5. Muscle Fatigue

A Workout For Your Thumb

Driving Question

What happens when muscles become fatigued?

Materials and Equipment

For each student or group:

- ☐ Data collection system
- ☐ Force sensor with rubber bumper attached

Safety

Follow all standard lab safety procedures.

Thinking about the Question

If you have ever had a muscle cramp, you know it can be very painful! A muscle cramp happens when the muscle involuntarily contracts and is not able to relax. The skeletal muscles in the legs and feet are commonly the location of cramps.

Before your muscles experience a cramp, they may have become fatigued. When a muscle is used past the point that enough energy is available to it, muscle fatigue occurs and the muscle cannot be voluntarily controlled any longer. If you experience muscle fatigue, your brain may send nerve signals to your muscles, but they will not be able to respond by contracting.

In this lab activity, you will use the muscles of your fingers to exert a continuous, steady force against the rubber bumper of the force sensor for a period of time that will be challenging to maintain. You will compare results within your lab group and with the rest of your class.

Sequencing Challenge

☐ **The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.**

◯	◯	◯	◯	◯
Zero the force sensor in the direction it will be used for this investigation.	Make certain that each member of your lab group is aware of the safety rules and procedures for this lab activity.	Grasp the force sensor with your thumb through one of the finger-holds.	Apply a steady, even force to the black rubber bumper on the force sensor.	Begin data recording.

Investigating the Question

☐ **Note:** When you see the symbol "" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide you with a copy of the instructions for these operations.

Part 1 – Making predictions

1. ☐ Discuss with your partners how long you think it will take the muscles in the thumb of your dominant hand to become fatigued from pushing steadily against the force sensor.

   Predicted time for muscles to become fatigued: _____

2. ☐ Predict whether it will be easier to maintain a steady pushing force without being able to watch the force graph or while watching the force graph.

_____

_____

Part 2 – Measuring a sustained push on the force sensor

3. ☐ Start a new experiment on the data collection system. (1.2)

4. ☐ Connect a force sensor to the data collection system. (2.1)

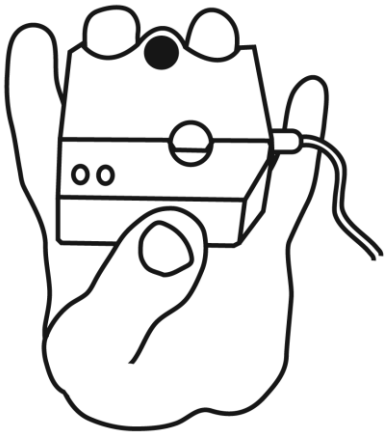
5. ☐ Display Force, with push positive, on the y-axis of a graph with Time on the x-axis. (7.1.1)

6. ☐ Zero the force sensor. Why is it important to zero the force sensor in this experiment?

_____

_____

7. ☐ Hold the force sensor comfortably, so your fingers go through the finger-holds and your thumb is positioned above the black rubber bumper.



8. ☐ Start data recording. (6.2)

9. ☐ Without looking at the graph of force versus time, begin applying a steady force with your thumb *only*, as strong as you can comfortably push without causing yourself discomfort or exceeding 50 newtons.

   ☐ **Note:** Another member of your lab group should be watching the graph to tell you if you are exceeding 50 newtons of force.

10. ☐ After 60 seconds stop applying force.

11. ☐ Stop data recording. (6.2)

12. ☐ Repeat the procedure for each member of your lab group. Remember not to look at the graph while you are applying the force to the force sensor.

13. ☐ Review your data. Adjust the scale of the graph in order to see specific data points. (7.1.2) What do you notice about the forces exerted by each lab group member? Note your observations below:

_____

_____

Part 3 – Applying a force while watching the graph

14. ☐ Hide the data runs from Part 2 of the activity. (7.1.7) This will allow you to begin with a blank graph, but keep the data from Part 2 for later analysis.

15. ☐ Zero the force sensor.

16. ☐ Start data recording. ◆(6.2)

17. ☐ While watching the graph of force versus time, begin applying a steady force with your thumb *only*, as strong as you can comfortably push without causing yourself discomfort or exceeding 50 newtons.

    ☐ **Note:** Be sure to use the same hand and finger as you did in the first trial of the activity.

18. ☐ After 60 seconds stop applying force.

19. ☐ Stop data recording. ◆(6.2)

20. ☐ Repeat the procedure for each member of your lab group. Remember to look at the graph while you are applying the force to the force sensor.

21. ☐ Review your data. Adjust the scale of the graph in order to see specific data points. ◆(7.1.2)

22. ☐ Save your experiment according to your teacher's instructions. ◆(11.1)

Answering the Question

Analysis

1. Review the data for each lab group member, first for applying force without looking at the graph and then for looking at the graph. How did your predictions compare to the results you obtained?

_____

_____

_____

2. In the first trial, you were not able to see the graph of force versus time while you were applying the force. In the second trial, you were able to watch the graph. Did you observe any differences between the trials? If you did, what do you think accounts for the differences? Explain your thinking.

_____

_____

_____

3. Describe what the arteries, veins, and skeletal muscles of your hand and fingers were doing while you were applying the steady force on the force sensor.

4. Muscles store energy for use after the supply of blood-delivered energy is completely used up. Each muscle cell contains an energy "reserve" of glycogen, a substance which must be broken down in order to be used by the muscle. What evidence do you have in your data to indicate that your muscles may have begun to use their energy reserves during this activity? Explain your thinking.

5. Muscle fatigue is the inability of a muscle to contract, even when you want it to do so. Recall your experience of pushing on the force sensor. Discuss this with the members of your lab group. Was there a point at which you felt it was difficult to control the muscles in your index finger? Describe how the muscles in your finger and hand felt.

6. Why was it important to adjust the scale of the graph during your analysis of the data? At what scale does the force data appear to look steadiest? At what scale does the force data appear to look least steady?

7. Review the data for each lab group member again. (7.1.7) What was the maximum variation in force data for each lab group member? By how many newtons did the force vary from the greatest force applied to the least force applied during a particular run of data?

Multiple Choice

☐ **Circle the best answer or completion to each of the questions or incomplete statements below.**

1. Bones are moved by the_____of skeletal muscles.

   A. Extension
   B. Contraction
   C. Metabolism

2. Muscle fatigue is:

   A. The inability of a muscle to contract when you want it to do so
   B. The inability of muscle cells to contain stored energy reserves
   C. The result of the circulatory system failing to carry off waste products

3. Force, in the SI system, is measured in:

   A. Newtons
   B. Kilograms
   C. BTUs

4. In order to function correctly, muscles need an adequate supply of:

   A. Work to be done
   B. Nerves
   C. Energy

5. A muscle cramp happens when the muscle:

   A. Involuntarily relaxes and cannot contract
   B. Involuntarily contracts and cannot relax
   C. Voluntarily contracts and cannot relax

6. Skeletal muscles are connected to bones by:

   A. Nerves
   B. Tendons
   C. Many different types of connective tissue

7. Which organ system in the human body is responsible for providing structure as well as supporting and protecting the organs?

   A. The muscular system
   B. The cardiovascular system
   C. The skeletal system

8. Which of the following are most likely to be susceptible to muscle fatigue?

A. Tibia, femur, clavicle, cranium
B. Aorta, femoral artery, capillaries, pulmonary artery
C. Triceps, biceps, deltoid, latissimus dorsi

True or False

☐ **Enter a "T" if the statement is true or an "F" if it is false.**

_____1. Skeletal muscles can become fatigued when they need more energy than is available to them.

_____2. Most of the time, muscle cramps are completely painless.

_____3. Muscles need both oxygen and nutrients to function properly.

_____4. Muscle fatigue can occur during prolonged periods of exertion.

_____5. Once skeletal muscles become fatigued, they easily obey nerve signals from the brain to voluntarily contract.