# A Therapist-Inspired Approach to Stiffness Modulation in Rehabilitation Exoskeletons

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## Introduction

### Background

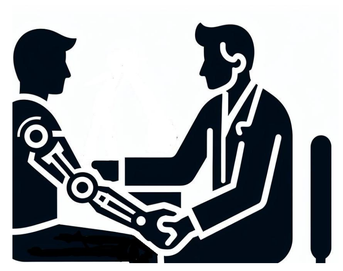
- In rehabilitation, therapists **naturally adjust arm stiffness** to provide **tailored assistance** to patients.
- Current exoskeletons lack an intuitive way to replicate this therapist-inspired adaptation, **limiting their effectiveness and acceptability.**

### Aim of the work

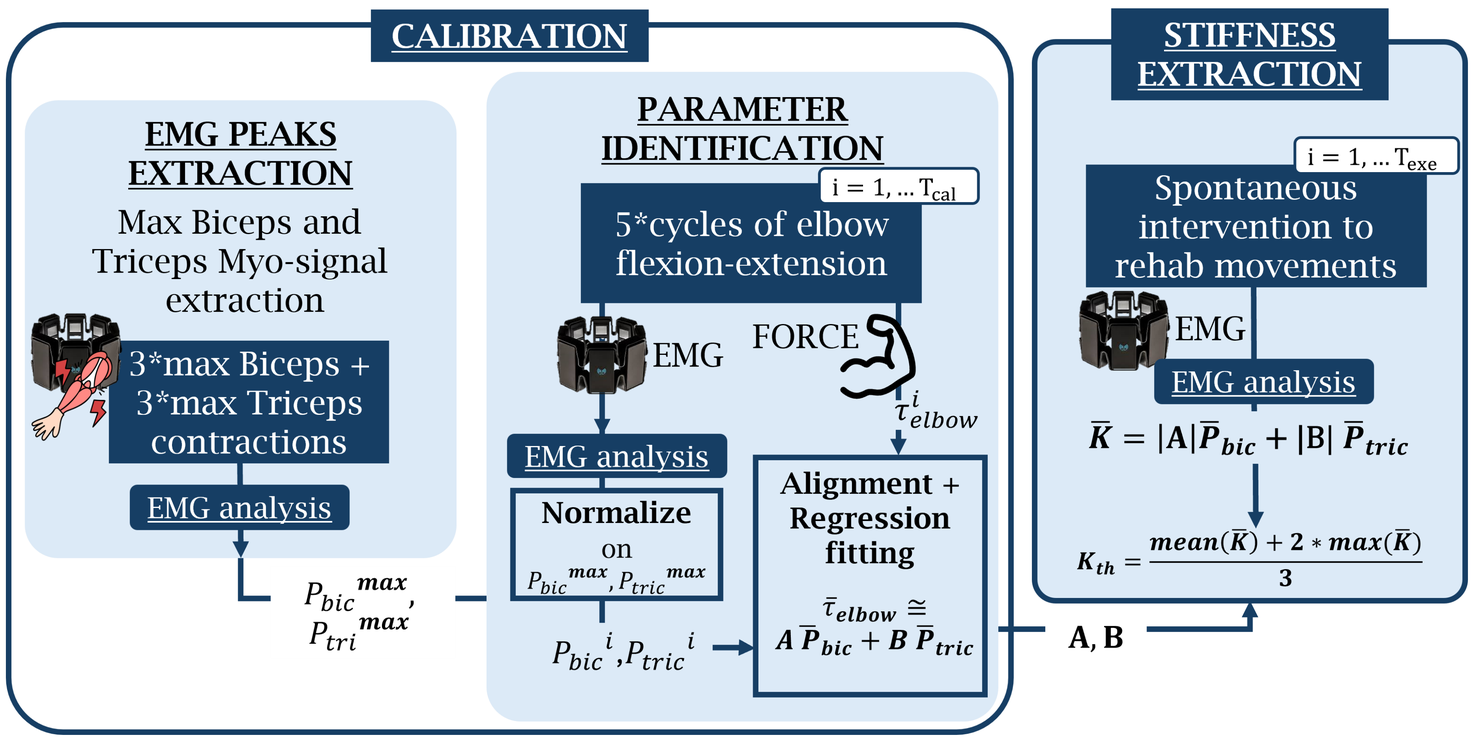
With this project, we aim to :

Develop a framework to **extract therapist-inspired stiffness from muscle activity**, through the analysis of surface electromyography **(sEMG);**

Transfer it to the **rehabilitation exoskeleton AGREE** to enable human-like assistance.



## Therapist's Stiffness Extraction Framework




The framework records muscle activity using a **Myo armband** and torque data from the **AGREE** exoskeleton:



**1. Calibration phase:**

- The **therapist wears the Myo and AGREE**, flexing and extending the elbow.
- We establish a **relationship** (A, B parameters) **between muscle activation and joint torque.**



**2. Stiffness extraction phase**:

- The therapist **manipulates** the arm of the patient (+ AGREE, if desired);
- We use the extracted parameters to perform a **stiffness estimation based on biceps-triceps co-contraction**.

The extracted stiffness is then **scaled and applied to AGREE**, enabling it to replicate therapist-like adaptive support.

## Experiments and Results

### Experiments




✓ **3 Healthy participants**:
- Acting as therapist
- Wearing Myo Armband

✓ Ethical Committee - Politecnico di Milano

**1** **Therapist Stiffness Modulation Under Different Conditions**

Participants manually guiding AGREE in an elbow flexion-extension task.

Two conditions:

**1.Simulated Severely Impaired Patient** (C1) – AGREE in a non-assisted mode, requiring full external support.

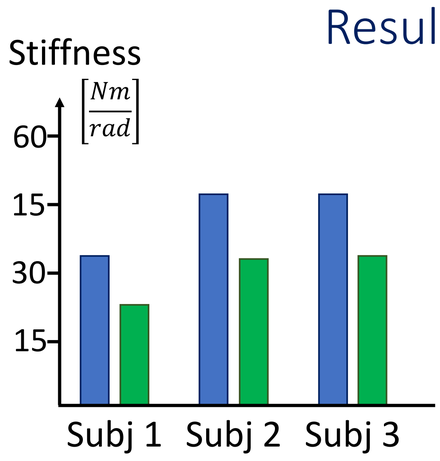
**2.Simulated Mildly Impaired Patient** (C2) – AGREE compensated for its weight, requiring less therapist assistance.

**2** **Validation of Therapist-Inspired Stiffness on AGREE**

Participant guiding AGREE along a predefined reaching trajectory. The extracted stiffness is then transferred to AGREE, which repeats the movement autonomously.

### Results

**1**



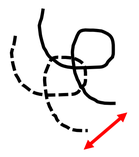

| | | | |
|---|---|---|---|
| $A$ | 2.80 | 1.73 | 1.54 |
| $B$ | 1.41 | 2.17 | 4.00 |

✓ Results showed **higher stiffness when assisting a "severely impaired" patient** and lower stiffness for a "mildly impaired" one, effectively mirroring therapist behavior.

**2**

✓ Therapist-extracted stiffness was transferred to AGREE, produces **trajectory-tracking errors (RMSE) closely comparable to those of human-guided movements.**

Kinematic accuracy of **AGREE** = Kinematic accuracy of the **therapist**



## Discussion

Our framework:

✓ **Extracts therapist behavior** and translates it into robotic stiffness.

✓ **Detects therapist behavior variations** and adapts accordingly.

✓ **Ensures robotic parameters** replicate the kinematic effects of learned therapist behavior.



FUTURE DEVELOPMENTS:

- Extraction of **real-time stiffness variations**.
- **Therapists' evaluation** of the system.

## References

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[4] R. **Arduini** et al., "Learningfrom demonstration of robot motions and stiffness behaviors for surgical blunt dissection" IEEE ROMAN, **2024**.

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