Application of Electromyography in Strength and Conditioning Research
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Electromyography in JSCR
- Journal of Strength and Conditioning Research
  - Pubmed.com
  - Searchable terms (2001 – current):
    - electromyography = 371 papers
    - EMG = 389 papers
      - 20 to 30 papers per year
Overview

- EMG hardware
- Motor units
- The EMG signal
- Study Design
- Interpretation

Technical sources:

EMG Acquisition Systems

- BIOPAC Systems
- Delsys
- iWorx
- National Instruments

EMG Electrodes
Motor Units

- Motor unit consists of a motor neuron in the ventral horn of the spinal cord or brain stem, its axon, and the muscle fibers it innervates.

Motor Unit Behavior

- The force exerted by a muscle during a contraction depends on the following:
  - The number of motor neurons that are activated.
  - The rates at which they discharge action potentials.
  - The force twitches of muscle fibers.

Motor Unit Behavior

- Cyclic dynamic contractions.
EMG Signal

- Represents the electrical activity generated in muscle fibers in response to the activation provided by motor neurons.
  - Bipolar (two electrodes) surface EMG contains information from overlapping action potentials from many MUs.
  - Source of information: the neural drive to the muscle provided by motor neurons and the electrical properties of the muscle fiber membranes.
  - Does not differentiate between MU recruitment and firing rate.
EMG Signal

• EMG recordings reflect extracellular field potentials.

• Action potential is generated for each muscle fiber of a MU.

EMG Signal

• Bipolar EMG provides information about the timing and intensity of muscle activation.
  – EMG decomposition techniques can provide information about the firing characteristics of single MUs.
  • Currently, EMG decomposition provides information from only isometric muscle actions.

EMG Signal

• Limitations (nonphysiological)
  – Amplitude cancellation

\[\begin{align*}
\text{A} & : \text{Cancellation} \\
\text{B} & : \text{No Cancellation}
\end{align*}\]
EMG Signal

- Limitations (nonphysiological)
  - Amplitude cancellation
    - Amplitude cancellation tends to reduce the contribution of individual or groups of MUs.
    - Despite a significant reduction in firing rates of lower-threshold MUs, EMG amplitude remained constant.

EMG Signal

- Limitations (nonphysiological)
  - Subcutaneous fat
    - Low-pass filter

EMG Signal

- Limitations (nonphysiological)
  - Unwanted signal content
    - Bandpass filter is typically applied to the signals.
      - Sampling frequency should be twice as high as the low-pass band frequency (500 Hz) to avoid aliasing.
    - Notch or band-stop filter can minimize a specific frequency (60 Hz).
  - Cross-talk
    - Influence of neighboring muscle on the EMG signal.
    - Double-differential signal can reduce cross-talk.
EMG Signal

- Limitations (physiological)
  - Distribution of conduction velocities.
  - Shape of intracellular action potentials.
  - Number and discharge rates of MUs.
  - Synchronization.

- Amplitude
  - Depends on the number of muscle fibers activated.
    - Not the number of MUs that were recruited.
  - Typically reported as a root mean square (RMS).
    - There are numerous ways to report amplitude of the EMG signal.
      - Need to rectify.

- Amplitude
  - Isometric contractions
    - Linear or a curvilinear relation between the rectified EMG and force.
      - Minimal changes in muscle length and when force is held constant.
EMG Signal

- Amplitude
  - Dynamic contractions
    - Relationship between muscle activation and force is minimized.
      - Non-stationarity of the signal
        - Shifts in position of electrodes relative to muscle fibers.
        - Changes in tissue conductivities.
        - Changes in MU activity.
    - It is possible that EMG amplitude can be unrelated to contraction intensity during a dynamic muscle action.

- Frequency spectrum
  - Influenced by
    - Action potential shapes.
    - MU firing rates.
    - Relative timing of the action potentials discharged by different MUs.
  - Typically reported as mean or median power frequency following a Fast Fourier Transformation.
    - Not sensitive to changes in power in small ranges.
    - Wavelet analysis with an intensity spectrum may be necessary to detect minor alterations in the frequency spectrum.
  - Understanding of the frequency spectrum is limited.

- Total intensity of 11 nonlinearly scaled Cauchy wavelets.
EMG and Strength and Conditioning

- What questions are we trying to answer by including EMG in our research?
- How can we minimize the limitations of the EMG signal?
- Are you interested in a discrete EMG value or the pattern of EMG values?

Study Design

- Dynamic muscle actions.
  - Limit confounding variables:
    - Standardized velocity?
    - Standardized position?
    - Standardized force?
    - Is the dynamic movement repeatable?
      - If the dynamic movement is not repeatable, the EMG value will not be meaningful.
Study Design

- Dynamic muscle actions.
  - Limit confounding variables.
    - Standardized velocity?
    - Standardized position?
    - Standardized force?

- Regardless of muscle action, cross-over design is preferred to test interventions.
  - Comparing EMG between groups is difficult because of potential differences in
    - subcutaneous fat.
    - MU distribution.
    - fiber pennation angle.
  - Subcutaneous fat at the site of the sensor should always be measured and reported.

- Training interventions.
  - Did EMG change as a function of subcutaneous fat?
- Muscle-related differences.
  - Is EMG different because subcutaneous fat overlying the muscle is different?
  - MU distribution different?
Study Design

- Helpful suggestions.
  - Normalize EMG to a maximal voluntary contraction.
  - Normalize EMG during dynamic movements to isometric muscle actions.
    - Minimizes the influence of EMG cancellation.
    - Reduces variability among subjects.
  - If possible, control for force regardless of muscle action.

Study Design

- Younger (YG) and older (AG) participants contracted at the same absolute submaximal force.
  - CC = contraction

Interpretation

- EMG amplitude
  - Muscle activation
    - Does not differentiate between firing rate and recruitment behavior.
      - Younger (YG) and older (OG) participants contracted at the same absolute submaximal force.
**Interpretation**

- **EMG amplitude**
  - Muscle activation
  - Can estimate timing and amplitude of muscle action.
  - EMG amplitude is strongly correlated with force.

**Interpretation**

- **EMG frequency**
  - Power spectrum has been reported to increase, not change, or decrease with an increase in muscle force.

**Interpretation**

- **EMG frequency**
  - May provide valuable information regarding muscle fatigue.
    - Decreases in action potential conduction velocity.
    - Changes in action potential shape.
    - Reduced relaxation rates of muscle.
    - Increased inorganic phosphate concentrations.
    - Decreased intramuscular pH.
    - Altered sarcolemmal ion gradients.
Interpretation

- EMG frequency
  - Traditional measures of EMG center frequency cannot distinguish
    - decreases in low-frequency power.
    - increases in high-frequency power.
  - or a combination of both.
- Salutation - Separate into
  - low-frequencies.
  - high-frequencies.

Questions?