# **Preliminary Evaluation of the MoBL-ARMS Dynamic Upper Limb Model**
# for Estimating Muscle Activation During End Effector Robot-Mediated Rehabilitation

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HRELab
HUMAN–ROBOT EMPOWERMENT

# Motivation

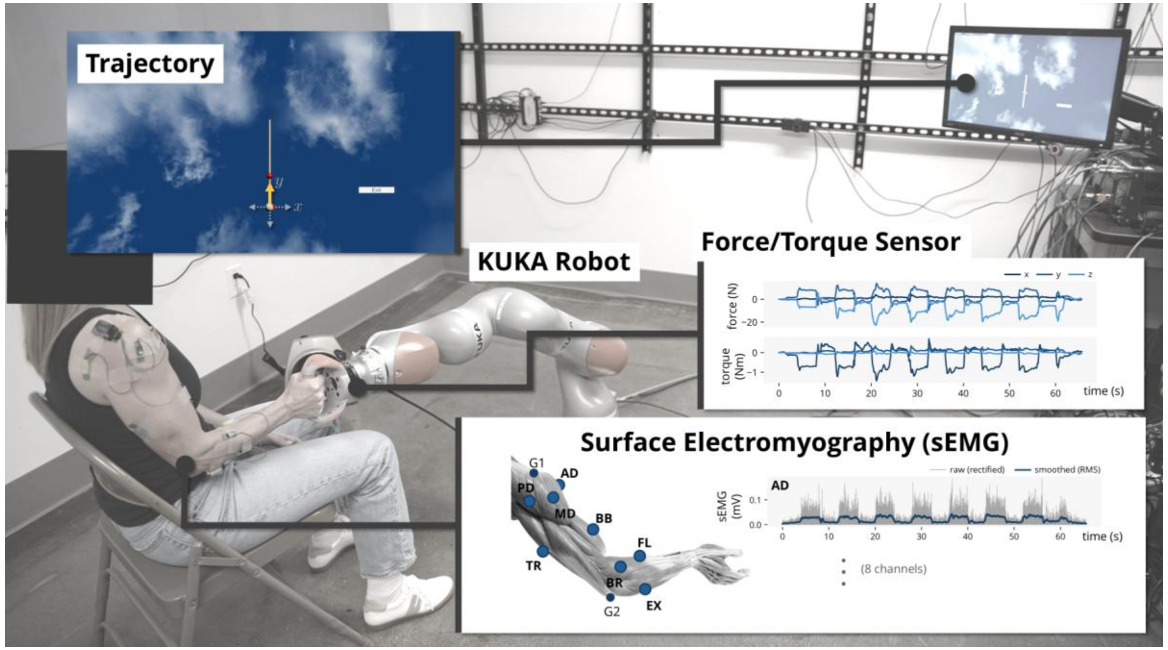
- Among the large number of people surviving stroke every year, **50–70%** experience motor dysfunction, **80%** in the upper limb [1].
- Physical therapy is **expensive, subjectively applied, and must be highly customized**, which limits access and efficacy.


*Five typical arm spasticity patterns [2]*

# **Solution**: Robot-Mediated Rehabilitation

Robots can enable rehabilitation exercise that is:

- accessible
- customizable
- quantifiable and repeatable [1]




*OpenRobotRehab platform [2]*

Standard control formulation: "**assistance as needed**" (error correction to desired motion)

**Is the motion actually rehabilitative?**



*[1] Raji et al. (2025), BioMedical Engineering OnLine* *[2] Anand et al. (2025), ICORR*

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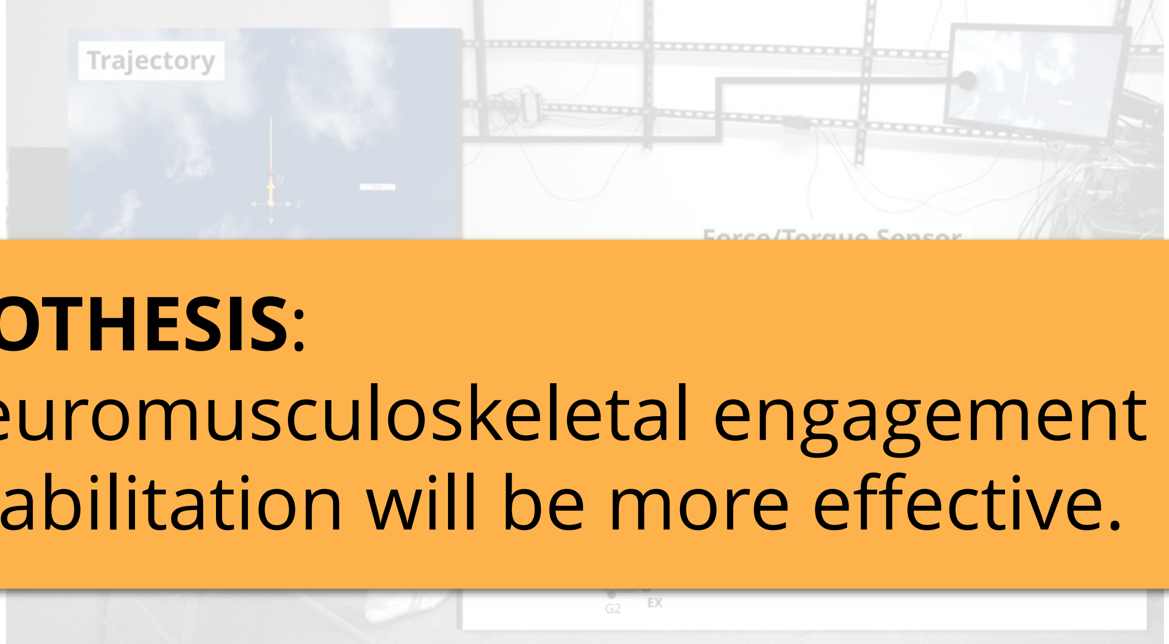


**KEY HYPOTHESIS**:
If we design robots to optimize neuromusculoskeletal engagement in addition to motion quality, rehabilitation will be more effective.

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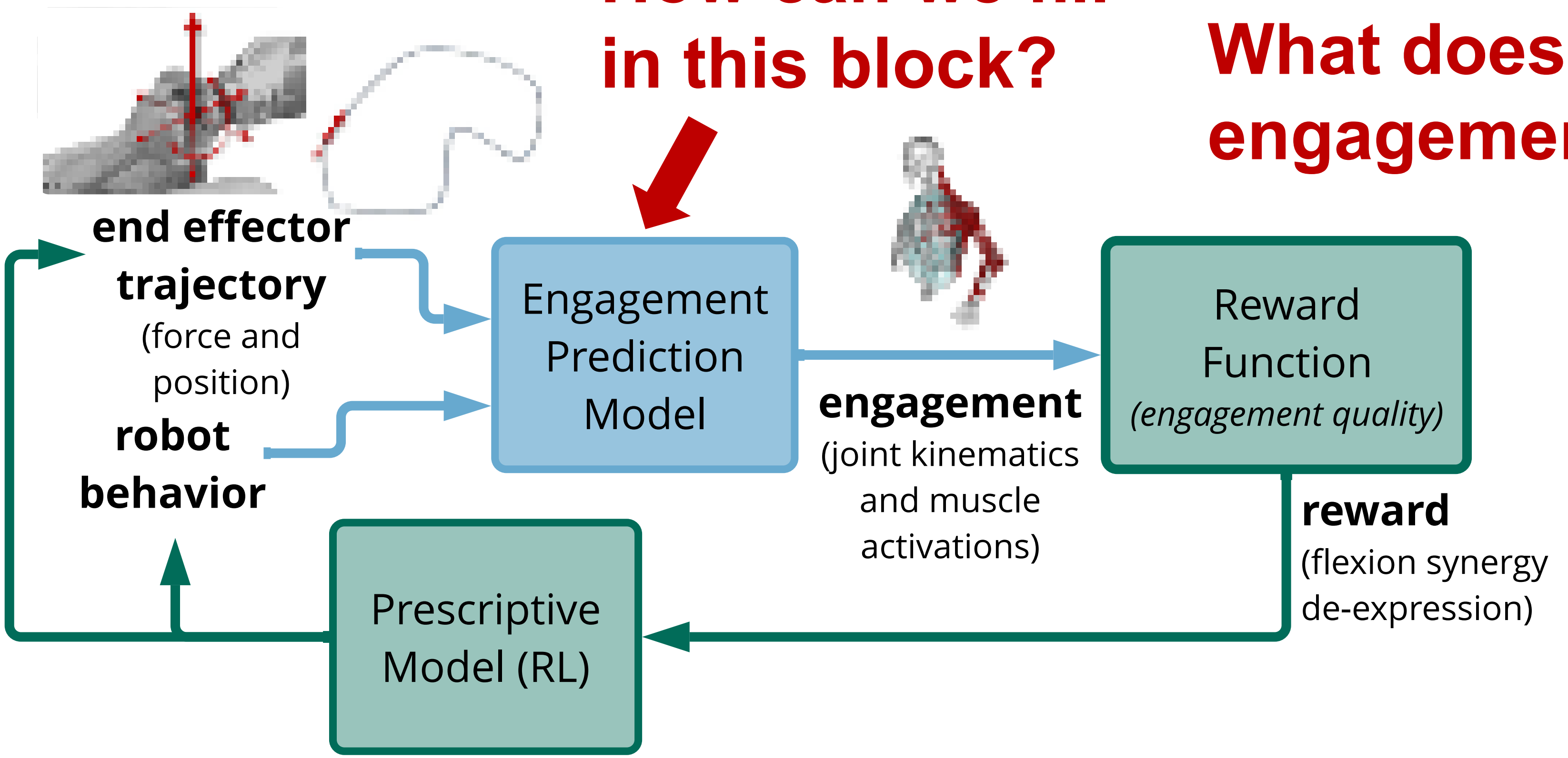
**KEY HYPOTHESIS:**

If we design robots to optimize neuromusculoskeletal engagement in addition to motion quality, rehabilitation will be more effective.

**How can we fill in this block?**

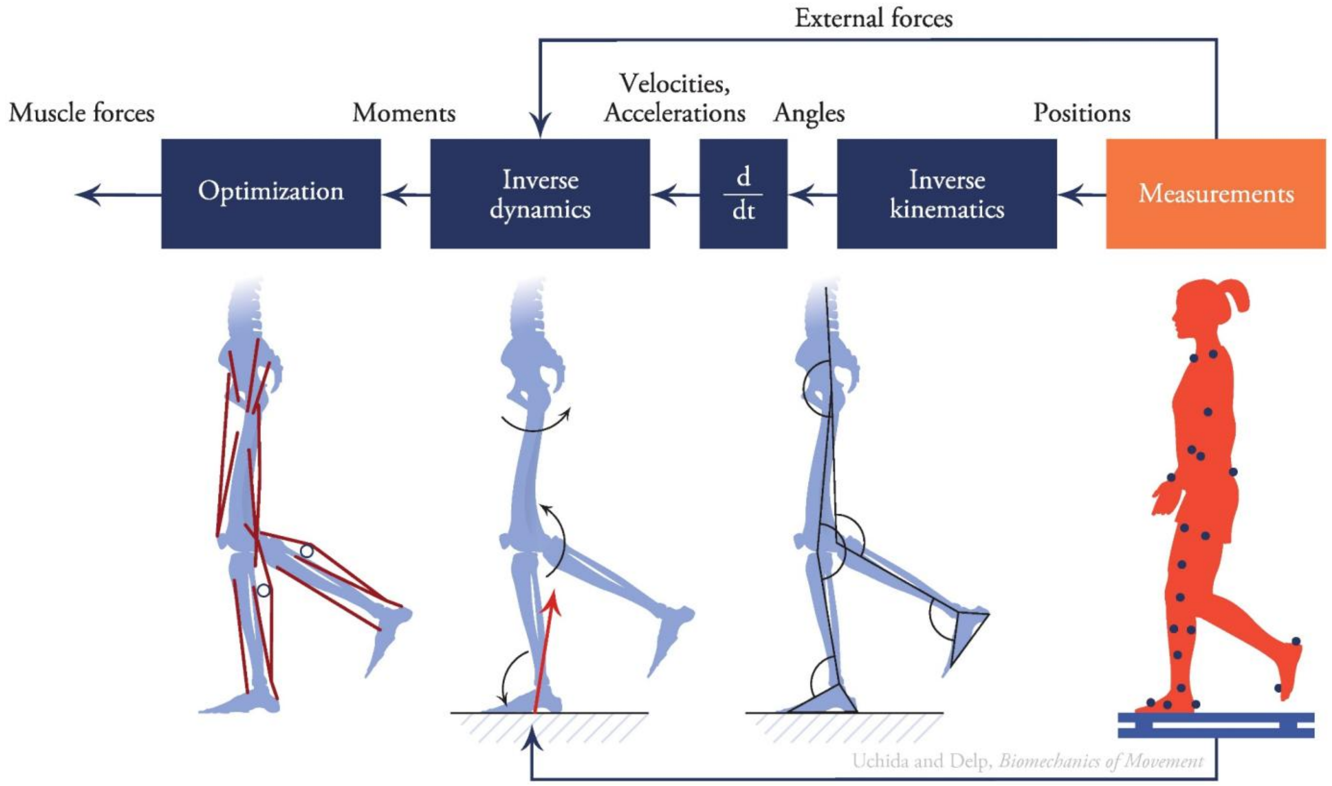
**What does healthy engagement look like?**



# **Quantifying Engagement:** Neuromusculoskeletal Modeling (OpenSim)

We aim to simulate **detailed kinematics and muscle activations ("engagement")** of the upper limb when interacting with an end-effector rehabilitation robot.

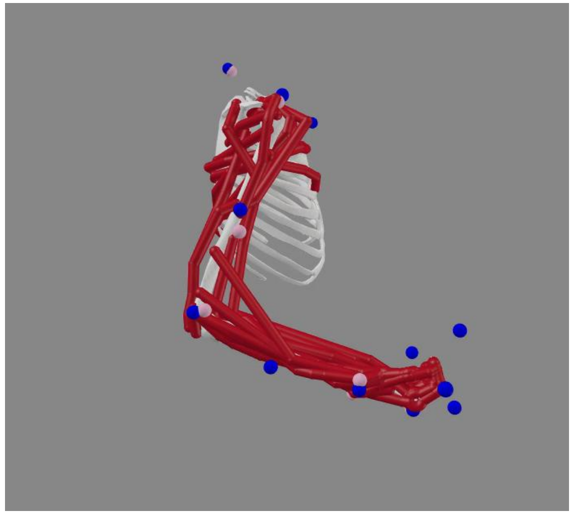
**→ Do these models work for end-effector robot interactions?**



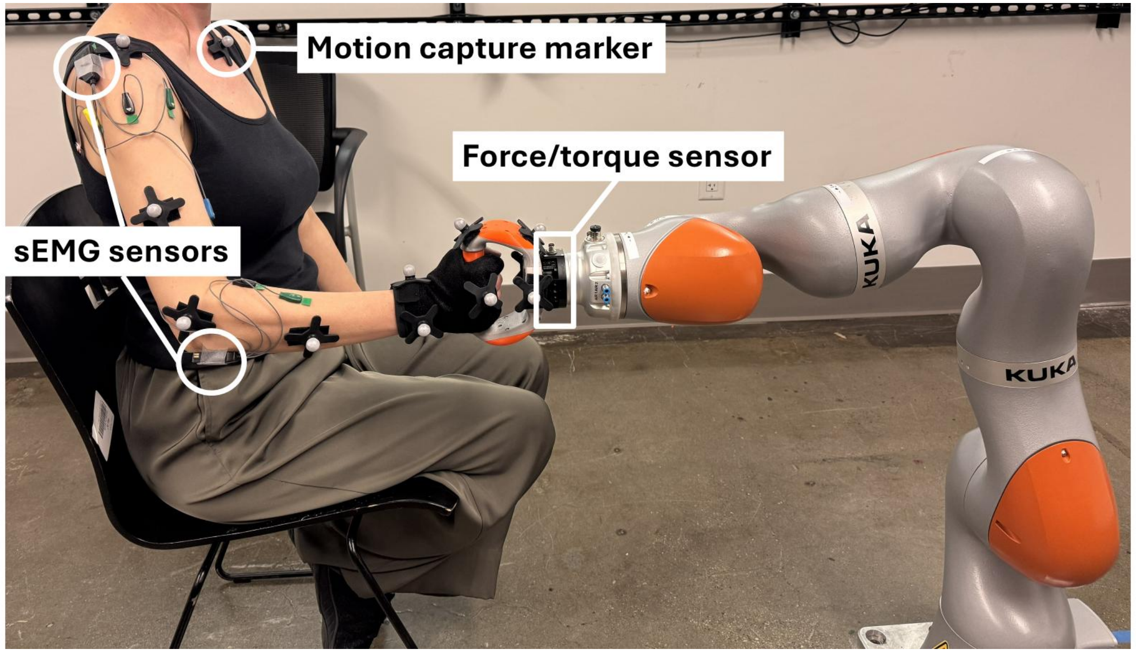

*Inverse dynamics [1]*

# **Baseline Model**: MoBL-ARMS

- n=1
- 4 isometric tasks
  - 0% effort (baseline)
  - 50% effort
  - 100% effort
  - **0→50→100% effort sequence**
- Scaled the model and solved inverse kinematics & dynamics → joint torques
- Ran static optimization → muscle forces and activations
- Compared predictions w/ measured sEMG



*MoBL-ARMS [1]*

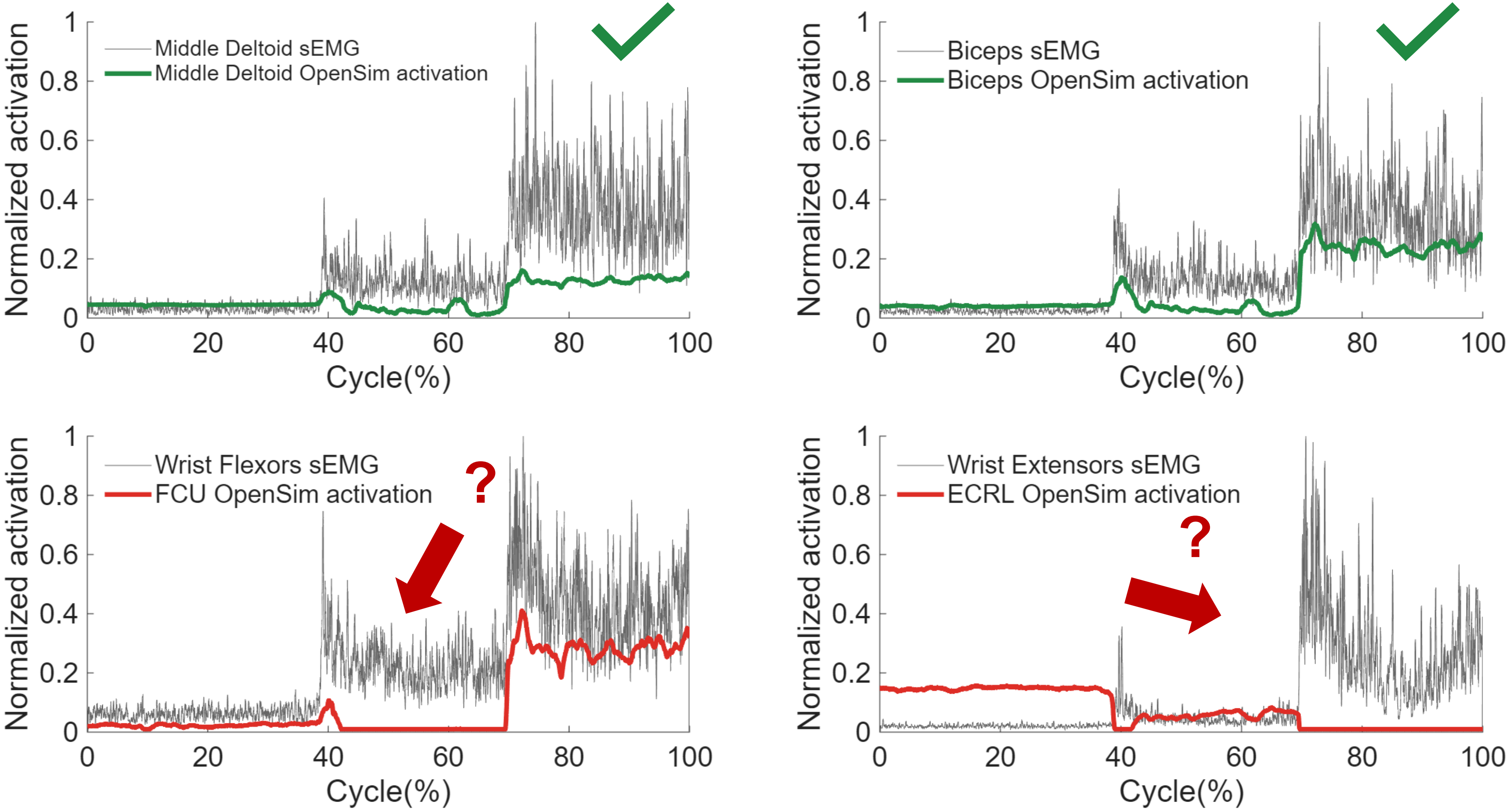



*Experimental Setup*

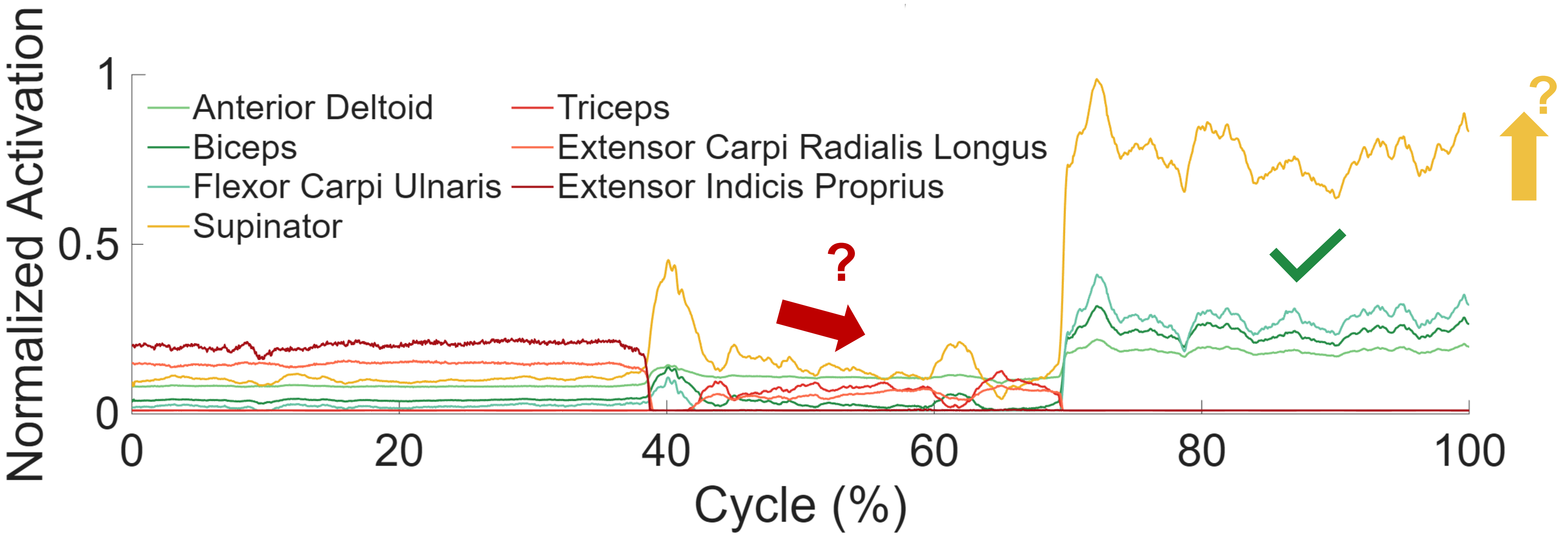


*[1] Saul et al. (2015), Comp. Meth. Biomed. Engin.* *[2] McFarland et al. (2019), J. Biomech. Eng.*

# **Results**: Static Optimization vs. sEMG



# **Results**: Exemplar Predicted Muscle Activations

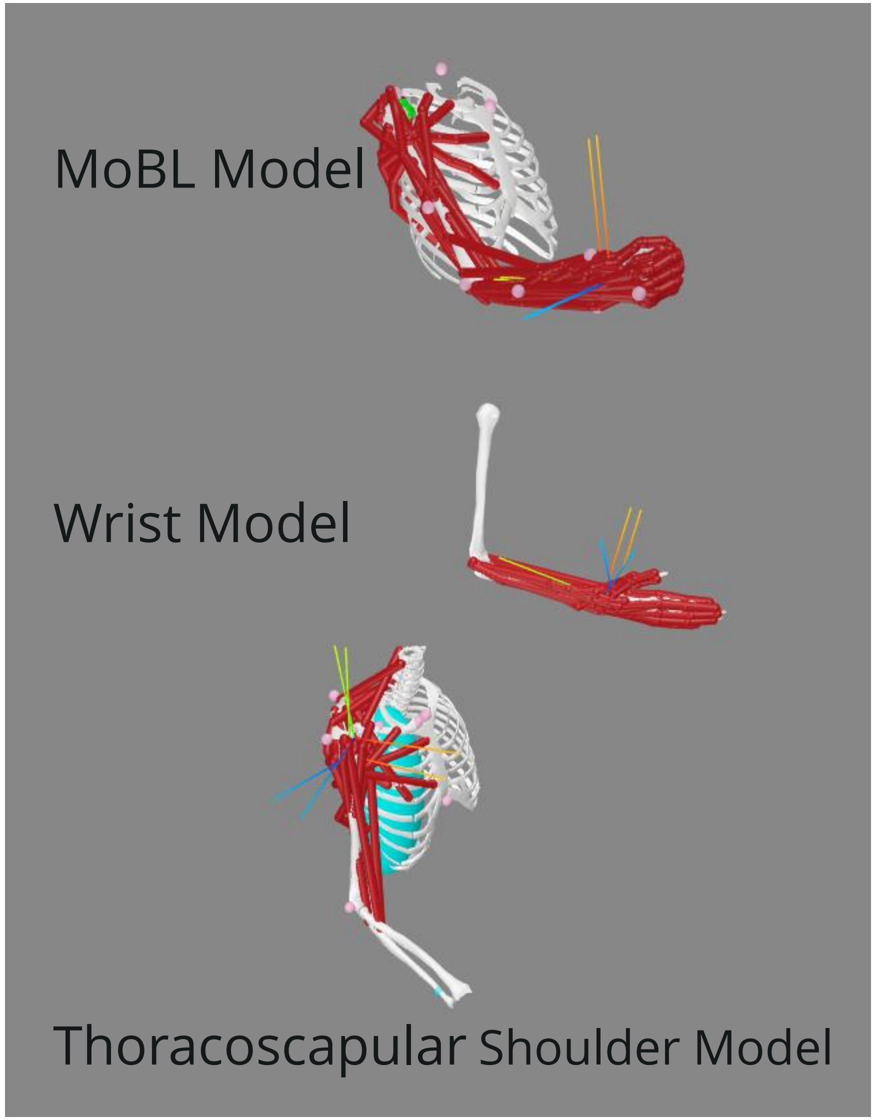


# Key Takeaways

- The **MoBL-ARMS model converged** for our end effector robot interaction, predicting activation of 50 muscles of the arm and torso.
- Most predicted activations using static optimization were **consistent with measured sEMG**, but some predicted activations were physiologically implausible.

# Current Directions

- **Comprehensively quantify model performance**
  - n>1 (more participants)
  - sEMG from more muscles
  - 6D isometric tasks
- **Address model limitations**
  - Dynamic optimization
  - Combine/expand model components (e.g., missing shoulder DOF)
- **Expand model capabilities**
  - Dynamic tasks
  - Participants w/ neuromotor pathology (e.g., stroke)




*Candidate upper body models to combine*

**Full abstract text & more!**

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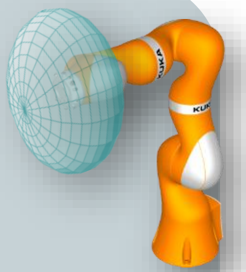
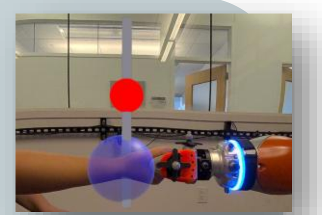
Gabriel Parra and Laura A. Hallock
Poster S1-43 (Friday)

***A Gradient-Descent-Based Null Space Planner for Dexterity Optimization during Upper-Limb Robot-Mediated Rehabilitation***



Ajay Anand, Charlie Lambert, Jono Jenkens, Carson J. Wynn, and Laura A. Hallock
Poster S1-41 (Friday)

***An Augmented Reality Display for 6-DoF Task Specification During Upper-Limb Robot-Mediated Rehabilitation***



Jono Jenkens and Laura A. Hallock
Poster S1-09 (Friday)