**Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_ Period\_\_\_\_**

**Muscle Fatigue and ATP Production**

**Problem:** How will the function of skeletal muscle tissue in your hands be affected over time when used consistently?

**Background:**

Under normal conditions, muscles utilize oxygen (**aerobic respiration**) to make ATP from glucose. This process is very efficient and **produces 36 ATPs for each molecule of glucose**. Carbon dioxide and water are the by-products of this reaction. When muscles undergo rigorous exercise they require more oxygen to make ATP than the blood can supply. At this point the muscle is forced to produce ATP without oxygen (anaerobic respiration).

**Anaerobic respiration** **produces only 2 ATPs for each molecule of glucose.** *The product of this reaction is lactic acid.* The advantages of anaerobic respiration are that the muscle cell can continue to make ATP without oxygen and it can make ATP very quickly. This is a particular advantage when lifting heavy objects. The big disadvantage to anaerobic respiration is that it produces lactic acid which gives muscles a temporary burning sensation. The accumulation of the lactic acid in the muscles lowers the pH in a muscle fiber and alters the effectiveness of key enzymes. Muscle fibers cannot continue to contract. Muscle fatigue results when the demand for ATP is greater than the rate at which ATP can be produced in the muscle fibers. As a consequence of fatigue, ATP levels are too low for muscle fibers to produce their maximum force contraction. Under conditions of extreme fatigue, muscles become incapable of contracting or relaxing.

Today you will experience the use of aerobic respiration and anaerobic respiration by the muscle fibers in your fingers. You will experience the production of lactic acid and the sensation it produces in your muscles. The lab will demonstrate how your body used the resources available to provide you with the energy you need to do work.

**Vocabulary:**

Aerobic respiration, Glucose, ATP, Anaerobic Respiration, Muscle Fatigue, Lactic Acid

**Pre Lab Questions:**

1. Write the chemical equation for aerobic respiration:
2. Write the chemical equation for anaerobic respiration:
3. In terms of ATP, how much more energy does the aerobic respiration process produce versus anaerobic respiration?
4. How are the reactants delivered to the cell?

**Hypothesis:** If muscles are required to contract over a period of time, then \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

**Materials: The material used in this experiment were:**

1. Clothespin [1]
2. Timer [1]
3. Pencil [1]

**Procedure: The procedures used in this experiment were:**

1. Hold a clothes pin in the thumb and index finger of the dominant hand and open and close it while the other fingers of the hand are held out straight. The number of times the clothes pin opens to its maximum distance in 30 seconds is recorded. Students should attempt to squeeze quickly and completely, to get the maximum number of squeezes for each trial.
2. Repeat this process for nine more 30 second trials recording the result for each trial. Do not rest the fingers between trials.
3. Conduct the same test using the non-dominant hand.
4. Prepare a line graph of the data you collected. The trial number is the independent variable and the number of squeezes is the dependent variable. Make sure to label your axes clearly and give your graph a clear, detailed title.

**Data:**

**Table 1: Dominant Hand Trials** **Table 2:** **Non-dominant Hand Trials**

|  |  |
| --- | --- |
| **Trial** | **# of Squeezes** |
| **1** |  |
| **2** |  |
| **3** |  |
| **4** |  |
| **5** |  |
| **6** |  |
| **7** |  |
| **8** |  |
| **9** |  |
| **10** |  |

|  |  |
| --- | --- |
| **Trial** | **#of Squeezes** |
| **1** |  |
| **2** |  |
| **3** |  |
| **4** |  |
| **5** |  |
| **6** |  |
| **7** |  |
| **8** |  |
| **9** |  |
| **10** |  |

**Calculations:**

To open and close the clothes pin, we must overcome the force of the spring holding the clothes pin together. To do this requires work. Energy is used to perform work. Work is measured in units known as **joules**. The amount of work needed to squeeze open the clothes pin completely is equivalent to:

**Work = 1.5 Joule/Squeeze**

To find the total work expended by your hand, you will need to multiply the amount of work needed to open the clothes pin by the number of times the clothespin was squeezed open. You must first **ADD** up the total number of times (for all 10 trials) the clothes pin was opened for the dominant and non-dominant hand. Write those values below.

**TOTAL # OF SQUEEZES FOR DOMINANT HAND = \_\_\_\_\_\_\_\_\_**

**TOTAL # OF SQUEEZES FOR NON-DOMINANT HAND = \_\_\_\_\_\_\_\_**

Do the following mathematical calculations to figure out the total work each hand did:

**Total Work = 1.5 Joule/Squeeze X \_\_\_\_\_\_\_ Total # of Squeezes for Dominant Hand = \_\_\_\_\_\_\_ Joules of Work**

**Total Work = 1.5 Joule/Squeeze X \_\_\_\_\_\_\_ Total # of Squeezes for Non-Dominant Hand = \_\_\_\_\_ Joules of Work**

Joules can be converted into units of energy known as **calories**:

**1.5 Joule = .36 Calories**

To convert the joules (those produced during total squeezes for the dominant and non-dominant hands) to calories, use the following equation:

**\_\_\_\_\_\_Dominant Hand Joules of Work x .36 Calories/Joule = \_\_\_\_\_\_\_\_Calories**

**\_\_\_\_\_\_Non-Dominant Hand Joules of Work x .36 Calories/Joule = \_\_\_\_\_\_\_\_Calories**

It requires 7.3 calories to create 1 mole of ATP. One mole of ATP can also use 7.3 calories to perform work. (In our case, the movement of muscles to open and close a clothes pin.)

**How many ATP were used to work your dominant hand? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**How many ATP were used to work your non-dominant hand? \_\_\_\_\_\_\_\_\_\_\_\_\_**

**On a separate sheet of paper, after the analysis and conclusion have been typed, please complete the following:**

**Claim**: [Restate the question as a complete sentence for your Introduction.]

How will the function of skeletal muscle tissue in your hands be affected over time when used consistently?

**Evidence:**

Compare the amount of ATP used with your dominant hand to the amount in your non-dominant hand. Which one used more ATP’s during the 10 trials of opening and closing the clothes pin, the dominant or non-dominant hand? How does the data and graph help support your claim? What is the difference between aerobic and anaerobic respiration? What evidence does this provide to support your claim?

**Rationale:**

How do muscles move bones?

Why do muscles fatigue?

Do you think cardiac muscle tissue functions the same as skeletal muscle tissue?