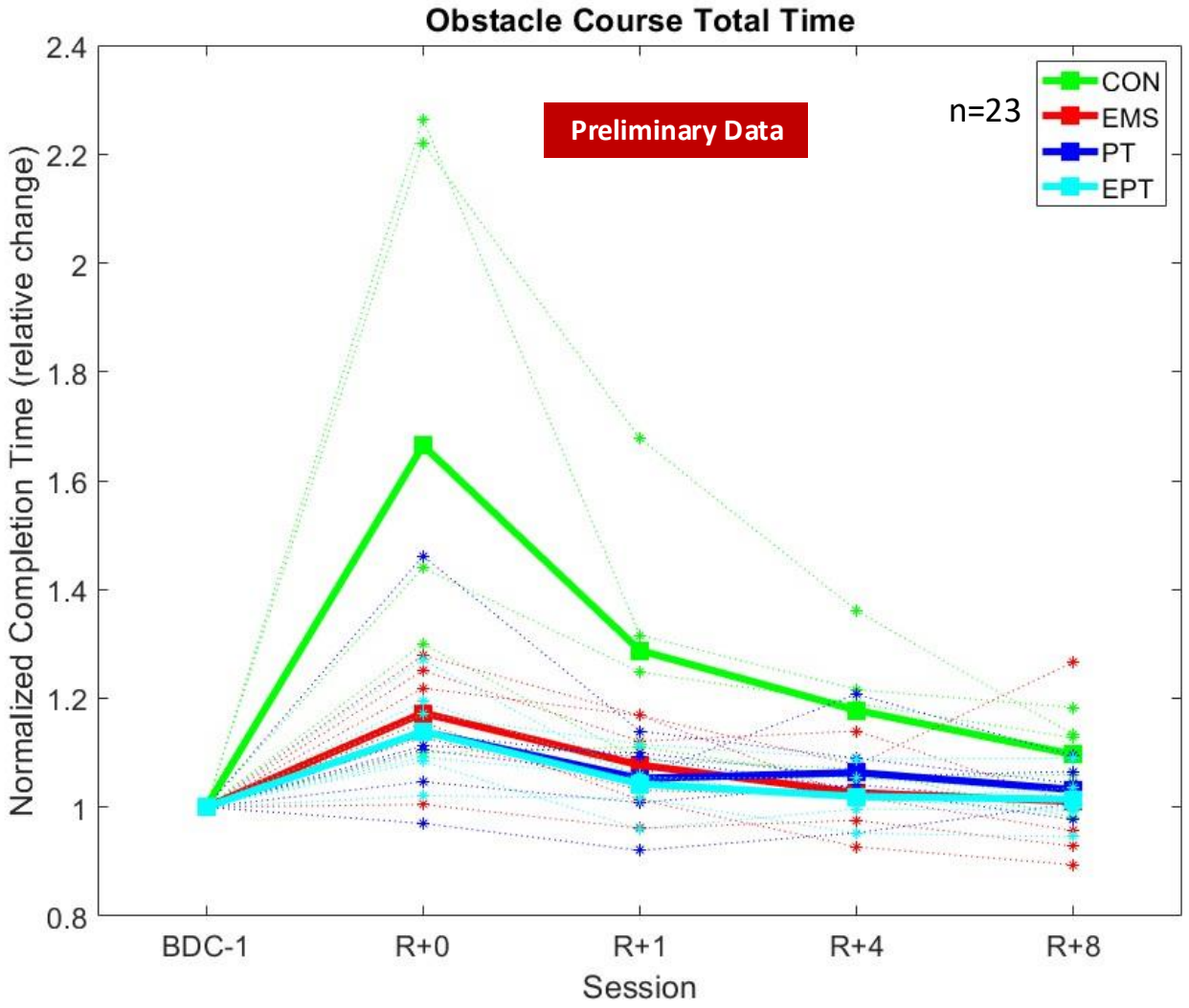
- 23 Subjects (11 female, 12 male, 32.3 ± 6.5 years, 174 ± 9 cm, 67.3 ± 11.7 kg)
  - CON (n=5)
  - EMS (n=6)
  - PT (n=6)
  - EPT (n=6)

Functional Performance Tests – Obstacle Course





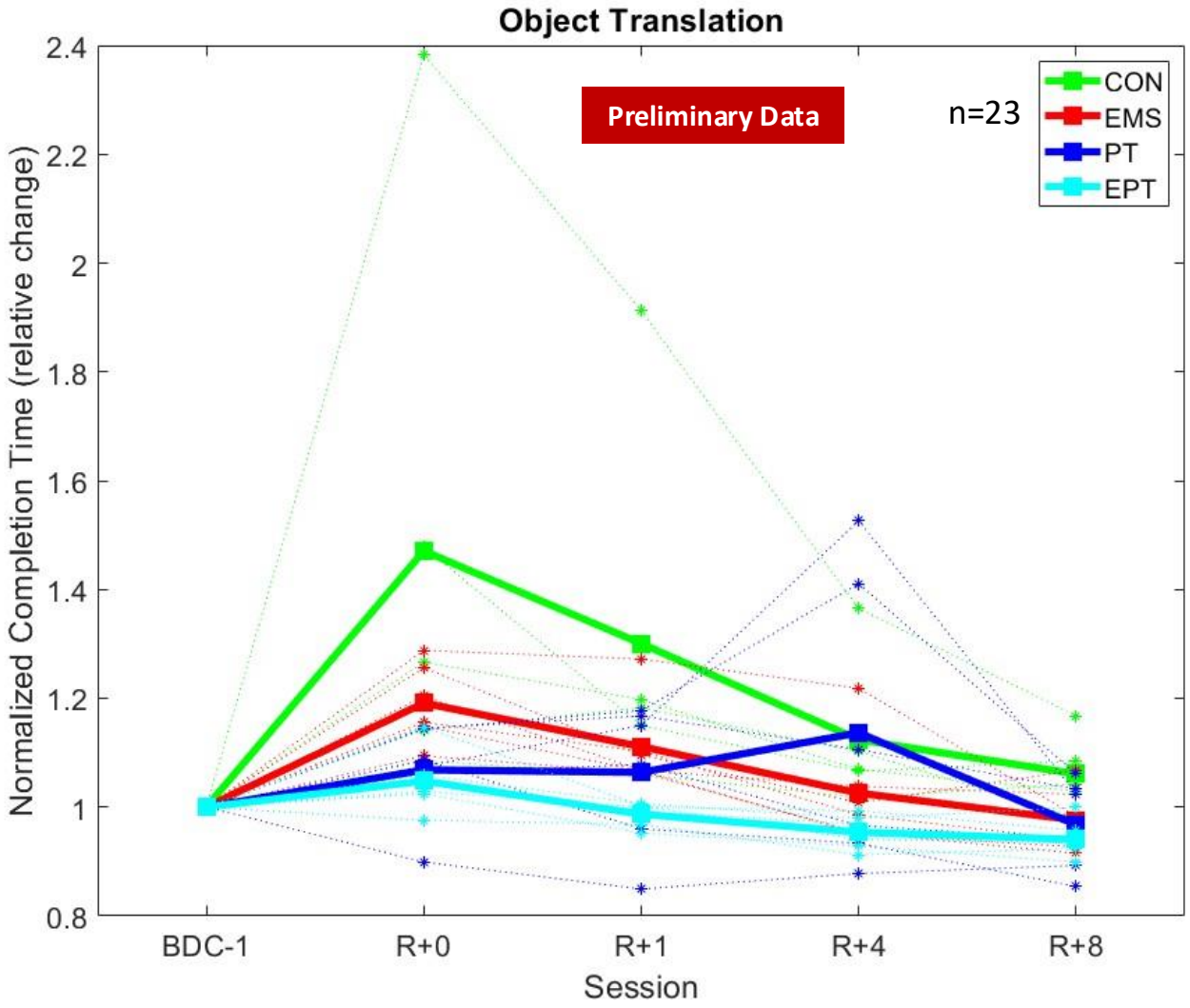




Functional Performance Tests – Object Translation



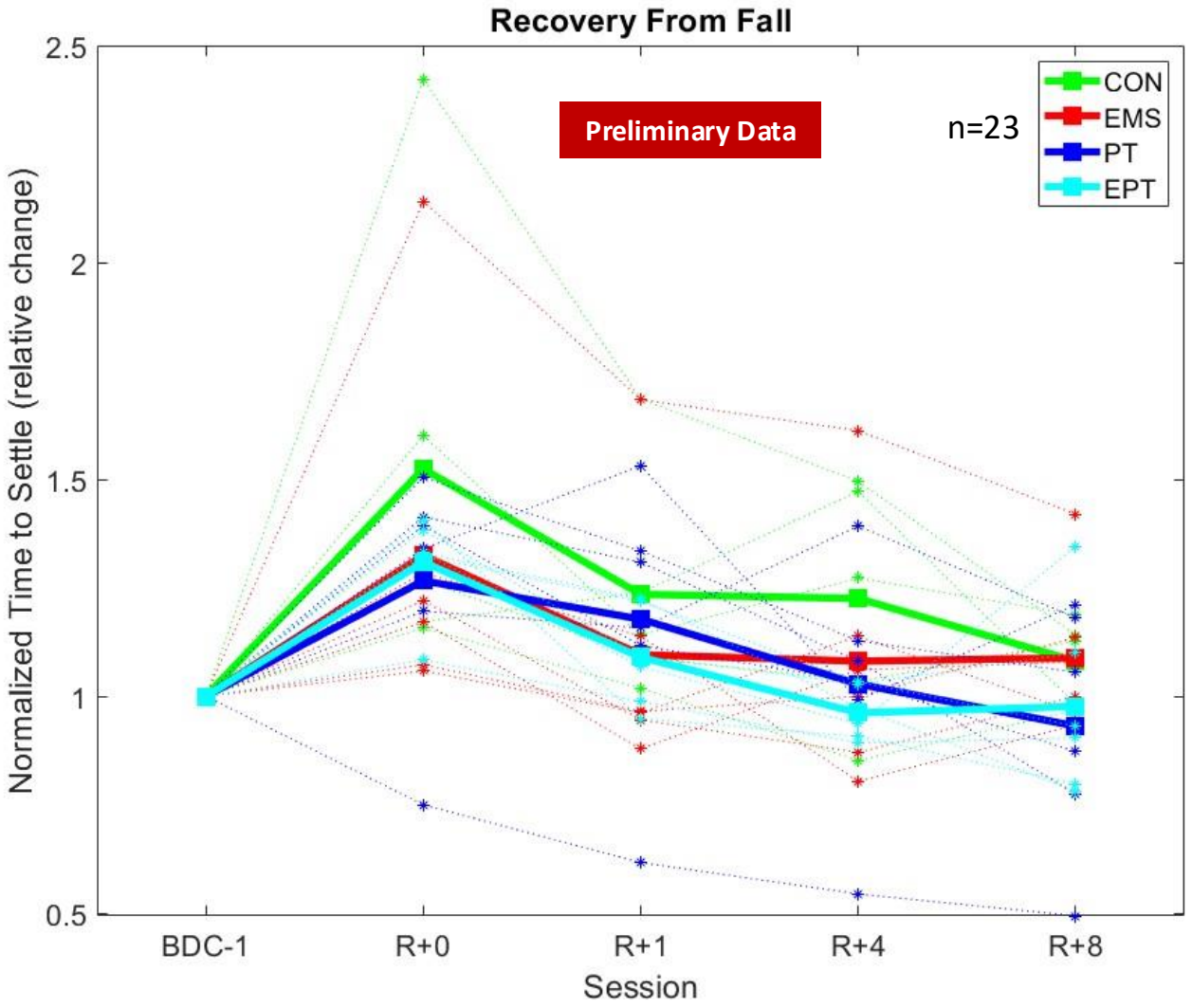




Functional Performance Tests – Recovery from Fall







Preliminary Statistical Analyses

Bayesian mixed-effects model outputs







Group	Vs	Session between	Mean of Ratio	95% CrI		Prob Ratio <1
EMS	vs Control	R+0 vs Pre	0.733	0.607	0.893	0.998
EPT	vs Control	R+0 vs Pre	0.712	0.583	0.856	0.999
PT	vs Control	R+0 vs Pre	0.708	0.587	0.862	0.999
EMS	vs Control	R+0 vs Pre	0.844	0.693	1.038	0.949
EPT	vs Control	R+0 vs Pre	0.743	0.604	0.900	0.997
PT	vs Control	R+0 vs Pre	0.757	0.623	0.930	0.995
EMS	vs Control	R+0 vs Pre	0.878	0.560	1.351	0.720
EPT	vs Control	R+0 vs Pre	0.891	0.566	1.375	0.695
PT	vs Control	R+0 vs Pre	0.845	0.537	1.327	0.770

- Group comparisons show promising countermeasure efficacy (~70-99% Probabilities)
  - However, Credible Intervals are wide, suggesting large uncertainty due to small sample sizes
- Based on a simulation analysis, increasing the sample size is projected to significantly improve both the probability of countermeasure effectiveness, and the uncertainty around the estimated effects
- Previous Control data will be used to refine the models

Proprioception Testing - UPRITE

- Inflight sensorimotor assessment tools are needed for tracking changes over time and predicting postflight functional performance limitations[1]
- These assessments use a Target Capture Task approach.

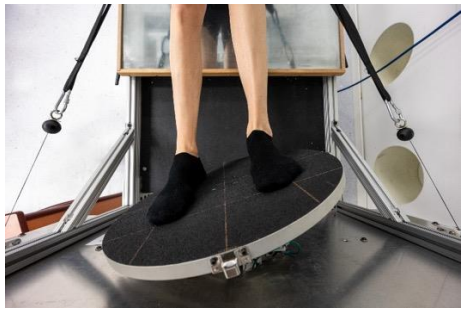
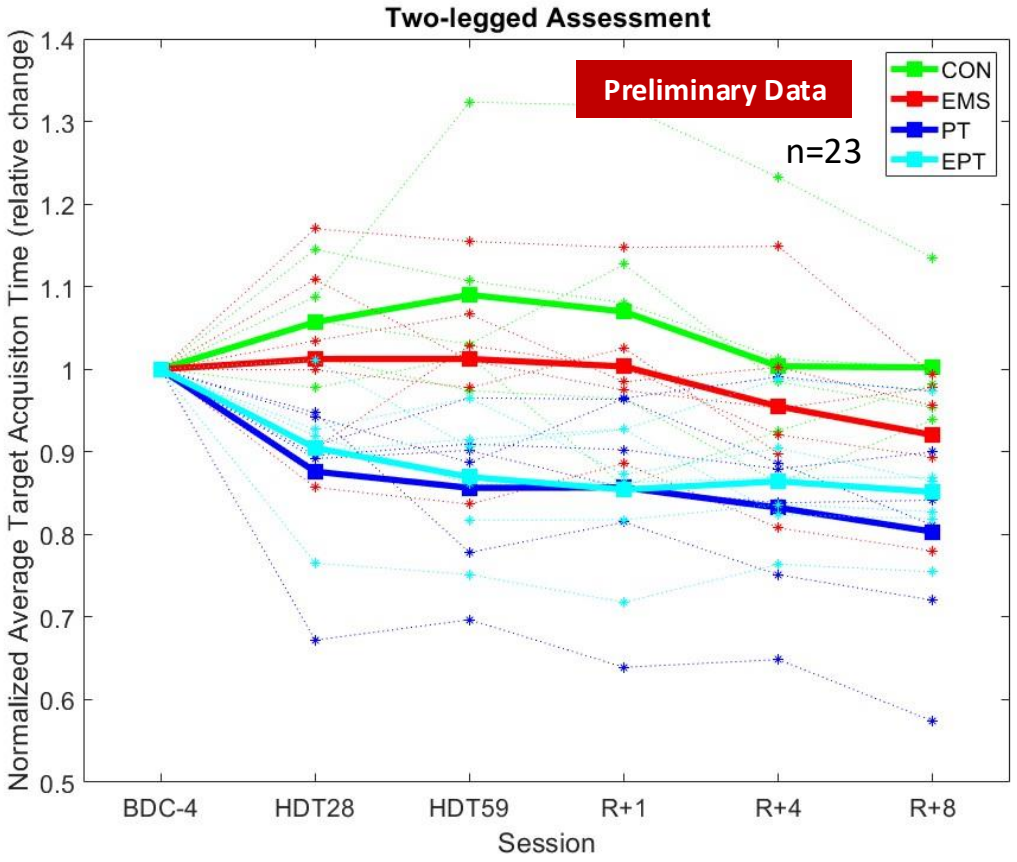
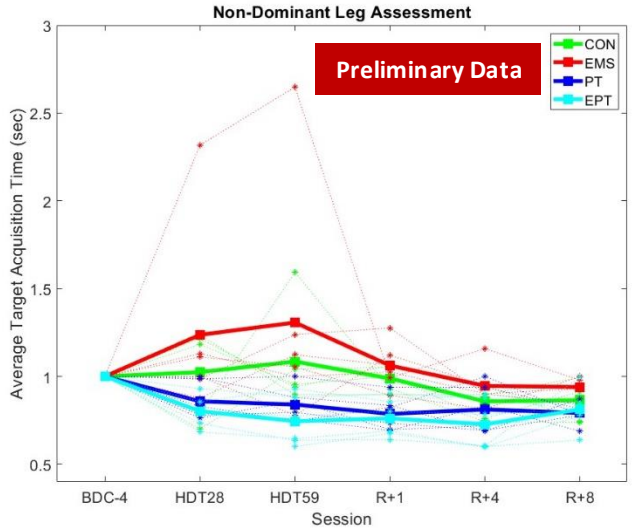
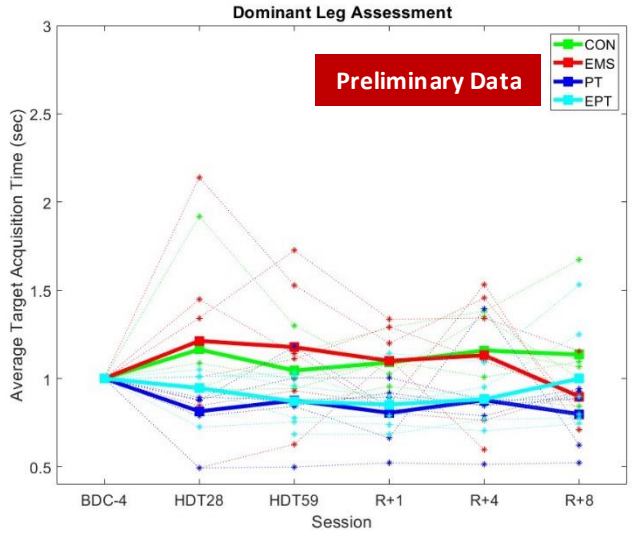


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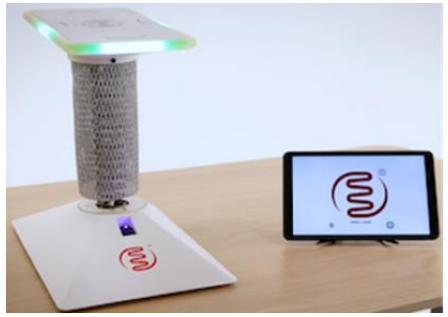


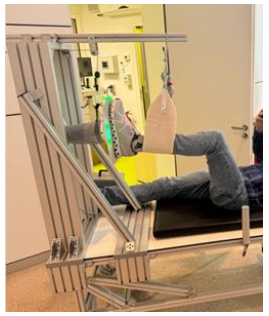




[1]Bellisle et al., Brain Sci, 2024

Proprioception Testing – Leg Dexterity





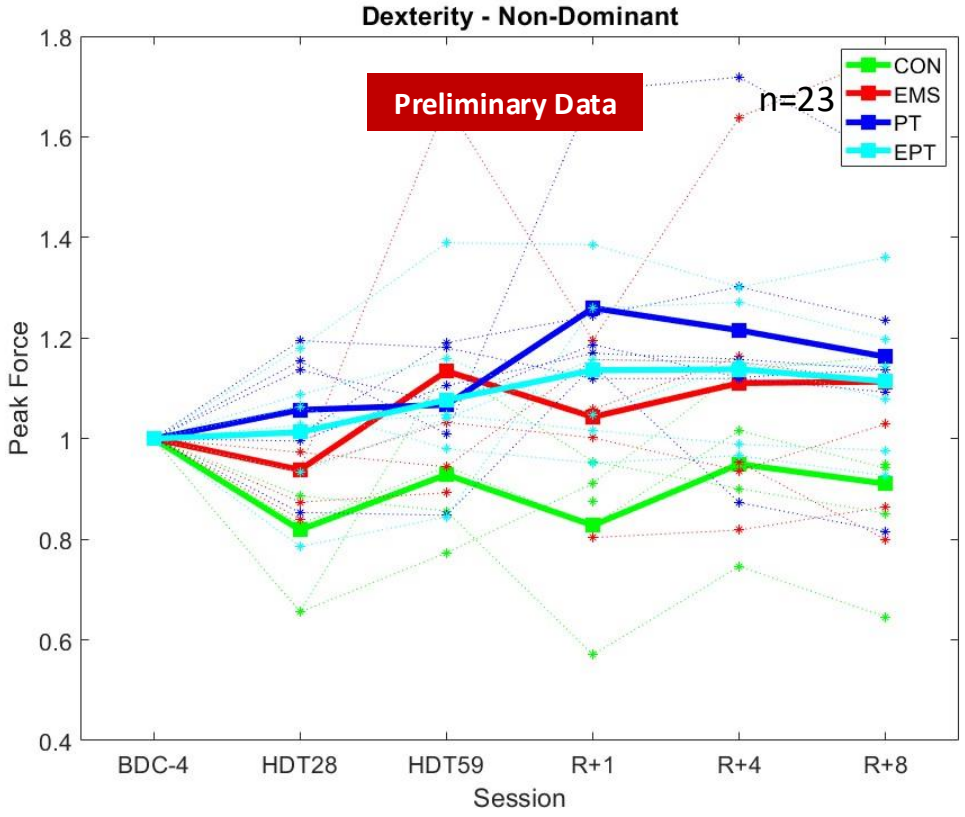
Neuromuscular Dynamics

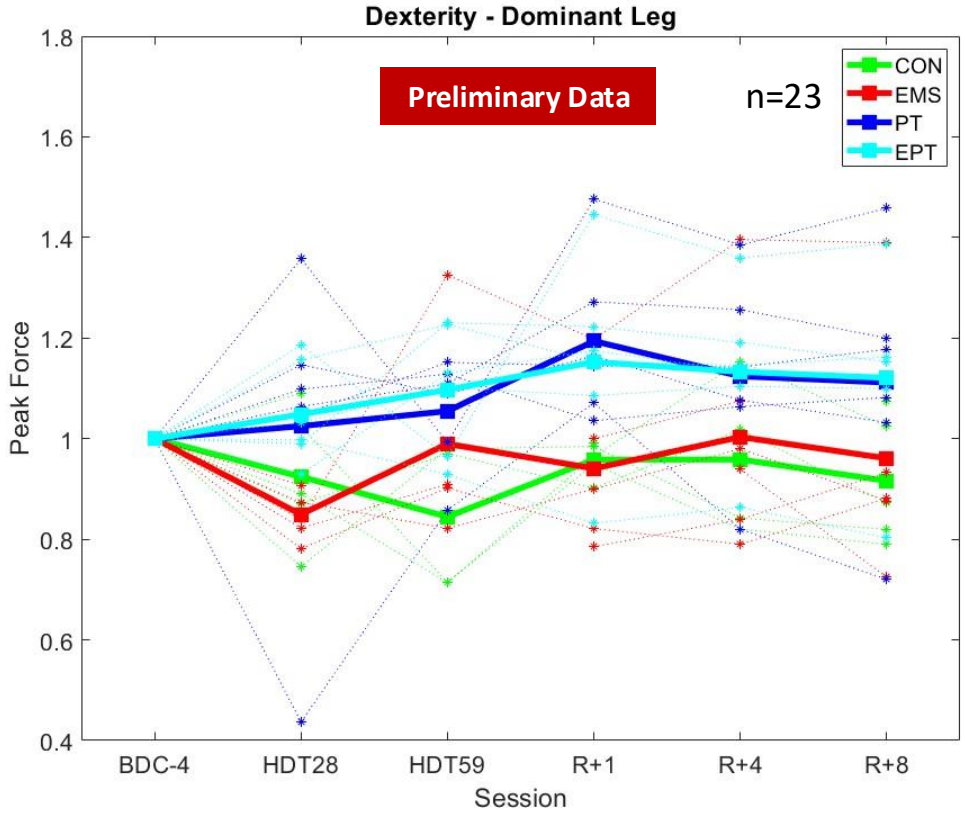
Francisco Valero-Cuevas and Emily Lawrence

Primary outcome measure:

Max Compression Force

(typically ~15% body weight)

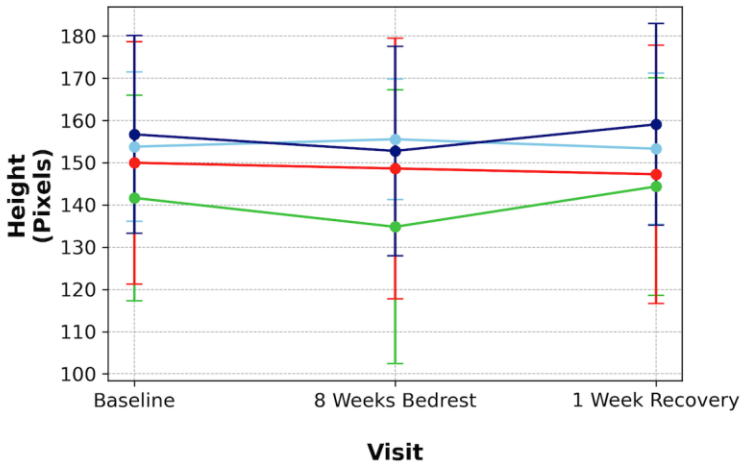


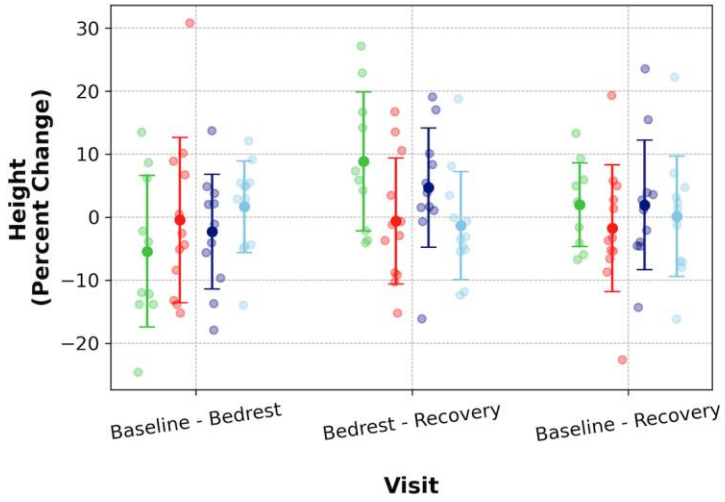


Rectus femoris

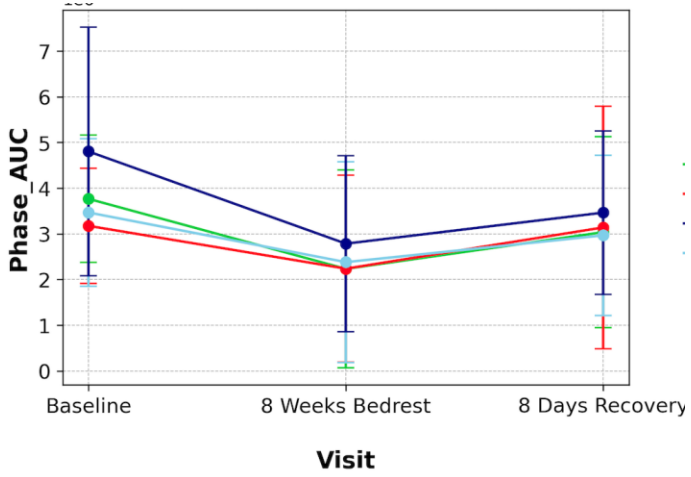
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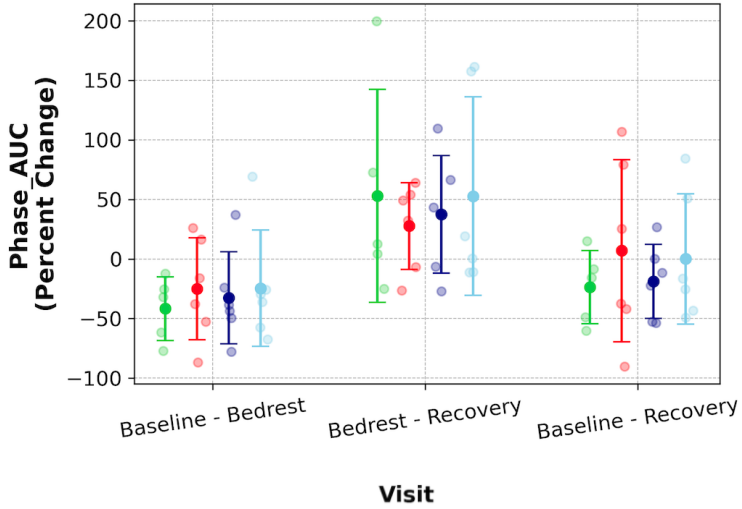
Ultrasound (muscle thickness)



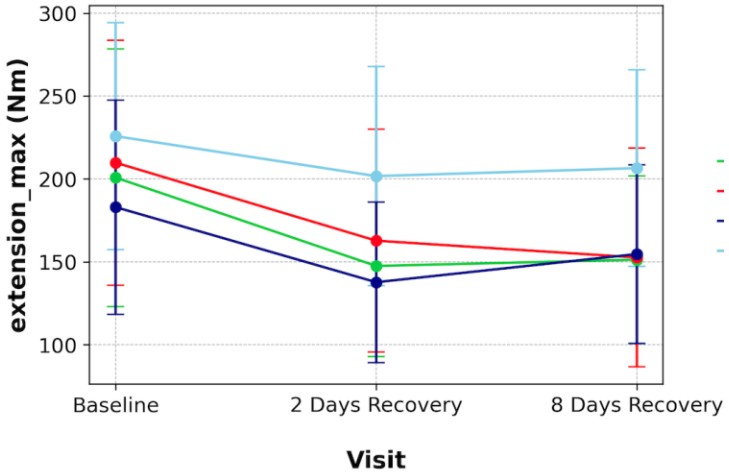


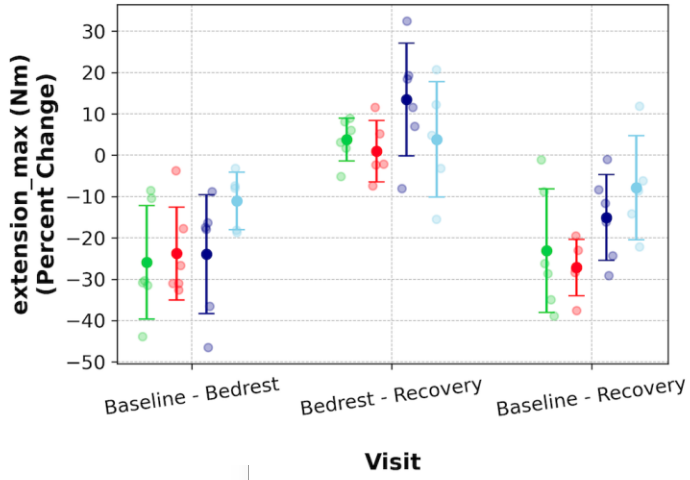
EIM summary phase measure

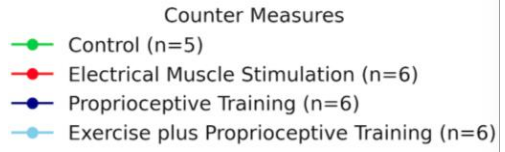




Knee extension force

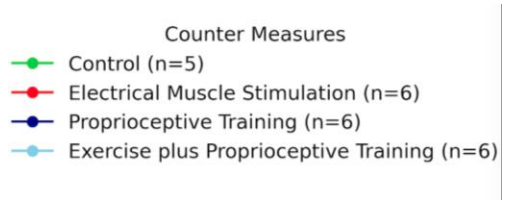




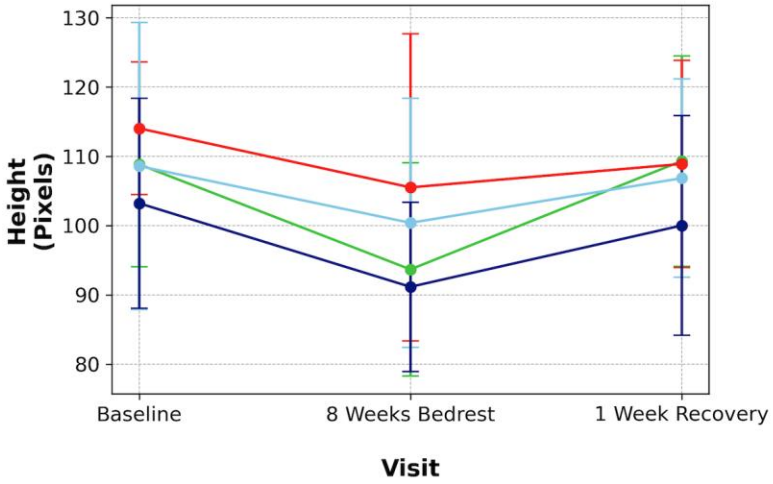


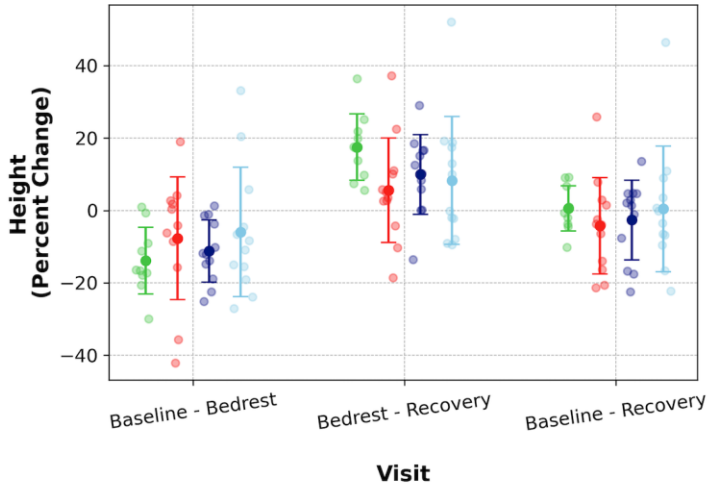
Medial Gastrocnemius

Preliminary Data n=23

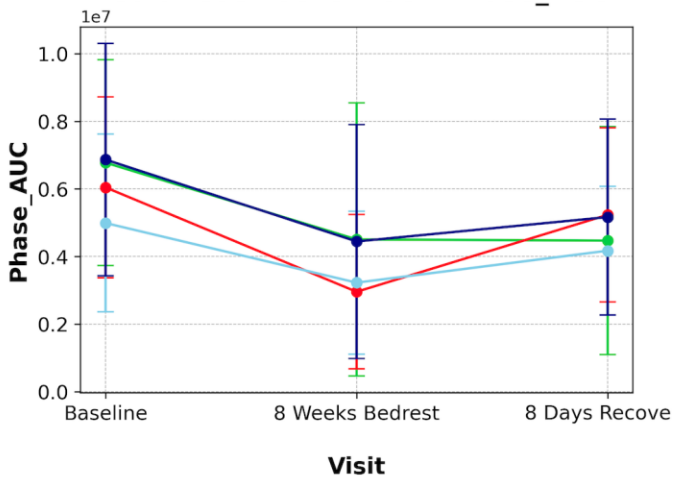


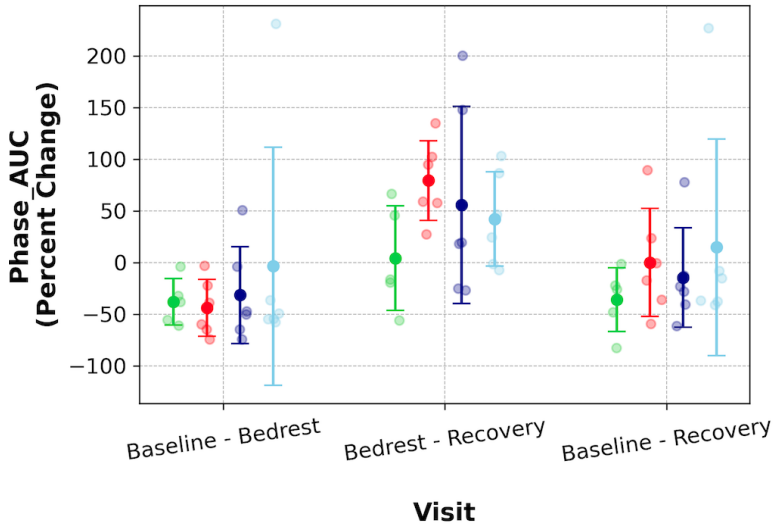
Ultrasound (muscle thickness)



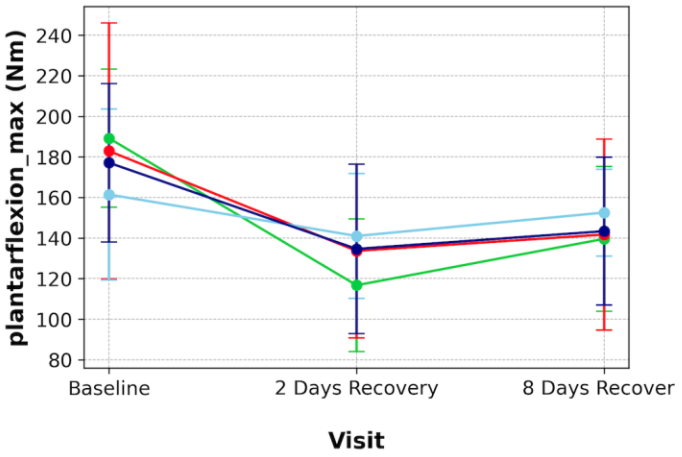


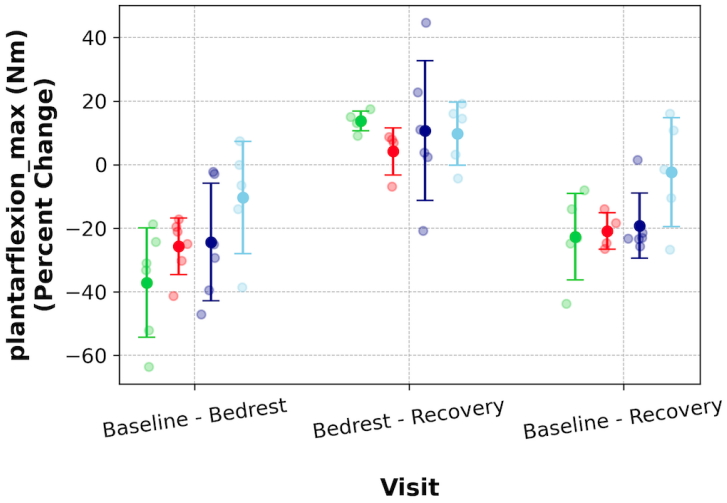
EIM summary phase measure





Plantar Flexion Force





Hypersole BedRest

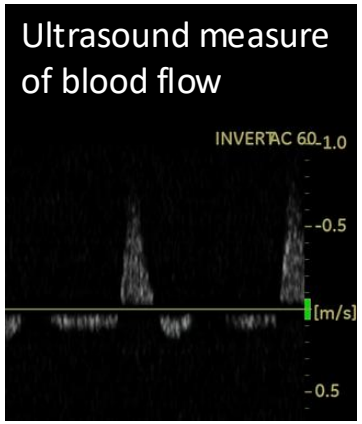
Leah R. Bent, Nicholas D.J. Strzalkowski, Ryan M. Peters

Cutaneous Sensitivity following 60 Day Head Down Bed Rest

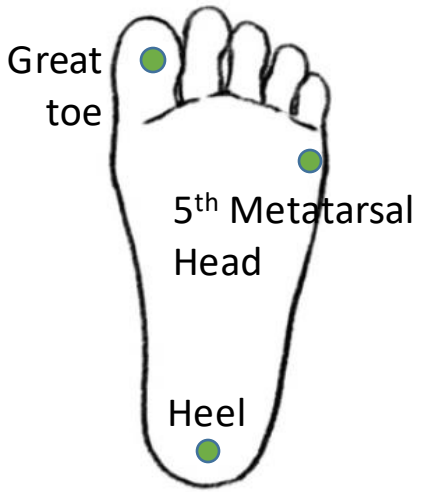
Experimental set-up



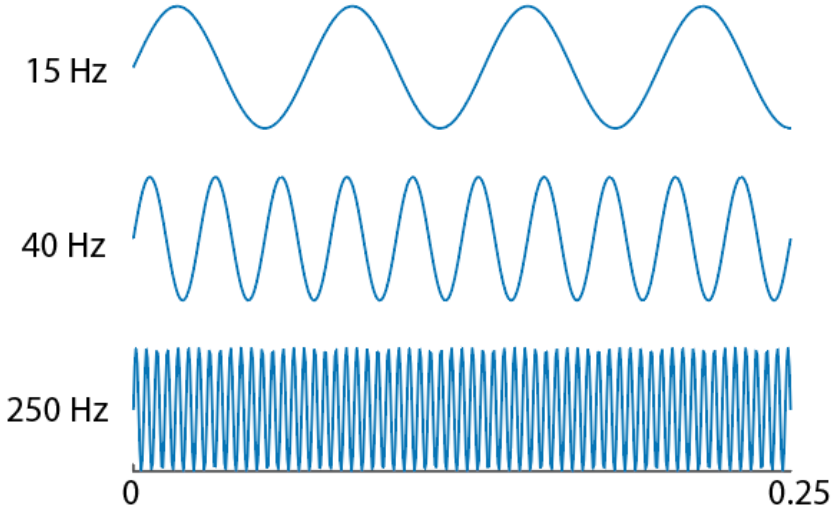




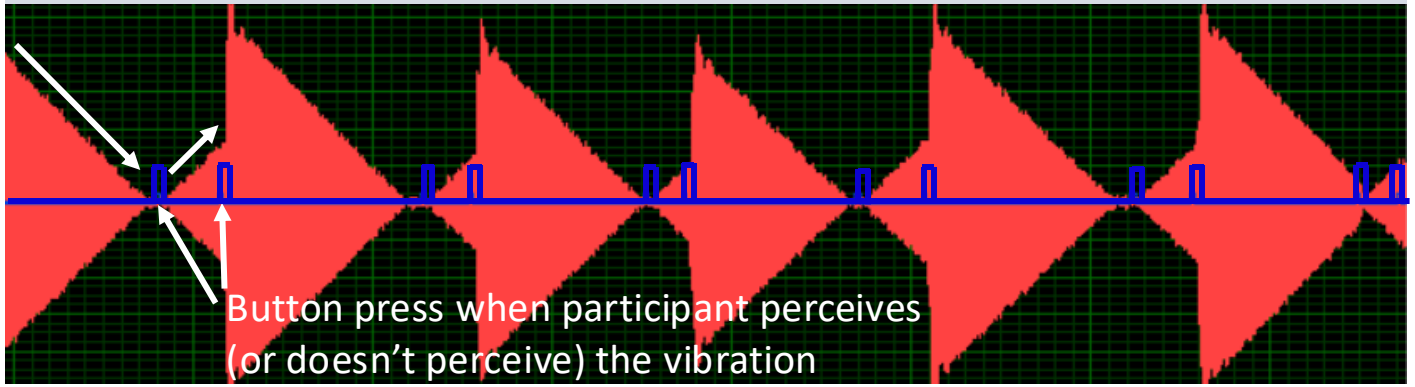
3 sites on foot sole



3 vibration frequencies



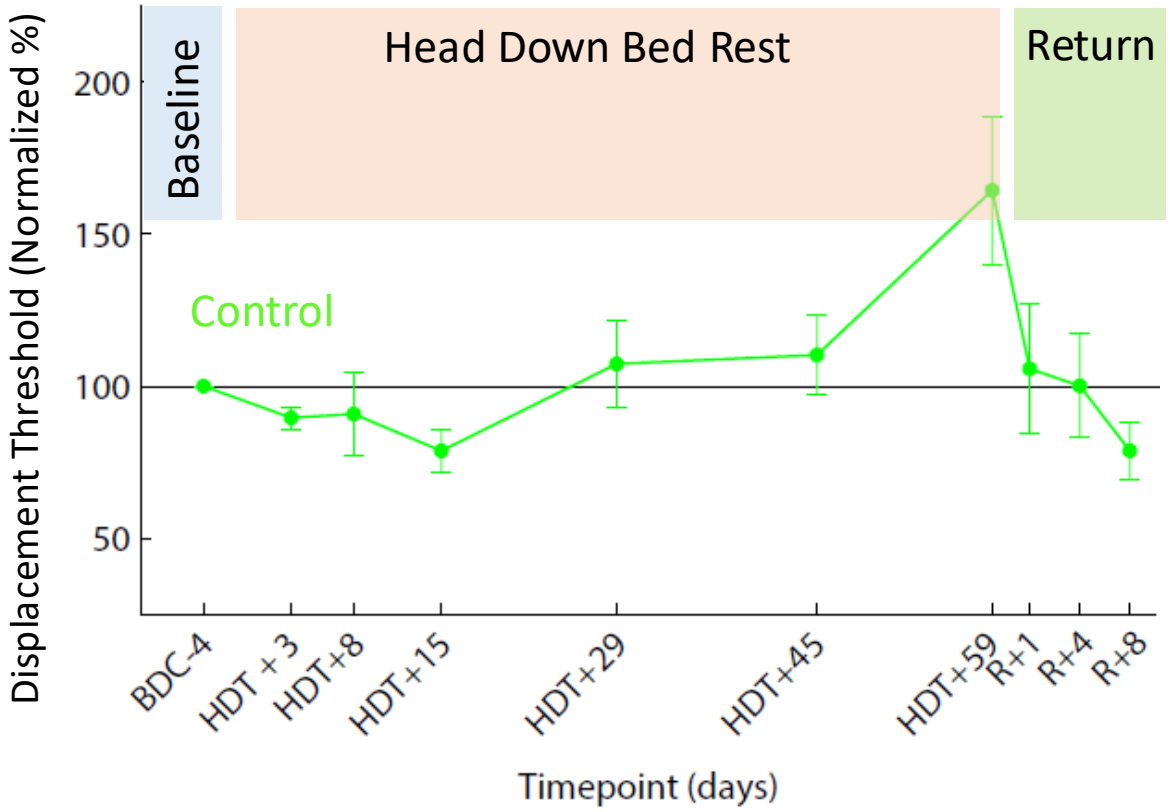
12 ramps per trial (6 decreasing amplitude, 6 increasing amplitude)

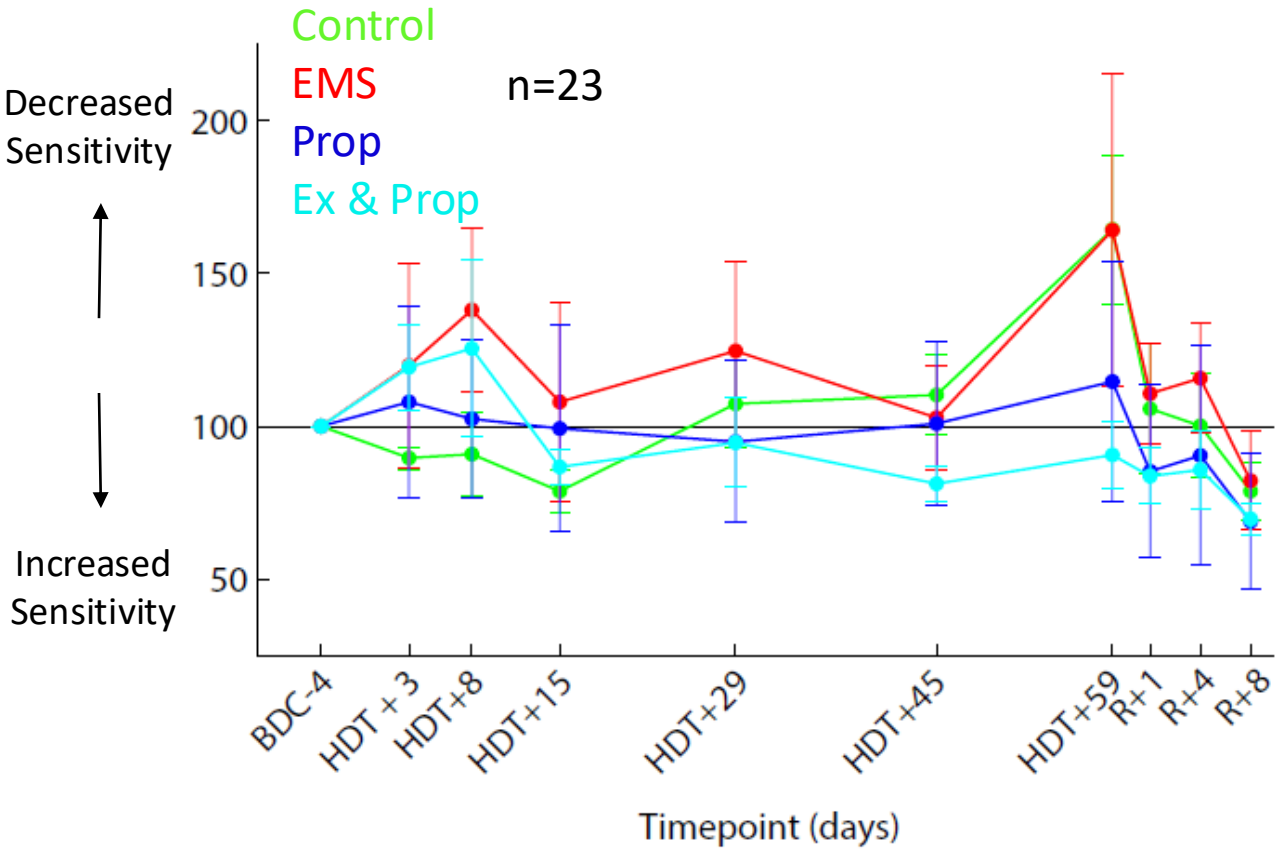


Hypersole BedRest **Preliminary findings:**

In the control group, thresholds to 250 Hz at the Heel were similar until HDT+59, when the sensitivity sharply decreased (shown as increased vibration threshold from baseline).

This decrease in sensitivity at HDT+59 seems to be muted in the Proprioception and Exercise + Proprio groups compared to control and EMS groups.

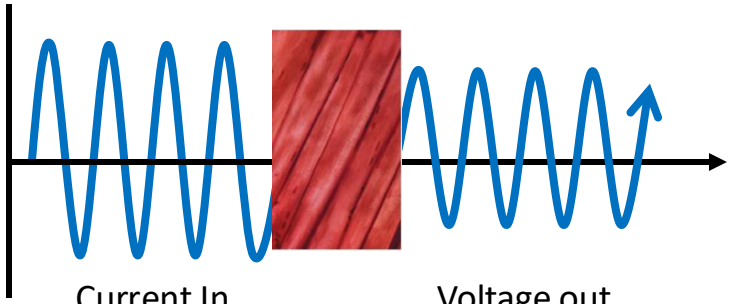


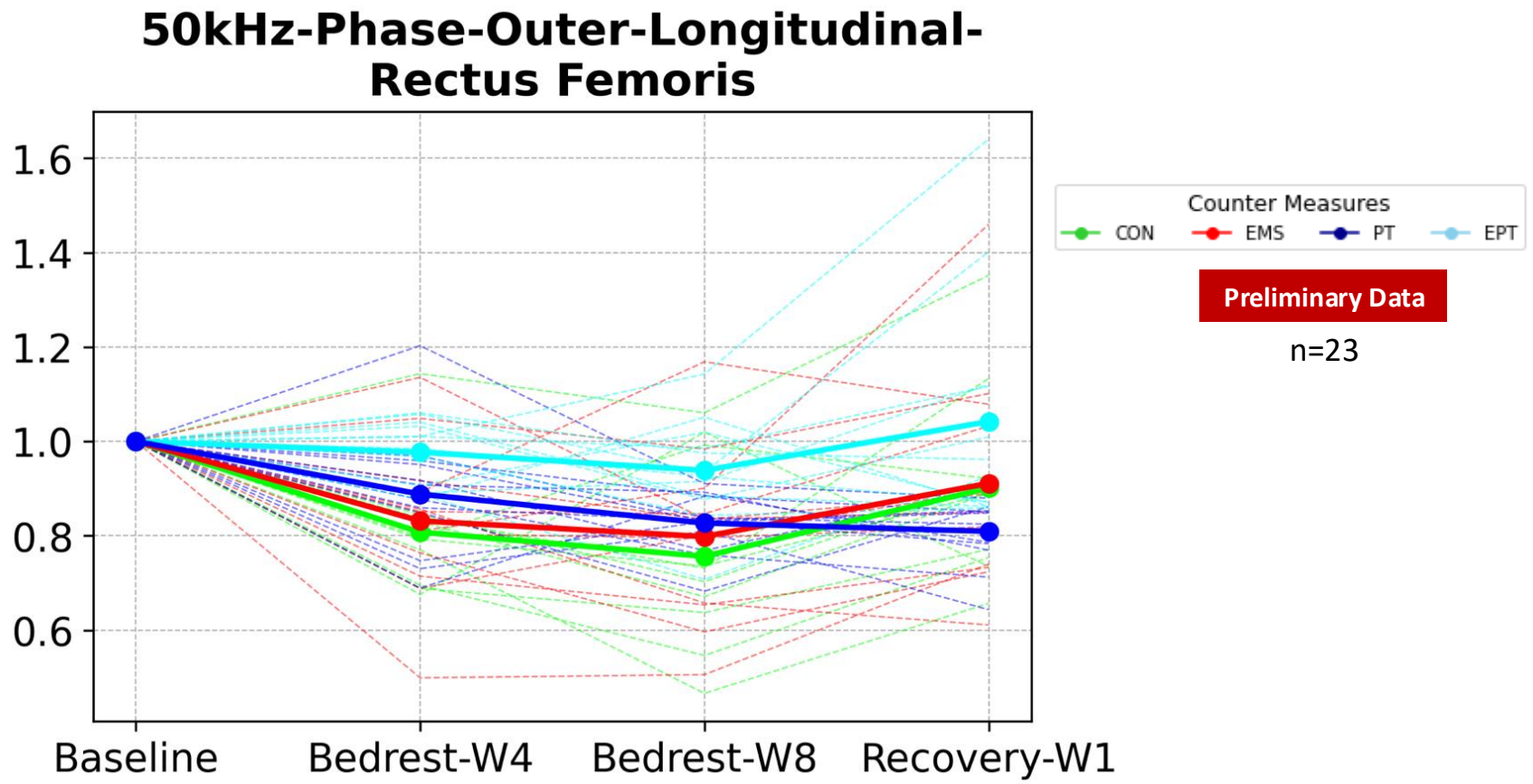


Electrical Impedance Myography (EIM)

Safe, user-friendly technique for assessing impedance characteristics of muscle (highly sensitive to myofiber size and tissue composition)







Preliminary Data

n=23

Additional Measures

- Jump Down
- Computerized Dynamic Posturography
- Tandem Walk (eyes open and eyes closed)
- Foot blood flow
- Muscle MRI
- Muscle ultrasound
- Muscular strength
- Muscular power
- VO2max
- Bone mineral density assessed via DXA and ultrasound
- Standard blood markers
- microRNA blood analyses

Discussion

- Data collection is ongoing: Campaign 3 (out of 4) begins in May 2026!
- Comparisons will be made to previous HDBR studies.
- The deliverable from this project will be proof-of-concept sensorimotor countermeasure designs with full assessment of efficacy in a spaceflight analog.

- In parallel, a flight version of the Proprioception Training hardware (UPRITE) is being developed for a Technical Demonstration on the ISS.



Acknowledgements

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- The HDBR campaigns are conducted in the :envihab medical research facility at the Institute of Aerospace Medicine of the German Aerospace Center (DLR)
- Thank you to all participants and Research Operations and Integration (ROI) for making this study possible!