Using high-density surface electromyography (HD-sEMG) decomposition to estimate neural connectivity in arm and shoulder of individuals with motor deficits

PhD in Artificial Intelligence in Medicine and Innovation in Clinical Research and Methodology.

INcEPTION
NEUROMUSCULAR PLASTICITY FOR NATURAL MOTOR REHABILITATION LABORATORY

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European Research Council
Established by the European Commission

UNIVERSITÀ DEGLI STUDI DI BRESCIA

General aim

Development of optimal neuromodulation protocols based on machine learning for restoring neural connectivity in individuals with motor deficits in arm and shoulder muscles.

Projects *on-going*

Effects of changing the length of Rectus Femoris on Motor Unit Properties

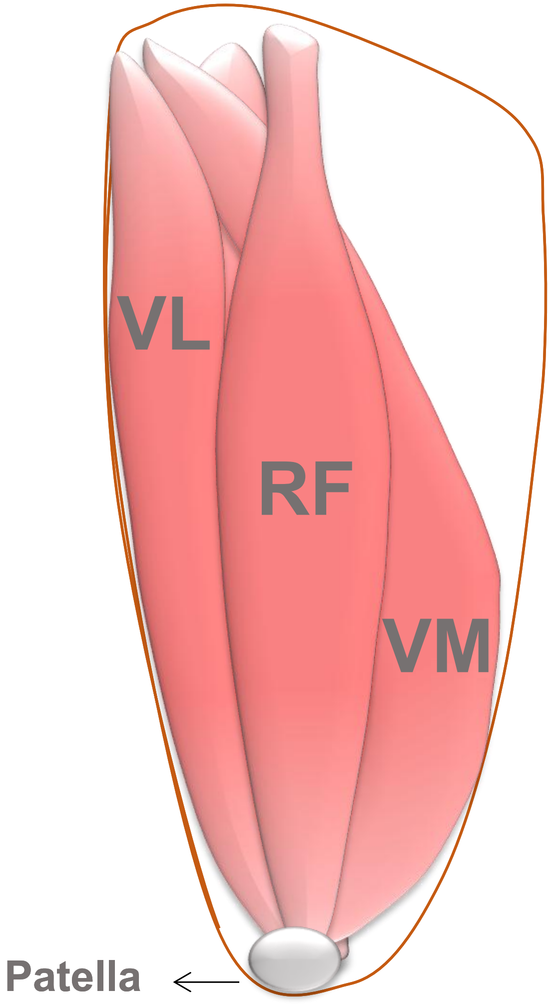
Corticospinal transmission to spinal motor neuron output using repeated transcranial magnetic stimulation

Effects of changing the length of Rectus Femoris on Motor Unit Properties

1. Introduction

- Quadriceps - Vastus Intermedius, Vastus medialis, Vastus Lateralis and Rectus Femoris

- Quadriceps muscle group works synergistically to perform knee extension



(Ema et al., 2017).

1. Introduction

Neural and mechanical properties influences how the force is being produced

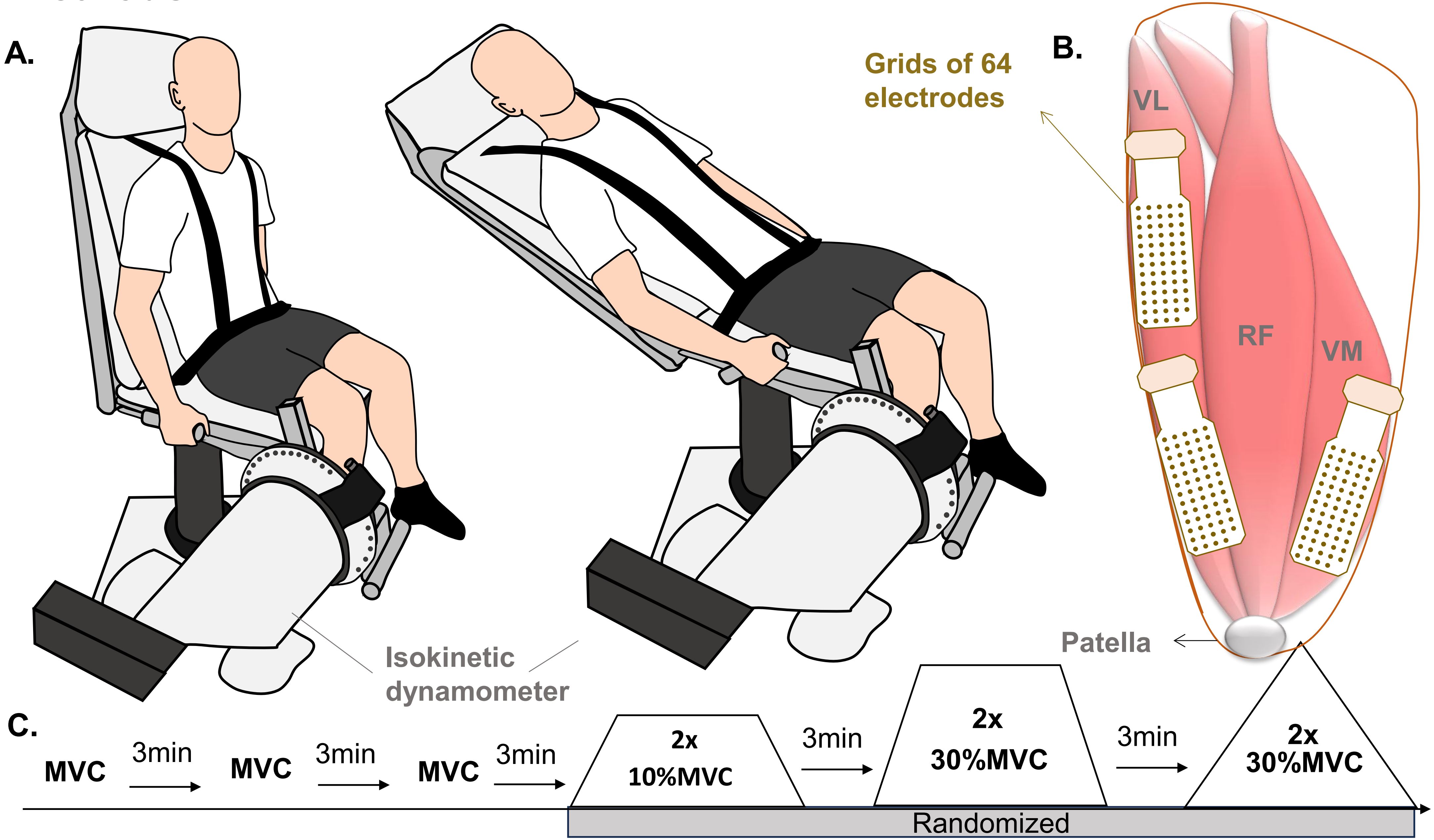
Majority of studies investigate the effects of lengthening the muscle MUs properties regarding the muscle that has been lengthened instead of the other muscles that helps producing the movement

Investigate the effect of modifying the length of the RF muscle, by altering the hip joint position from 90° to supine position at 180°, on motor unit contractile properties of the synergistic VM and VL muscles.

Enoka (2015).

Effects of changing the length of Rectus Femoris on Motor Unit Properties

2. Methods

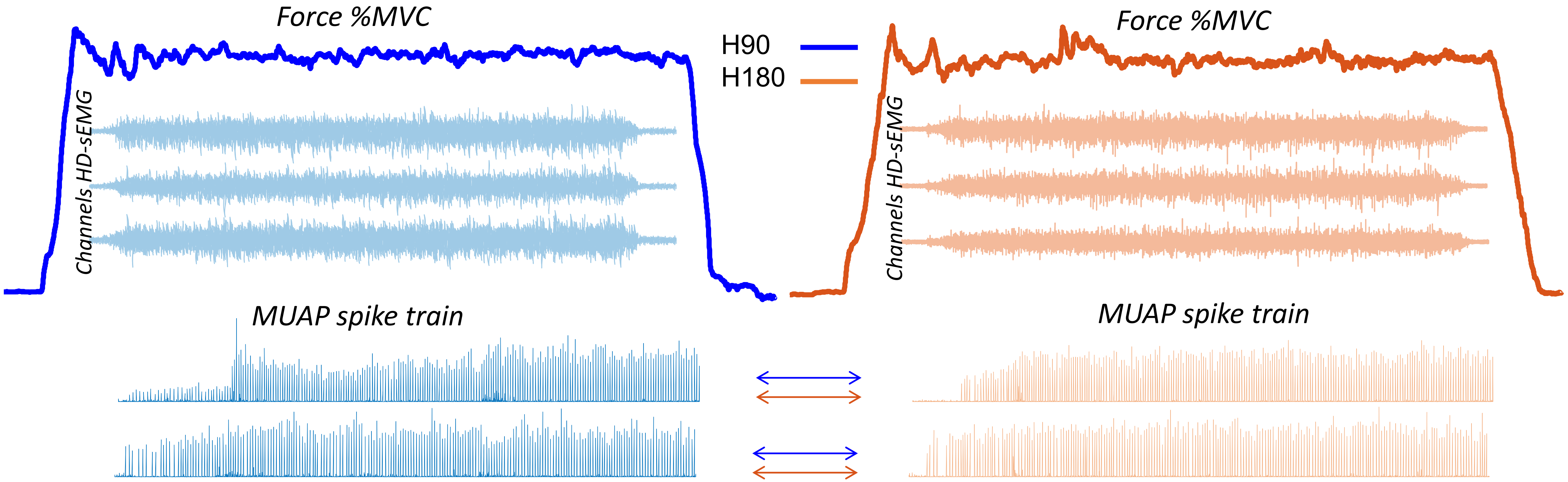


Effects of changing the length of Rectus Femoris on Motor Unit Properties

2. Methods

Channels were visually inspected and then the signals were decomposed using a convolutive blind source algorithm

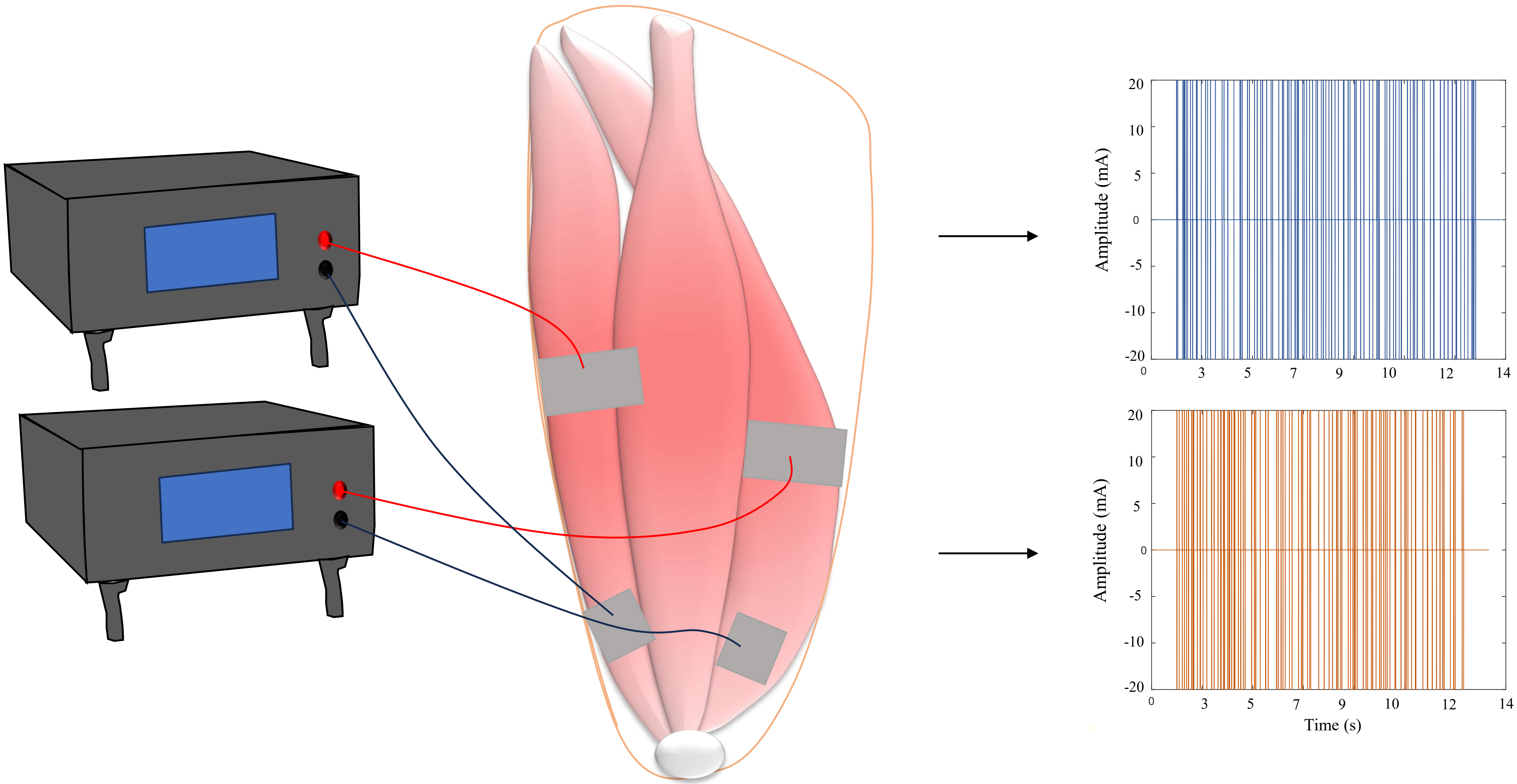
The MUAP spike trains were tracked between the two hip positions at 90° and 180°



(Negro et al., 2016, Martinez-Valdes et al., 2017).

Effects of changing the length of Rectus Femoris on Motor Unit Properties

2. Methods



2. Methods

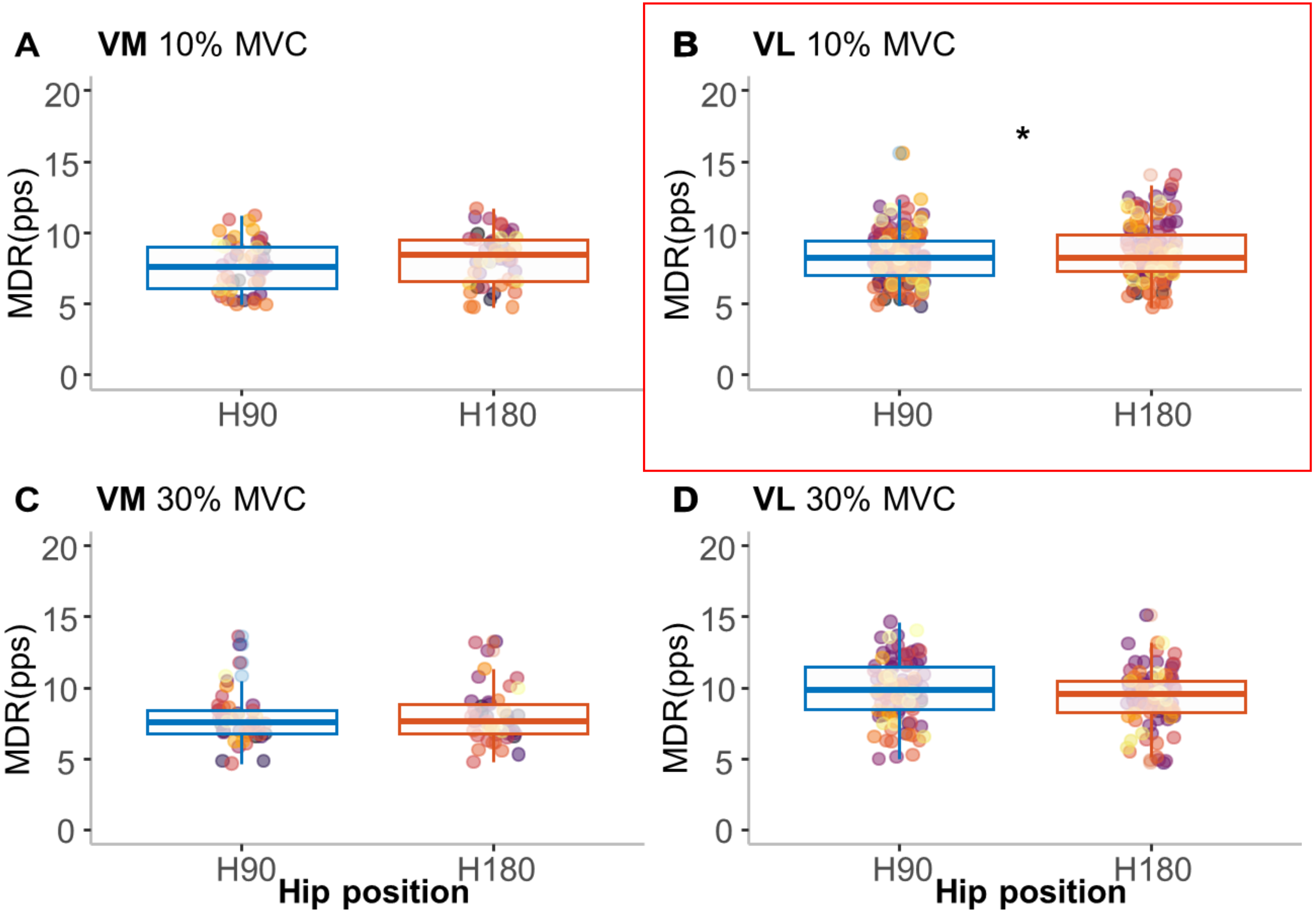
1. The mean discharge rate of matched MUs were calculated and compared using linear mixed models (LMM);

2. Force was compared between 90°(shorter) and 180°(longer) hip position using a Wilcoxon-test;

3. Muscle twitch results are presented as descriptive statistics.

Effects of changing the length of Rectus Femoris on Motor Unit Properties

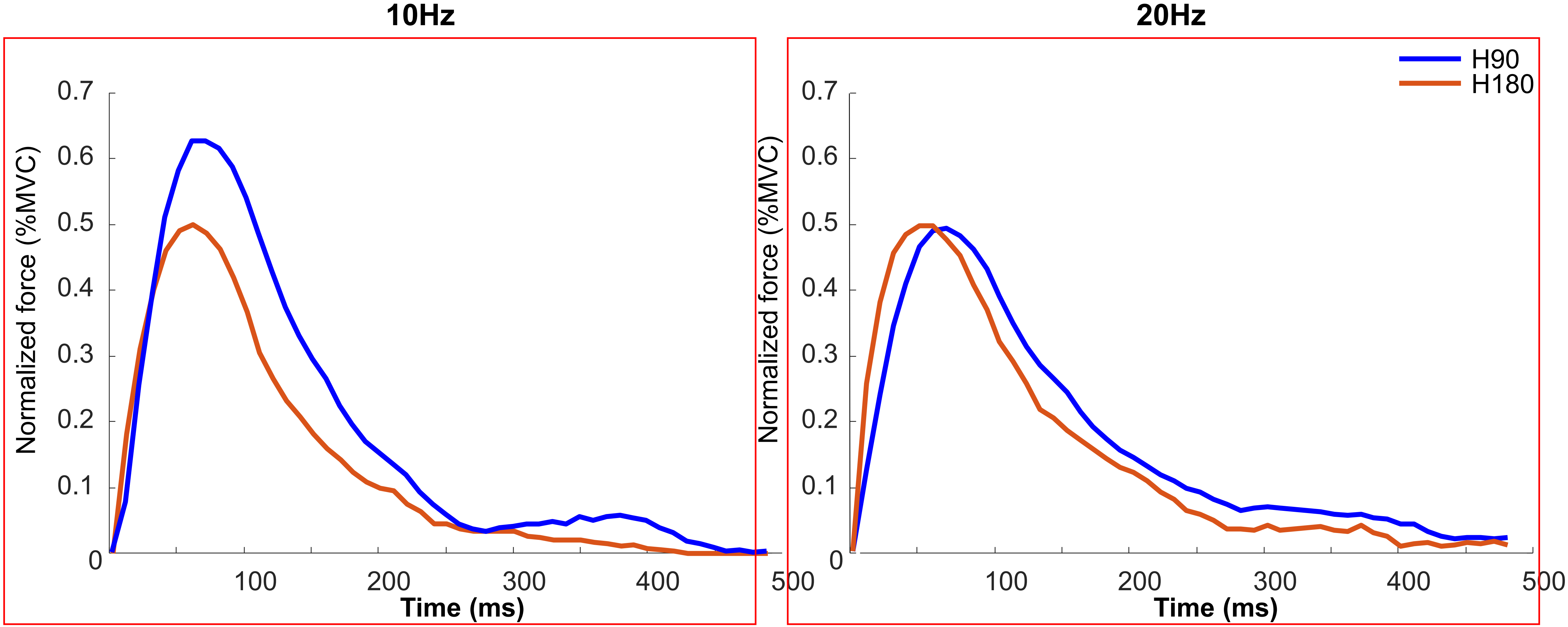
3. Results



Effects of changing the length of Rectus Femoris on Motor Unit Properties

3. Results

Summation of VM VL twitches



4. Conclusion

To maintain the same force output between 90° and 180° hip joint angles, the neuromuscular system relies on a higher discharge rate of the synergistic VL, subsequently coping with the decreased force generation capacity of RF.

This behaviour seems to be influenced by the level of contraction and differs between VL and VM since this increase in MDR just appeared at 10%MVC for VL.

5. Dissemination and next steps

- Preliminary results had been presented at the International Motoneuron Society 2024 (Bordeaux, France)

- The complete work will be presented at the Congress of International Society of Biomechanics 2025 (Stockholm, Sweden)

- Article phase: Methods, Results, Introduction has been done, finishing discussion, preparing to submit

Corticospinal transmission to spinal motor neuron output using repeated transcranial magnetic stimulation

1. Introduction

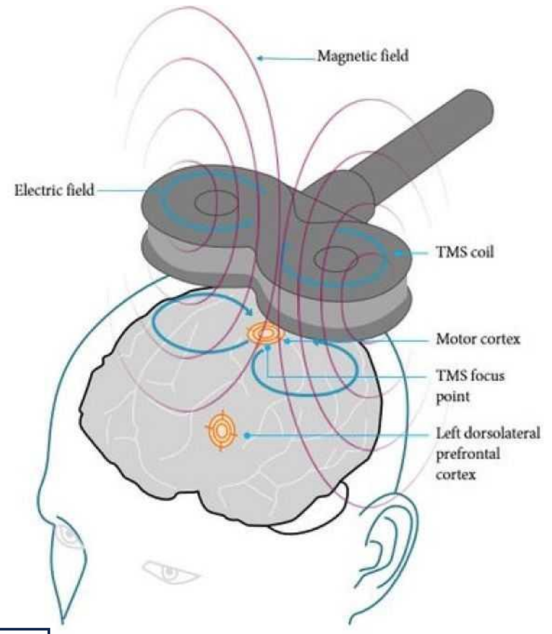
Non-invasive brain stimulation

Research

Rehabilitation

rTMS

Psychiatric and neurological disorders



Neuro cortical changes, increasing or reducing excitability depends on the stimulation parameters.

J. Williams, M. Imamura, and F. Fregni (2009); J.-P. Lefaucheur et al.(2020); P. Bawa and R. N. Lemon(1993); A. Pascual-Leone et al.(1994)

Corticospinal transmission to spinal motor neuron output using repeated transcranial magnetic stimulation

1. Introduction

- The effects of TMS at motor cortex area have been investigated by evaluating the motor-evoked potentials (MEPs) using electromyography (EMG);

- HD-sEMG could be more sensitive to capture the responses elicited by TMS by analysing the motor unit output;

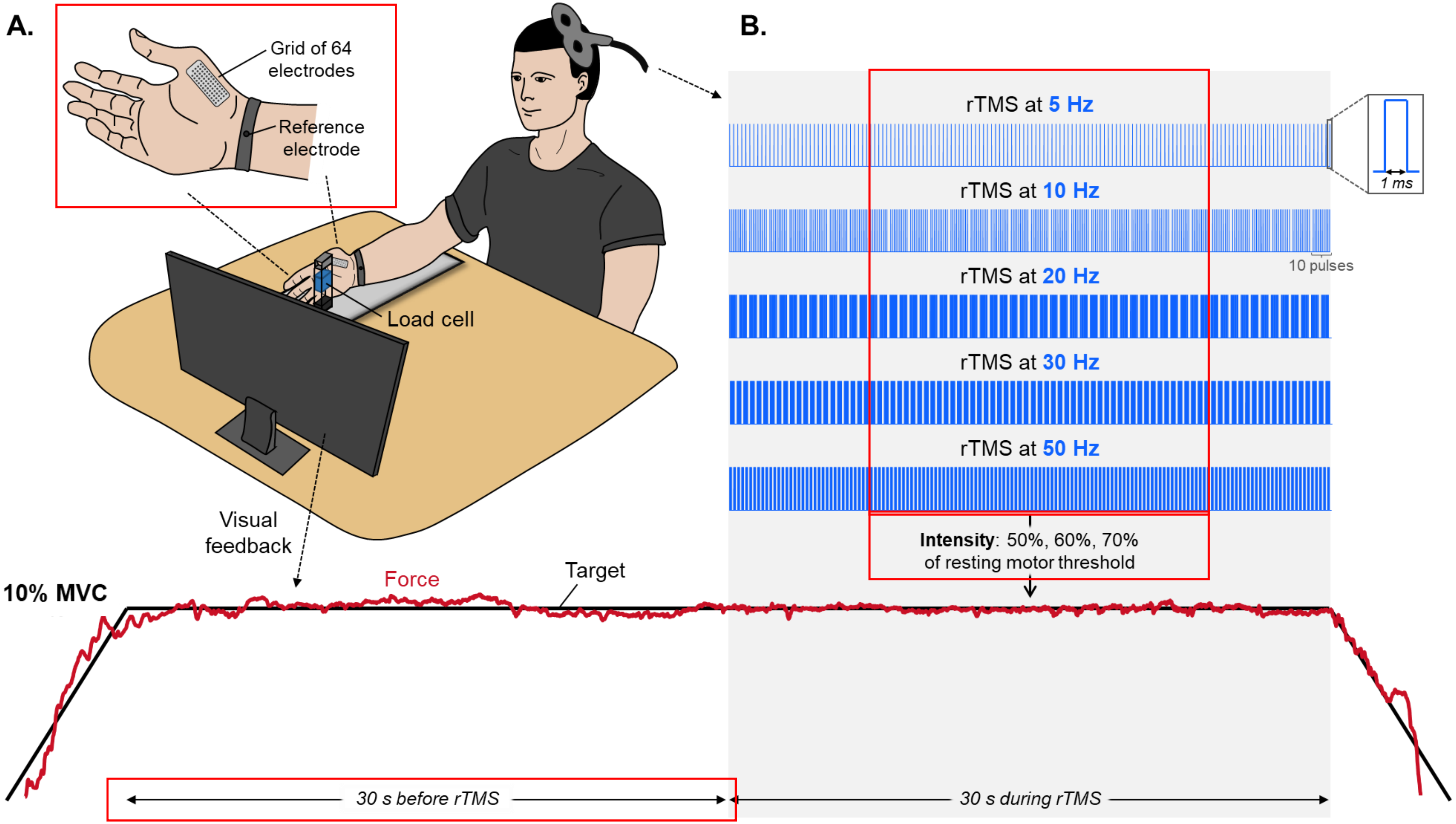
- Still not clear at which extent different frequencies of rTMS are effectively transmitted to the activity of motor neurons.

Investigate the corticospinal transmission of rTMS at different stimulation frequencies applied over the M1 area to the spinal motor neuron output by decomposing HD-sEMG.

Corticospinal transmission to spinal motor neuron output using repeated transcranial magnetic stimulation

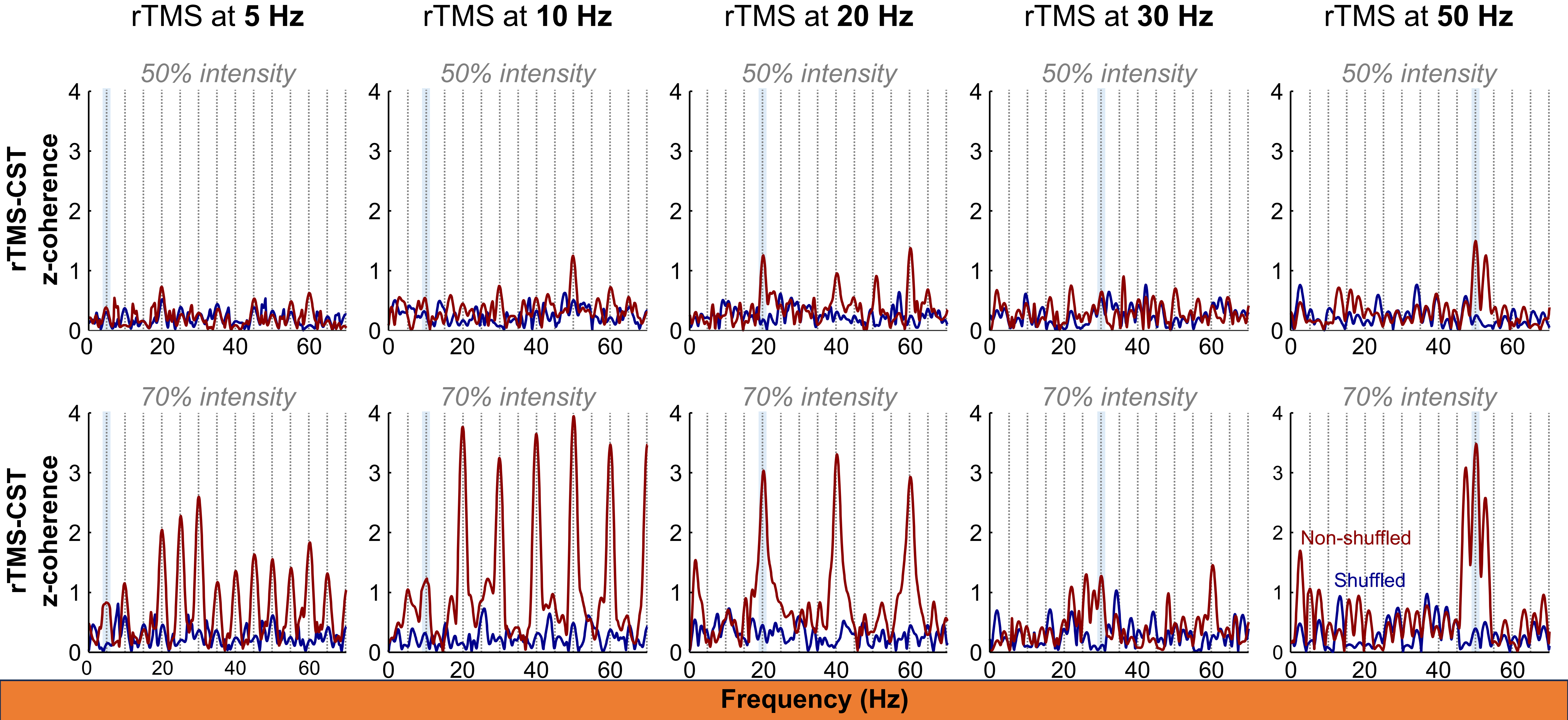
2. Methods

8 participants
Thenar muscles – 1 grid of 64 electrodes



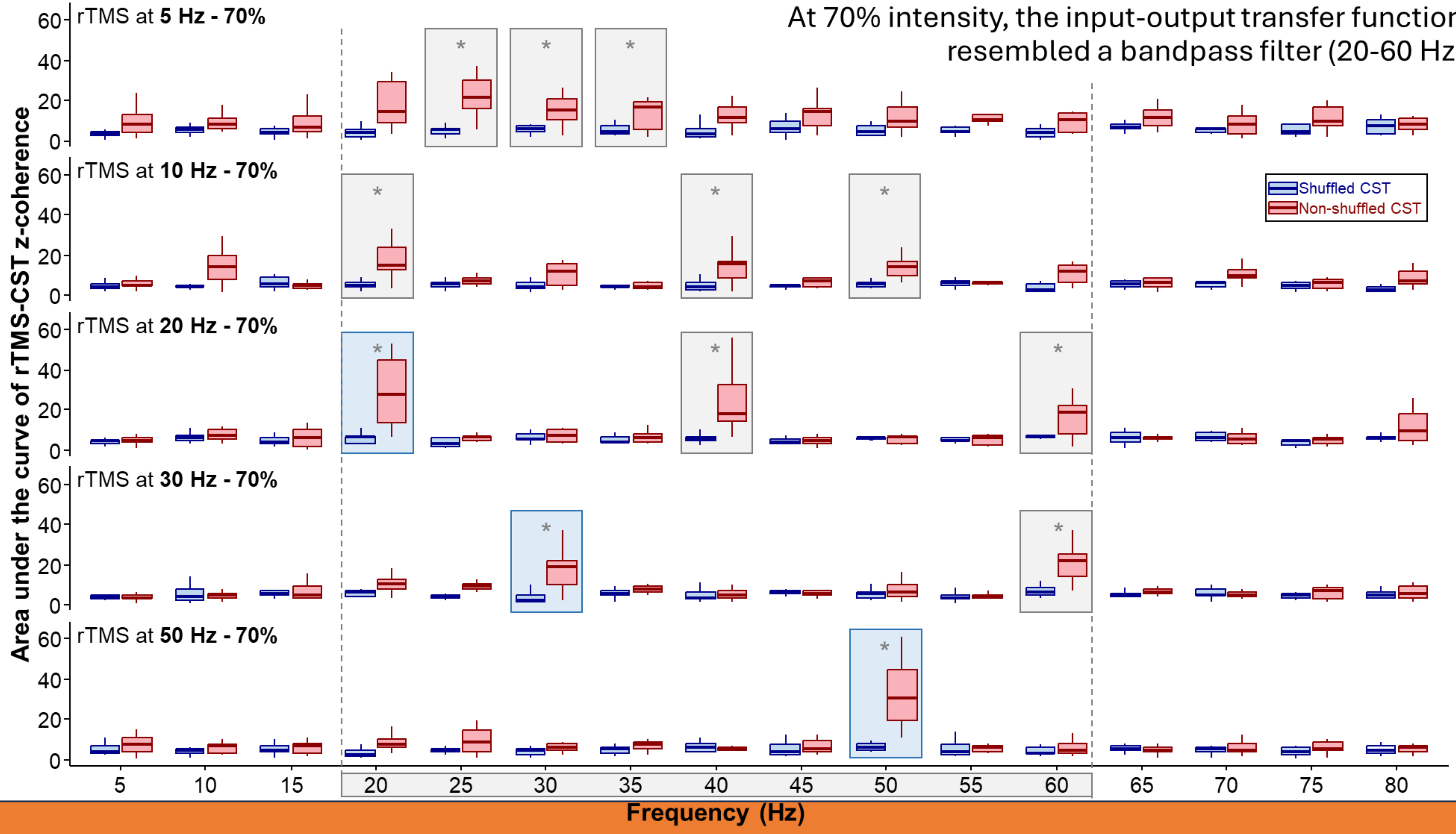
Corticospinal transmission to spinal motor neuron output using repeated transcranial magnetic stimulation

3. Results



Corticospinal transmission to spinal motor neuron output using repeated transcranial magnetic stimulation

3. Results



At 70% intensity, the input-output transfer function resembled a bandpass filter (20-60 Hz)

4. Conclusion

There is a band between 20Hz and 60Hz that increases the coherence between rTMS input and the CST output.

The efficiency of the transmission of the synaptic input generated by rTMS to the neural drive to the muscle is frequency and intensity dependent.

Corticospinal transmission to spinal motor neuron output using repeated transcranial magnetic stimulation

5. Dissemination and next steps

- Conference article had been presented at International Conference on NeuroRehabilitation, 2024 La Granja, Spain.

- Conference abstract had been presented at International Conference on Society for Neuroscience Annual Meeting (2024) Chicago, United States.

- Article under preparation.

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Transfer Function of Spinal Motor Neurons in Response to Different Frequencies of Repeated Transcranial Magnetic Stimulation

Conference paper | First Online: 27 February 2025

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Additional projects

Changes in the effective neural drive to synergistic muscles following the acquisition of a new motor skill task. Caterina Cosentino, Hélio V. Cabral, Milena A. dos Santos, Elmira Pourreza, J Greig Inglis, Francesco Negro. (**Article submitted under revision**)

A consistent low-dimensional neural mode underlies motor unit control across repetitive isometric tasks. Hélio V. Cabral, J. Greig Inglis, Elmira Pourreza, Milena A. Dos Santos, Caterina Cosentino, David O'Reilly, Ioannis Delis, Francesco Negro. **(Preprint online)**

Conference abstract: Exploring motor unit modes in repetitive isometric tasks. Cabral, H. V., Inglis, J. G., Pourreza, E., Cosentino, C., dos Santos, M. A., Negro, F. International Society for Electrophysiology and Kinesiology XXIV (2024) Nagoya, Japan

Conference abstract: Changes in common synaptic oscillations of synergistic muscles during the acquisition of a new motor skill task. Cabral, H. V., Cosentino, C., dos Santos, M. A., Pourreza, E., Inglis, J. G., Negro, F. International Motoneuron Meeting (2024) Bordeaux, France.

Next steps

Upcoming projects and collaboration:

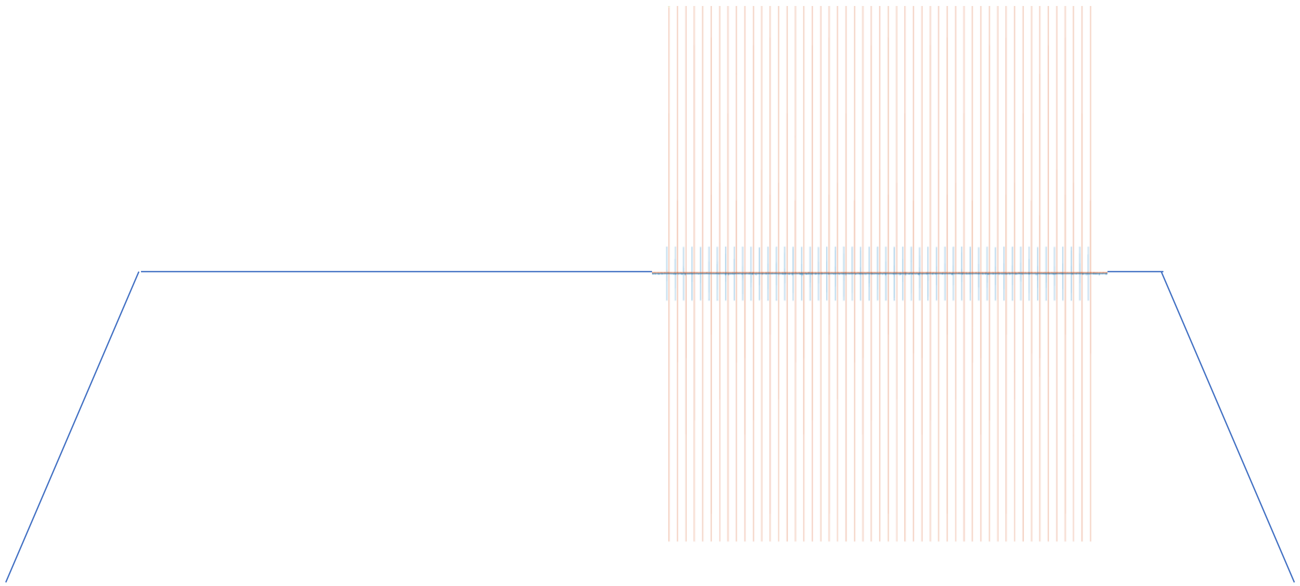
- Peripheral stimulation of a lower limb muscle and upper limb
  - Nerve stimulation to enable the analysis of motor unit output with HD-sEMG
  - Similar to the rTMS protocol.

Collaboration with Professor Allison Hyngstrom from Marquette University, Milwaukee USA – September/October/November

Piloting from peripheral stimulation + HDsEMG

Muscles tested for H-reflex:

Flexor carpi radialis;
Abductor pollicis brevis;
First dorsal interosseous;
Tibialis Anterior;
Soleus.



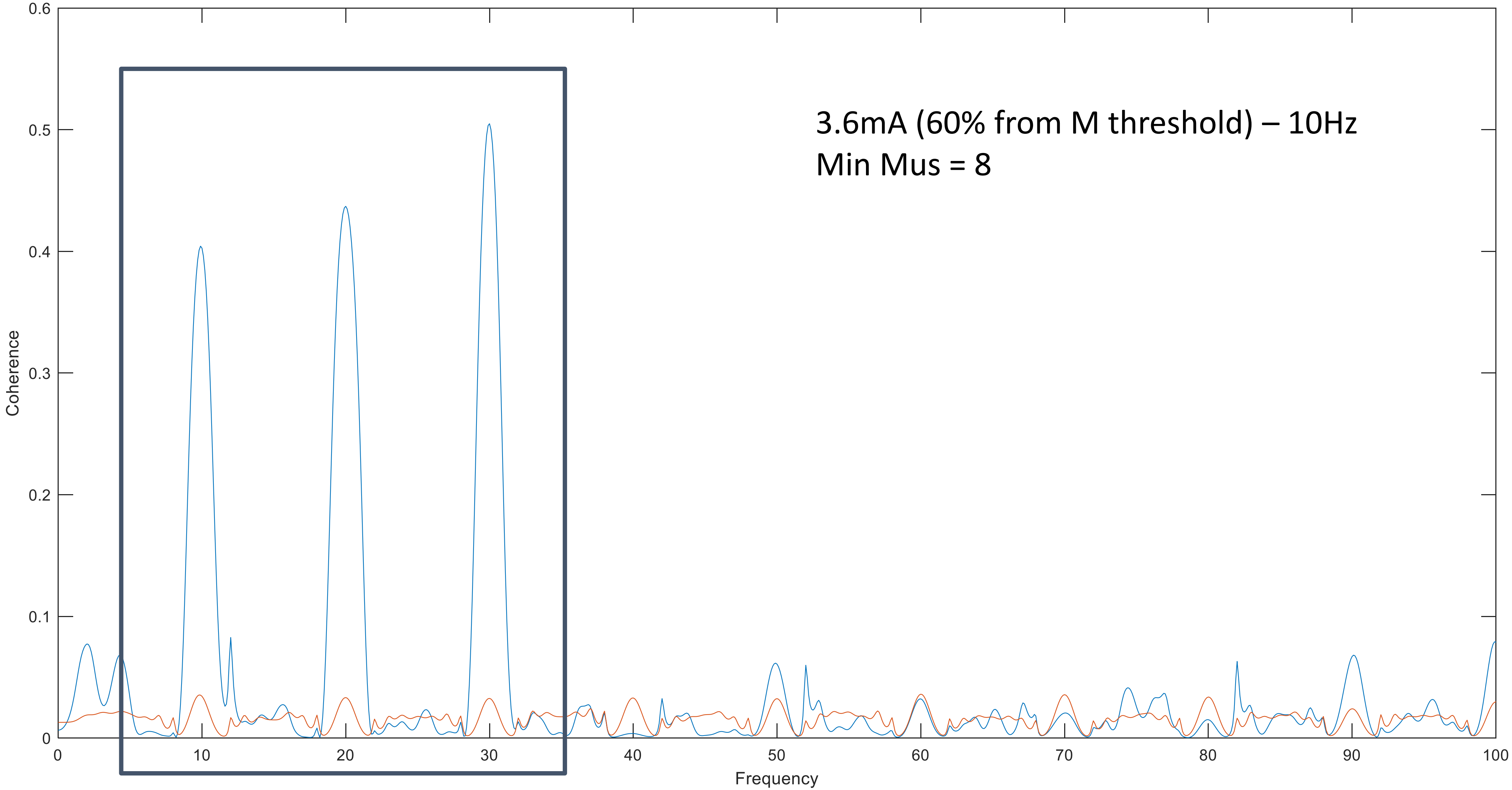
10%MVC

20s Stimulation

Frequency:5Hz 10Hz 20Hz 30Hz 50Hz

Intensity: 25% 50% 75% of M-wave threshold or Hmax

Input-Output coherence



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