Electromyogram (EMG)

- When a muscle is contracted, a small electric potential is produced. Surface electrodes can sense this muscle activity potential when placed over the muscle. The signal detected by the electrodes is amplified and recorded with instrumentation, and is known as the EMG.
- To the researcher, the EMG signal is virtually meaningless "as is." However when the signal is analyzed, a measure of work done by the muscle, called an activity index, can be derived. In practice, an activity index for a specific muscle is established as a benchmark. This benchmark is then compared to another activity index of the same muscle, but generated under a different set of conditions (such as after fatigue, or after the administration of a drug, etc.). This comparison normalizes the activity index and provides a way of measuring the effect fatigue or the drug had on the muscle. The primary tools used to analyze the acquired EMG signal are the rectification and integration functions.
- Electromyography (EMG) is the study of muscle electrical activity. Its origins can be traced back to the late 18th century work of Galvani, who demonstrated a relationship between muscle contraction and electricity. However, it wasn't until the 1920s, when Gasser and Newcomer displayed muscle electrical activity on a cathode ray oscilloscope, that the noninvasive field of surface EMG (SEMG) was born.
- In an SEMG recording, a bipolar electrode is placed on the skin surface overlaying a muscle of interest. As the muscle contracts, myoelectric activity is revealed as complex waveform with an amplitude range of >0-10 mV.

Alternatively, intramuscular EMG techniques may be used where increased signal specificity is required. This requires the use of fine needle electrodes placed within the muscle of interest.

Characteristics of the EMG signal

- The amplitude of the EMG signal is stochastic (random) and can be reasonably represented by a Gaussian distribution function. Signal amplitude can range from 0 to 10 mV (peak-to-peak) or 0 to 1.5 mV (rms)
- Usable energy of the signal is limited to the 0 to 500 Hz frequency range, with the dominant energy being in the 50 - 150 Hz range.

EMG is suited to the study of generally any skeletal muscle that can be accessed with surface or intramuscular electrodes.

SEMG

Surface EMG recordings provide information about aggregate motor unit activity in superficial muscle. The advantage of SEMG is its convenience and good overall correlation to generated muscle force. Signal amplitudes recorded with SEMG typically range from >0 to 10 mV, with most signal power between 10 to 400 Hz.

Electrode Placement

Bipolar surface electrodes (Ag-AgCl) should be positioned between a motor point (Fig. 1; source of alpha motor neuron innervation of the muscle) and tendon insertion, or between two motor points. Both electrodes should also be placed along the midline of the muscle in order to prevent signal crosstalk between adjacent muscles (e.g., Fig .2). By placing both electrodes parallel to the longitudinal axis of the muscle this also ensures the detection surfaces will intersect common muscle fibres.

Note: Placing electrodes directly over a motor point may result in increased frequency components in the signal. Action potentials spread in opposite directions from the motor point. A bipolar electrode placed over a motor unit, depending on the geometric relationship, may result in an increased number of recorded potentials due to phase addition and subtraction of the action potentials. Motor units can be identified using artificial stimulation: the point on the muscle whereby the application of minimal electrical current produces a perceptible muscle twitch will correspond to a motor unit.

Intramuscular EMG

1. Unlike SEMG, intramuscular EMG recordings provide high spatial selectivity allowing for individual superficial or deep muscle groups to be recorded from. Because the current source is highly localized with respect to the electrode tip, i.e., only involving a few muscle fasicles, the recorded EMG waveform will appear less complex and is therefore more amenable to studies relating motor unit firing rates to generated muscle force. A second advantage of intramuscular EMG is that multiple recording sites within the same muscle group may used.
2. Like SEMG, recordings using needle electrodes also have amplitudes within the >0 to 10 mV range, although due to being closer to the current source amplitudes will predictably be more toward the high end of this range. As with SEMG, most of the signal power will also be between 10 Hz and 400 Hz.

Figure 1. Schematic representation of a motor unit, consisting of a single spinal alpha motor neuron and the muscle fibers it innervates. The source of innervation in the muscle is the motor point.

Figure 2. Illustration of SEMG involving bipolar surface electrodes located on biceps brachii and triceps brachii

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EMG is the recording of the electrical activity of the muscle using surface electrodes placed on the muscle or more commonly, needle electrodes inserted into the muscle. The needle electrode consists of a pointed steel cannula through which runs a fine silver, steel or platinum wire that is insulated except at its tip. The potential difference between the outer cannula and inner wire is recorded and the patient is grounded by a separate surface electrode. The ground lead is attached to the same limb as the muscle to be examined.

The Standard Protocol for EMG recording is as follows:

1. The electrode is inserted into the muscle while it is relaxed and insertion activity is noted.
2. The muscle is then explored systematically with the electrode for the presence of any spontaneous activity. Normally, there is no spontaneous activity.
3. Thereafter, the subject is asked to contract the muscles voluntarily and the MUPs are recorded from different sites on the muscle at different grades of contraction.
4. Finally, the subject is asked to contract the muscle maximally against resistance and interference pattern is recorded.

There are two kinds of EMG in widespread use: surface EMG and intramuscular (needle and fine-wire) EMG. To perform intramuscular EMG, a needle electrode or a needle containing two fine-wire electrodes is inserted through the skin into the muscle tissue. A trained professional (such as a neurologist, physiatrist, chiropractor, or physical therapist) observes the electrical activity while inserting the electrode. The insertional activity provides valuable information about the state of the muscle and its innervating nerve.

Muscle tissue at rest is NORMALLY ELECTRICALLY INACTIVE. After the electrical activity caused by the irritation of needle insertion subsides, the electromyograph should detect no abnormal spontaneous activity (i.e., a muscle at rest should be electrically silent, with the exception of the area of the neuromuscular junction, which is, under normal circumstances, very spontaneously active). When the muscle is voluntarily contracted, action potentials begin to appear. As the strength of the muscle contraction is increased, more and more muscle fibers produce action potentials. When the muscle is fully contracted, there should appear a disorderly group of action potentials of varying rates and amplitudes (a complete recruitment and interference pattern).

ABNORMAL EMG is used to diagnose diseases that generally may be classified into one of the following categories: neuropathies, neuromuscular junction diseases and myopathies.

Neuropathic disease has the following defining EMG characteristics:
- An action potential amplitude that is twice normal due to the increased number of fibres per motor unit because of reinnervation of denervated fibres.
- An increase in duration of the action potential.
- A decrease in the number of motor units in the muscle (as found using motor unit number estimation techniques).
Myopathic disease has these defining EMG characteristics:

- A decrease in duration of the action potential
- A reduction in the area to amplitude ratio of the action potential
- A decrease in the number of motor units in the muscle (in extremely severe cases only)

Normal muscles at rest are electrically inactive, make certain, normal electrical signals when the needle is inserted into them. Then the electrical activity when the muscle is at rest is studied. Abnormal spontaneous activity might indicate some nerve and/or muscle damage. Then the patient is asked to contract the muscle smoothly. The shape, size, and frequency of the resulting motor unit potentials are judged.

Reliability of the EMG Signal

- possible interference with movement artifacts
- trial to trial variations due to electrode placement and skin/muscle interface impedance.
- cross-talk from other muscles

Electromyograph (EMG)

- An instrument used for recording the electrical activity of the muscles to determine whether the muscle is contracting or not
- Also used for displaying on the CRO and loudspeaker the action potentials spontaneously present in a muscle or those induced by voluntary contractions as a means of detecting the nature and location of motor unit lesions
- It is also used for recording the electrical activity evoked in a muscle by the stimulation of its nerve
- This instrument is useful for making a study of several aspects of neuromuscular function, neuromuscular condition, extent of nerve lesion, reflex responses, etc.

These are also useful for myoelectric control of prosthetic devices (artificial limbs). This involves picking up EMG signal from the muscles at the terminated nerve endings of the remaining limb and using the signals to activate a mechanical arm.

- Usually recorded by using surface electrodes or more often by using needle electrodes which are inserted directly into the muscle.
- Surface electrodes may be disposable, adhesive types or the ones which can be used repeatedly. A ground electrode is necessary for providing a common reference for measurement. These electrodes pick up the potentials produced by the contracting muscle fibres.
- The signal can be then amplified and displayed on the screen of the CRO. It is also applied to an audio-amplifier connected to a loudspeaker.
- A trained EMG interpreter can diagnose various muscular disorders by listening to the sounds produced when the muscle potentials are fed to the loudspeaker.
- Here tape recorder is included in the system to facilitate playback and study of the EMG sound waveforms at a later convenient time.
- Amplitude of EMG signal depends upon various factors, eg:- the type and placement of electrodes used and the degree of muscular exertions. the needle electrode in contact with a single muscle fiber will pick up spike type voltages whereas a surface electrode picks up many overlapping spikes and therefore produces an average voltage effect.
- Typical EMG signal ranges from 0.1 to 0.5 mV. They may contain frequency components extending up to 10 KHz.

Note: Refer Block diagram of R.S.Khandpur

Applications for EMG Signals

- Biofeedback to train subjects to increase, decrease or stabilize muscle tension
- Diagnose and treat neuromuscular disorders such as musculoskeletal injury, low back pain
- Ergonomic studies in the workplace for such disorders as carpel tunnel syndrome and to assist in job risk analysis
- As a component of gait analysis and motion analysis
- Sports medicine and training
- Product development