INVESTIGATION 2.2.1

Energy Consumption During Exercise

Inquiry Skills

○ Questioning	○ Planning	● Analyzing
○ Hypothesizing	● Conducting	● Evaluating
● Predicting	● Recording	● Communicating

In this investigation, you will compare your power during aerobic and anaerobic exercise and determine the amount of glucose that you consume.

Question

How does the power of aerobic exercise compare to the power of anaerobic exercise, and how much glucose does exercise consume?

Prediction

(a) Predict how many times more powerful aerobic exercise is than anaerobic exercise.

(b) Predict how many teaspoons of table sugar you will "burn" exercising your arm to exhaustion.

Materials

dumbbell or mass (2.5 kg or 80% of the heaviest mass you can lift once)
metre stick

Procedure

1. Place the mass or dumbbell on a desk.
2. Grip the mass or dumbbell with your hand and place your arm flat on the desk with arm, hand, and dumbbell resting on the desktop.
3. Place a metre stick on the edge of the desk so that there is no movement. Have a partner hold a metre stick securely on the desk (**Figure 1**).

Figure 1
Setting up the apparatus

4. Lift the dumbbell by bending your arm at the elbow one time so that your partner can measure the vertical distance the dumbbell covers when it reaches its highest point. Measure the lowest point on one edge of the dumbbell before you lift it and the same edge of the dumbbell after the lift (**Figure 2**).

Figure 2

5. While you perform step 6, your partner will
   - note the time elapsed at the end of Stage 1 (Aerobic Exercise; exercise in which no muscular discomfort is felt) and again at the end of Stage 2 (Anaerobic Exercise; exercise in which you feel muscle soreness)
   - count the number of lifts in each stage
   - make sure you cover the full distance on each lift of the dumbbell
6. Lift the dumbbell repeatedly and quickly until your arm feels sore. Tell your partner to note the end of Stage 1 (Aerobic Exercise). Continue to lift the dumbbell repeatedly and quickly until you can no longer lift it anymore. Tell your partner to note the end of Stage 2.

INVESTIGATION 2.2.1 *continued*

Observations

Complete the following measurements and calculations.

(c) Dumbbell mass = __________ kg

(d) Vertical distance dumbbell moves = ______m

(e) Time elapsed by the end of Stage 1 = ____________ s
= Stage 1 total time

(f) Number of lifts in Stage 1 = ______________

(g) Total time elapsed by the end of Stage 2 =
_______________ s (subtract Stage 1 time from total time to determine Stage 2 time, ___________ s)

(h) Number of lifts in Stage 2 = ______________

Calculations

1. To lift the dumbbell, you must overcome the gravitational force on the dumbbell. The gravitational force on the dumbbell equals the dumbbell's mass multiplied by the acceleration due to gravity, 9.81 m/s^2.

   Force needed to lift the dumbbell
   = mass of the dumbbell × 9.81 m/s^2 (F = ma)

(i) Force = ____ kg × 9.81 m/s^2
= ________ kg m/s^2

2. Each time you lift the dumbbell, you must give it gravitational potential energy (E_g). This energy equals *mgh* (mass × acceleration due to gravity × vertical distance).

(j) E_g = _____ kg × 9.81 m/s^2 × _________ m
= _________ J

   We will assume that each time you lower the dumbbell, gravity does an equal but opposite amount of work on the dumbbell.

3. You can determine the amount of work done per lift, because work is equal to the change in potential energy.

(k) Work = ΔE_g
= ______ J / lift

4. To find the total work done by your arm, multiply the amount of work needed to raise the dumbbell once by the number of times the dumbbell was lifted in each stage.

(l) Total work done during Stage 1
= _____ J / lift × ____ lifts
= ______ J

(m) Total work done during Stage 2
= ______ J / lift × ____ lifts
= _______ J

5. Power indicates the rate at which you do work. It is determined by dividing total work by total time ($P = W/t$). One watt is equivalent to one joule per second. You will determine your power during aerobic exercise (Stage 1) and anaerobic exercise (Stage 2).

(n) Power during Stage 1 = __________ J ÷ _______ s
= ___________ W

(o) Power during Stage 2 = __________ J ÷ _______ s
= ___________ W

6. In cellular respiration, one mole of ATP allows a muscle to perform 2870 kJ of work

(p) Moles ATP used during exercise (Stages 1 and 2)
= ______ J total work × (1 kJ / 1000 J) × (1 mol ATP / 2870 kJ)
= _____________ mol ATP

7. On average, cellular respiration produces 30 moles of ATP molecules per mole of glucose respired.

(q) moles of glucose used
= _______ mol ATP × 1 mol glucose/30 mol ATP
= _______ mol glucose

8. Each mole of sucrose (table sugar) is approximately equivalent to 2 moles of glucose. Determine the number of moles of sucrose used:

(r) __________ mol glucose used × (1 mol sucrose / 2 mol glucose)
= _____ mol sucrose used

9. The chemical formula of sucrose is $C_{12}H_{22}O_{11}$. The molar mass of sucrose is 342 g/ mol. Determine the number of grams of sucrose used:

(s) _______ mol sucrose used × 342 g/mol
= ________ g sucrose

10. There are approximately 4 g of sucrose in a teaspoon of table sugar. Determine the number of teaspoons of sugar you may have used for the total exercise performed.

(t) _______ g sucrose × (1 teaspoon sugar / 4 g sucrose)
= __________ teaspoons of table sugar

Analysis

(u) After lifting the dumbbell, did you feel hot? Explain your answer using the concepts of cellular respiration in this chapter.

(v) Could you tell when most of your muscles went into anaerobic respiration? What evidence was there for this?

Evaluation

(w) How many times more powerful were you during aerobic exercise than during anaerobic exercise? How did this compare with your predictions?

(x) List sources of error and suggest some improvements to the experimental design.