3. Electromyography

The record of the potentials from muscles during movement is called the **e**lectro**m**yo**g**ram or EMG. Small electrical currents are generated by muscle fibers prior to the production of muscle force. These currents are generated by the exchange of ions across muscle fiber membranes, a part of the signaling process for the muscle fibers to contract. The signal called the (EMG) can be measured by *applying conductive elements or electrodes to the skin surface*, or *invasively within the muscle*. When detecting and recording the EMG signal, there are two main issues of concern that influence the fidelity of the signal. The first is the signal to noise ratio. That is, the ratio of the energy in the EMG signals to the energy in the noise signal. In general, noise is defined as electrical signals that are not part of the wanted EMG signal. The other is the distortion of the signal, meaning that the relative contribution of any frequency component in the EMG signal should not be altered. A muscle is made up of many motor units. A motor unit consists of a:

1. Single branching neuron from the brain stem or spinal cord.
2. 25 to 2000 muscle fibers (cells) it connects to via motor end plates (figure 1).

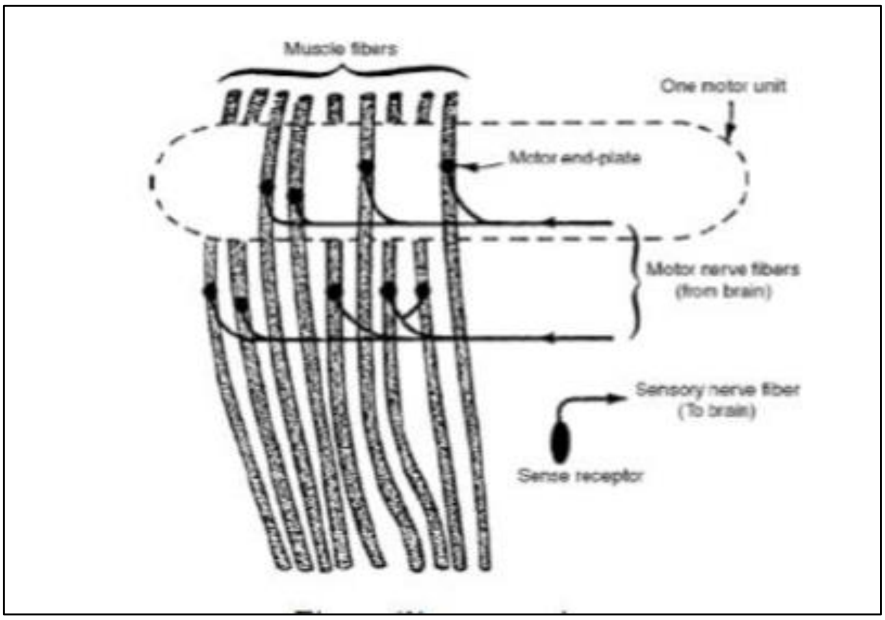

Figure (1) motor unit.

The resting potential across the membrane of a muscle fiber is similar to the resting potential across the nerve fiber. Muscle action is initiated by an action potential that travels along an axon and is transmitted across the motor end plates into the muscle fibers, causing them to contract.

Surface EMG

Surface EMG is the more common method of measurement, since it is non-invasive and can be conducted by personnel other than Medical Doctors, with minimal risk to the subject. Measurement of surface EMG is dependent on a number of factors and the amplitude of the surface EMG signal (sEMG) varies from the uV to the low mV range. **The amplitude and time and frequency domain properties of the sEMG signal are dependent on factors such as:**

- The timing and intensity of muscle contraction
- The distance of the electrode from the active muscle area
- The properties of the overlying tissue (e.g. thickness of overlying skin and adipose tissue)
- The electrode and amplifier properties
- The quality of contact between the electrode and the skin

There are methods to reduce the impact that non- muscular factors have on the properties of the EMG signal. **For example, much of this variability in the sEMG signal can be minimized through:**

- using the same electrodes and amplifier (i.e. same signal conditioning parameters)
- ensuring consistency in the quality of contact between the electrodes and the skin

Within subjects, the variability of the sEMG signal can also be reduced in consecutive recording sessions by placing the electrodes over the same skin location. In addition, there are other methods of normalizing the EMG signal to reduce the variability both within and between subjects.

Measuring and accurately representing the sEMG signal depends on the:

a. Properties of the electrodes

b. The interaction with the skin

c. Amplifier design

d. Conversion and subsequent storage of the EMG signal from analog to digital form (i.e. A/D conversion).

The quality of the measured EMG is often described by the ratio between the measured EMG signal and unwanted noise contributions from the environment. The goal is to maximize the amplitude of the signal while minimizing the noise. Assuming that the amplifier design and process of A/D conversion exceed acceptable standards, the signal to noise ratio is determined almost exclusively by the electrodes, and more specifically, the properties of the electrode – electrolyte – skin contact.

Types of Electrodes

Two types of surface electrodes are commonly in use:

• Dry electrodes in direct contact with the skin

• Gelled electrodes using an electrolytic gel as a chemical interface between the skin and the metallic part of the electrode

Dry Electrodes

Dry electrodes are mainly used in applications where geometry or size of electrodes does not allow gel‖. Bar electrodes and array electrodes are examples of dry electrodes. With dry electrodes it is common to have the pre-amplifier circuitry at the electrode site, due in part to the high electrode – skin impedance associated with dry electrodes. As such, dry electrodes (typically >20g) are considerably heavier than gelled electrodes (<1g). This increased inertial mass increases the difficulty in maintaining electrode fixation, as compared to gelled electrodes.

Gelled Electrodes

Gelled electrodes use an electrolytic gel as a chemical interface between the skin and the metallic part of the electrode. Oxidative and reductive chemical reactions take place in the contact region of the metal surface and the gel. Silver - silver-chloride (Ag- AgCl) is the most common composite for the metallic part of gelled electrodes. The AgCl layer allows current from the muscle to pass more freely across the junction between the electrolyte and the electrode. This introduces less electrical noise into the measurement, as compared with equivalent metallic electrodes (e.g. Ag). Due to this fact, Ag-AgCl electrodes are used in over 80% of surface EMG applications. Gelled electrodes can either be disposable or reusable.

The recommendations for construction of bipolar sEMG electrodes (sensors) including:

- Electrode shape
- Electrode size
- Inter-electrode distance
- Electrode material
- Electrode construction

EMG DISPLAY: A typical arrangement for recording the EMG is shown in figure (4) as following steps**:**

1. The muscles electrical signals can be displayed directly on one channel on an oscilloscope.

2. The signal can be integrated and displayed on the second channel.

3. The signal can also be passed through an amplifier and made audible by a loudspeaker.

4. The integrated record (in volt seconds) is a measure of the quantity of electricity associated with the muscle action potentials.

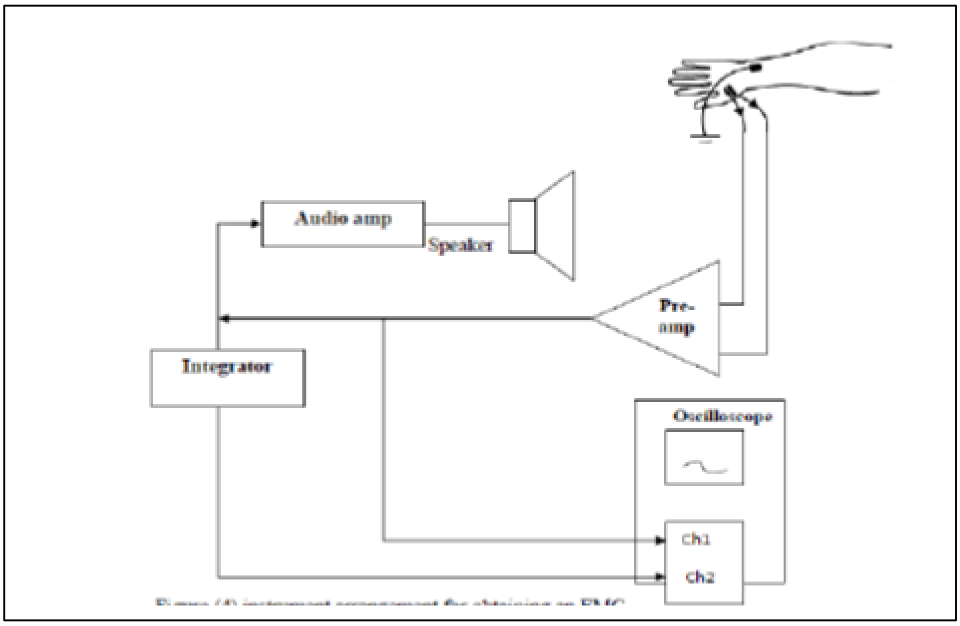

Figure 2: instrument arrangement for obtaining an EMG

More forceful contractions lead to greater action potential activity. It is easier to evaluate the integrated form of action potential activity because it is a smooth curve. In the clinic, the audible EMG and the integrated form are often used to determine the condition of a muscle during contraction. The EMG can be obtained from muscles or motor units that are stimulated electrically, and this method is often preferred to the voluntary contraction.

Properties of an ideal pre-amplifier

There are several important properties to consider in a pre-amplifier:

• High common mode rejection ratio

• Very high input impedance

• Short distance to the signal source

• Strong DC signal suppression