Lesson Title	16. Physics of Exercise
Lesson Designer	Nicole Granucci
Standards	☐ CCSS ☑ NGSS ☐ ASCA ☐ Other HS-PS3-1 Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. CC - Energy and Matter Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-PS3-3)
Learning Objectives	Students will calculate work and power of an exercise and evaluate the amount of energy produced by exercise as compared to food.

Timeline	Duration
Day 1: laboratory simulation	90 minutes

Teaching Strategies/Student Actions	Monitoring
Students can be given the notes sheet to read for information from, or the instructor can just use the notes as a basis for the necessary information. The laboratory activity contains detailed instructions for students to conduct independently.	• Teacher monitors student progress • Teacher facilitates discussion • Teacher questioning

Product Description	
Evaluation	Student analysis of questions embedded in lab.

Resources and Materials	Additional Notes
Web resources: • Definition of Work - https://www.physicsclassroom.com/class/energy/Lesson-1/Definition-and-Mathematics-of-Work • Calculation of Work - https://www.physicsclassroom.com/class/energy/Lesson-1/Calculating-the-Amount-of-Work-Done-by-Forces • Definition and Calculation of Power - https://www.physicsclassroom.com/class/energy/Lesson-1/Power • Joules/Calories - https://www.livestrong.com/article/49686-labels-use-calories-instead-joules/	

Physics of Exercise Laboratory Activity

Introduction

The human body is subjected to the laws of physics just like the rest of nature. While performing an exercise, the body dissipates energy through heat and work. The amount of energy can be calculated using the physics concept of work. Work is defined as how effective a force is at moving an object a specific distance. It can also be interpreted as how much the object changes its energy. The work equation shown below demonstrates how to calculate the amount of work (energy dissipated) by a force through a distance

Work = Force x Distance (1)

$$W = Fd$$

For this lab, the force is the weight lifted while performing the exercise in Newtons (N) and the distance is the vertical measurement of the length the object was lifted by the force in meters (m). Gravity only acts vertically, therefore vertical distance measurements are needed to accurately calculate work. The units for work is Joules (J), the standard unit of work in physics. To find the force in this lab, it will be the force due to gravity. This is because as you lift the object, you are doing work against the downward pull of gravity. To calculate the force lifted, the following formula will be used,

Force Lifted = mass of lifted weight x acceleration due to gravity (2)

$$Force_{lift} = m_{lift}g$$

Where "m" is the mass in kg of the lifted weight and the acceleration due to gravity is a constant value of 9.81 m/s^2.
If you wanted to calculate the work done by doing an arm curl, the force would be the weight of the forearm. The distance measured would be the distance of the forearm as that's the vertical height the arm moved through its motion. Multiplying the two values together will determine the amount of energy used in the unit of Joules.

Photo Credit: https://experiencelife.com/article/expert-answers-are-bicep-curls-really-useless/

How fast that energy is dissipated is described by the amount of power exerted. One can also time how long it takes to perform the exercise (in seconds) to move through the exercise. The power can be calculated with the following:

Power = Work / Time (3)
P = W/t

Power is measured in the unit of Watts (W). **Note: The symbol for work and the symbol for the units of power are the same (W). Use context to determine what the (W) represents.** Exercise machines can calculate your energy and power dissipated in an exercise by typing in your weight. When you are running you are lifting the full weight of your body while you switch your legs. Knowing your weight and the general vertical distance as you run, you can calculate your energy exerted. They display the energy in another unit called a Calorie, but ultimately its the same calculation. Since the exercise machine uses a timer, they can easily calculate your power as well.

The energy of food is measured in a different unit called calories. In fact, foods are technically labeled in kcal. Although the apple is listed at 50 calories, it really represents 50,000 Cal. By eating food, you provide your body energy. Different foods provide different amount of energy. In this lab, you will compare your exercise to one of the foods listed in the table date below (not the image below).

Photo credit: https://www.news-medical.net/health/How-Many-Calories-Should-You-Eat-Per-Day.aspx

To conversion from kcal to joules is shown below:

1 Joule = 0.000239006 kcal

Required Equipment/Supplies

1. Bleachers and/or stairs
2. Stopwatch
3. Meterstick
4. Weights
5. Rope

Procedure

1. Choose an exercise from below.
    a. Curl - Distance: forearm, Force: Weight of forearm
    b. Do push-ups - Distance: arm Force: Body weight
    c. Sit-ups - Distance: half body, Force: Half body weight
    d. Run up stairs or bleachers: Distance: Vertical height of stairs, Force: Body Weight
    e. Jump: Distance: vertical height of jump, Force: Body Weight
    f. Jog: Distance: vertical height of jog, Force: Body Weight
2. Measure the distance in meters and record the value in Data Table A.
3. Measure the weight or estimate the weight.
    - Convert the weight from pound to Newtons. (1 lb = 4.48 N)
    - Or if you have the mass in kg, calculate the weight in Newtons using (Weight = mass * 9.81m/s^2)
4. Perform 3 reps (or more/if applicable) of these activities. Start the stopwatch and time how long it takes to do the 5 reps (or whatever amount you choose). Record the total time in seconds in Data Table A.
5. Calculate the time for one rep by taking the total time and dividing it by the number of reps.
6. Repeat for a second activity.

Data Table A : Measurements of a given Activity

	Activity 1	Activity 2
Activity name		
Major Muscle Group		
Weight lifted (N)		
Distance (m)		
# reps		
Total Time (s)		
Time for 1 rep (s)		

Calculations

1. Calculate the work done by the exercise using Equation 1 for Work.
2. Calculate the power exerted by the exercise using Equation 2 for Power.
3. Convert your energy from Joules to kcal using equation (3).
4. Assume that you can maintain that exercise for 1 hour. Determine the number of reps you can do in 1 hr and multiply that by how much energy it takes to do one rep.

a. Take 3600 seconds (1hr in seconds) and divide it by the time for one rep.
# of reps = 3600s / time for 1 rep (s)
b. Multiple the number from the step above by the energy calculated in step 1.
Total energy in 1 hr = (# of reps) * (work done)

5. Compare your energy exerted to one of foods. How many (insert food of choice here) would you need to eat to perform your exercise? Take your total energy in kcal and divide it by the total kcal of the food item you chose.
# of food consumed = (Total energy 1 hr) / (food item kcal)

Recall, foods listed below are in kcal. For example, 50 calories on a food label is actually = 50,000 cal.

Food	1 apple	1 egg	1 can of soda	1 chicken breast	1 Egg McMuffin	1 muffin
Energy in kcal	95	78	140	231	300	426
Food	1 protein shake	2 cups of lettuce	1 snickers bar	1 slice of pizza	1 Carrot	1 double cheeseburger
Energy in kcal	140	10	215	285	25	437

6. Repeat all calculations for the second activity:

	Activity 1	Activity 2
Calculation of Work		
Calculation of Power		
Calculation of kcal		
Calculation of (# of reps)		
Calculation of (total energy 1 hr)		
Chosen food & kcal Value		
Calculation of (# of food consumed)		

Analysis Questions

1. Which activity did the most amount of work?

2. Which activity did the most amount of power?

3. Did the activity that used the largest force result in the largest power produced? Explain how a large force can result in a relatively small power?

4. What types of food give the most amount of calories?

5. If you are running a big race, what would be the best food choice and why?