Ultrasound-paired Surface Electromyography as a Non-invasive Tool to Assess Muscle Structure and Function

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Introduction

Neuromuscular disorders are conditions affecting muscles and nerves leading to progressive weakness, loss of movement, and can be life-threatening if breathing muscles are involved. Diagnostic delays make these conditions worse [1]. While treatments are improving, finding better ways to detect them early is very important. A safe, simple, and comfortable tool could allow quicker diagnosis, more effective care, and a better quality of life for patients.

A motor unit consists of a motor nerve cell and the muscle fibres it controls, producing muscle contraction when stimulated. This can be studied by stimulating a nerve using a nerve stimulator and and recording muscle electrical activity using surface electromyography (sEMG), alongside observing muscle movement using ultrasound (USS).

This study uses a new combined technique (surface electromyography paired with ultrasound) and **aims** to explore how muscle structure and function change with age, building on the well-established concept that muscle mass and performance decline over time.

Methods

This pilot study included healthy participants of different ages without muscle or nerve conditions or other medical concerns.

In each participant, we focused on **three muscle groups and their corresponding nerves**.
They were:

1. **Abductor pollicis brevis (APB) – Median nerve**
2. **Abductor digiti minimi (ADM) – Ulnar nerve**
3. **Tibialis anterior (TA) – Deep fibular nerve**

(1 and 2 represent hand muscles, while 3 represents one of the leg muscles.)

The tools used in this study were:

- **Nerve stimulator and recording device** (Figure 1) – delivers small electrical pulses to stimulate nerves and records responses using sEMG, alongside ultrasound. The system synchronises stimulation with USS and sEMG recordings
- **Stimulating electrodes** (Figure 2: *blue colour*) – placed on the skin over specific nerves to deliver stimulation
- **Recording electrodes** (Figure 2: *white colour*) – placed over the target muscles to detect its electrical activity (EMG signals)
- **Ultrasound** – captures images of muscle movement with each stimulus using a probe (Figure 2: *green colour*), displays real-time images on a screen (Figure 3)

The stimulating current was gradually reduced from a level where full muscle contraction occurred until individual muscle fibres stopped contracting, while recording muscle responses at different current strengths. This procedure was repeated for three different muscle groups, and the results were compared between age groups.

- Muscle responses were visualised simultaneously on sEMG graph and ultrasound screen

Figure 1

Figure 2

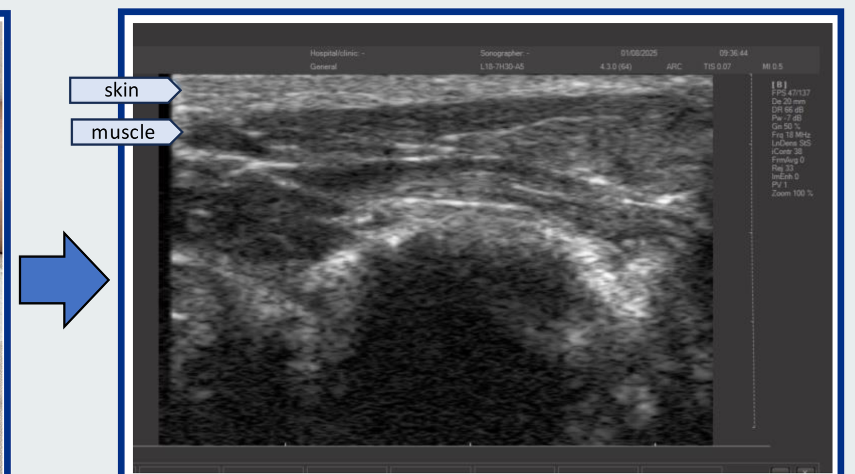

Figure 3

Figure 1: Nerve stimulator and recording device
Figure 2: Ulnar nerve stimulating electrodes *(blue colour)* with ADM recording electrodes *(white colour)* and Ultrasound probe *(green colour)*
Figure 3: Ultrasound image of muscle motion

Results

For early analysis, we compared the graphs of two male participants, aged 23 and 63.

Figure 4. Longer Half-Relaxation Time and Higher Stimulation Needed in Older Adult

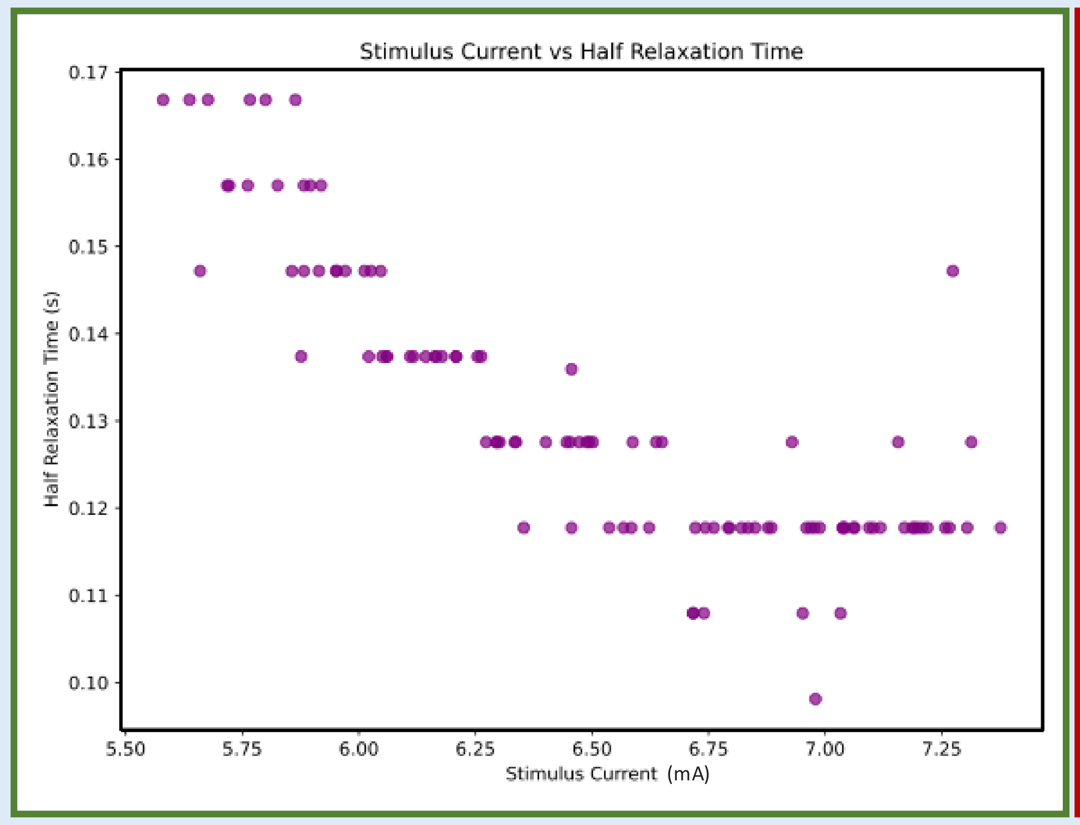

Figure 4 (a)

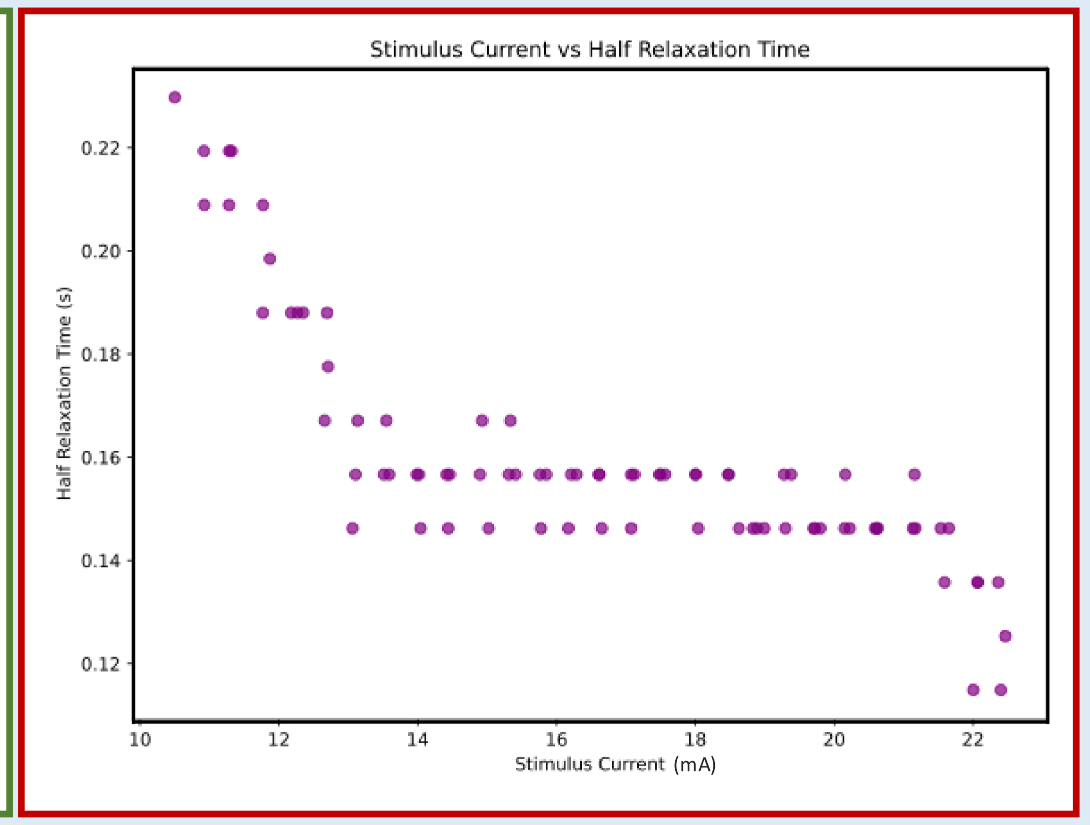

Figure 4 (b)

Half-Relaxation Time: time taken for a muscle to relax from peak contraction to half of its peak.

Green outline – Young adult
Red outline – Older adult
Figure 4 – Stimulus Current vs Half-Relaxation Time
Figure 5 – Stimulus vs Response Relationship

This shows slower muscle relaxation and stronger electrical current required to produce muscle responses in the older adult compared to younger participant.

Why slower muscle relaxation in older adult?

- **Smaller fast muscle fibres (Type II) and more slow fibres (Type I)** [2]
  (Type II (fast) fibres produce quicker and stonger movements)
- **Less energy (ATP) production and decreased calcium pump function** [3]
  (Both affect muscle contraction and relaxation)

Figure 5. Lower sEMG Signals and Steeper Ultrasound Slope in Older Adult

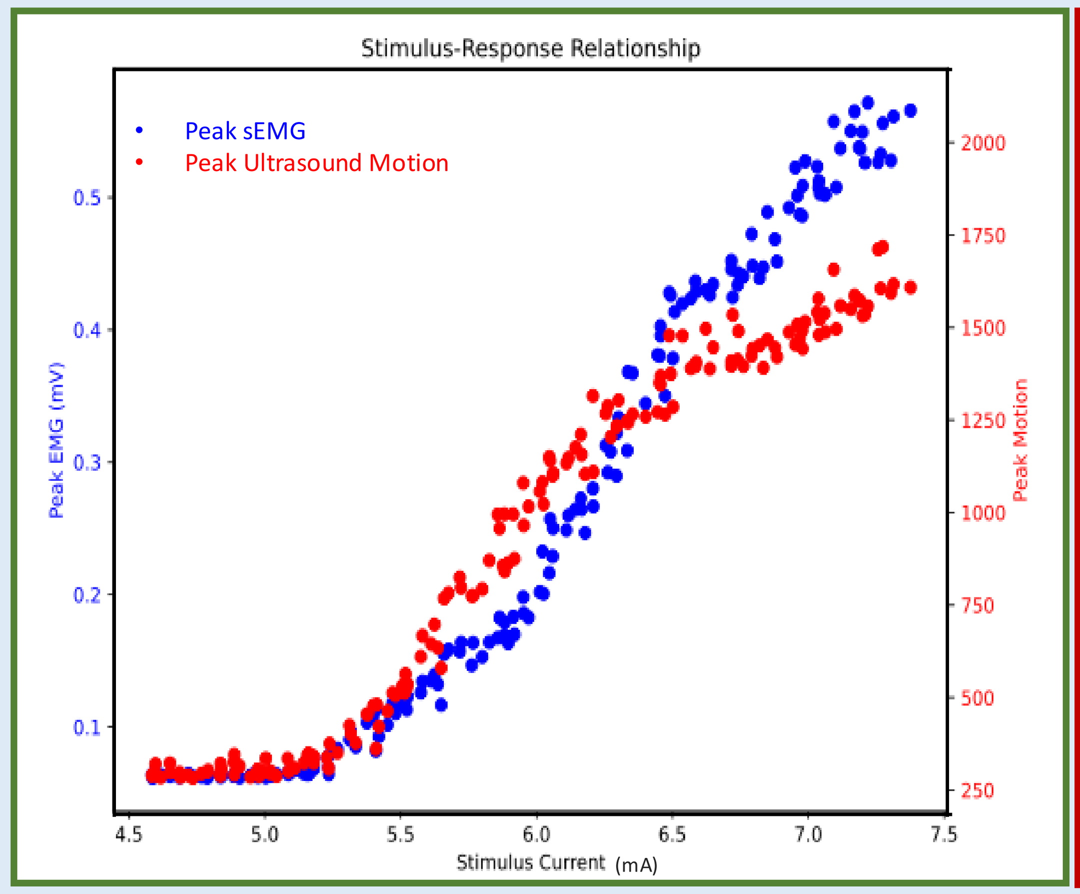

Figure 5 (a)

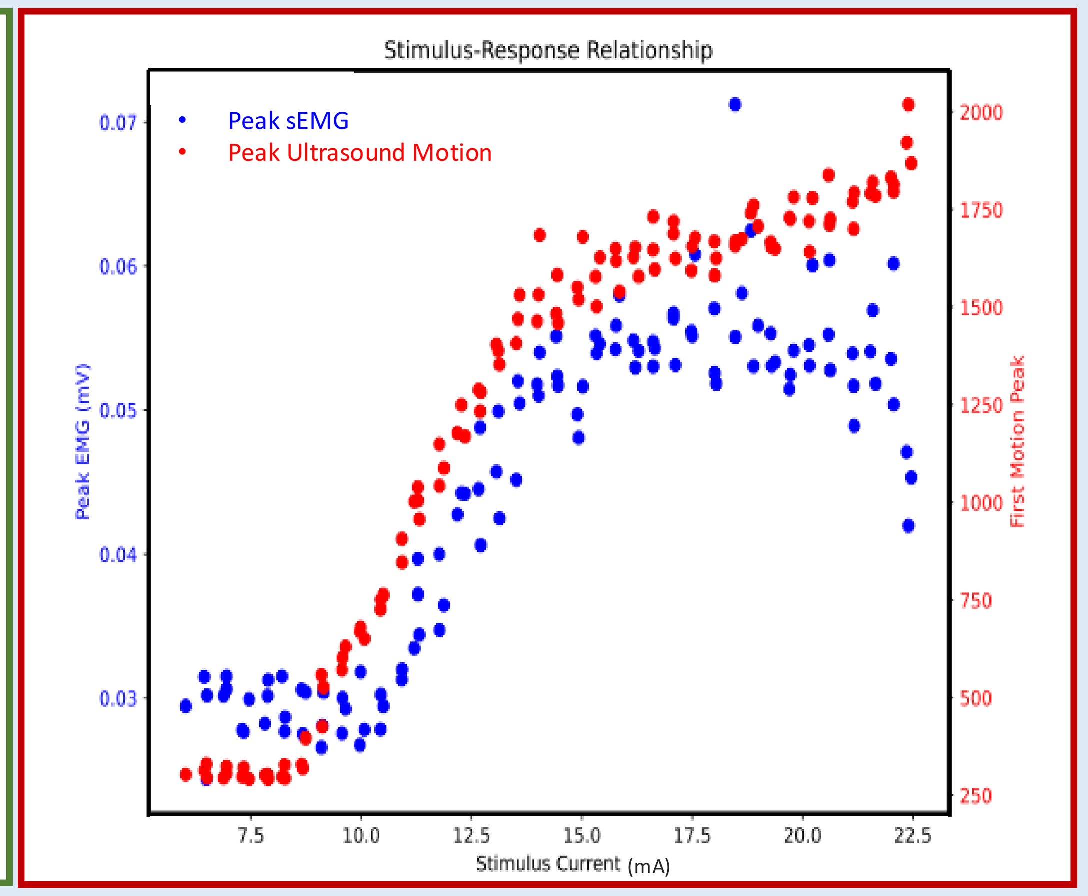

Figure 5 (b)

This suggests a smaller muscle response (measured by sEMG) but greater muscle movement (seen on ultrasound) with increasing stimulation current in the older adult compared to the younger participant.

In older adult,
Why lower sEMG signals?

- **Muscle fibres and muscle membrane surface area shrink with age** [2]
  (muscle fibres generate weaker electrical signals when stimulated, so, sEMG detects less activity)

Why greater movement on ultrasound?

- **Reasons – unclear**
  (further analysis is required)

Why higher stimulation needs?

- **More fat and scar tissues in muscles** [4,5]
- **Mitochondrial (powerhouse) function declines with age** [3]

Conclusion

Using surface electromyography paired with ultrasound, we observed differences in stimulation current strength, muscle relaxation time, sEMG records and ultrasound-detected motion between these two participants; maybe explained by selective loss of type II muscle fibres and mitochondrial function declines with age.
Our preliminary results support previous studies that suggest muscle structure and function change with age.

Future work:
i. Complete analysis of all our participants in this study
ii. Recruit and study more healthy people of different ages to further validate the result findings
iii. Recruit and study participants with neuromuscular diseases to compare with healthy controls

Eventually, this raises questions about whether this combined technique could serve as a painless diagnostic and monitoring tool in neuromuscular disorders.

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