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HIGHER EDUCATION

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BSL *PRO* Lesson H07: EMG Active Learning

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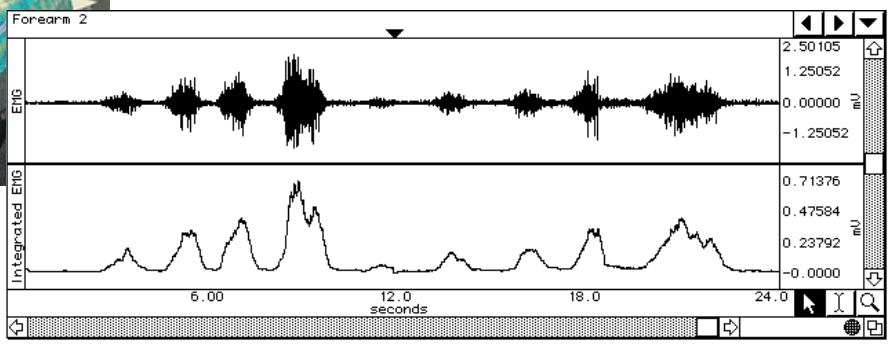
This lesson is based on a presentation given by Dr. Jennifer Lundmark and Ms. Andrea Salmi at the HAPS Conference, Maui, HI, June 2-7, 2001



Overview

Active Learning

Active Learning Lessons convert traditional physiology laboratory experiments

into inquiry-based exercises. Students perform a lab exercise designed to encourage them to make observations and develop and test multiple hypotheses during a single lab period using the BIOPAC data acquisition system. These inquiry-based exercises are designed to give students experience with the scientific method, group discussion, design of simple experimental protocols, and the responsibility of making their own decisions.

This "Active Learning" lesson allows students to participate in, rather than merely receive, their own education. This lesson assumes students are familiar with the concepts of concentric, eccentric, isometric, and isotonic contractions* and provides only the basic setup and recording steps students need to *create their own experiment.* Students will design an experiment to measure how electrical activity changes when a muscle contracts with varying degrees of force.

To learn more about the benefits of Inquiry-based, Active Learning Labs, read these results from an NSF-CCLI Grant-Supported Project on Inquiry-based labs using the Biopac Student Lab System. (Page 5)

*For explanation of these terms and further experimental guidance, review the Appendix.

EMG

Human skeletal muscle consists of hundreds of individual cylindrically shaped cells (called **fibers**) bound together by connective tissue. In the body, these muscles are stimulated to contract by somatic motor nerves that carry signals in the form of nerve impulses from the brain or spinal cord to the skeletal muscles (Fig. 1.1). Nerve cells that innervate skeletal muscle are called **somatic motor neurons**. They are located in the gray matter of the spinal cord and brain. **Axons** (or

nerve fibers), which are long cylindrical extensions of the neurons, leave the spinal cord via spinal nerves and the brain via cranial nerves, and are distributed to appropriate skeletal muscles in the form of a peripheral nerve, which is a cable-like collection of individual nerve fibers. Upon reaching the muscle, each nerve fiber branches and innervates several individual muscle fibers.

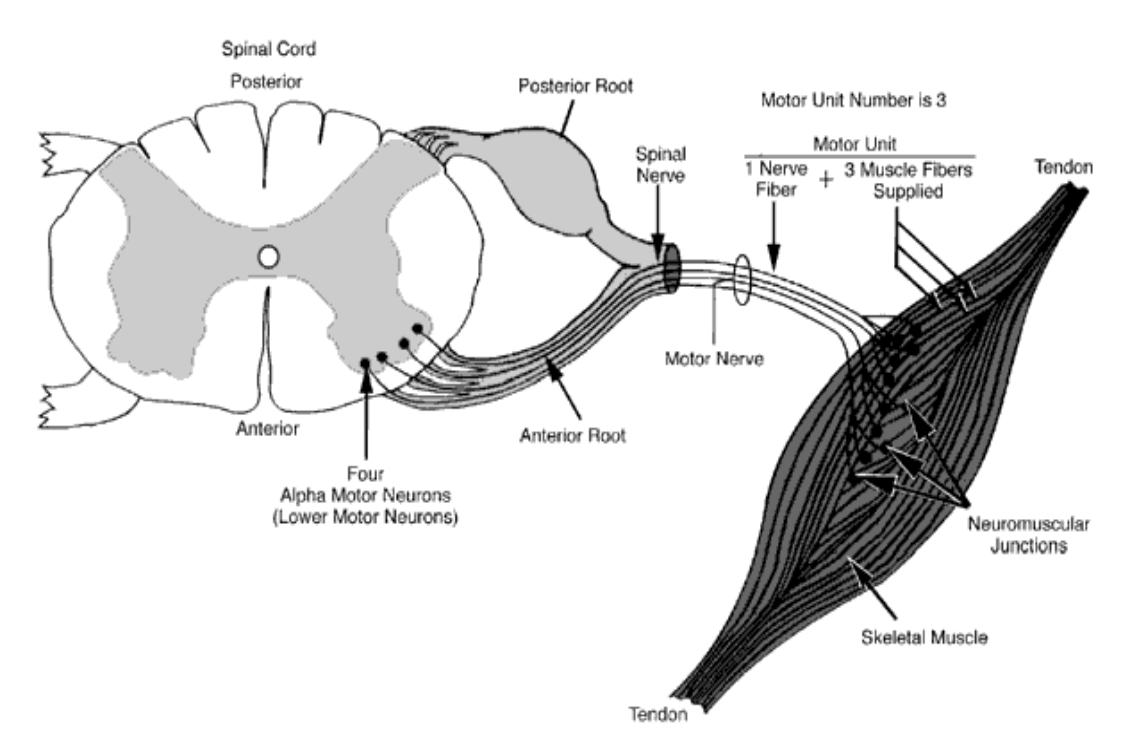


Fig. 1.1 Example of Motor Units

Although a single motor neuron can innervate several muscle fibers, each muscle fiber is innervated by only one motor neuron. The combination of a single motor neuron and all of the muscle fibers it controls is called a **motor unit** (Fig. 1.1). When a somatic motor neuron is activated, all of the muscle fibers it innervates respond to the neuron's impulses by generating their own electrical signals that lead to contraction of the activated muscle fibers.

When a motor unit is activated, the component muscle fibers generate and conduct their own electrical impulses that ultimately result in contraction of the fibers. Although the electrical impulse generated and conducted by each fiber is very weak (less than 100 microvolts), many fibers conducting simultaneously induce voltage differences in the overlying skin that 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**. The recording thus obtained is called an **electromyogram** (EMG). The changes in amplitude of the recording indicate changes in the amount of electrical activity in the muscle.

Objectives

1. To investigate the electrical activity of different muscles as they contract with varying degrees of force.
2. To design experiments by selecting muscles to record EMGs from, and by creating activities those muscles will perform.

Equipment

- Computer running Windows 7/Vista/XP or Mac OS X
- BIOPAC Software: Biopac Student Lab *PRO*
- BIOPAC Data Acquisition Unit (MP30/MP35/MP36/MP45)
- BIOPAC electrode lead set (SS2L)—one or more, depending on experiment design
- BIOPAC disposable vinyl electrodes (EL503)
- Electrode gel (GEL1) and abrasive pad (ELPAD)

Experiment Design

Design an experiment to measure how electrical activity changes when a muscle contracts with varying degrees of force. Experiment must:

1. Specify which muscle will be used
2. Specify how the force of contraction will be altered
3. Specify what measurements will be taken and how they will be recorded (table, etc.)
4. Conform to the Scientific Method, specifically:

   A. Identify a problem or objective.
   B. Form a hypothesis.
   C. Test the hypotheses by observation and experimentation.
   D. Interpret the data.
   E. Draw conclusions (design a new experiment if data does not support the hypothesis)
   F. Report observations and conclusions.

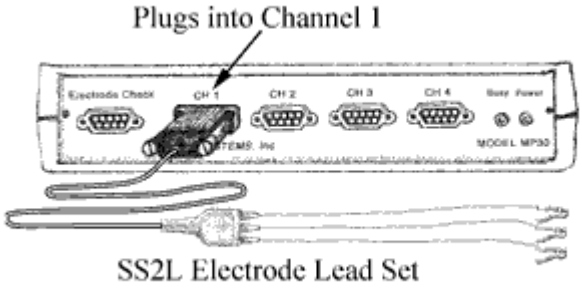
See **Additional Study** (page 4) for more experiment ideas.

Setup

Note This setup demonstrates the basic EMG connections on the human forearm. Student experiments may require variations in the setup.

Hardware

1. Plug the **Electrode Lead Set** into **CH 1** on the **MP** unit. (If recording more than one muscle simultaneously, plug another electrode lead set into CH 2.)
2. Turn on the **MP** data acquisition unit.
3. Turn on the computer.
4. Launch the **BSL *PRO*** software on the host computer.
5. Open the EMG graph template by choosing **File menu > Open > choose Files of type: GraphTemplate (*GTL) > File Name: H07 EMG.gtl**.



Calibration

No calibration is required.

Subject — Electrode Connections

The electrode connections for setting up the EMG recording consist of an **electrode lead set** attached to the Subject and plugged into an **MP** unit.

1. Lightly abrade the surface of the skin where you wish to record muscle activity. You must select locations over the proximal and distal ends of the belly of the muscle, as demonstrated below.
2. Locate a nearby area, but not the same muscle, for the ground electrode and abrade that area as well.
3. Apply gel-filled vinyl electrodes to each area.
4. Attach the electrode lead set as follows:

Proximal End:	White
Ground:	**Black**
Distal End:	**Red**

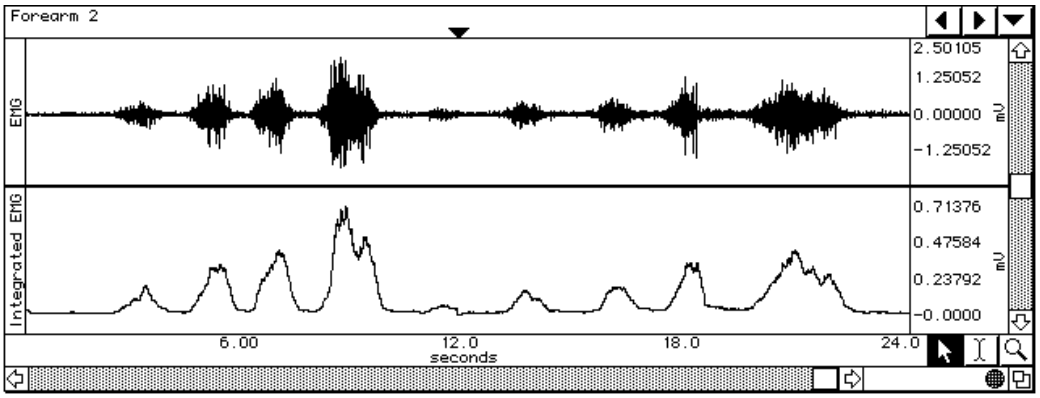
Running the Experiment

Hints for minimizing data error

- The Subject should not look at the computer screen during data collection.
- The Subject must avoid excessive extraneous movement.
- Remove all jewelry or other metal objects.
- Check all cable connections.

Here's a simple example of the type of recording student experiments might require:

1. Make sure the Subject is relaxed, and then click **Start** in the graph window to begin recording.
2. Tell the Subject to contract and hold the designated muscle for 2 seconds about every 5 seconds.
3. Insert a marker (press the **F9** key, **Esc** key on Mac) to mark the exact time the subject contracts a muscle.
4. After 30 seconds, click **Stop** in the Graph window to end.



Sample EMG Data from the Biopac Student Lab *PRO*

Additional Study

1. Repeat the above experiment using at least two other muscles.
2. Design an experiment to demonstrate concentric and eccentric contraction in the same muscle.
3. Design an experiment to demonstrate isotonic and isometric contraction and compare the EMGs.
4. Review and apply what you have learned by answering the questions in the following worksheet. WORKSHEET

Sample Experiment Variation

Calf muscle:

1. Subject stands flat footed.
2. Subject rises to his toes, holds for 2-3 seconds, then returns to a flat-footed position.
3. Allow sufficient recovery time (5-10 seconds) between each trial.
4. Repeat, now giving the Subject a moderate weight (5-10 lb) object to hold.
5. Continue for a total of 3-4 trials with increasingly greater weight in 5-10 lb increments.

Appendix

Definitions

Contraction	Definition	Example
Isometric	constant muscle length and joint angle	pushing against a wall, without moving
Isotonic	constant resistance to muscle	weight lifting
Concentric	muscle shortens	"positive" weight lifting (lifting the weights)
Eccentric	muscle lengthens	"negative" weight lifting (lowering the weights)

INQUIRY-BASED LABS USING THE BIOPAC STUDENT LAB SYSTEM: RESULTS FROM AN NSF-CCLI GRANT-SUPPORTED PROJECT.

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The objective of this NSF-funded project is to incorporate modern computerized data acquisition equipment into Introductory Human Anatomy and Physiology courses, thus allowing the investigators to revise the laboratory curriculum to improve critical thinking skills and understanding of physiological principles. It is also believed that using this new equipment will give students technical experience that will improve their workplace skills. This is a collaborative project between Dr. Jennifer Lundmark, a faculty member at California State University, Sacramento, and Andrea Salmi, a faculty member at Cosumnes River College, a community college. Students at both institutions participate in the experimental laboratory exercises.

The revision of our lab curriculum involved the translation of pre-existing laboratory exercises into inquiry-based lab exercises. The new exercises include Scientific Inquiry, Electromyography, Electrocardiogram, Pulmonary Ventilation, and Respiratory Volumes. It is our goal that in providing inquiry-based exercises, students will improve their critical thinking skills, achieve a greater understanding of the physiological processes explored in the laboratory, and experience less frustration in gathering data. We closely observed the students during the labs, and evaluated the effectiveness and problems associated with each lab exercise. The input provided by the students and by all instructors using the lab exercises is continually incorporated into revisions of the lab exercises. One of our most profound findings was the sense of understanding we now have of the amount of freedom vs. the amount of guidance that the students required during the labs. We believe this understanding is one of the more important aspects that we can share with other faculty. Therefore, our workshop at the 2001 HAPS conference focuses on how to make the transition from instructor-dictated to student-driven laboratories. Participants in our workshop perform the same EMG exercise as our students and experience this guided inquiry firsthand.

In addition to increasing student understanding of physiological processes, this project has also attempted to increase student appreciation of the scientific process. Several of the lab exercises have been specifically written to reach this goal. For example, the Scientific Inquiry exercise has students observe a drop in heart rate as a subject holds their breath and immerses their face in cold water (the diving reflex). The students are challenged to develop and test their own hypotheses to isolate the variable responsible for the drop in heart rate. It gives the students experience in scientific thinking, stimulates their curiosity, gives them more control over their own learning, allows them to test and retest and to more fully understand the steps involved in scientific inquiry. We have gathered anonymous feedback from students, and the data indicate their substantial enthusiasm for this approach to learning.

Another goal of this project was to improve student skill with and confidence in using current technology. Since the new equipment allows for relatively easy collection of real time data (for example ECG, EMG, respiratory volumes), students can efficiently collect the data, evaluate it and design additional experiments during the same lab period. They have time to critically evaluate the data, correct mistakes, or expand their inquiry. Specifically, we have observed students evaluate EMG data from a muscle, realize that it didn't match their expectations, evaluate their subject preparation, correct an error and redo the experiment. We have seen them analyze respiratory volumes data, note that it didn't appear to be valid, study their equipment calibration procedures and redo the exercise. It is important that students learn to evaluate their experimental procedures and see the impact on their results. The new equipment has given students the freedom to make mistakes and learn from them in a nonthreatening manner. They learn that very sophisticated equipment can be easy to use without fear.

We have also created an environment for students to ask "What would happen if..." questions, then set up an experiment and answer their own questions. The equipment provides immediate feedback, which increases their enjoyment of learning and their overall enthusiasm for science. The lab exercises have been written to give students freedom to explore questions of their own design, and to expand on the physiological principle being investigated.

This project has been very successful in many respects. Students have shown increased enthusiasm during labs, their responses to exam questions and homework problems show their understanding of the principles investigated, and they are very comfortable using the equipment. The laboratory exercises are more inquiry-based and less "cookbook" than in the past, engaging students as more active participants in their learning. This is of great benefit to students as learners in general. The use of modern, computerized technologies also benefits students widely, and will increase their confidence as they encounter related equipment in other aspects of their college education and in their workplaces.

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