INVESTIGATING MUSCLE FATIGUE

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OBJECTIVE/RATIONAL

Muscle contraction is important for muscles to function properly. The student will learn the molecular basis of muscle contraction. Grip strength will be measured indirectly and the effects of decreased blood flow on muscle contraction will be analyzed.

TEKS 121.13 (c) 1A, 1B, 5B, 10B, 10C

TAKS ELA 1, 5
Mathematics 2, 8, 9, 10
Science 1, 2, 5

KEY POINTS

I. Review muscular system
   A. Types of muscles
      1. Skeletal
      2. Smooth
      3. Cardiac
   B. Structure of muscles
      1. Fibers
      2. Myofibrils
         a. Striated – I bands and A bands make up the sarcomere.
         b. Unstriated
      3. Neuromuscular junction
      4. Motor units

II. Muscle contraction – depends on several cellular and chemical processes to make the myofibrils move.
   A. Contractile Proteins
      1. Thin filaments
         a. actin
         b. tropomyosin
         c. troponin
      2. Thick filaments – The myosin molecule has a “head” and a “tail”.

III. Molecular basis of contraction
   A. Sliding filament theory – Individual sarcomeres shorten when the muscle contracts.
   B. Crossbridge cycle – Actin binds to myosin and forms a “crossbridge” (linkage) shortening the muscle fiber.
   C. Regulatory proteins and calcium
      1. Tropomyosin and troponin inhibit actin from binding to myosin.
      2. Calcium allows actin to form a crossbridge with myosin

        3. Dystrophin supports the sarcolemma against the forces of contracting. Prevents Duchenne Muscular Dystrophy
    D. Stimulus for contraction
        1. Depends on a neurotransmitter diffusing across the synaptic cleft causing a muscle impulse .
        2. The muscle impulse causes the release of calcium from the sarcoplasmic reticulum.
    E. Energy sources for contraction
        1. ATP – is the immediate source of energy but it is only found in small amounts in muscle.
        2. Creatine phosphate –
            a. Stores high energy bonds that can be used to make ATP
            b. present in muscles four to five times the concentration of ATP

IV. Mechanics of muscle contraction
    A. Types of contractions
        1. isotonic – the muscle shortens
        2. isometric (static)
            a. the muscle develops tension but does not shorten.
            b. the heart must work harder because little vasodilation takes place in the periphery.
    B. Neural systems at work when muscles are exercised.
        1. "Central command" located in the higher centers in the brain and is responsible for heart rate and strength of contraction..
        2. Feedback mechanism which monitors the buildup of cellular waste and signals the brainstem to increase cardiac output.
    C. Twitch
    D. Tetanus

V. Muscle fatigue – The inability of a muscle to contract (maintain tension).
    A. build up of lactic acid
    B. lack of ATP
    C. lack of blood flow to muscle

ACTIVITY

I. Complete the <u>Muscle Fatigue Laboratory Investigation.</u>

II. Complete the **<u>Response to Isometric Exercise Laboratory Investigation.</u>**

MATERIALS

Grip exerciser or spring clamp
Metric ruler
Blood pressure cuff
Grip dynamometer
Stopwatch
Two sphygmomanometers
Stethoscope

ASSESSMENT

Laboratory Investigation Rubric

ACCOMMODATIONS

For reinforcement, the student will review and repeat the muscle fatigue laboratory.

For enrichment, the student will design an experiment that could be used to investigate the effects of muscle fatigue on fine motor skills of the fingers. (Came from Lab: Going further)

REFLECTIONS

Investigating Muscle Fatigue

Purpose:
In this activity students will investigate some of the factors that affect skeletal muscle fatigue.

Background Information:

Materials:
Grip exerciser or spring clamp
Metric ruler
Blood pressure cuff

Procedure:

Part I

1. Using your dominant hand, squeeze the handles of the exerciser together as hard as you can.
2. Exercise the hand by rapidly squeezing the handles together 10 times in quick succession (no slacking!). Hold the jaws open on the 10^{th} try and immediately measure the width of the opening. Record this value in the data table.
3. After a brief rest (5 seconds) repeat Step 2. Continue to do so until you have completed a total of 5 measurements. Be sure to record the data each time.
4. Allow a 5-minute recovery period.

Part II

1 Repeat Step 1 with the hand used previously. Record the initial data in the table.
2 Place the blood pressure cuff around the upper arm and inflate to about 180 mm Hg.
3 Repeat the exercise portion of the activity as described above, recording all data.

Data:

Part I-without cuff	Part II-with cuff
Distance jaws held apart (cm)	*Distance jaws held apart (cm)*
Before exercise ______	*Before exercise ______*
Trial 1 ______	*Trial 1 ______*
Trial 2 ______	*Trial 2 ______*
Trial 3 ______	*Trial 3 ______*
Trial 4 ______	*Trial 4 ______*
Trial 5 ______	*Trial 5 ______*

Prepare a line graph of the data you collected. The trial number should be on the x-axis and the distance the jaws were held open on the y-axis. You should have two sets of data points on the same graph, one without the cuff and one with the cuff in place. Be sure you label axes and give your graph a descriptive title.

Conclusion:

1. What happened to your "strength" as you progressed through Part I? How does your graph show this?

2. How did the rate at which you became fatigued differ from Part I and Part II? How does your graph show this?

3. What types of nutrients are required by muscles during exercise? How are these actually delivered to the muscle?

4. How is the delivery of these nutrients hampered by the exercise of a muscle?

5. What are some other factors that may lead to muscle fatigue besides an inability to deliver adequate nutrients?

6. Describe how your experimental results from Parts I and II explain the role of circulation in maintenance of an environment conducive to sustained muscular activity.

Response to Isometric Exercise

Purpose: The student will investigate the effects of isometric (static) exercise on cardiovascular response and relate this to the underlying neural mechanisms at work

Background:

Materials:

Grip dynamometer
Stopwatch
Two sphygmomanometers
Stethoscope

Procedure:

1. Divide into groups of five. Choose one person for each of the following jobs: subject, blood pressure monitor, pulse monitor, timer/recorder, and someone to inflate the second occlusion cuff.
2. Read over the entire procedure, making note of the timing of the measurements. Practice the procedure at least once with all participants. Do not inflate the occlusion cuff during practice runs.
3. Have the volunteer sit in a chair. Using the grip dynamometer, determine the maximum force that the volunteer can exert with their dominant hand. Their target force for this activity will be about 30% of that value. (If a rubber ball or spring exerciser is used, they should try to estimate their grip force to be in this range.)
4. Place the blood pressure cuff on the other arm. Take an initial reading. Record the systolic and diastolic pressures in the data table. Leave the cuff on the volunteer's arm.
5. Determine the volunteer's resting heart rate by taking their radial pulse. Record the heart rate in the data table.
6. Place the occlusion cuff on the upper part of the exercising arm. Do not inflate;
7. The volunteer will then exert a force on the dynamometer approximately 30% of their maximum and maintain it for three minutes.
8. At on e minute the blood pressure will be taken. The monitor will have to anticipate this reading and inflate the cuff prior to the time mark so that the reading is as close to one minute as possible.
9. A pulse reading should be taken immediately following the blood pressure reading.

10. Repeat the readings of blood pressure and pulse rate at the two and three minute marks.
11. Just following the three-minute reading, the occlusion cuff should be inflated to 200mm Hg. This will cut off all blood flow to the arm. As soon as the pressure reaches 200 mm Hg the volunteer should stop exercising.
12. At four minutes, check blood pressure and pulse. Deflate the occlusion cuff immediately.
13. Take a final blood pressure reading and pulse at 5 minutes.
14. Calculate MAP and record the values in the table.
15. Make a line graph of your results. You should have one line for each of the values, systolic pressure, diastolic pressure, MAP and heart rate.

Data:

	Initial	1 Minute	2 Minutes	3 Minutes	4 Minutes	5 Minutes
Systolic						
Diastolic						
MAP						
Heart Rate						

Conclusion:

1. Describe what happened to the volunteer's MAP and heart rate during isometric (static) exercise. How would these values differ from values taken during a dynamic exercise? What would account for any difference?

2. How did heart rate and blood pressure change during the time the blood flow was occluded? Which of the two systems, Central Control or Feedback was most active at this time? Relate this information to your observations.

3. What was happening during the last minute? How does the data show this?