Extraction of muscle synergies in sport

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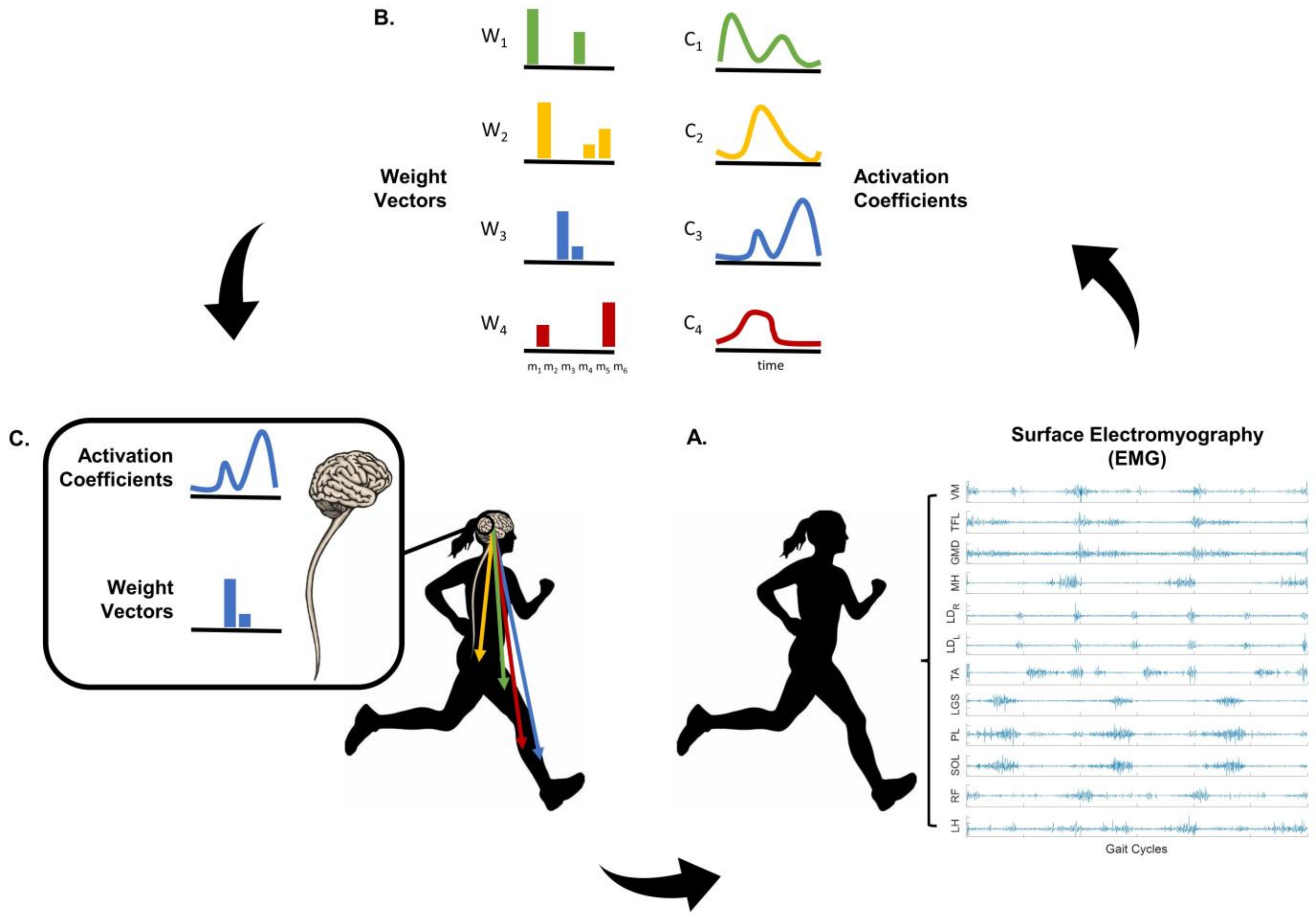
Extraction of muscle synergies in sport

The study of **muscle synergies** can provide an in-depth understanding of **how the Central Nervous System** (CNS) **controls many muscles to perform a specific motor task** or an athletic gesture. This tool can be used to evaluate:

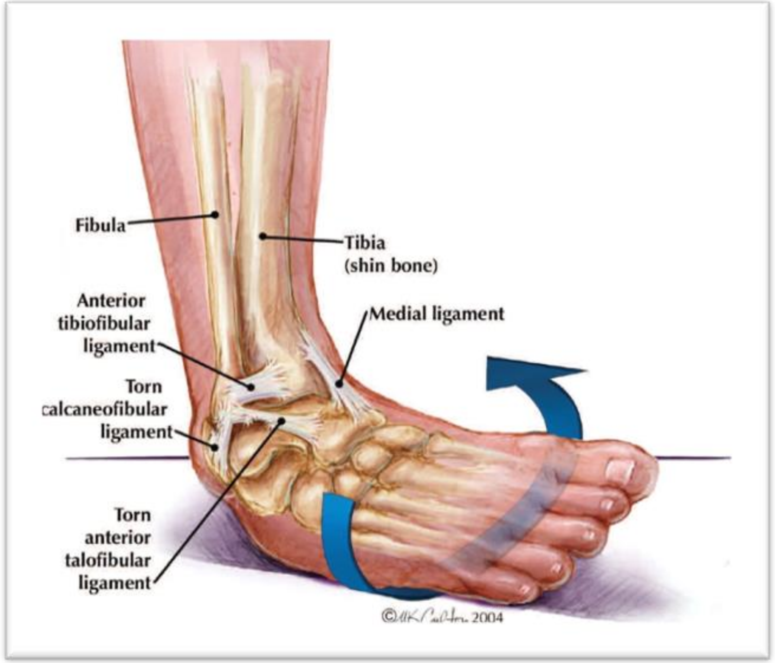
- Motor skill competencies & intermuscular coordination of athletes with different levels of expertise, before/after specific training programs
- Motor biomarkers for injury and re-injury prevention & assessment of Return-To-Sport.



[Courtesy of Dr. Marco Ghislieri, from The Bioengineering of Sport – 2023 Patron Editore]

Chronic Ankle Instability (CAI)

- **Ankle sprain** is the most common lower limb injury in athletes and accounts for 16%-40% of all sports-related injuries.
- Individuals involved in the first episode of ankle sprain frequently undergo further injuries, developing **CAI**, a condition characterized by recurrent ankle sprain episodes, perception of ankle "giving-way", reduced ROM, self-reported function, weakness, & pain, that can persist for more than 1 year after the first episode.
- The persistence of **ankle instability** can alter the athlete **proprioception** (and it may also lead, in the long term, to joint degenerative pathologies, e.g. osteoarthritis).



Ankle sprain

Chronic Ankle Instability (CAI)

The genesis of CAI has been identified in both **mechanical** and **neural** factors:

- MECHANICAL: The first episode of ankle sprain causes damage to the structures of the foot-ankle complex (ligaments, nerves, tendons, & muscles), increasing ankle joint laxity.

- NEURAL: Spinal and supraspinal alterations which persist over time cause maladaptation in the control of movement. During the performance of balance tasks, individuals suffering from CAI show a proximal muscle excitation strategy.

The speaker

Dr. Marco Ghislieri – *RTD-A researcher*

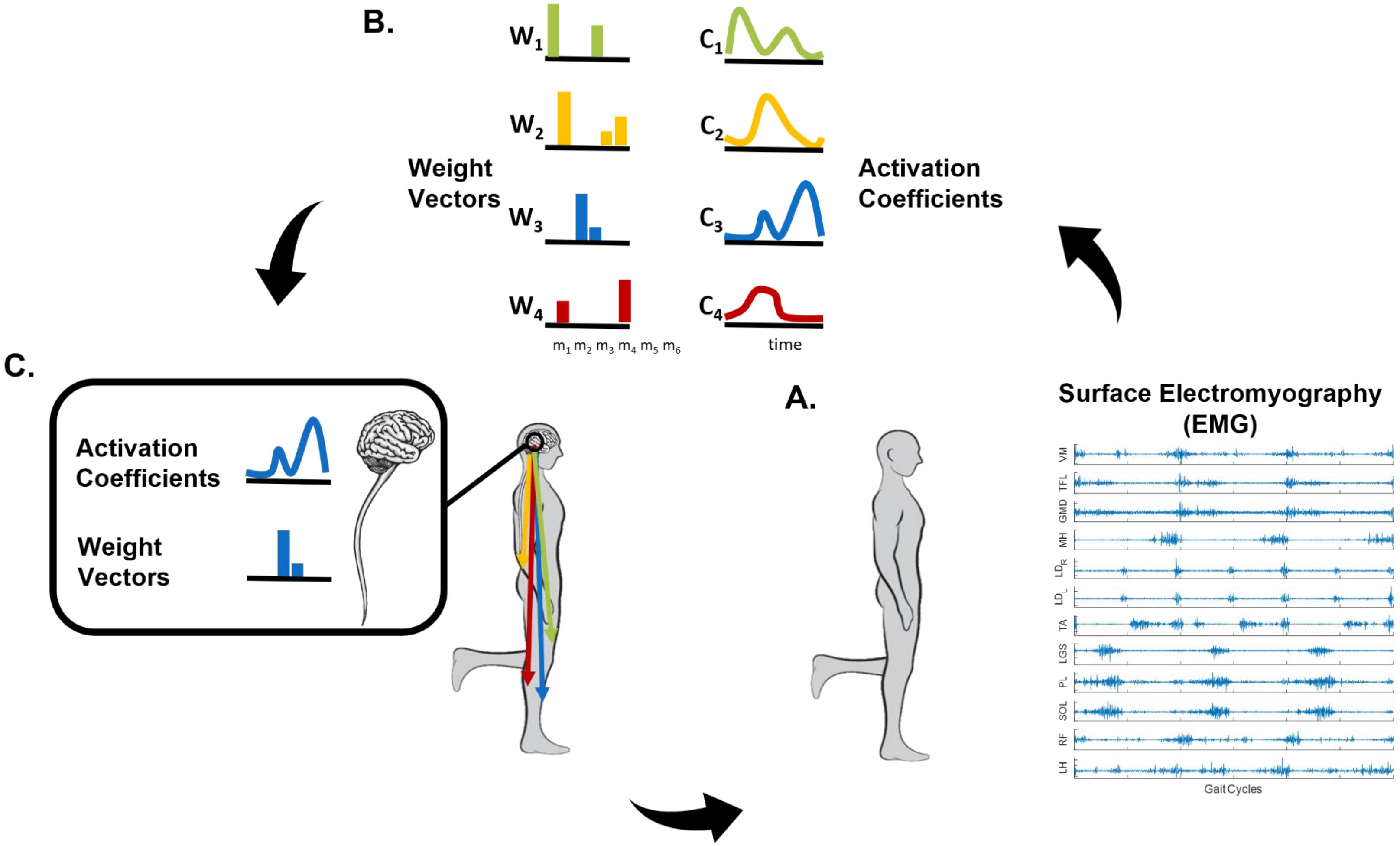
Politecnico di Torino

- M.S. degree in **Biomedical Engineering** (2016)@Politecnico di Torino
- Ph.D. **Bioengineering and Medical and Surgical Sciences** (2021) @Politecnico di Torino

- His research mainly focuses on understanding how the CNS manages motor control during movements, in both healthy and impaired individuals.

- For his contributions to technological advances in EMG acquisition and signal processing, he received the 2022 Carlo J. DeLuca Award from the International Society of Electrophysiology & Kinesiology (ISEK).

Evaluation of Chronic Ankle Instability



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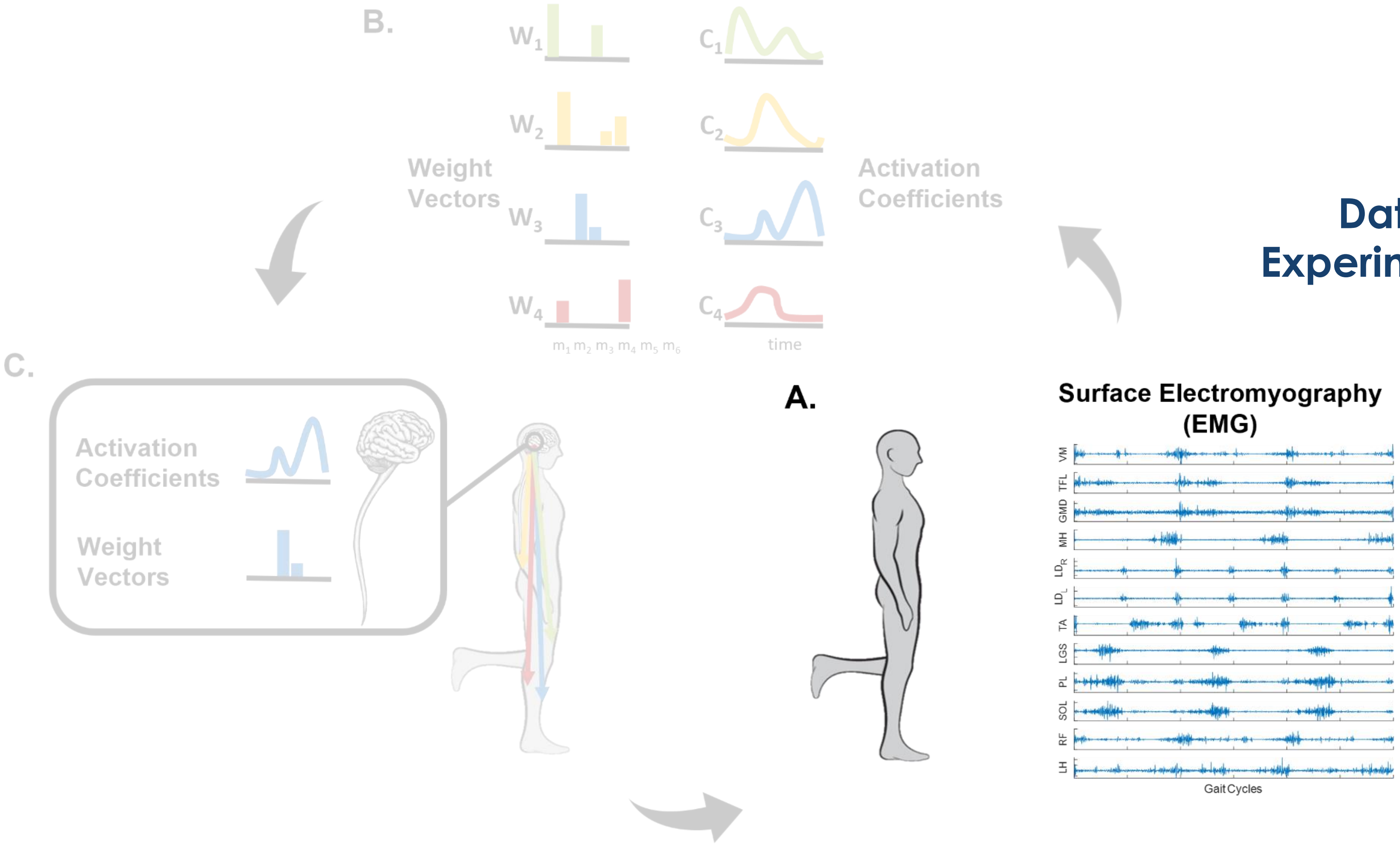
Evaluation of Chronic Ankle Instability

Data acquisition & Experimental protocol



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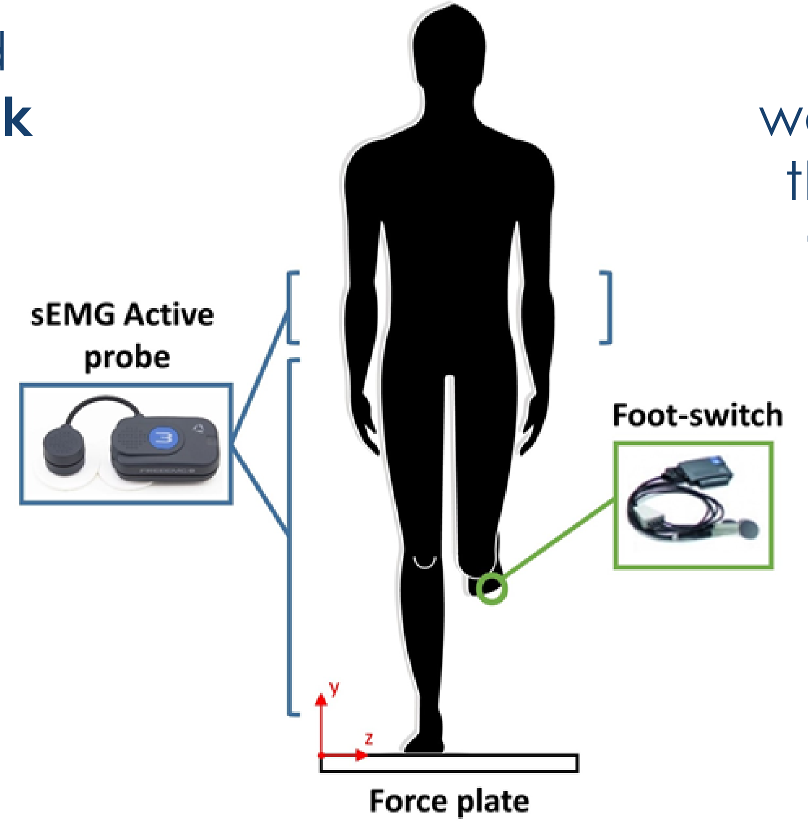
Evaluation of Chronic Ankle Instability

Acquisition system

EMG signals were acquired from **13 lower-limb and trunk muscles** of the affected (or dominant) side



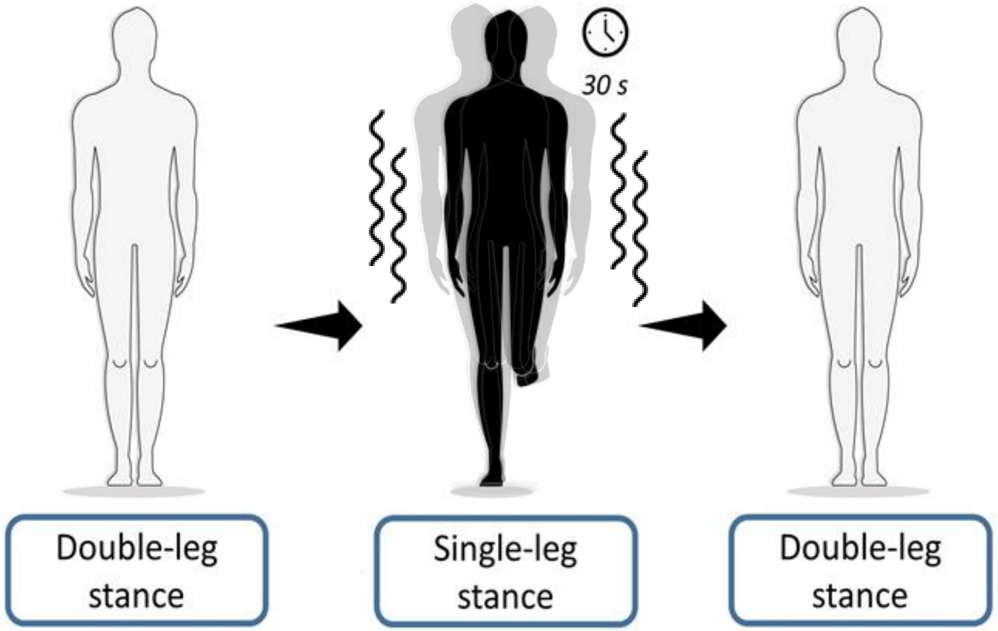
Foot-switch was placed under the foot of the limb raised from floor to **time-segment SLS epochs**

[Ghislieri et al., Muscle synergy assessment during Single-Limb-Stance, IEEE Trans. Neural Sys. Rehab. Eng., 2020. Doi: 10.1109/TNSRE.2020.3030847]

Evaluation of Chronic Ankle Instability

Experimental protocol

Subjects were asked to **maintain SLS balance** with their injured (CAI) or dominant (control) lower limb for at least **30 seconds.**



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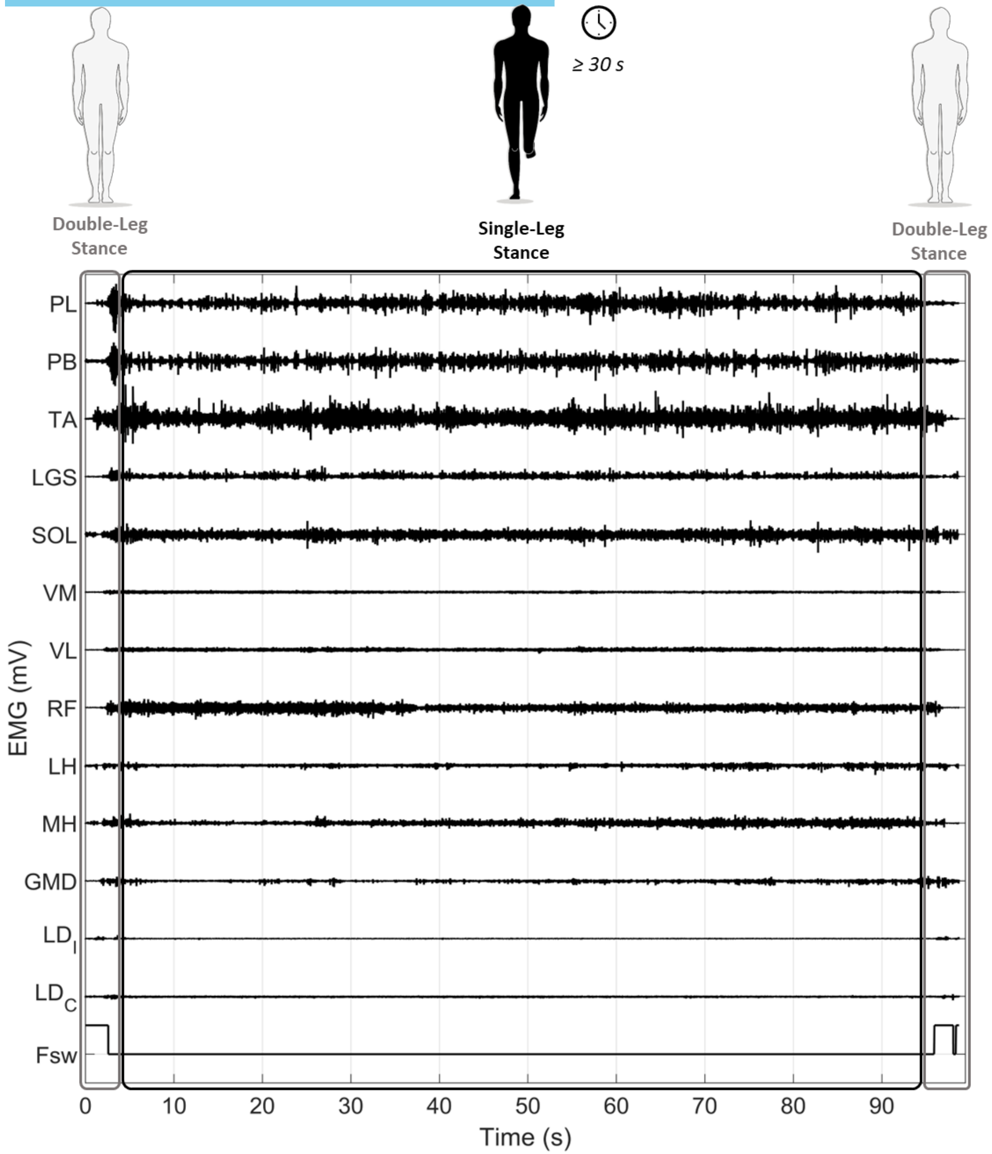

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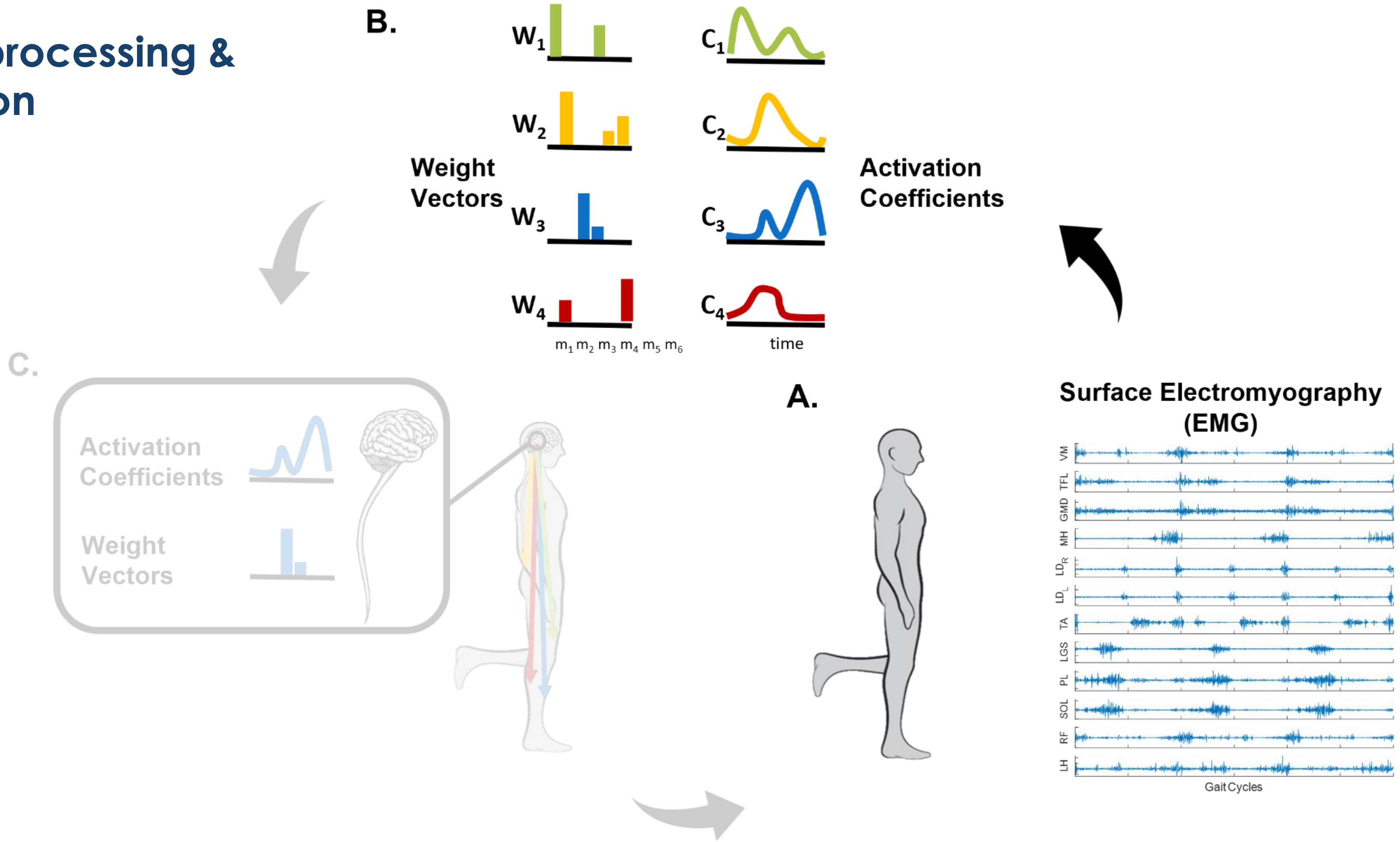
Evaluation of Chronic Ankle Instability

EMG pre-processing & factorization



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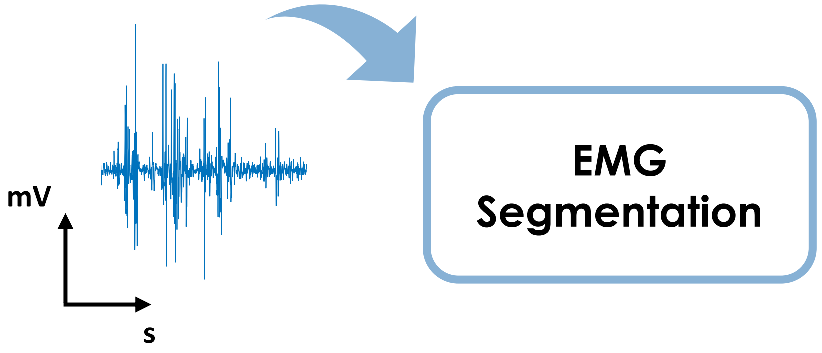
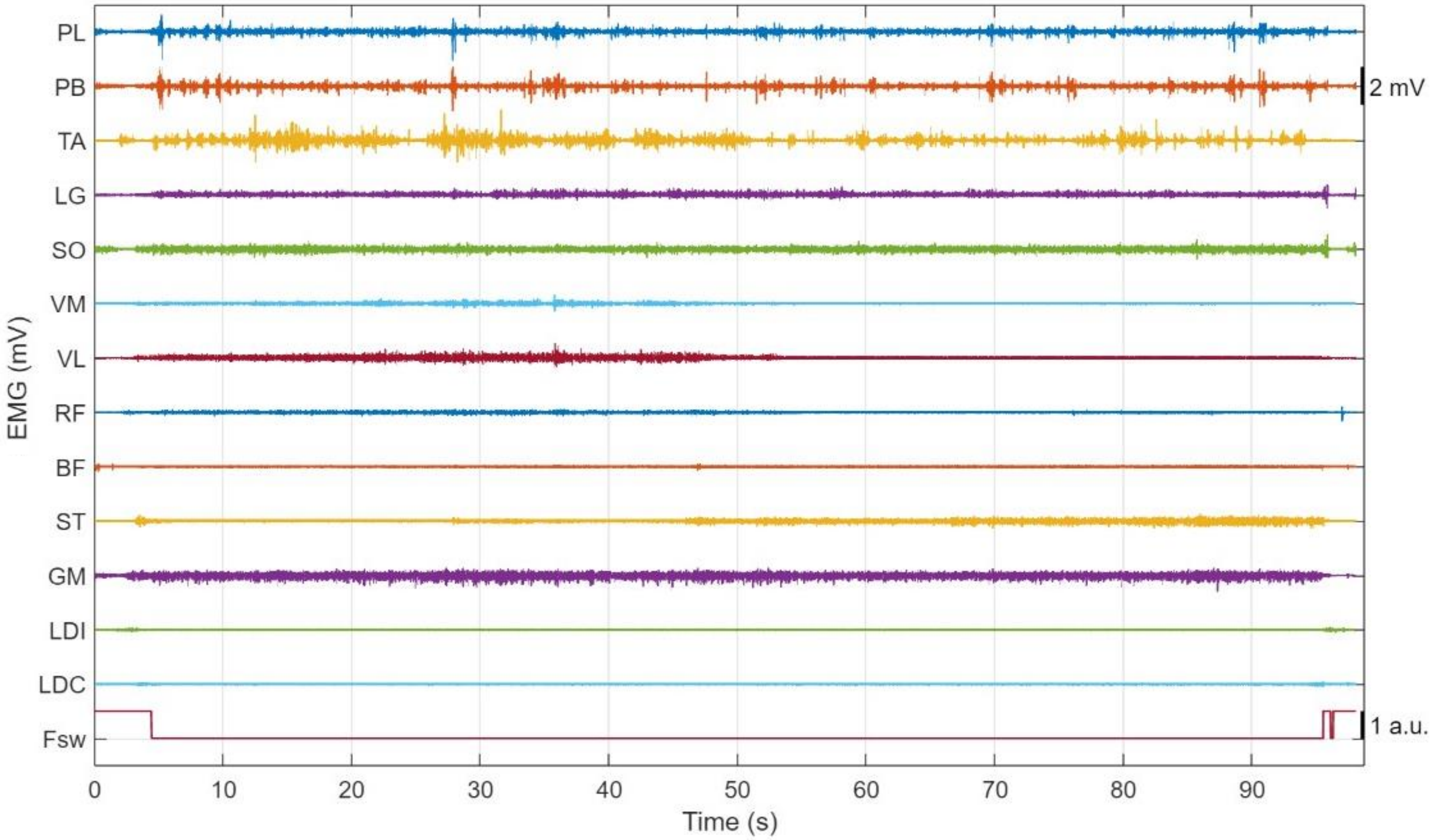
Evaluation of Chronic Ankle Instability

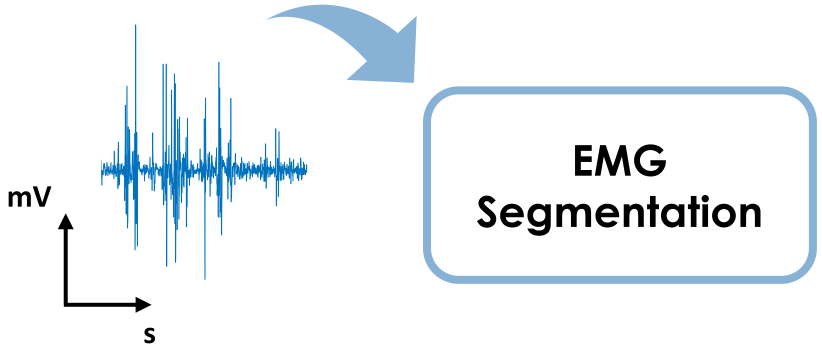


SLS epoch is defined as the **longest 0-level epoch**, excluding **2 seconds following the Double-Leg to Single-Leg Stance transition** and **2 seconds preceding the Single-Leg to Double-Leg Stance transition.**



Raw EMG and Fsw signals acquired from a representative healthy subject.

Evaluation of Chronic Ankle Instability



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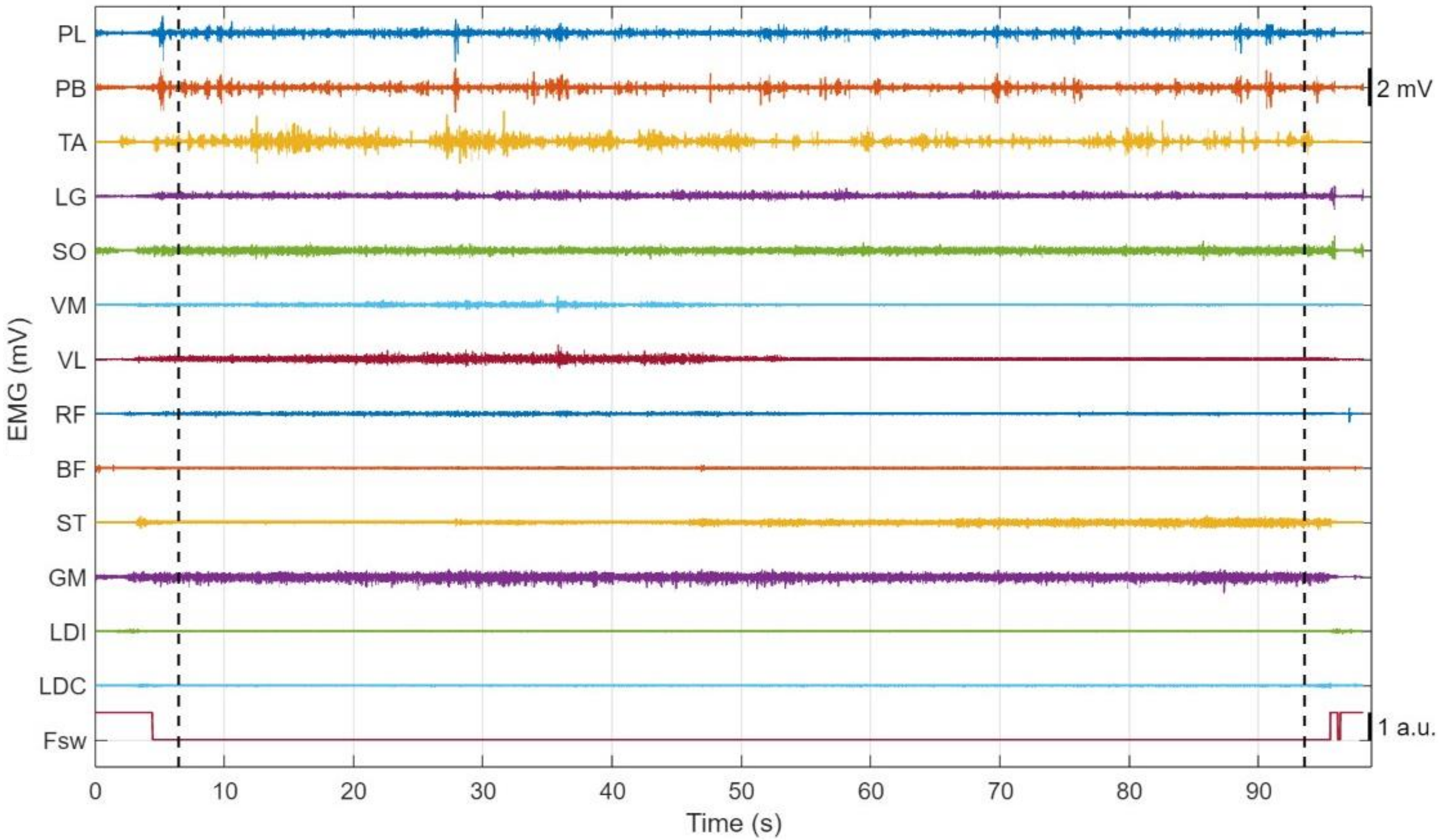
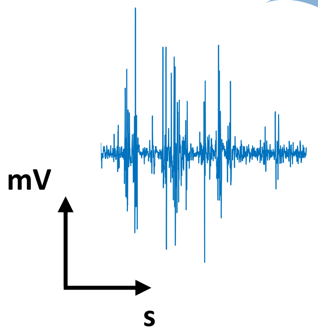


Raw EMG and Fsw signals acquired from a representative healthy subject.

Evaluation of Chronic Ankle Instability

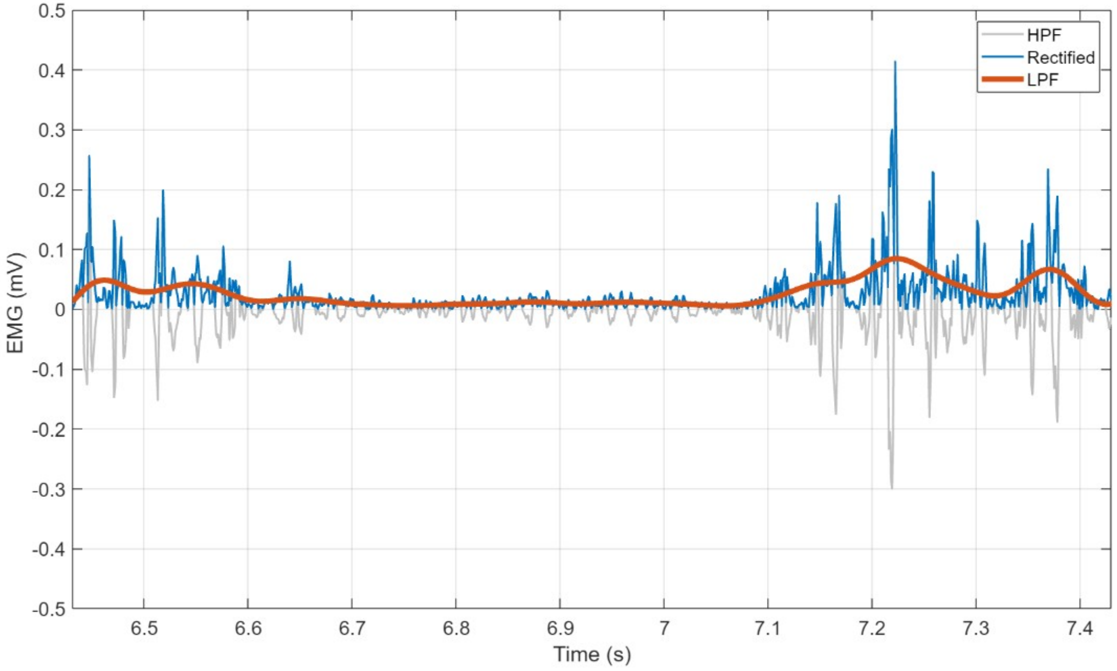


EMG Segmentation → **EMG Pre-processing**

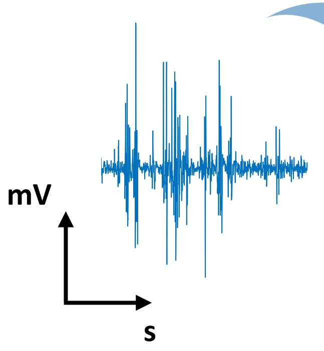
EMG Pre-processing

High-pass filter @35Hz → EMG Rectification → Low-pass filter @12Hz → Amplitude Normalization

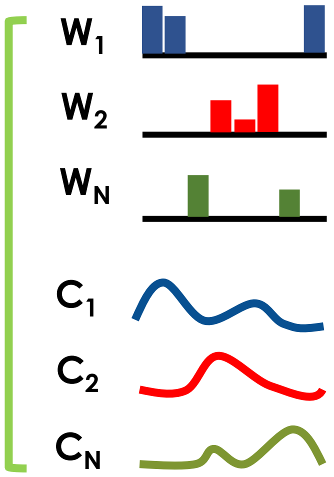
Filtered EMG signals acquired from Tibialis Anterior muscle of a representative healthy subject.



Evaluation of Chronic Ankle Instability



EMG Segmentation → **EMG Pre-processing** → **Muscle Synergy Extraction** (NNMF)



EMG Pre-processing

High-pass filter @35 Hz → EMG Rectification → Low-pass filter @12 Hz → Amplitude Normalization

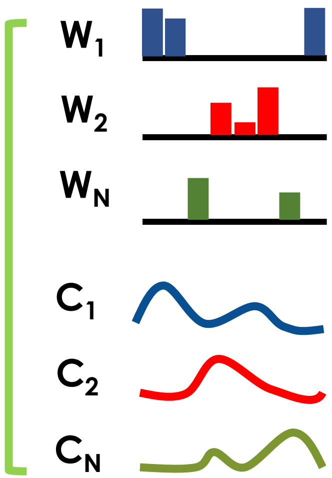
Muscle Synergy Extraction (NNMF)

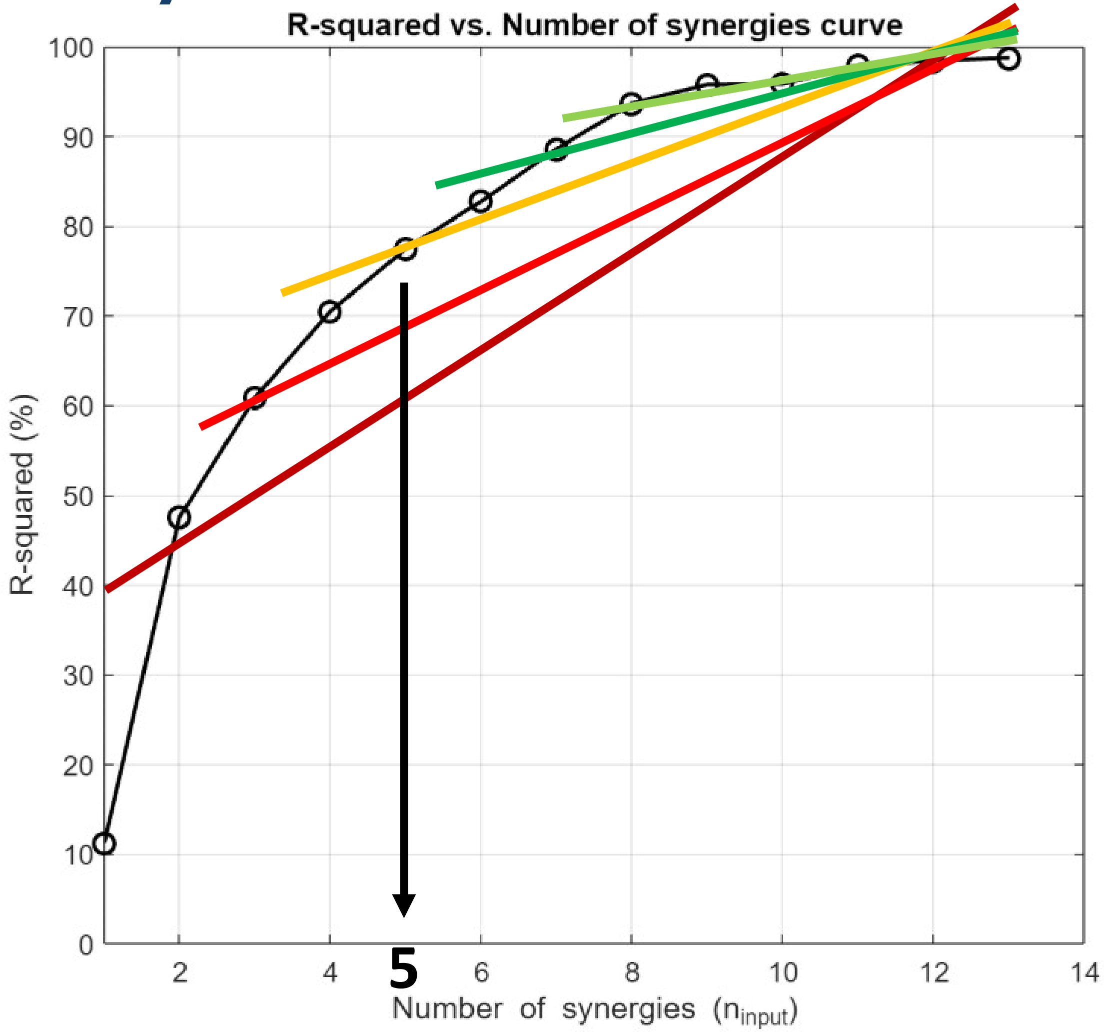
$$M(t) = \sum_{k=1}^{N} C(t)_k \cdot W_k + e$$

- **Activation coefficients (C):** temporal activation pattern of each synergy (temporal information)
- **Weight vector (W):** contribution of each muscle to a specific synergy (spatial information)

Evaluation of Chronic Ankle Instability

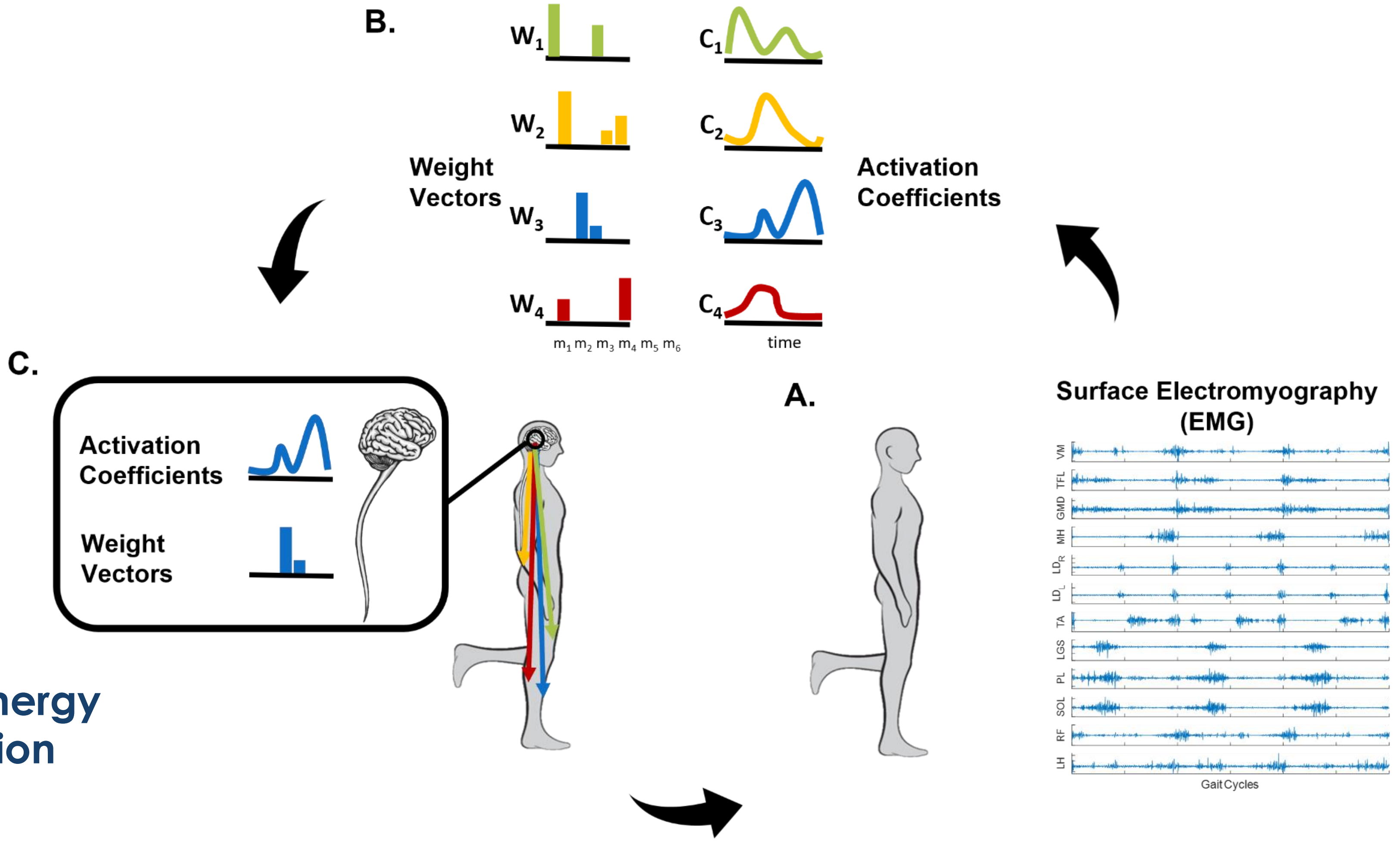
Selection of the number of muscle synergies (N)





Coefficient of determination (R-squared) is computed the quantitatively assess the **percentage of variability accounted for by the muscle synergy model.**

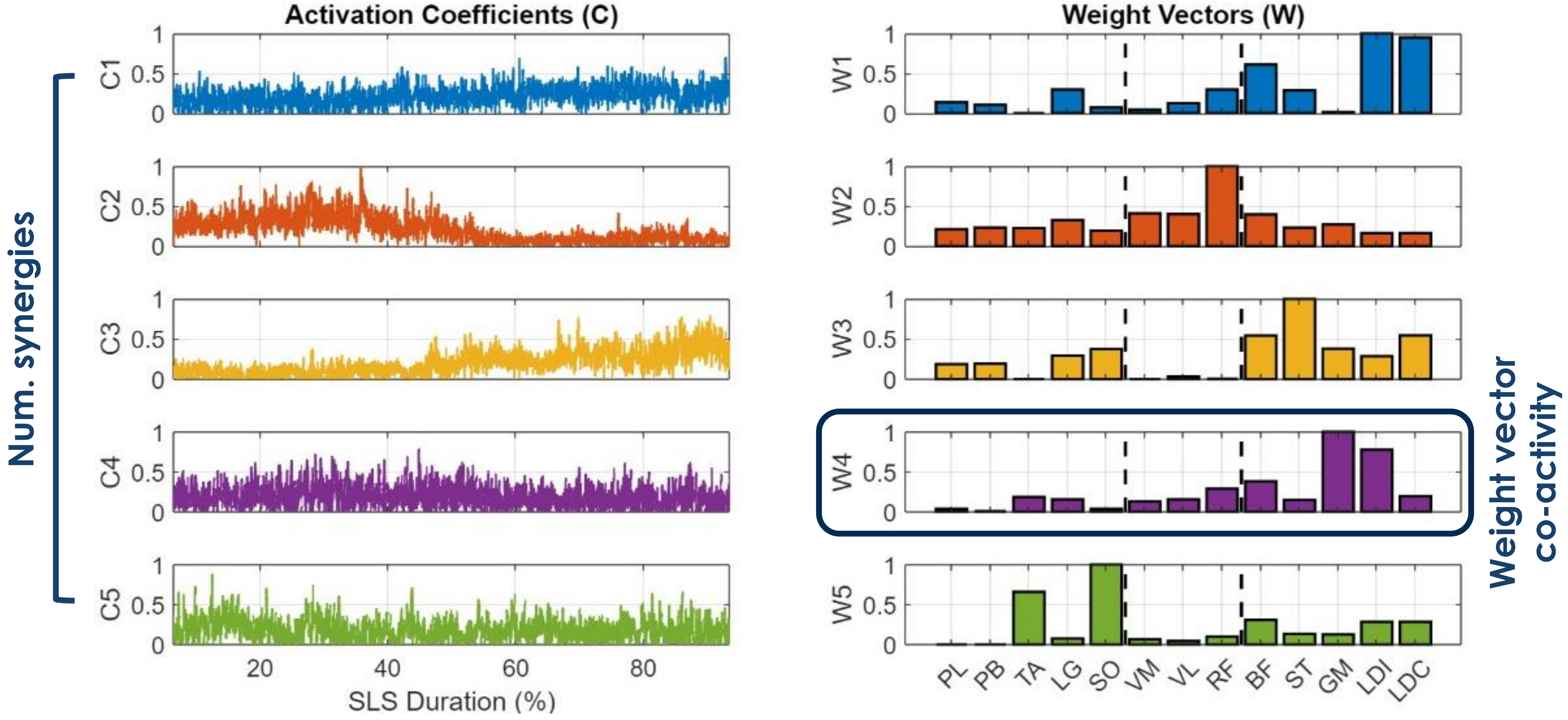
Evaluation of Chronic Ankle Instability



Muscle synergy interpretation

[Courtesy of Dr. Marco Ghislieri, from The Bioengineering of Sport – 2023 Patron Editore]

Evaluation of Chronic Ankle Instability



Muscle synergies extracted from a representative healthy subject.

Evaluation of Chronic Ankle Instability

Hands-on session

Each team will be provided with **MATLAB® routines** to extract muscle synergies and **surface EMG data from two subjects** (one of which is affected by CAI).

The team should **compare the two subjects** and **establish which one shows ankle instability and which one shows the better ankle stability**.

Hands-on session guidelines and **data** are available in the **GitHub repository**