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Biopac Student Lab® Lesson 2
ELECTROMYOGRAPHY (EMG) II
Introduction

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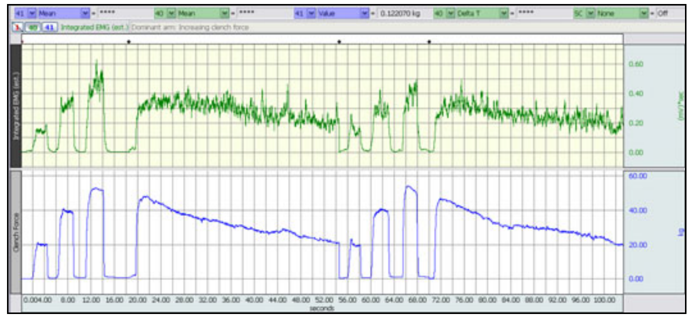

I. Introduction

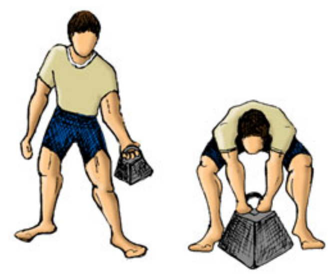
Fig. 2.1

Mechanical **work**, in the physical sense, refers to the application of a force resulting in the movement of an object. Skeletal muscle performs mechanical work when the muscle contracts and an object is moved, as in lifting a weight. To lift a weight, your muscles must exert a force great enough to overcome the weight. If you exert less force, then the weight does not move (Fig. 2.1).

Physiologically, skeletal muscle is stimulated to contract when the brain or spinal cord activates **motor units** of the muscle.

Motor units are defined as a motoneuron and all of the muscle fibers that the motoneuron innervates. An action potential (AP) in a human motoneuron always causes an action potential in all of the muscle fibers of the motor unit. As a matter of fact, humans generally do not send just one AP at a time down a motoneuron. Instead, a train of APs is sent — enough to induce tetany (the sustained fusion of individual muscle twitches) in the muscle fibers of the motor unit.
(A discussion of motor units and their control was presented in Lesson 1.)

Most human skeletal muscles are composed of hundreds of motor units (Fig. 2.2). When a skeletal muscle is called on to perform mechanical work, the number of motor units in the muscle activated by the brain is proportional to the amount of work to be done by the muscle; the greater the amount of work to be done, the greater the number of motor units activated. Thus, more motor units are simultaneously active when a skeletal muscle lifts 20 kilograms than when the same muscle lifts 5 kilograms.

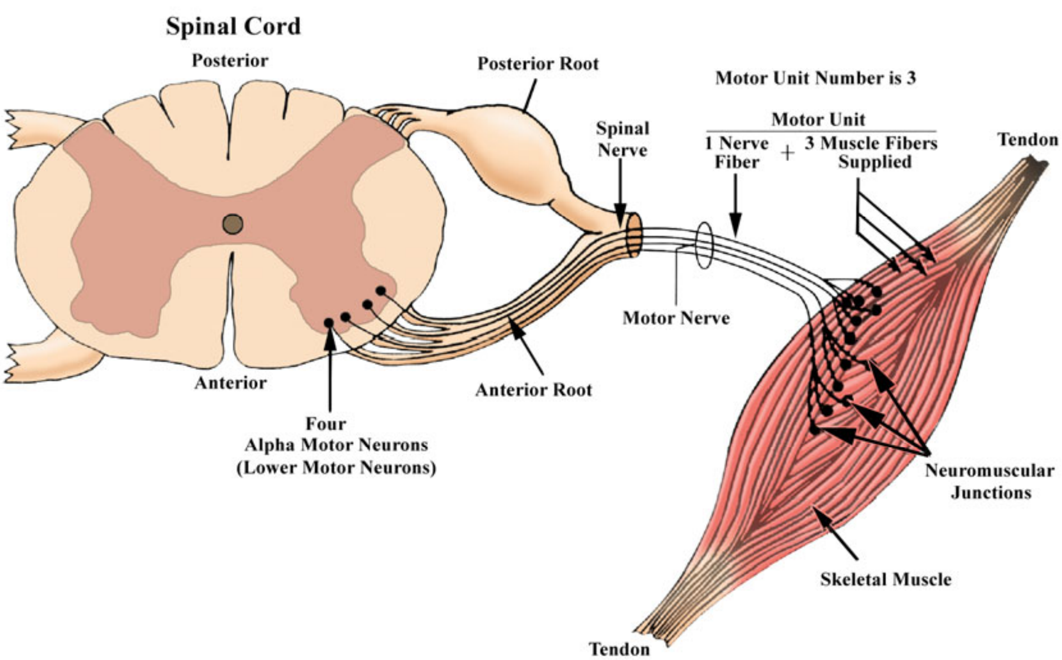

Fig. 2.2 Example of Motor Units

The brain determines the number of active motor units required for a muscle to perform a given task by utilizing sensory information from stretch receptors in the muscle and associated tendons and joint capsules. For example, when lifting a bucket of water from the ground, the brain first activates several motor units in the requisite skeletal muscles. If sensory information returning from the muscles indicates the muscles are contracting but not developing adequate power to lift the bucket, the brain activates additional motor units until the sensory information indicates the bucket is being lifted. The sequential activation of motor units to perform a designated task is called **motor unit recruitment**.

Once you have lifted a light object, the brain recruits approximately the same *number* of motor units to keep the object up, but cycles between *different* motor units. The muscle fibers consume stored energy available in the muscle, and generate a force by contracting. As the muscle fibers deplete this fuel source, more energy must be created in order to continue contracting. By recruiting different motor units, motor units can relax and replenish their fuel sources.

Skeletal muscles performing acute maximum work or chronic submaximum work of a repetitive nature will eventually **fatigue**. Fatigue is defined as a decrease in the muscle's ability to generate force. Fatigue is caused by a reversible depletion of the muscle's fuel supply. If the muscle uses its energy sources faster than they can be generated by cellular metabolism, fatigue occurs. During contraction, skeletal muscle cells convert chemical energy into thermal and mechanical energy, and, in the process, produce chemical waste products.

Normally the waste products are removed from the muscle by the circulatory system as the blood brings nutrients to the muscle for energy transformation. If certain waste products (metabolites) are not removed at an adequate rate, they will accumulate and chemically interfere with the contractile process, thereby hastening the onset of fatigue. Some accumulated waste products also stimulate pain receptors in surrounding connective tissue and induce cramping of skeletal muscle, a general sign of inadequate blood flow to the muscle.

In this lesson, you will examine motor unit recruitment and skeletal muscle fatigue by combining **electromyography** with **dynamometry**.

When a motor unit is activated, the component muscle fibers generate and conduct their own electrical impulses, which cause the fibers to contract. Although the electrical impulse generated and conducted by each fiber is very weak (less than 100 µvolts,) many fibers conducting simultaneously induce voltage differences in the overlying skin which are large enough to be detected by a pair of surface electrodes.

The detection, amplification, and recording of changes in skin voltage produced by underlying skeletal muscle contraction is called electromyography, and the recording thus obtained is called an **electromyogram (EMG)**.

The EMG signal is the recorded consequence of two principal bioelectric activities: 1) propagation of motor nerve impulses and their transmission at the neuromuscular junctions of a motor unit, and 2) propagation of muscle impulses by the sarcolemma and the T-tubular systems resulting in excitation-contraction coupling. The magnitudes of the action potentials of active motor units are not all the same nor are they in phase with one another. Furthermore, the timing sequence of motor unit activation is variable. The net result of these and other factors is a **complex EMG signal**. Remember we are recording all of this activity as it is detected by surface electrodes, and propagation of muscle and nerve impulses involves both depolarization and repolarization phenomena. The "spikes" therefore, will have a negative and a positive component and the amplitudes will be influenced by the location of the recording electrodes with respect to the number of active underlying skeletal muscle and motor nerve fibers.

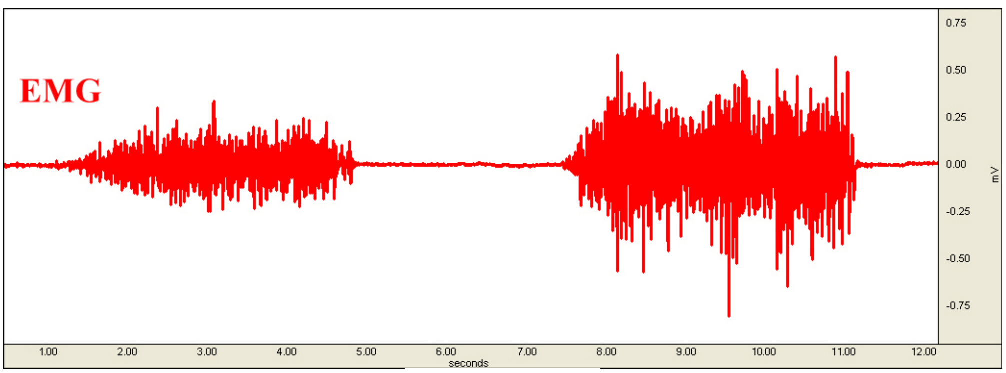

Fig. 2.3 EMG signal

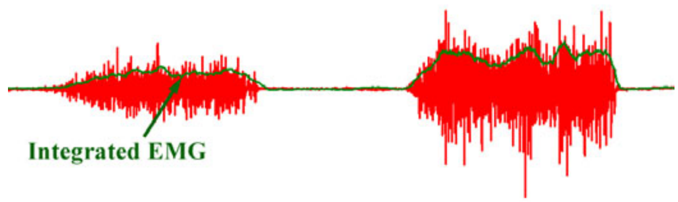

Fig. 2.4

Integrated EMG is an alternative view of the EMG signal that clearly shows the pattern of muscle activity. Integrated EMG "averages out" noise spikes in the raw EMG data to provide a more accurate indication of the EMG output level. Integrated EMG calculates a moving average (mean) of the EMG data by first rectifying each point in the sample range (inverting all negative values) and then computing the mean. In this lesson, each data point of Integrated EMG is calculated using 100 samples of data from the EMG source, so the first 100 sample points should be ignored since they reflect the number of zero values being averaged in with the first few samples of data.

Power is defined as the amount of work done per unit of time. **Dynamometry** means the measurement of power (*dyno* = power, *meter* = measure,) and the graphic record derived from the use of a dynamometer is called a **dynagram**.

In this lesson, the power of contraction of clench muscles will be determined by a **hand dynamometer** equipped with an electronic transducer. Model SS25LA/L measures force in "kg" units; model SS56L measures proportionality of bulb pressure to clench force in "kgf/m^2" units (a pressure unit). Both measures are accurate for the relative measures recorded in this lesson.

The BIOPAC system will simultaneously record three bands of information:

1) The force you exert on the transducer,
2) The electrical signal produced by the muscle during contraction, and
3) The integrated waveform, which is an indication of the activity levels of the muscle.