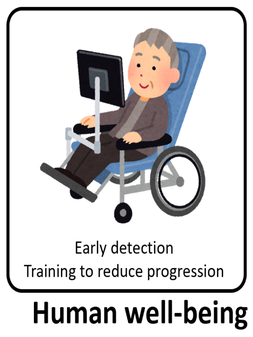
Tailoring neuromuscular dynamics:

A modeling framework for realistic sEMG simulation

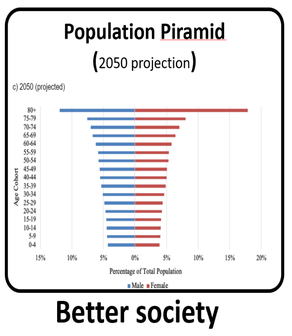
- Model for biologically realistic sEMG simulation
- Tool for non-invasive diagnosis and monitoring of muscle condition
- Potential technology for the early detection of sarcopenia

Background & Goals

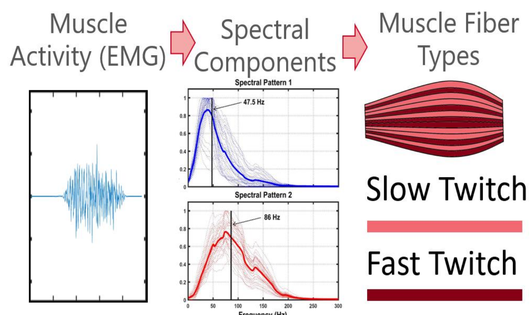
This study introduces an advanced computational model for simulating surface electromyography (sEMG) signals during muscle contractions. The model integrates five elements that represent the chain of processes from motor intention to voltage variations over the skin: motor control system, motor neurons, muscle fibers, biological tissues, and electrodes. Beyond realistic signal generation, the framework enables exploration of how early neuromuscular alterations, such as preferential loss of fast-twitch fibers, manifest in sEMG features, providing a potential tool for the early detection of sarcopenia.



Human well-being



Better society



Materials & Methods

1. Modeled Elements

From Intention to Contraction

Muscle Fiber
- Trigger Activation
- Generation of Potentials
- Generation of Force

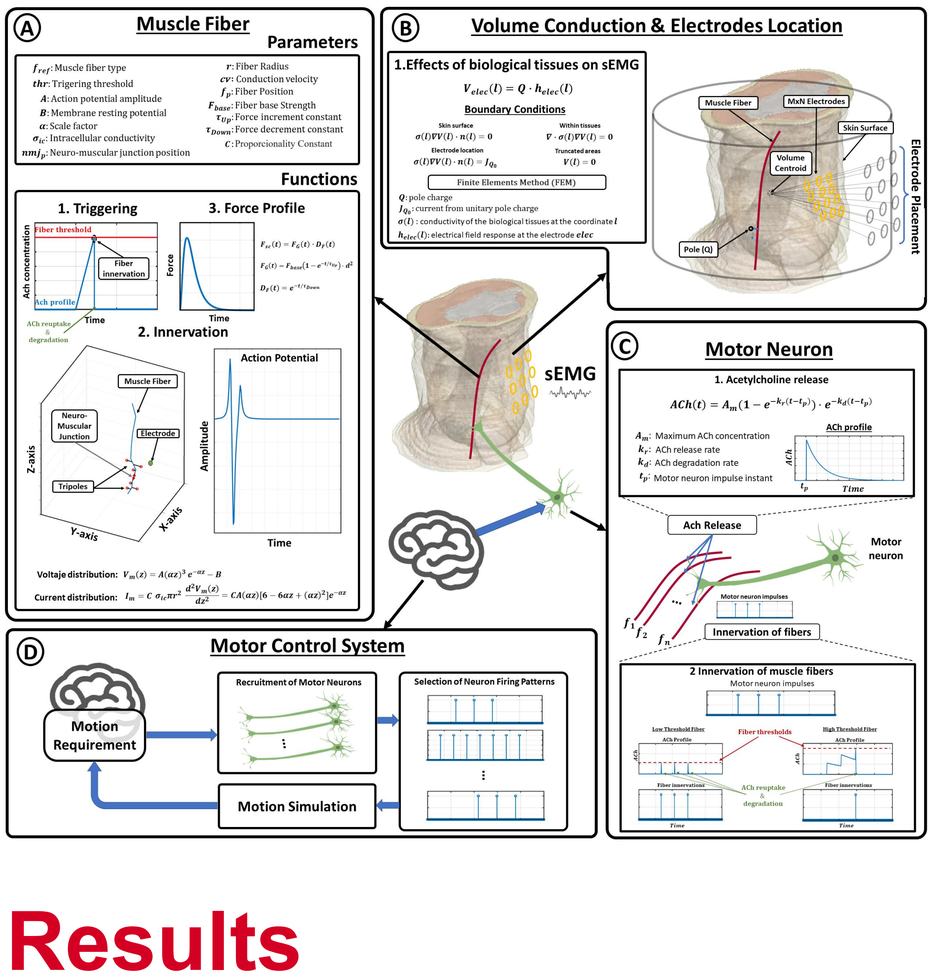
Motor Neuron
- Recruit Pool Fibers
- Compute MUAPs

Motor Control System
- Recruit Motor Units
- Choose Activation Rate

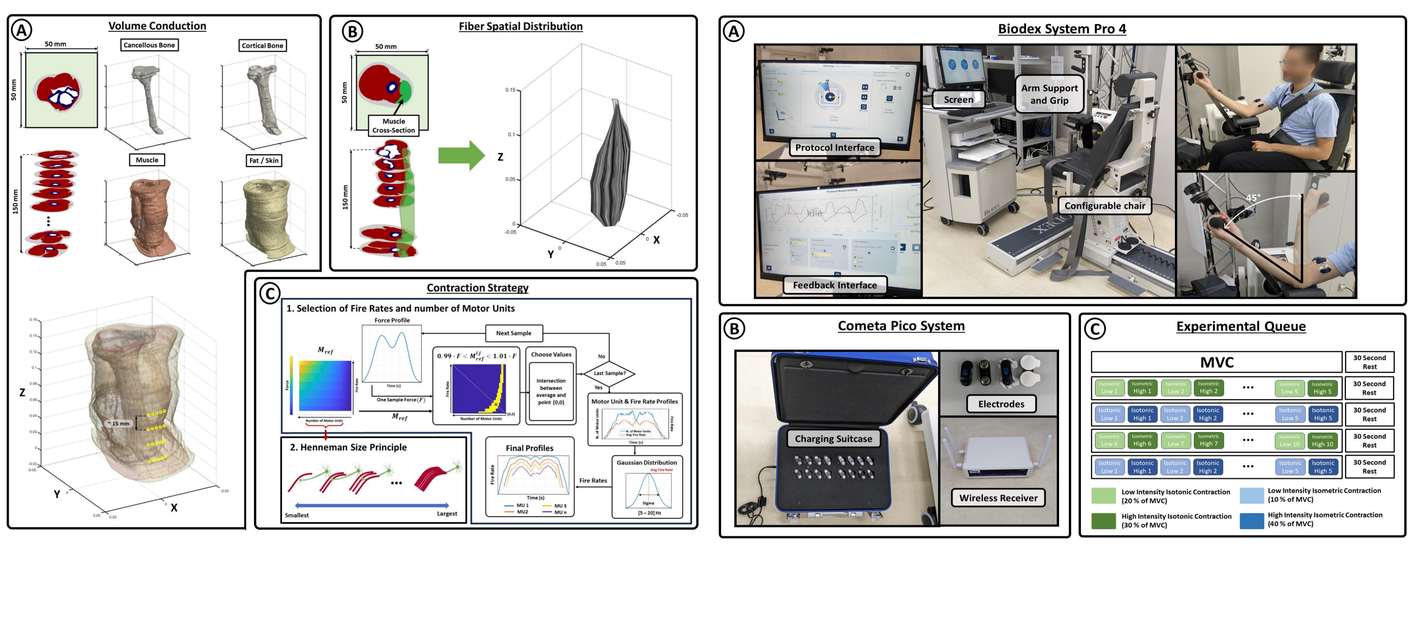
From Contraction to sEMG

Electrodes
- Define sEMG Recording Location
- Simulate Monopolar and Bipolar Recordings

Biological Environment
- Compute Surface Voltage
- Define Skin Surface



2. Simulation Details



3. Experiments for Validation

Results

Dispersion Similarity (for RMS & MF)

$$Feat_{Simi} = 1 - \frac{1}{2}(avg_{Simi} + std_{Simi})$$

$$avg_{Simi} = \frac{|avg(f_{REAL}) - avg(f_{SIM})|}{avg(f_{REAL}) + avg(f_{SIM})}$$

$$std_{Simi} = \frac{|std(f_{REAL}) - std(f_{SIM})|}{std(f_{REAL}) + std(f_{SIM})}$$

Correlation Coefficient (for envelopes)

$$Feat_{CC} = \frac{\sum_{i=1}^{n}(X^i_{REAL} - avg(X_{REAL})) \cdot (X^i_{SIM} - avg(X_{SIM}))}{\sqrt{\sum_{i=1}^{n}(X^i_{REAL} - avg(X_{REAL}))^2} \cdot \sqrt{\sum_{i=1}^{n}(X^i_{SIM} - avg(X_{SIM}))^2}}$$

General Similarity Index

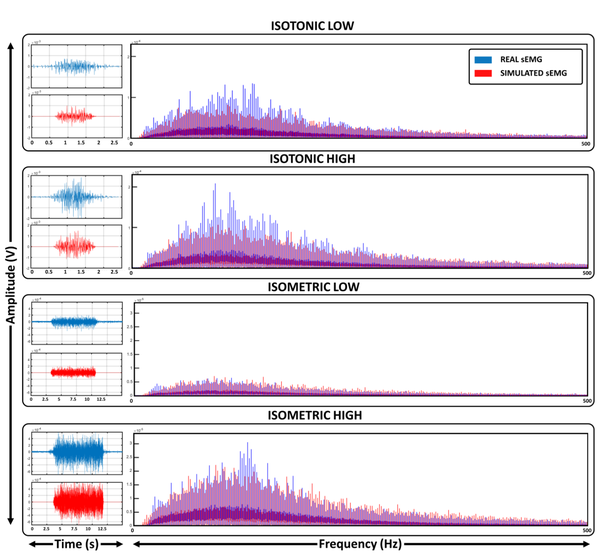
$$GSI = \frac{1}{4}(RMS_{Simi} + MF_{Simi} + Time_{CC} + Freq_{CC})$$

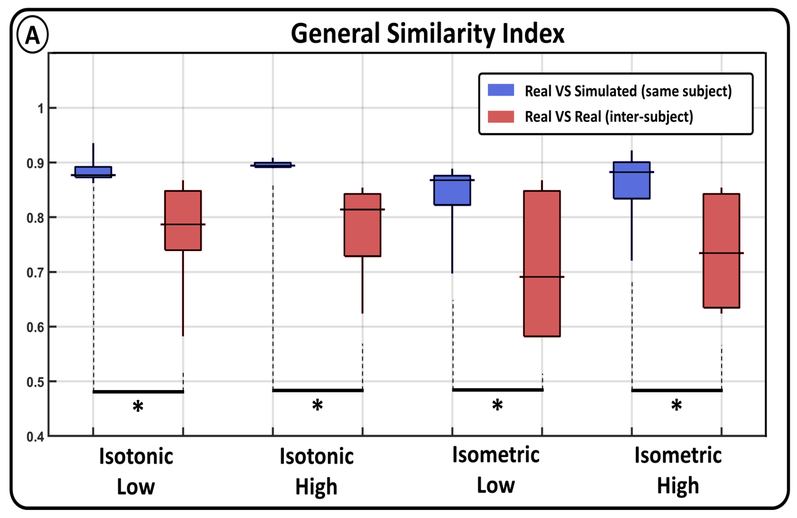
Ground Truth for assessment

Real sEMG
Simulated EMG

VS

Real (one participant)
Real (rest of participants)





[1] Costa-Garcia A et al. Tailoring neuromuscular dynamics: A modeling framework for realistic sEMG simulation. PLOSONE. 2025

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