NEURAL ADAPTATIONS TO STRENGTH TRAINING: HOW MUCH DO WE ACTUALLY KNOW?

Dr. Jason DeFreitas
Associate Professor of Health & Human Performance
Oklahoma State University

“NEURAL FACTORS”

For untrained individuals, neural adaptations have been found to be the primary contributor to initial strength gains (first few weeks).

BICEPS sEMG

TRICEPS sEMG

"NEURAL FACTORS" FROM sEMG

A.) Strength gain due to neural factors
B.) Strength gain due to hypertrophy

Increased Activity
No Change in Activation

Before Training
After Training

Pre 2 4 6 8 10 12

Strength

"Neural Factors"

Time (Weeks)
**NEURAL FACTORS** FROM sEMG

- Decreased Antagonist Co-Activation

Carolan and Cafarelli 1992, J Appl Physiol

- Adaptations within 3 days!!

**PROBLEM WITH “NEURAL FACTORS” FROM sEMG**

Amplitude Cancellation

- At the surface of the skin, all of the action potentials are summed, providing a "global" measurement of the muscle as a whole.

- By the time all of the action potentials reach the skin, many of them cancel each other out (due to being out of phase with each other).

- Up to 2/3 of the original signal may be cancelled out by the summation

Influence of amplitude cancellation on the simulated surface electromyogram:

Surface electromyographic amplitude does not identify differences in neural drive to synergistic muscles.

Amplitude cancellation influences the association between frequency components in the neural drive to muscle and the rectified EMG signal.

**Key**

- Excitatory connection
- Inhibitory connection
- Neuron Cell Body (Soma)
MOVING BEYOND SEMG... MOTOR UNIT RECORDINGS

Motor Units

Activation Threshold

Force Production

KEY
- Motor unit 1
- Motor unit 2
- Motor unit 3

MOVING BEYOND SEMG... MOTOR UNIT RECORDINGS

20 RM

8 RM

1 RM

Force Production

Force Production

Force Production

MOVING BEYOND SEMG... MOTOR UNIT RECORDINGS

Raw sEMG Signal

Surface Electrode

DECOMPOSITION

Individual Motor Unit Action Potential Trains (MUAPs)

MOVING BEYOND SEMG... MOTOR UNIT RECORDINGS

MU 1

MU 2

MU 3

MU 4

MU 5

MU 6

Force (N, MVC)

Time (s)

MU 1

MU 2

MU 3

MU 4

MU 5

MU 6

Force (N, MVC)

Time (s)
**NEURAL FACTORS** FROM MOTOR UNITS

**Increased Motor Unit Firing Rates**

Kamen and Knight 2004, J Gerontol

**Increased “Doublet” Firings**

Van Cutsem et al. 1998, J Physiol

**Tracking the same Motor Units over time**

Del Vecchio et al. 2019, J Physiol

**Decreased Recruitment Thresholds**

Del Vecchio et al. 2019, J Physiol

**PROBLEM WITH “NEURAL FACTORS” FROM MOTOR UNITS**

• Motor Units are the last link in a long chain in the neural control of movement

• Using Motor Unit recordings exclusively doesn’t allow us to distinguish if the adaptations are spinal (in the motor neurons themselves) or upstream (supraspinal sources)
**SPINAL “NEURAL FACTORS”**

Increased # of Excitatory Synapses

Remple et al. 2001, Behav Brain Res

**HOW DO WE PRODUCE FORCE?**

Our brain does not control each motor neuron individually. Instead, it sends a common drive down the spinal cord, and it is the membrane properties of each motor neuron that dictates whether that drive is enough to produce an action potential or not.

- Contralateral Motor Cortex
- Brain Stem
  - (Medulla Oblongata)
- Cervical Spinal Cord
  - At the level that the nerve exits
- Muscle

Courtine et al. 2007

**COMMON DRIVE**

**SUPRASPINAL “NEURAL FACTORS”**

Transcranial Magnetic Stimulation (TMS)

Courtine et al. 2007
**SUPRASPINAL “NEURAL FACTORS”**

**Functional Brain Imaging**

*Griffin and Cafarelli 2007, J Electromyogr Kinesiol*

- Increased Motor Cortex Excitability

**SUPRASPINAL “NEURAL FACTORS”**

**Increased Motor Cortex Excitability**

Kidgell and Pearce 2010, Hum Mov Sci

- Reduced Cortical Inhibition

**SUPRASPINAL “NEURAL FACTORS”**

Kidgell et al. 2015, Neurosci

- Eccentric > Concentric

**SUPRASPINAL “NEURAL FACTORS”**

Mason et al. 2017, Eur J Appl Physiol

- Synergist control benefits as well

**SUPRASPINAL “NEURAL FACTORS”**

Hortobágyi et al. 2009, J Appl Physiol

- Depression of Motor Cortex reduces strength gains
• The motor cortex is **not responsible** for planning the pattern of **movement**, but is the final station for conversion of the design into the execution of movement.
**TAKE HOME MESSAGE**

- **Limitation #1:** Years of focus on the final outputs of our motor control system (force output, EMG, Motor Unit firing behavior) may have led to misconceptions and confusion about what adaptations are actually occurring, and where.

- **Limitation #2:** Everything shown today has been in sedentary, previously untrained individuals.
  - What, if any, neural adaptations occur as training continues??

**CONTACT INFORMATION**

Dr. Jason M. DeFreitas  
Associate Professor, Health & Human Performance  
Co-Director, Applied Neuromuscular Physiology Lab  
Oklahoma State University  
jason.defreitas@okstate.edu  
Twitter: @Dr_DeFreitas