EMG-triggered surface FES for arm reaching in tetraplegia

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A mid-cervical level spinal cord injury results in loss of **wrist and elbow extension**, while the muscles providing **elbow flexion** and **shoulder abduction** retain at least partial voluntary control.

Surface functional electrical stimulation (FES) is typically used therapeutically to strengthen and retrain atrophied muscles, but if applied in a coordinated way, can be used to restore useful function.

In this case study, we used EMG-triggered FES to restore some control of arm reaching. The algorithm used is shown below.

Reaching out:

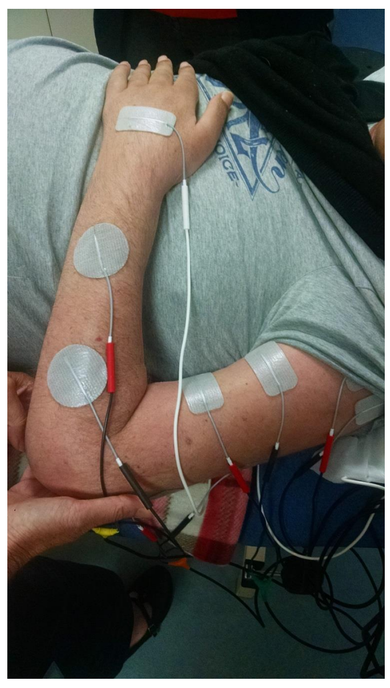
Deltoid ↑ + Biceps ↓ → Triceps & wrist extensors **ON**

Bringing the arm in:

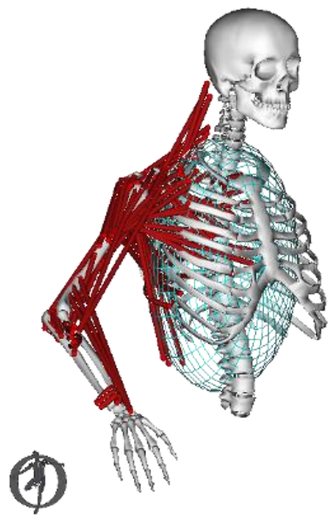
Biceps ↑ → Triceps & wrist extensors **OFF**

The patient was a 56-year old male, 19 months post injury (C4 Frankel A with some denervation at C8, but stimulatable C5,6 & 7).

We used an Ottobock STIWELL surface stimulator and placed recording EMG electrodes on the biceps and anterior deltoid, and stimulating electrodes on the triceps and wrist extensors.



With the algorithm described, **the patient was able to successfully reach out, and bring his arm in at will**.

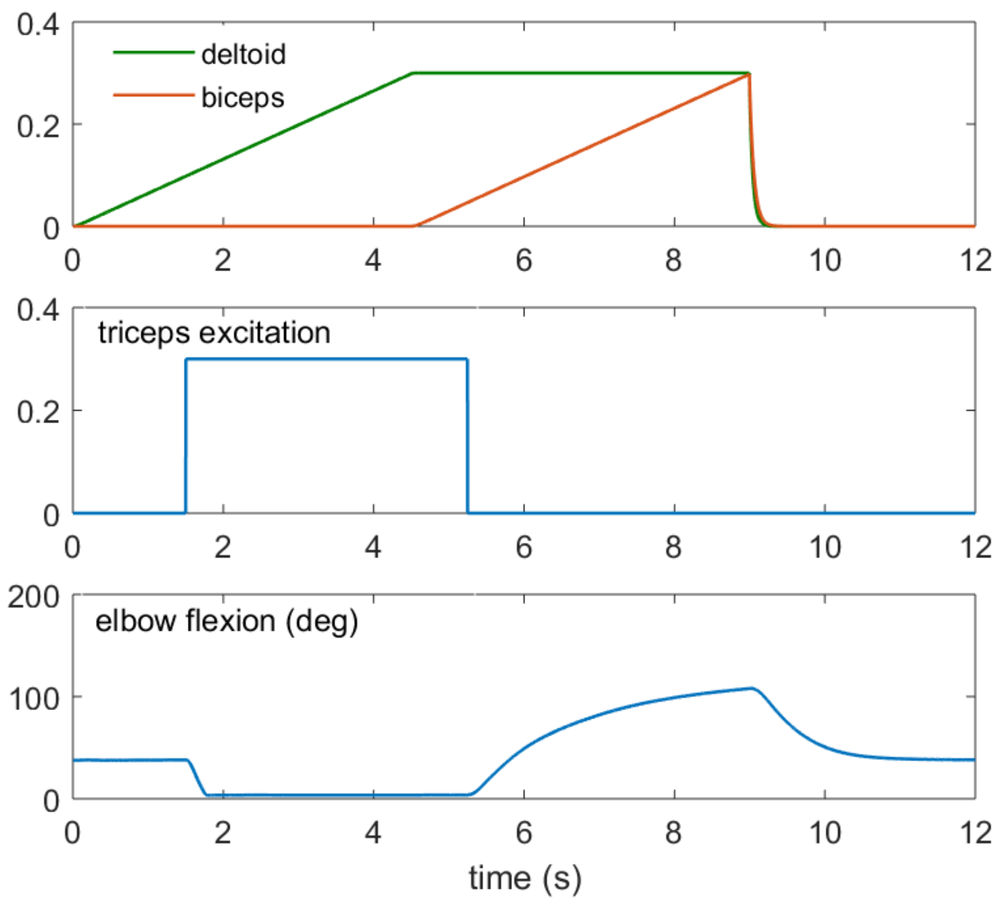


To allow us to optimise this algorithm, we re-created it in a computer simulation using a musculoskeletal model of the upper limb.

The **deltoid activity** is slowly increased while the biceps is off. When the deltoid reaches the threshold of 10% (of full activation), **the triceps is stimulated and the elbow fully extends** (as seen in the bottom panel below).

The **biceps activity** is then slowly increased, and when it reaches a threshold of 5%, **the triceps stimulation is turned off and the elbow flexes to 100 degrees**.

When both deltoid and biceps are off, the triceps stimulation is also off.



Both the case study and our computer simulations show that **the combination of EMG signals from voluntary muscles can be a useful control signal for functional electrical stimulation.**

More detailed modelling will allow us to **optimize the combination of EMG control signals**, in order to maximize the benefit of FES for each individual.

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