University of Diyala/ College of Medicine
Department of Physiology
Physiology Lab

Electromyography EMG

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What is EMG?

- Technique of recording the electrical activity of motor unit firing.
- Not muscle force per sec, but the electrical signal sent by the motor nerves to muscle fibers to create a force.

- The electromyogram is the trace of the electrical signal detected by the electrode.

- EMG uses electrodes applied on the skin (surface) or implanted into the muscle (indwelling) as "antennas" to pick up voltage signals.

- EMG assesses the physiology of nerve and muscle.

How Does EMG Test Help?

An EMG measures the muscles response or electrical activity that results from a nerve's stimulation of the muscle. ***The test translates the electrical signals into numbers or graphs, which, in turn, helps the physician diagnose patient's condition.***

The doctor orders an electromyography test if there are signs of muscle or nerve disorder. In addition to help the doctor in ***determining the specific location of the injury, the test provides information about the degree to which the muscle and/or nerve damage has occurred.***

EMG testing is being used for a variety of medical conditions ranging from relatively simple like carpal tunnel syndrome to more complex conditions like Amyotrophic lateral sclerosis (ALS).

The Functional Unit of Neuromuscular System

➢ **The Motor Unit (MU) is comprised of:**

✓The cell body and dendrites of one motor neuron.

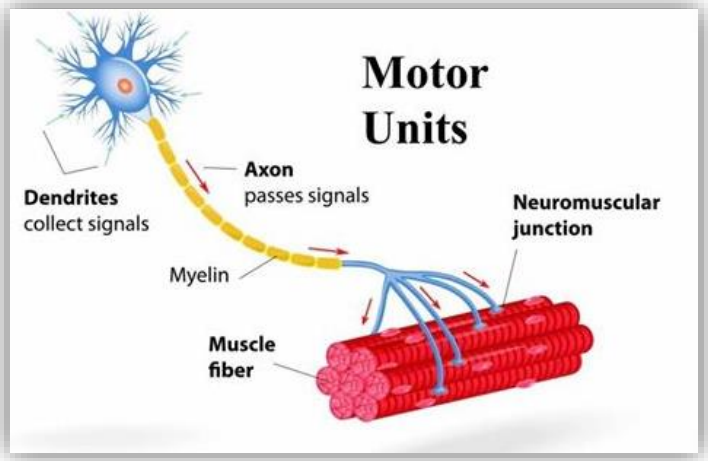
✓The multiple branches of its axon.

✓The muscle fibers that are innervated by this neuron.

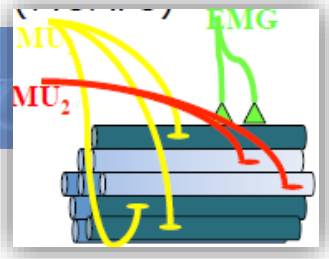
➢ **Motor unit size can greatly vary:**

✓ As little as 5-10 muscle fibers innervated by one motor neuron. Where fine motor control is required (e.g. eye).

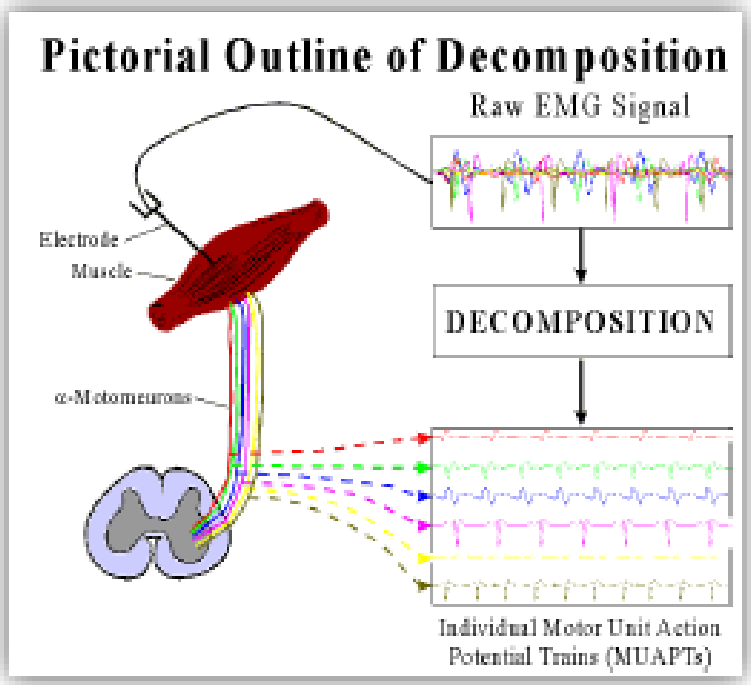
✓ As many as thousands of muscle fibers in the biggest motor units (e.g. quadriceps).

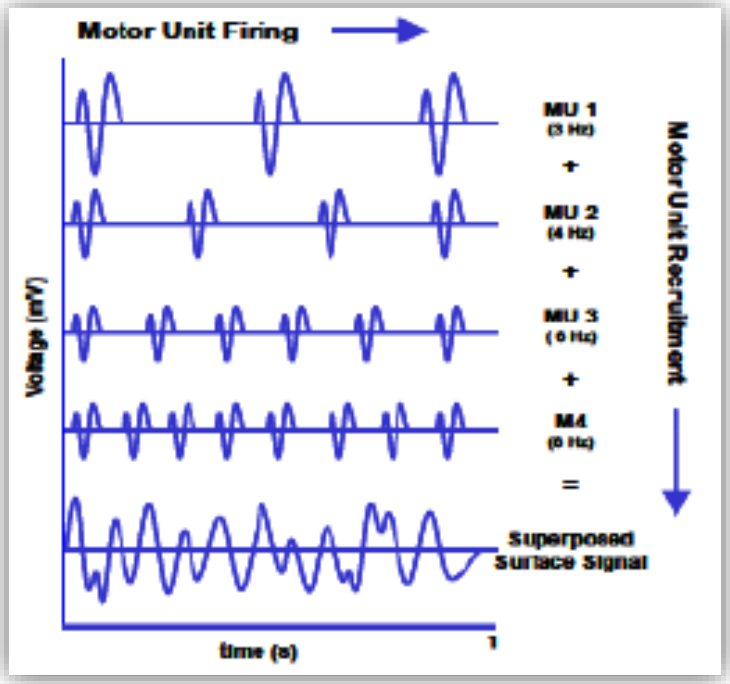


Origin of the EMG Signal



- The EMG signal (as perceived from surface electrodes) is composed of many individual motor unit action potentials (MUAPs).
- Each MUAP has its own unique firing profile. Muscular efforts usually require the activation of more than 1 motor unit.
- The result is a curve summation that can be difficult to analyze and interpret.





Main Characteristics of the EMG Signal

Amplitude Range: 0–10 mV (+5 to -5) prior to amplification

Useable Frequency : Range of 0 - 500 Hz

Dominant Frequency : 30 – 200 Hz

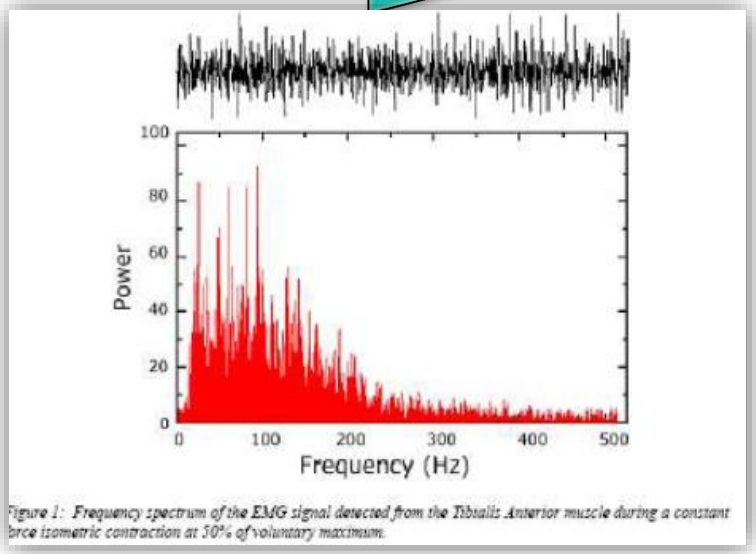
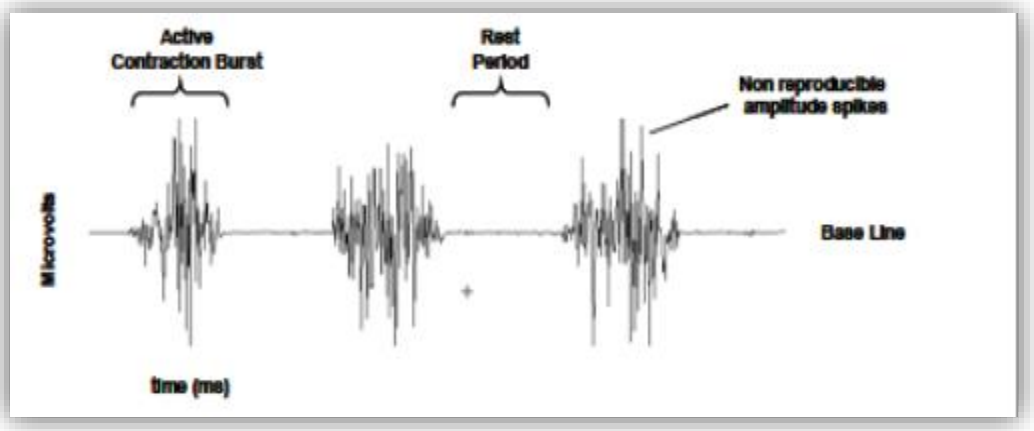


Figure 1: Frequency spectrum of the EMG signal detected from the Tibialis Anterior muscle during a constant force isometric contraction at 50% of voluntary maximum.

Main Characteristics of the EMG Signal

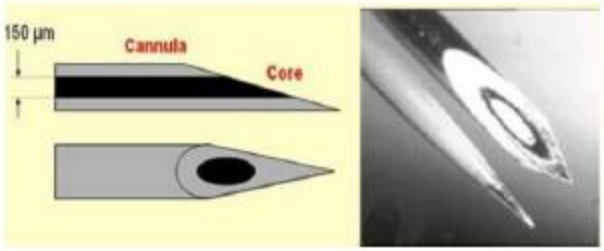
- **Dynamic:** repetitive activation is easy to see (clear bursts).
- **Tonic:** static activation is more difficult to see.
- There is always some **baseline noise** (at least 1-2 microvolts).
- **Typical amplitude:** microvolts (up to a few thousands in athletes).
- **Typical frequency:** 20 – 150 Hz.



Types of EMG Electrodes

Inserted

- Fine-wire (Intra-muscular)
- Needle



Surface

- Bipolar
  (wired or wireless)
- Array
  (wired)

Surface Electrodes

Advantages

– Quick, easy to apply.

– No medical supervision.

– Minimal discomfort.

– Easy to reposition.

Disadvantages

– Generally used only for superficial muscles.

– Crosstalk concerns.

– No standard electrode placement.

– May affect movement patterns of subject.

Fine-wire Electrodes

Advantages

– Extremely sensitive.

– Record the activity of a single motor unit.

– Access to deep musculature.

– Little crosstalk concern.

Disadvantages

– Extremely sensitive.

– Requires medical personnel, certification.

– Repositioning nearly impossible.

– Detection area may not be representative of entire muscle.

EMG Signal Quality

- The quality of the detected EMG signal determines the usefulness of the information extracted from the EMG signal. It is important to maximize the quality of the acquired signal.

- **The quality of the acquired signal depends on:**
- Sensor location (upon the middle of muscle belly)
- Sensor characteristics
- Electrode-skin interface (good skin preparation)
- Cross-talk from other muscles
- Noise contamination

EMG Signal Noise

Physiological Noise

- EKG, EOG, respiratory signal, etc.
- Reduced by proper positioning of the sensors (location and orientation).

Ambient Noise

- Power line radiation (50, 60 Hz).
- Removed by differential amplification.

Baseline Noise

- Electro-chemical noise (skin-electrode interface).
- Reduced by effective skin preparation.

Movement Artifact noise

- Movement of electrode with respect to the skin (the most obstreperous noise).
- Reduced by effective skin preparation, proper fixation of the sensor to the skin and filtering.

Nerve conduction study , also called electroneurography (ENG)

Nerve Conduction Study (NCS)

- **NCS** *means recording & analysis of an electric waveforms elicited in response to electric stimuli to evaluate function & diagnose diseases of peripheral nerves (motor & sensory).*

- Usually surface electrodes are used for both stimulation and recording, though needle electrodes may be used to evaluate a nerve that is deep in the tissue .

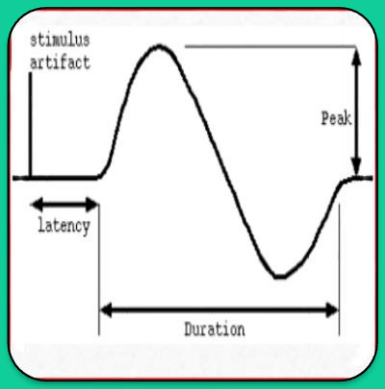
- They are sensory (SNCS) & motor (MNCS).

- Another type of NCS is referred to as late response: F-wave & H-reflex testing, they are usually performed to study nerves more proximal to the spine.

Nerve Conduction Study (NCS)

NCS are done by placing electrodes on the skin and stimulating the nerves through electrical impulses.

This is the basic setup for a sensory nerve conduction study.



The machine gives a tracing of the sensory nerve action potential.

Process of the NCS

To study motor nerves, electrodes are placed over a muscle that receives its innervation from the nerves you want to test (stimulate).

The electrical response of the muscle is then recorded and you can determine both how fast and how well the nerve responded.

This can determine whether the problem stems from a nerve or muscle.

Nerve Conduction Study (NCS)

Sensory Nerve Conduction Study

Applies electrical stimulation near a nerve & record response from a distant site along nerve. *Response parameters include amplitude, latency, & sensory conduction velocity.*

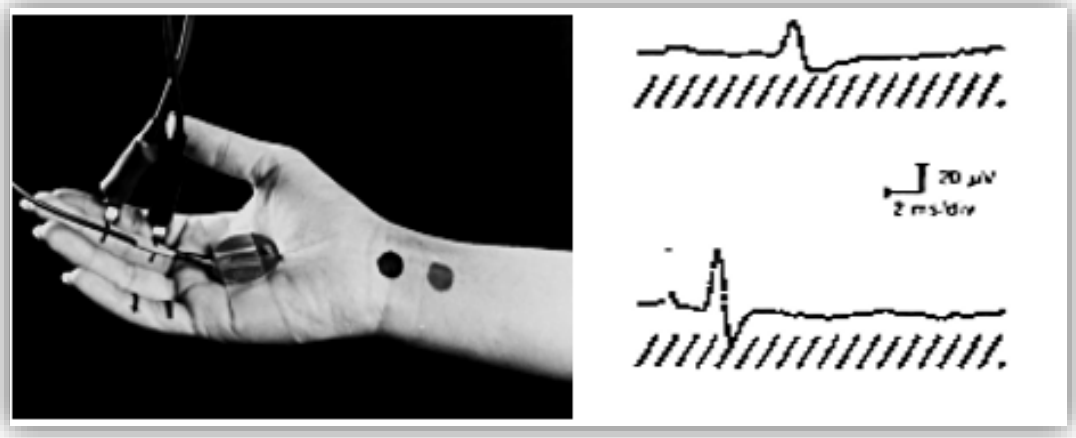
Motor Nerve Conduction Study

Applies electrical stimulation at various points along motor nerve coarse,& record response from an appropriate muscle(muscle supplied by that nerve). Response parameters include:

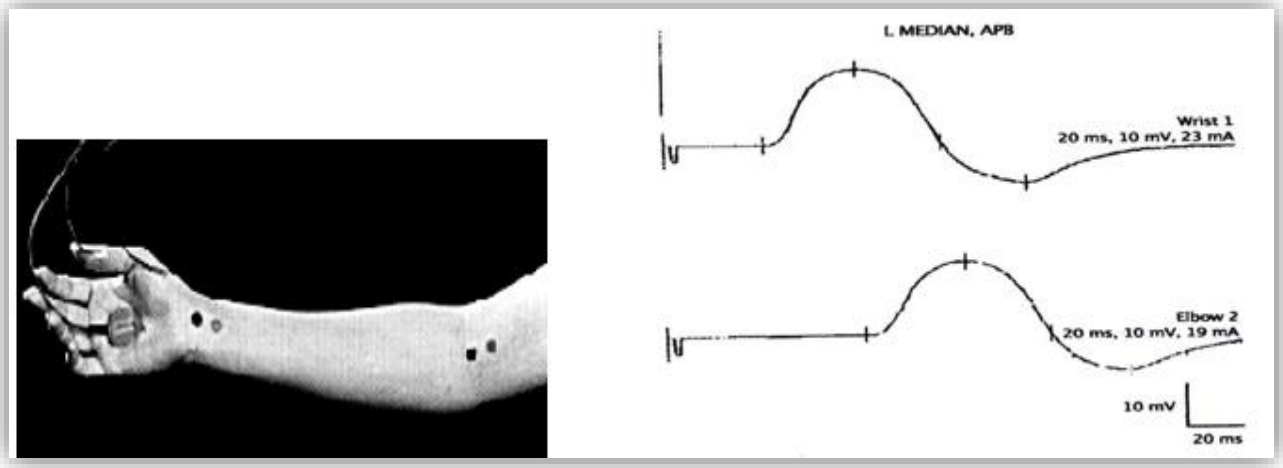
- **1. Distal motor latency (DL):** interval between delivery of a stimulus to the most distal point of stimulation on a nerve & onset of response measured in milliseconds(msec).
- **2.motor nerve conduction velocity(MNCV) :** value obtained represents time required for nerve impulse to travel between two stimulus points which is important to localize lesion if present.MNCV is a reference to different nerve parameters (myelination , fiber size , nodal & inter nodal length , & internal & external axonal resistance).It is calculated from dividing distances between two stimulation points in meters by difference of latencies in seconds.
- **3. CMAP amplitude :** number of functioning axons in a nerve , & amount of muscle still innervated, it is determined from peak –ve & +ve peaks, expressed in millivolts (mV) .

Nerve Conduction Study (NCS)

SNCS



MNCS



Factors Determine the Conduction Velocity

Myelination

Fiber size: larger the diameter →faster conduction.

Temperature

- Warming facilitates activation of Na conductance → ↑ its rate of transmission .

Aging & gender

- At birth, motor conduction velocity is one- half those of the normal adult.
- Women have faster conduction velocity than men for yet undetermined reason.

Nerve Conduction Study Terms

- ✓ **Action Potential:** this is the waveform you see on the screen.
- ✓ **Latency:** Time interval between the onset of a stimulus and the onset of action potential .
- ✓ **Conduction Velocity:** How fast the fastest part of the impulse travels (sensory or motor conduction velocity) .
- ✓ **Amplitude:** the maximal height of the action potential.
- ✓ **Antidromically:** Physiologically opposite direction an impulse travels on a certain nerve.
- ✓ **Orthodromically:** Physiologically normal direction an impulse travels on a certain nerve.
- ✓ **F-Wave:** a compound muscle action potential evoked by antidromically stimulating a motor nerve from a muscle using an electrical stimulus.
- ✓ **H-Reflex (Hoffman Reflex):** a compound muscle action potential evoked by orthodromically stimulating sensory fibers, synapsing at the spinal level and returning orthodromically via motor fibers.

Needle Electromyography

- ✓ EMG studies measure electrical activity of muscles detected by a needle electrode inserted directly into a skeletal muscle .
- ✓ Factors that may affect the outcome of recording include: age, particular properties of muscle under study, electrical specification of needle electrodes and recording apparatus.
- ✓ EMG examination of skeletal muscle is usually performed in four steps (see figure).

	Lesion / EMG steps	Normal	Neurogenic Lesion		Myogenic Lesion		
			Motoneuron	CNS	Myopathy	Myotonia	Polymyositis
1	Insertional activity	Normal	Increased	Normal	Normal	Myotonic discharge	Increased
2	Spontaneous activity		Fibrillation Positive wave			Myotonic discharge	Fibrillation Positive wave
3	Monitor unit potential	0.5-1.0 mV 5-10 ms	Large unit Limited recruitment	Normal	Small unit Early recruitment	Myotonic discharge	Small unit Early recruitment
4	Interference pattern	Full	Reduced Fast firing rate	Reduced Slow firing rate	Full amplitude Low	Full amplitude Low	Full amplitude Low

EMG Steps

1. **Insertional activity:** Insertion of a needle electrode into muscle normally gives rise to bursts of electrical activity, this activity originate from muscle fibers injured or mechanically stimulated by the penetrating needle.
2. **Spontaneous activity:** electrical activity recorded from a muscle at rest after needle insertion. Normally, no spontaneous activity outside end plate region. While in end plate region due to release of Ach in packets. Pathological spontaneous discharges from a diseased (denervated or inflamed) muscle : fibrillation potentials, +ve sharp waves, fasciculation potentials & complex repetitive discharges.
3. **Motor unit action potential (MUAP or MUP):** Compound action potential of a single motor unit whose muscle fibers lie within recording range of an electrode . After recording electrode is placed in muscle, MUP configuration (including amplitude, duration, number of phases) & recruitment categories are measured .

EMG Steps

3. Motor unit action potential (MUAP or MUP):

- ✓ ***Duration :*** It is measured from initial take off to the return to baseline. It indicates synchrony among muscle fibers with variable conduction velocity ,membrane excitability & fiber length.
- ✓ ***Amplitude:*** It is the maximum voltage measured from peak to peak. It is determined by muscle fiber density & their diameter .
- ✓ ***Phases :*** portion of a waveform between departure from & return to baseline . (normal ≤ 4).

4. interference pattern (recruitment pattern): with greater contraction, many motor units begin to fire very rapidly. Full (normal). Interference patterns are graded as full, reduced, discrete & single unit pattern.

EMG Test

Preparation of the test

- Brief Hx & exam.
- Simple explanation of the test to the patient.
- No need to a specific preparation of the patient (like diet or stopping drugs).

When to order NCS & EMG

- Nerve injury, Mono-neuropathy, Radiculopathy, Plexopathy (Brachial or Lumbosacral), Motor Neuron Disease (MND), Diffuse neuropathies , Cranial neuropathies, Neuromuscular Junction Disorders, and Myopathy

When Not to order NCS and EMG

- CNS Disorders (Stroke, TIA, Encephalopathy, spinal cord injury)
- Multiple Sclerosis
- Total body fatigue.
- Joint pain
- Unexplained weakness (without a neurologic consultation)

EMG Test

Contraindications

- Pacemaker.
- Drugs like warfarin & Heparin.
- Thrombocytopenia due to any cause.

What about pregnancy?

- There is no evidence for harm with NCS/EMG testing during pregnancy.

EMG and NCS

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Indications for EMG and NCS

Numbness

Radiating pain

Tingling sensation

Reduced sensation

Refrences

- ✓ Physiology lecture/university of Diyala/ Dr. Asmaa Khalaf.
- ✓ ELECTROMYOGRAPHY (EMG): INTRO TO THE MUSCLE ACTIVITY ASSESSMENT TECHNIQUE 2015, Julie N. Cote.
- ✓ Electromyogram (EMG), Jhoniel Viloria.
- ✓ https://www.verywellhealth.com/understanding-emg-and-ncs-results-2488642