What is Electromyography (EMG)?

- Electromyography (EMG) is an experimental technique concerned with the development, recording and analysis of myoelectric signals. Myoelectric signals are formed by physiological variations in the state of muscle fiber membranes.
- The focus of “Kinesiological EMG” can be described as the study of the voluntary neuromuscular activation of muscles within postural tasks, functional movements, work conditions and treatment/training regimes.
What is Electromyography (EMG)? – Signal Origin

- The Motor Unit:
  - The smallest functional unit to describe the neural control of the muscular contraction process is called a **Motor Unit**. It is defined as “…the cell body and dendrites of a motor neuron, the multiple branches of its axon, and the muscle fibers that innervates it. The term *units outlines the behavior, that all muscle fibers of a given motor unit act “as one” within the innervation process.*
What is Electromyography (EMG)? – Signal Origin

- **Resting potential**
  - Cell-Membrane Pump
  - Electrical gradient
  - Steady state at 80mV due to ionic pump

- **Depolarization**
  - Increased Na influx
  - Over-shoot

- **Repolarization**
  - Increased Na efflux
  - Repolarization
  - After Hyperpolarization
What is Electromyography (EMG)? – Signal Origin

How is EMG Measured?

• EMG is measured using similar techniques to that used for measuring EKG, EEG or other electrophysiological signals.
• Electrodes are placed on the skin overlying the muscle.
• Alternatively, wire or needle electrodes are used and these can be placed directly in the muscle.
• EMG signals are small and need to be amplified by an amplifier designed to measure physiological signals. These amplifiers include a differential amplifier circuit, and frequently include some filtering and other signal processing features.
What does the EMG signal actually indicate?

- When EMG is acquired from electrodes mounted directly on the skin, the signal is a composite of all the muscle fiber action potentials occurring in the muscle(s) underlying the skin.
- These action potentials occur at somewhat random intervals so at any one moment, the EMG signal may be either positive or negative voltage.
- Individual muscle fiber action potentials are sometimes acquired using wire or needle electrodes placed directly in the muscle.

Applications of EMG

- **Medical Research**
  - Orthopedic
  - Surgery
  - Functional Neurology
  - Gait & Posture Analysis

- **Rehabilitation**
  - Post surgery/accident
  - Neurological Rehabilitation
  - Physical Therapy
  - Active Training Therapy

- **Ergonomics**
  - Analysis of demand
  - Risk Prevention
  - Ergonomics Design
  - Product Certification

- **Sports Science**
  - Biomechanics
  - Movement Analysis
  - Athletes Strength Training
  - Sports Rehabilitation
EMG Equipment / Settings

• Amplifiers
  – EMG signals are small and need to be amplified by an amplifier designed to measure physiological signals. These amplifiers include a differential amplifier circuit, and frequently include some filtering and other signal processing features.

• Sampling Rate/Frequency
  – Sampling a signal at a frequency which is too low results in aliasing effects
  – Sampling rate of at least 1000 Hz (i.e. 1000 samples per second) is recommended.

Fig 18. The effect of A/D sampling frequency on a digitized signal. Too low frequencies (lower traces) result in significant loss of signal information.
EMG Equipment / Settings

• Bandpass Filtering
  – High Pass Filter
    • Allows signals of a frequency higher than the cut-off values (i.e. High Pass Filter) to pass to the data acquisition system.
    • In other words, it filters out the signals of a very low frequency.
  – Low Pass Filter
    • Allows signals of a frequency lower than the cut-off values (i.e. Low Pass Filter) to pass to the data acquisition system.
    • In other words, it filters out the signals of a very high frequency.
    – Recommended:
      • 10 Hz (High Pass) to 500 Hz (Low Pass)

EMG Equipment / Settings

• Electrodes
  – Silver/Silver Chloride (Ag/AgCl)
**Subject Preparation**

- Hair removal
- Cleaning the skin

**Method A:**
Special abrasive and conductive cleaning pastes are available which remove dead skin cells (they produce high impedance) and clean the skin from dirt and sweat.

**Method B:**
Alternatively, a very fine sandpaper can be used. A soft and controlled pressure in 3 or 4 sweeps usually is enough to get a good result. Attention: Avoid any harm to the skin from rubbing too hard! The use of sandpaper should be combined with an alcohol pad cleaning.

**Method C:**
The pure use of alcohol may be another alternative if used with a textile towel (that allows soft rubbing). This latter method may be sufficient for static muscle function tests in uncompromised conditions.

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**Subject Preparation**

**Electrode Placement**

![Electrode Placement Diagrams]

**Fine Wire Sites:**
- Scalene anterior
- Scalene posterior
- Pectoralis major
- Pectoralis minor
- Deltoideus
- Erector spinae
- Biceps brachii
- Brachioradialis
- Brachialis

**Surface Sites:**
- Pectoralis major
- Biceps brachii
- Brachioradialis
- Brachialis

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![Electrode Placement Diagrams]
Subject Preparation

- Securing Cables
  - Finally, securing an appropriate cable and pre-amplifier on the skin is necessary. This point may be not as important for static or slow motion tests, but in dynamic studies it helps to avoid cable movement artifacts and minimizes the risk of separating the electrodes from the skin. Use regular tape, elastic straps or net bandages to secure each electrode lead, however, avoid too much tension. It is recommended not to directly tape over the electrodes to keep a constant application pressure for all electrodes.

Analysis of the EMG Signal

Raw Signal
Analysis of the EMG Signal

• Full Wave Rectification
  – Because the raw signal is biphasic, its’ mean value is zero. The rectifier allows current flow in only one direction, and so "flips" the signal's negative content across the zero axis, making the whole signal positive.
Analysis of the EMG Signal

• Smoothing
  – The non-reproducible part of the signal is minimized by applying digital smoothing algorithms that outline the mean trend of signal development. The steep amplitude spikes are cut away; the signal receives a “linear envelope”.
  – Really, a way to gauge the amplitude of the EMG signal.
  – Root Mean Square (RMS)
    • Based on the square root calculation, the RMS reflects the mean power of the signal (also called RMS EMG) and is the preferred recommendation for smoothing.

Analysis of the EMG Signal

RMS at 300 ms
Analysis of the EMG Signal

- Statistics
  - Area (mV/s or µV/s)
  - Mean Amplitude (mV or µV)
  - Peak Amplitude (mV or µV)
Analysis of the EMG Signal

- Normalization
  - One major drawback of any EMG analysis is that the amplitude (microvolt scaled) data are strongly influenced by the given detection condition.
  - It can vary greatly between electrode sites, subjects and even day to day measures of the same muscle site.
  - One solution to overcome this “uncertain” character of micro-volt scaled parameters is the normalization to a reference value, e.g. the maximum voluntary contraction (MVC) value of a reference contraction.
  - The basic idea is to “calibrate the microvolts value to a unique calibration unit with physiological relevance”, the “percent of maximum innervation capacity” in that particular sense.
  - The main effect of all normalization methods is that the influence of the given detection condition is eliminated and data are rescaled from microvolt to percent of selected reference value.
  - It is important to understand that amplitude normalization does not change the shape of EMG curves, only their Y-axis scaling!
Analysis of the EMG Signal

- Normalization (cont’d)
  - Typically, MVC contractions are performed against static resistance. To really produce a maximal contraction, excellent stabilization and support of all involved segments is very important.
  - The MVC test needs to be performed for each investigated muscle separately. The first step is to identify an exercise/position that allows for an effective maximum innervation (not force output!).
Analysis of the EMG Signal

Class Laboratory Exercise

• Unfortunately, this laboratory experience will be more demonstration based (we only have one EMG system)

• We will examine the EMG response to static contractions of the biceps and triceps against increasing loads.

• We will examine the changes in the EMG response of the forearm muscles during an isometric fatigue test.
Class Laboratory Exercise

• Goals of this laboratory exercise
  – To visualize the EMG signal in response to various conditions.
  – Visualize the concept of muscle “co-activation”.
  – Visualize the changes in the EMG signal in response to an isometric fatigue test.
  – Become familiar with the procedures for the collection of EMG data and the analysis of the data.
  – Become familiar with using the EMG system and the associated software (ADInstruments Chart).
  – To be entertained and “wowed”!