CB 6 Effects of Exercise on Pulse and Breathing Rates

Your body is always adjusting to changes that take place in your activity or conditions in the environment. In this inquiry, you will observe changes in the rate at which blood transport takes place (as measured by changes in your pulse rate) and your respiration rate (as measured by the relative amount of carbon dioxide in your breath) with changes in your activity.

Before you begin this exercise, list some factors that you think would affect your heart beat (pulse) and breathing rates. Estimate the degree to which you think the rate would be affected by each. How would different people be affected by the same factors? What mechanisms do you think the body uses to sense and respond to changes in pulse and breathing rate?

Materials for Low Technology Data Collection

- clock that indicates seconds
- small paper bag
- 200-mL flask
- soda straw for each student
- step stool or steps
- ice pack
- phenolphthalein solution
- 0.04% NaOH in a dropping bottle

Materials for High Technology Data Collection

- Casio QV2800 Digital Camera (for visual images of changes body activity)
- Casio fx2 Graphing Calculator: Input and display of data
- Casio Data Collector EA-100
- Vernier Exercise Heart Rate Monitor
- Vernier EKG sensor
- Vernier Respiration Monitor Belt
- Vernier Gas Pressure Sensor (needed to use Respiration Monitor Belt)
- Vernier pH Sensor (used to estimate dissolved CO_2)

Low-technology (traditional) Measurement Techniques

1. Pulse Rate

   Place your first two fingers lightly against the bone on the inside of your wrist at the base of your thumb. Another method is to place your fingers on your neck just below the angle of your jaw. In either case, be sure to use your fingers, not your thumb. When you feel the pulse, count the number of pulses in a 15-second period. Multiply this number by 4 to get the pulse rate in beats per minute.

2. Breathing Rate

   Visually count the number of breaths that your partner takes in 30 seconds. Convert this to the number of breaths in one minute and record the value.

3. CO_2 Production

   Half fill two 200-mL flasks with tap water. Add 3 drops of phenolphthalein to each flask. If you do not get a pink color in both flasks, add sodium hydroxide (NaOH) to the water drop by drop until you obtain a light pink color. One of the flasks will be a control for matching the pink color to reuse the flask. After counting breaths, have your partner use a straw to blow gently into the water in one of the flasks for one minute. This may be done in several breaths, but the total exhalation time should be one minute. Begin timing as the person exhales. Take care not to blow so hard that water is splashed out of the flask.

   Exhaled carbon dioxide dissolves in water to create an acidic solution (water and carbon dioxide react to form carbonic acid). As the pH of the solution drops below 8, the phenolphthalein in the solution changes from pink to colorless.

   Restore the original pink color for reuse by adding sodium hydroxide (NaOH). The relative amount of carbon dioxide in the solution can be measured by counting the number of drops of sodium hydroxide that are needed to restore the original pink color. Add the 0.04% NaOH drop by drop to the flask, counting the number of drops it takes to return to the original pink color without fading out. (Use the control to compare.) Swirl the flask gently while adding the NaOH to mix the contents thoroughly. In your *Log*, record the number of drops you used.

High-technology (modern) Measurement Techniques

1. Digital Camera

   The digital camera has almost unlimited uses as a data collector in biology experiments. For CB 6, it can be used to take digital images of the experimental setup, different human activities for which sensor data are collected. Operations are described in the owner's manual but most newer digital cameras are menu driven.

2. Graphing Calculator

   This calculator will be used for mathematical calculations of data, such as means and other statistics, tabling data, data printing, and for data readout from the EA-100. Specific hookup directions are given for each sensor application.

3. Data Collector EA-100

   The EA-100 is used as a data recognition interface between data sensing probes and the graphing calculator. Specific hookup directions are given for each sensor application. Set up procedures are given separately.

4. Exercise Heart Rate Monitor
   The heart rate monitor determines the heart beat rate of moving or active humans. This consists of a wireless transmitter belt and a receiver module that plugs into the EA-100. For each heart beat detected, a signal is transmitted to the plug-in receiver module. Once the EA-100 is set up, it will record the beats per minute and the results are displayed on the calculator screen.
5. EKG sensor
   The EKG sensor works just like in a hospital. It measures electrical signals produced by the heart using three disposable electrodes. An EKG graph is displayed, demonstrating the contraction and repolarization of the heart's chambers
6. Respiration Monitor Belt and Gas Pressure Sensor
   The respiration monitor belt measures breathing rate by sensing the expansion and contractions of the chest during breathing. It is used in conjunction with the gas pressure sensor, which sends the changes in pressure signals to the EA-100 for readout of breaths per minute on the calculator screen.
7. pH Sensor
   The pH sensor can be used to estimate the relative changes in the concentration of dissolved CO_2 in a solution, such as into which one exhales through a straw after various levels of physical activity. It provides a more quantitative measure of the CO_2 concentration than does an acid-base color indicator. CO_2 dissolves in water as follows:

$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow 2H^+ + CO_3^-$$

   The readout on the calculator screen is pH from 1-14 and can be converted to concentration of H^+ ions by raising ten to the negative of the pH because pH is the negative log base 10 of the pH value. So for a pH of 4, the concentration of CO_2 can be estimated as follows:

$$4 \text{ x } 10^{-4} = .0001 \text{ m/L of } H^+ \text{ or } .0001 \text{ m/L } CO_2 \text{ or } .01\%$$

   Since the balanced equation indicated $2H^+$ per disassociation of one CO_2 you would need to divide the above percentage by 2 to estimate the actual CO_2 concentration, yielding .005%.

   One caution: This is a pH sensor not a dissolved oxygen sensor and does not directly measure the amount of dissolved CO_2 because CO_2 does not dissolve well in water. The pH increase due to increased CO_2 can only indirectly measure relative changes in the amounts of CO_2.

Procedures

1. Construct a hypothesis for the effects of various levels of human exercise on the pulse rate, breathing rate and amount of CO_2 produced by respiration. What is the independent variable? What are the dependent variables?
2. Work in groups of two. One of you will be the subject and the other the experimenter. Design an experiment to test your hypotheses. Be sure to include a

wide range of activity, from resting quietly to running in place. Use the measuring techniques above for pulse rate, breathing rate and CO_2 production.

3. Have your exercise conditions approved by your teacher and begin your experiment. Record data in your *Log*.
4. Switch roles with your partner, if there is time, and repeat the experiment. Use a fresh straw.
5. (Optional exercise) Determine your resting pulse rate as you lie on your back. Then place an ice pack on the top half of your face. If you use a plain plastic bag, be sure to place a wash cloth between your face and the bag. After 30 seconds, take your pulse and record.

Analysis

1. Graph your data. Since the scales and units of the three independent variables are likely to be so different, make a graph for each dependent variable. Since your independent variables were not quantified, you can make a histogram if you wish.
2. Contribute to a class graph similar to the ones you constructed. Use dots for all data points on the class graph without attempting to connect them. This will make a scatterplot of all class data. Have someone draw a straight, thick line, which would best represent a "best fit" of the data.
3. Based upon the graphs of class data, explain how your hypothesis is either supported or rejected.
4. Describe any differences that you perceive between: (a) your data and that of the class, (b) males and females and (c) athletes and non-athletes.
5. Why are the resting pulse and resting breathing rates important in this activity?
6. How are the pulse rate, breathing rate and amount of CO_2 produced affected by each of the activities? Why do you think such changes occur?
7. What differences between class members did you observe with respect to recovery time after exercise? How do you explain their differences?
8. What would make the heart of an overweight person work harder than if this person were thinner?
9. How could obesity affect the life of one's heart?
10. Sarah MacLaughlin, from Scotland, handily won the women’s 5000 M run in the 1995 Olympics. She has a resting pulse rate of less than 50 bpm. A couple of minutes after winning, she was able to speak to reporters without taking heavy breaths. How do you explain these observations?

Extra Credit

In the library, research the physiological mechanisms in the human body that regulate pulse rate, breathing rate and carbon dioxide output. How is this information related to your hypothesis?

Casio FX2.0 Calculator Procedures for CB 6

Make a Table to Organize Your Data

Making a table to organize your data for this problem will be helpful before attempting to enter data into the calculator for exploration. First you will need to determine what the independent and dependent variables are. Since this problem involves 3 types of exercises that are affecting pulse rates, breathing rates, and CO_2 production, the exercises are the independent variables. Since the type of exercise is a *qualitative* description, but the calculator will only receive *quantitative* data, you will need to use numbers to describe the exercise types. The table below is one possible way of organizing the data in preparing it for entry into the calculator. You may use another method of organization if you prefer. By all means be flexible in accepting methods of organization.

Outcomes→ ↓Exercise Method	Pulse Rate (heartbeats per minute)	Breathing Rate (breaths per minute)	CO_2 Produced (number of drops of 0.04% NaOH solution)
Low Level 1			
Medium Level 2			
High Level 3			

Making a Histogram of the Data

There are a number of ways you may want to set up your histogram. For this example we will set it up to compare one outcome at various levels of exercise. Thus we can make 3 different histograms, one to compare pulses, one to compare breathing rates, and one to compare CO_2 production at the three different levels of exercise. From the Main Menu, choose STAT by pressing [2]. If you already have data stored in Lists 1, 2, 3, and 4 there are several different things you can do:

1) Delete the data from the lists.
   Move the cursor so that List 1 is highlighted. Press [F4] for DEL-A (delete all). Then press [EXE] for Yes. Do a similar procedure to delete data for other lists, highlighting the list name that you wish to delete entries from.
2) Use empty lists.
   Each File contains 20 lists, so you can cursor over until you find 4 empty lists side by side. Just be sure that you remember the name of the lists because when you set up the graph you will need to enter the correct list numbers into the XList.
3) Change Data Files.
   You can change the "drawer" into which you are filing information. From the main stat screen, press [CTRL] (the green button), followed by [F3] for SET UP. Cursor down to the third line List File. Press [F1] for FILE then enter a number 1 through 6,

excluding from your choice the number of the current file listed on the screen. Then press [EXE], then [ESC]. This will take you back to the main stat screen. If there is new data listed, you can either delete it or follow the procedure again and change files. (While in this window, you should also check that the Stat Wind is set at Auto.)

Whichever four lists you decide to enter your data into, be sure that you remember the lists' names. You may want to jot down the list name above each outcome on your table and next to the exercise level. For the sake of uniformity, we will enter the data into List 1-4 for this example.

- ☞ List 1 will contain the independent values, which will be the numbers you have assigned to the exercise levels, 1, 2, and 3 for low, medium, and high in this example. List 2 will contain the pulse rates corresponding to the appropriate exercise levels, List 3 will contain the breathing rates corresponding to the appropriate exercise levels stated in List 1, and List 4 will contain the CO_2 production (number of drops) corresponding to the appropriate exercise levels stated in List 1. Remember to press [EXE] after each entry into a list.

For each of the histograms we will use the first list of exercise levels as the independent XList. The desired dependent variable will determine the Frequency list. Once you have entered the data into the lists, press [F1] for GRPH, then [5] for Set. For this example we will graph pulse rates in StatGraph1, breathing rates in StatGraph2, and CO_2 production in StatGraph3.

- ☞ While the top line is highlighted press [F1] to choose GPH1. Cursor down to the next line. If Hist (histogram) is not among the choices available on the bottom of the screen, press [F6] for more options. Once you find Hist, press [F1] to choose it.
- ☞ Cursor down to the third line, XList. Press [F1] to activate LIST, then [1], then press [EXE]. For Frequency you will enter the list number of the list that contain pulse (or which ever of the three dependent variables you want to describe using the histogram). Press [F2] to activate LIST here, then for the pulse rates press [2]. (Note: Rates are frequency measures.)
- ☞ Stay at this screen and cursor back up to the top line. Press [F2] to choose StatGraph2 and simply change the Frequency list to correspond to the number for the list containing breathing rates, which would be List 3. With Frequency highlighted, press [F2] for List, then [3], and [EXE].
- ☞ Cursor back to the top line and press [F3] to choose StatGraph3. Change Frequency to correspond to the CO_2 list. With Frequency highlighted, press [F2] for LIST, then [4], then [EXE].
- ☞ Once you have set up all 3 graphs, press [ESC] to return to the main stat screen. Press [F1] for GRPH, then choose 1 to view the histogram for pulse, 2 to view the histogram for breathing rate, or 3 to view the CO_2 production histogram.
- ☞ When the Set Interval window appears enter 1 for Start and for pitch, pressing [EXE] after each entry. Press [EXE] to draw the graph.

Scatter Plots of the Data and "Best Fit" Regressions

You will use the same lists of data that you entered for the histograms, but you will set the data up in a different manner in order to observe the interaction between data sets in a slightly different way. With the histograms you were able to compare pulse rates at different levels of exercise. With scatter plots and regressions, you will be able to make similar comparisons, but you will also be able to see how pulse rate changes, breathing rate changes, and CO_2 production changes compare to one another.

- ☞ From the main stat screen press [F1] for GRPH, then press [5] for Set. Again we will use StatGraph1 for pulse, StatGraph2 for breathing rates, and StatGraph3 for CO_2 production.
- ☞ While StatGraph is highlighted press [F1] for GPH1.
- ☞ Cursor down to Graph Type. This time we want to draw a scatter plot. Choose Scat by pressing [F1]. This will produce an XList and a YList line on the screen.
- ☞ Cursor down to XList, which should be List 1. If it is not, press [F1] for LIST, the [1] followed by [EXE].
- ☞ Cursor down to YList. Press [F1] for LIST, then [2], followed by [EXE].
- ☞ Cursor to Frequency. This time the Frequency should be 1, so if it is not, press [F1] to activate this.
- ☞ Cursor to Mark Type. There are 3 choices for marks, so we will use a different on for each of the 3 graphs. Choose [F1] for the first one.
- ☞ Scroll back up to StatGraph and change the number to 2 by pressing [F2].
- ☞ Scroll down to the YList and change it to List 3 by pressing [F1] for LIST, then [3], followed by [EXE].
- ☞ Scroll down to Mark Type and change to [F2].
- ☞ Scroll back up to StatGraph and change the number to 3 by pressing [F3].
- ☞ Scroll down to the YList and change it to List 4 by pressing [F1] for LIST, then [4], followed by [EXE].
- ☞ Scroll down to Mark Type and change to [F3].
- ☞ When you have completed the set up for all 3 graphs, press [ESC]. This will return you to the main stat screen. Press [F1] for GRPH, the press [4] for Select. Turn on all 3 graphs, by highlighting each one and pressing [F1] for On. Then press [F6] to draw the 3 graphs on the same screen.
- ☞ From the graph screen you can draw three best fit lines through the 3 scatter plots. Press [F4] for CALC. Press [2] for Linear. This will return you to the graphs, with a large "plus" cursor blinking on one of the graphs. The top the screen will indicate which graph the cursor is on. Press [EXE] to determine the regression for that graph. The linear regression will appear on the screen. Write the regression down in your *Log.* Press [F6] to DRAW the best fit line through the scatter plot.
- ☞ Press [F4] again for CALC. Press [2] for Linear. Use the disk arrow button's up or down arrow to cursor through the graphs so that one of the other graphs is named at the top of the screen. Write the regression in your *Log.* Press [EXE] to determine the regression then [F6] to draw the best fit line.
- ☞ Repeat the above process for the last graph. The screen will show three best fit lines. Press [ESC] and you can press [F1] to trace through the graphs.