

Skeletal muscles and fatigue

Inexpensive equipment and classroom materials

Skeletal muscle comprises about 1/3 to 1/2 of one's body weight and is the largest internal organ. It allows us to move our body parts and respond to various types of stimuli for survival. Skeletal muscle grows and shrinks based on use and it has an amazing ability to repair itself. Understanding how skeletal muscle functions from a cellular level to whole tissue is important in knowing how it functions in one's body normally as well as in diseased states. Secondary effects from non-skeletal muscle dysfunction can have an impact on muscle such as obesity, depression and other neural disorders. In starting to address how muscle functions, experimental exercises using their own body can help to engage students to want to learn concepts and principles behind the observations they made personally. This laboratory exercise is unique in the use of relatively inexpensive equipment now available from Backyard Brains and the design in using class room materials to probe fundamental physiological questions.

When one initiates contraction of skeletal muscle, the electrical activity generated from the movement ions produces electrical potentials which can be picked up with surface electrodes on the skin. The electrical activity monitored from muscle is referred to as the electromyogram (EMG). In this exercise the Spiker box from Backyard Brains will amplify this EMG signal for audio and to be able to record to an iPhone or iPad device. The frequency, amplitude and profile of the signals can be related to muscle function (Bergquist and Hammert, 2013; Ghaoui et al., 2013). Exercise of skeletal muscle can

relate to fatigue, but understanding the mechanisms of fatigue are complicated as there is a motivational aspect to fatigue within an animal as compared to excised muscle in a dish which is stimulated to the inability to maintain force (Beneke and Böning, 2008; Kent-Braun et al., 2012). In this experimental design students can test a relationship of muscle size to rate fatigue and to the amount of force generated by the biceps.

Extensions of the provided protocol can readily be performed for student driven inquiry and problem based learning. The use of an iPhone/iPad without the need to be plugged into an electrical outlet provides additional freedom in the locations this protocol can be performed to collect data. If the teacher wished to go the extra step the parts for the EMG Spiker Box are able to be purchased from Backyard Brains and students can solder the parts together make their own recording device. This is not difficult as even middle school students are performing such activities in building these recording units. This would also bring in an engineering and design feature from the Next Generation Science Standards to this laboratory exercise.

The recorded files in the iPhone/iPad are able to be saved and emailed or downloaded. An analysis is able to be made directly on the recorded iPhone/iPad file such as duration of enhanced activity and amplitude of the electrical signals. The graphical representations can be compared to different times in the experiment such as at the initial stage and fatigued stage or the amount of activity related to the weight being lifted (Figure 1). In addition, the files can be played back on the iPhone/iPad as audio files. The detailed procedures from Backyard Brains web site details how to set up the equipment for use. The amplitude of the signals can be roughly measured with the scale

on the recorded signal. The large spikes as well as an rough average amplitude can be obtained and recorded in a notebook. The time scale can be obtained directly off the recorded signal and also recorded in a notebook for later graphing and analysis. Such analysis can be a graph of the average amplitude over time of contraction until fatigue. Taking data points ever minute and comparing graphs with different weights or bicep diameter are some ways of representing the data.

A movie showing the exercises described herein is provided in supplemental information.

The concepts and activities presented are aligned with various Next Generation Science Standards (NGSS) (SS Lead States. 2013).

S3 Planning and carrying out investigations

S4 Analyzing and interpreting data

S5 Using mathematics, information and computational thinking.

S8 Obtaining, evaluating, and communicating information.

Middle school

MS-LS1 From Molecules to Organisms: Structures and Processes

MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

High school

HS-LS1 From Molecules to Organisms: Structures and Processes

HS-LS1-3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

Crosscutting concepts:

Patterns. Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. (1-LS1-2)

Cause and Effect. Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (LS3.A)

Stepwise procedures:

1. Download free Backyard brain AP to iPhone or iPad
2. Set up Backyard brain EMG recording. Turn on amplifier to hear the activity. The sound in the data collection is useful to the experimenter to know when muscle activity is decreasing or increasing.
3. Set up EMG electrodes on bicep in dominate arm. Record before lifting and while lifting a light weight to 90 degrees.
4. Measure how long until fatigue occurs with a light weight
5. Repeat above but with more weight (heavy weight to 90 degrees).
6. Measure how long until fatigue occurs with a heavy weight
7. Increase mental focus to override the fatigue. The decreasing sound of the muscle activity may also be a an addition key to participants that fatigue is occurring to make a measure in the time. Also the motivation aspect of the sound decreasing or increasing with concentration in contracting a fatigued muscle can aid in maintaining the strength of contraction.
8. Repeat the experiments with measuring the EMG activity with greater than 90 degrees at the elbow with heavy weight.
9. If time permits repeat the fatigue experiment with non-dominate arm with heavy weight.
10. Weigh on a scale the light weight and heavy weights used in the experiments.

11. Collect variables on the experimenter: upper arm circumference, gender, what type of exercises they may perform with their upper arms, how the person feels on the day of experiment, information on use of their upper arms within the last 24 hours.

Table:

	Time to fatigue	Weight of objects	Experimenter information
used in grams			
Light weight			
Heavy weight			

Questions to answer after data is collected

1. Looking over the data with lifting the weight and measuring fatigue, what suggestions might one make to explain the results?
2. Looking at the data in Table 1 what is the relation time to fatigue and amount of weight?
3. What suggestions would one make to help recover from fatigued skeletal muscles?
4. What might one suggest if a heavy object needed to be carried in one's hand, such as the books on a rope in these experiments?
5. If this is done in a classroom with many people, one could measure upper arm circumference and relate to time of fatigue with mass. (In measuring circumference have elbow at 90 degree and forearm resting on a surface so bicep is not contracted but in a relaxed state.) What kind of relationship in the class did one find with bicep circumference and time to fatigue?
6. If one did these experiments with dominate and non-dominate arms, where there differences in the time to fatigue for the same amount of weight lifted? (Explain the results).

The following materials are needed to perform this EMG experiment:

1. Iphone/iPad
2. Download free AP from Backyard Brains
3. Spiker Box for EMG (obtained from Backyard Brains. Order on line).
4. Wires for Iphone/Ipad to connect to Spiker Box. Comes with Spiker Box

5. Rope to tie book (weights)
6. Books or some weight
7. Scale to measure the weights to be lifted

References

Backyard Brains. <https://backyardbrains.com/>

Bergquist, E.R., Hammert, W.C. (2013) Timing and appropriate use of electrodiagnostic studies. *Hand Clin.* 29(3):363-70. doi: 10.1016/j.hcl.2013.04.005

Beneke, R., Böning, D. (2008) The limits of human performance. *Essays Biochem.* 44:11-25. doi: 10.1042/BSE0440011.

Ghaoui, R., Clarke, N., Hollingworth, P., Needham, M. (2013) Muscle disorders: the latest investigations. *Intern Med J.* 43(9):970-8. doi: 10.1111/imj.12234.

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SS Lead States. 2013. *Next Generation Science Standards: For States, By States.* Washington, DC: The National Academies Press.

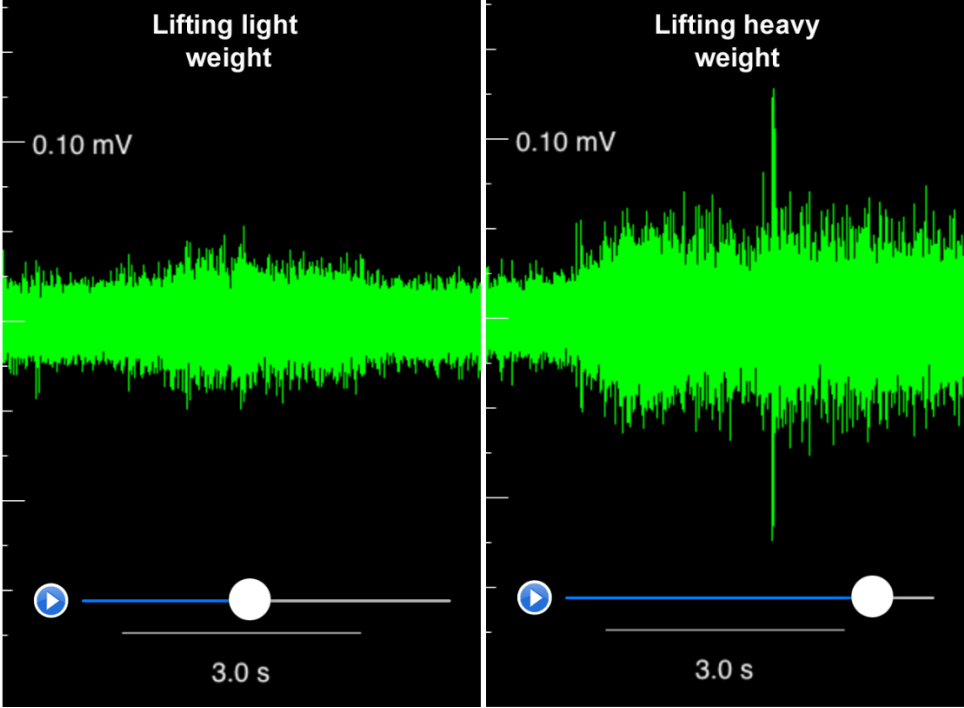


Figure 1