

Physiology II – Human heart rate and physical fitness

Hypothesis Writing and Experimental Design

Objectives

1. Students will determine the effect of body position on heart rates.
2. Students will write and test their hypotheses about their physiology.
3. Students will design short experiments to test their hypotheses.
4. Students will describe their experimental controls and variables.
5. Students will carry out physiological experiments on themselves and members of their lab group.
6. Students will test hypotheses, accept or reject null hypotheses, and consider alternate hypotheses.
7. Students will graph results, and write analyses of their results.

Physiology

What is physiology? Physiology is the study of how living things work, specifically, how cells, tissues, and organisms function. Last week we measured the direct impact of different conditions on the heart rate of *Daphnia*, a small invertebrate. You were told what conditions to test on the *Daphnia*, and how to collect, graph, and analyze the data. This week we will look at your own physiology, examining your own testable questions about the physiology of your group.

How do we design an experiment? Most people who attempt to solve a problem in a logical and organized manner are using the scientific method to a certain degree. Scientists have been trained to apply this tool in a more rigorous and disciplined manner, making it a powerful means of solving problems. Some textbooks provide a list of steps to define this thought process, known as the scientific method. Although you might think that all scientists follow these steps in performing their experiments, researchers do not always follow an exact sequence of steps as they work toward solving a problem.

One of the most important characteristics of scientific work is the use of careful observation. Through observations, researchers begin to ask questions, and these questions eventually lead to hypotheses. A **hypothesis** is typically defined as an ‘educated guess’, but a well-stated hypothesis is much more than this. It not only postulates an answer to the question, but it also gives researchers a sense of direction in their work. A workable hypothesis must be logical and, most importantly, testable.

In many cases, a hypothesis is tested by doing a **controlled experiment**. An experiment is a situation designed to produce results supporting the hypothesis being tested. Well-designed experiments have an **experimental group** and a **control group**. In the experimental group (or groups), one factor - the experimental variable - is altered in some manner. In the control group, the same test is performed under the same conditions as in the experimental group; however no change is made to the experimental variable. Experiments produce quantitative data and help scientists arrive at conclusions that indicate whether or not the hypothesis is substantiated. An unsubstantiated hypothesis is usually abandoned for a new hypothesis.

Not all hypotheses are easily tested by controlled experiments; some must be tested by making detailed observations of conditions that already exist. For example, evolutionary biologists sometimes test hypotheses by collecting and observing fossils and then drawing conclusions based on this information.

An example of experimental design to answer the question:

Does exercise affect heartbeat in humans?

1. Make some observations.
2. Ask questions about these observations.
3. Set up the testable hypotheses
 - a. It is easier to test a hypothesis that calls for a YES or NO answer
 - b. Determine the null hypothesis, H_0 , and any alternative hypotheses, H_A
 - c. The null hypothesis states that there is no effect of the experimental variable (exercise, in this case) on the variable you are measuring (heartbeat rate).
 - d. Alternate hypothesis (there can be one or several) states that the experimental variable (exercise) does affect heart rate (it could increase heartbeat, decrease heartbeat, etc.).
4. Determine the experimental conditions needed to test these hypotheses
 - a. How do you measure the variables involved?
 - b. How many times should the experiment be repeated?
 - c. How can you draw satisfactory conclusions (that is, how will you analyze your results?)
 - d. What is the control?
5. Make predictions based on what you expect to find.
6. Test the formulated hypotheses (see section on hypothesis testing). The calculations and statistical analyses required to test hypotheses are usually carried out on computers.
7. Report results and draw conclusions - that is, accept or reject each of the hypotheses

Hypothesis testing—what is involved? The results of biological experiments are usually not clear-cut, and researchers use a variety of statistical tests to decide which of the alternative hypotheses posed is best supported (and which are best rejected) by the experiment. These statistical tests examine a set of data and determine whether these data provide support for a particular hypothesis or not. In fact, the most likely hypothesis - the one that best explains the data collected - is the hypothesis that best resists falsification, and experimental science is based on testing hypotheses in order to falsifying one hypothesis; the alternate hypothesis (the one that has resisted falsification by your data) is the one accepted as the most likely explanation for the data you have collected. The key, then, to doing science is to use observations to set up alternative hypotheses (usually two), design an experiment to test these hypotheses, collect data and analyze them statistically in order to reject one of the two initial hypotheses.

One of the alternate hypotheses posed initially is considered the **null hypothesis**, which means that there is no effect of your experimental treatment on the variable you are measuring. For example, in an experiment designed to test the effect of exercise on heart rate, the **null hypothesis** is:

H_0 = exercise has no effect on heart rate

The alternate hypothesis is that exercise does affect heart rate and - more specifically - increases heart rate:

H_A = exercise increases heart rate

These are examples of the hypotheses you might pose to determine whether exercise has any effect on heart rate, although there are many other alternate hypotheses possible. Once you have designed an experiment to test these hypotheses (you need to figure out what kinds of data you need to test them), and collected the required data, you need to figure out which hypothesis is falsified by your data.

The results of your experiment may not be clear-cut; individuals vary in their heart rates and in the extent to which a certain amount of exercise changes heart rate. This is where statistics should in to play. In later Biology labs, you will receive more instruction on statistics, and you could test your data in a data analysis program (EXCEL), and then use a **Students t-test** to determine whether there are recognizable differences in heart rate between individuals that have exercised and those that have served as controls. Your null hypothesis would indicate that the heart rate of the control group should be equal to the heart rate of the treatment (exercised) group, because exercise has no effect on heart rate. The **Students t-test** would compare the mean values of each group, taking into consideration how much variation exists among individuals within each group.

How is a t-test used? The t statistic is a number that indicates how different the two groups are; how is this number evaluated? Simply due to chance alone, you might expect small differences between the control and treatment group - these small differences then are not due to exercise. The **probability** that the differences you observe between control and treatment groups are due to chance alone is indicated by the term 'p'. Every t statistic calculated from your data will have an associated 'p' value indicating the probability or the likelihood that the differences you measured were due to chance alone. If the t-statistic is very small, the p value will be quite large (perhaps 0.5); this tells you that there is a 50% likelihood that the differences you measured were due to chance alone. In other words, exercise does not have a very strong effect on heart rate (chance alone has an equal effect). For a treatment to have a **significant** effect on the variable measured, we usually require that the p value be at least 0.05. In words, the likelihood that the differences you measured between control and variable are due to chance alone (and not exercise) is only 1 in 20, or 5%. Ideally, the likelihood that chance alone can explain your results should be even smaller - say 1 chance in 100 ($p=0.01$) or 1 chance in 1000 ($p=0.001$).

How does all of this relate to hypothesis testing? The null hypothesis posed above is that heart rate of the control group is equal to that of the treatment group. **This hypothesis will be falsified if the t-statistic you calculate has an associated p value or probability that is equal to or smaller than 0.05**; in other words, the null hypothesis is falsified if the probability is less than 1 in 20 that the differences you measured are due to chance alone. Because chance alone cannot explain the differences you measured, your data **support** your alternate hypothesis, which is that exercise affects heart rate.

What is the ultimate goal of today's lab? Today's lab is designed to allow you (after a semester of following pre-written hypotheses) to write and test your own hypothesis. Yes, you are limited by the equipment at hand, but try to come up with an interesting and yet answerable question based on you and your group members' physiology...

What are we doing today? Specifically, in this lab, you will start by writing down some hypotheses, testable statements, describing what you think will happen to you under conditions that you will decide and test. Your hypotheses should include details about conditions you believe will affect your human subjects including testable details about those conditions. You can also make and test hypotheses about how long the effect of different exercises lasts on your different human subject groups. You will work in groups of three to five subjects. Before you leave, hand in your two hypotheses (H_0 and H_A) and graph(s) of the results of your experiments. Be certain that the activity that you design for your experiment will test your hypothesis, and that you produce a graph showing results for your control and experimental groups. You will use your graphed results to explain whether your hypotheses were correct.

Note: If you have health issues→, you should not be an active participant in this laboratory. Instead, you should be recording and participating in an intellectual, but not physically stressful, manner.

Using the Blood Pressure Monitors or Taking Your Pulse

- 1) You can use the **blood pressure monitor** to measure blood pressure and heart rate, from which you can calculate pulse. Your pulse is the number of heart beats per minute. See instructions at end of this lab.
- 2) **Taking your pulse:** You can easily determine your own heart rate; use your finger to feel and count the number of beats at your wrist for 15 seconds. Multiply the number of beats by four to calculate “beats per minute.” Repeat this three times to find an average beats per minute heart rate.

Procedure

1. **Make some observations.** Discuss within your group different hypotheses you could make about your individual differences. Think of ways you could split the members of your group in to an **experimental group** and a **control group**. Aside from looking for differences in your group (eg. Athletes vs. Couch-Potatoes, Smokers vs. Non-Smokers, Healthy-Eaters vs. Junk-Food-Junkies, or other differences), you should make some concrete observations in the classroom.

Your preliminary observations should include *heart rate measurements & *lung capacity measurements, see descriptions below...

Observation 1: Heart rate measurements

For all group members, determine A) standing heart rate
B) reclining heart rate

- A. **Standing heart rate determination.** With the group member standing, determine your pulse, calculated to beats/minute using the finger counting method, or the blood pressure monitor. (Or, you can also count HR for a whole minute and record that value as beats/min.) Record the person’s name and HR (in beats/min) in Table 1.
- B. **Reclining heart rate determination.** Follow the above instructions with the person reclining (comfortably ☺) in their chair with their feet up on the lab bench. Record the value in Table 1.

Data: Table 1. Observations.

Names of Group Members	Heart Rate in Different Positions (beats/min)		Lung Capacity (liters)	
	Standing HR	Reclining HR	Tidal volume	Vital lung capacity
<i>Name:</i>				

Observation 2: Lung capacity measurements

For all group members, determine

A) normal tidal volume

B) vital lung capacity

A) Normal tidal volume— Start with black pointer on 0. When seated, each group member should breathe into the spirometer in a normal fashion, five (5) breaths. Record the total volume, divide by 5 to determine tidal volume, the normal breathing range of each person.

B) Vital lung capacity — Start with black pointer on 0. When seated, student should inhale as deeply as possible. With nose plugged, exhale completely into the spirometer. Record the total volume. Repeat this measurement a total of three times. Record the highest value attained.

2. **Ask questions about your observations.** Based on what you measure from your preliminary heart rate findings, and using the personal information that group members share about their physical fitness, decide as a group what questions you can pose about your physical fitness.

Summary of above observations and personal information on group members

3. **Set up a testable hypothesis.** Remember:

a) it is easier to test a hypothesis that calls for a YES or NO answer

b) determine the null hypothesis, H_0 , and any alternative hypotheses, H_A .

→ **Identify one factor** that is different about your two groups; this is the **experimental variable** that will be different between the two groups. Write down your variable.

Determine the experimental conditions needed to test these hypotheses and address the following questions:

a) **How do you measure the variables involved?** (*If your variable is activity level, where you might be comparing “couch-potatoes” to “athletes”, you might want to quantify the amount of activity, e.g., those who exercise, say, 3x/week for 30minutes each time are “athletes” and those less than that are “couch-potatoes”. Or, those that smoke 1x/day are “smokers” and those that smoke 1x/month or less are “non-smokers.” BE CREATIVE! Think of your own interesting variables and hypotheses!*)

b) **How many times should the experiment be repeated?** (*Sorry, restrict your study to our lab time.*)

c) **How can you draw satisfactory conclusions?** (*That is, how will you analyze your results?*)

d) **What is the control?**

4. **Make predictions** based on what you expect to find. How will you graph your data??

5. **Test the formulated hypotheses** (*see section on hypothesis testing*). Perform some type of physical fitness test to generate data to test your hypothesis. For example, you might try to have subjects from the “smoker” and “non-smoker” group. Usually scientists then continue on to do calculations and statistical analyses to test their hypotheses. However, we will simply **graph our data**, report any obvious results. You may use a computer or draw by hand on graph paper.

You will be expected to follow the same standards as used in previous homework assignments. Your graphs must be clearly labeled, axes labeled, units given, descriptions clearly explaining what the graph shows. You must follow all standard graphing rules to receive full credit on this last assignment.

You may hand in one graph for the group, or member of the group may hand in their own graph and conclusion page.

6. **Report results and draw conclusions** – Write up a conclusion page, stating clearly if you accept or reject each of your hypotheses. Write a short paragraph about what you found, and whether you accept or reject each of the hypotheses. Use your data to support your final conclusions.

Human Physiology Lab — Design Your Own Experiment — Example page

Example page....

Question: _____

(for example: Does getting a good night's sleep affect heart rate after exercise?
or: Does drinking coffee during class affect heart rate?)

Variable: _____

(example: One group had good sleep (>6h). Other group, not, <4h sleep last night. Measure HR before and after exercise to determine change in HR.

or: One group will drink caffeine, one group will drink water. Then, measure HR before drinking caffeine and measure HR after exercise to determine change in HR.)

Experimental group student names: _____

Control group student names: _____

Null Hypothesis (H₀):

Amount of sleep will not affect heart rate after exercise. OR Drinking caffeine will not affect heart rate after exercise.

Alternate Hypothesis (H₁):

A good night's sleep will decrease effect of exercise on heart rate.

(Optional) Second Alternate Hypothesis (H₂):

A good night's sleep will increase the effect of exercise on hear rate.

Show how you will graph your data.

The data on your graph must be presented in a way that tests your hypothesis.

Examples:

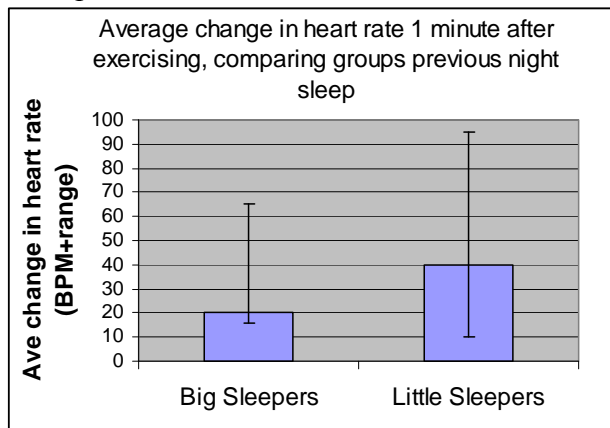


Figure 1. Change in HR after 1 minute of exercising, comparing of two groups of students those who sleep >7hrs/ night and those who sleep <7hrs/ night. HR measured using HR monitors, before exercise and <1min post exercise; average BPM for 3 students in each group, ± 1 SD.

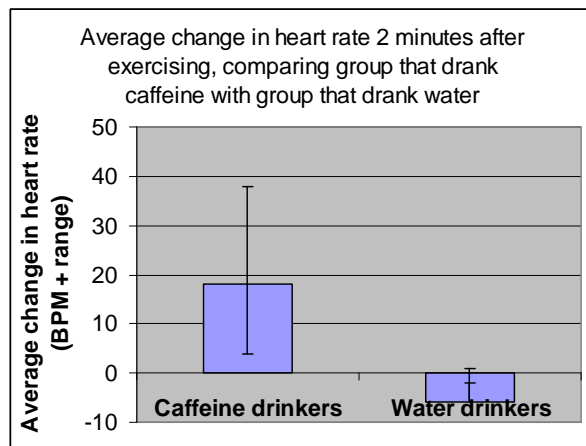


Figure 2. Change in HR after 1 minute of exercising, comparing of two groups of students, those who drink 1 large cup caffeinated cola and those who drink one large cup water. HR measured using HR monitors, before exercise and <1min post exercise; average BPM for 3 students in each group, ± 1 SD.

Name: _____ TA: _____

Human Physiology Lab — Design Your Own Experiment

SHOW the following completed sheet to your TA before you begin your experiment.

Question: _____

Variable: _____

Experimental group student names: _____

Control group student names: _____

Null Hypothesis (H_0):

Alternate Hypothesis (H_1):

(*Optional*) Second Alternate Hypothesis (H_2):

Show how you plan to graph your data.

The data on your graph must be presented in a way that tests your hypothesis.

Results and Conclusions

1) Present a table and graph of your data.

(You may change from your original plan and make a graph to best represent your data.)

2) What can you conclude? Which hypothesis does your data support?

3) If you could do your experiment again, what would you do next or do differently?

HAND IN BEFORE YOU LEAVE:

- 1) Table 1 and the Design Your Own Experiment sheet
 - 2) Final graphs of your data
 - 3) Answers to the Results and Conclusion questions (2 & 3 above)
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Thought Questions

1. How did your heart rate change after moving from a standing position to a reclining position?
Is this what you expected?
How do you account for this?
2. How did your heart rate change after moving from a reclining position back to a standing position?
Is this what you expected?
How do you account for this?
3. Current research indicates that most heart attacks occur as people get out of bed after sleep. Account for this observation.
4. How did your blood pressure change in comparison to changes in your heart rate when going from reclining to standing?

Blood Pressure Cuff Information (if needed)

**You may decide you want to measure blood pressure before and/or after an activity.
Here are instructions on what you should do.**

1. Use the sphygmomanometer to measure your blood pressure.
Remember, the cuff should be placed above the elbow; over light clothing is fine.
Be sure the cuff is loose enough for 2 fingers to slip in.
Be sure the black cord runs over the brachial artery (see picture below).
2. Instruct the subject to recline on a clear surface for 2 min. When the 2 min have passed, measure the subject's blood pressure. Record the systolic pressure, the diastolic pressure and the heart rate in Table 2.
3. Keep the blood pressure cuff on your subject. Instruct the subject to do your activity that you are testing for your experiment (e.g. they could do 10 jumping-jacks and then stand still).
4. Immediately record the subject's blood pressure and heart rate again.

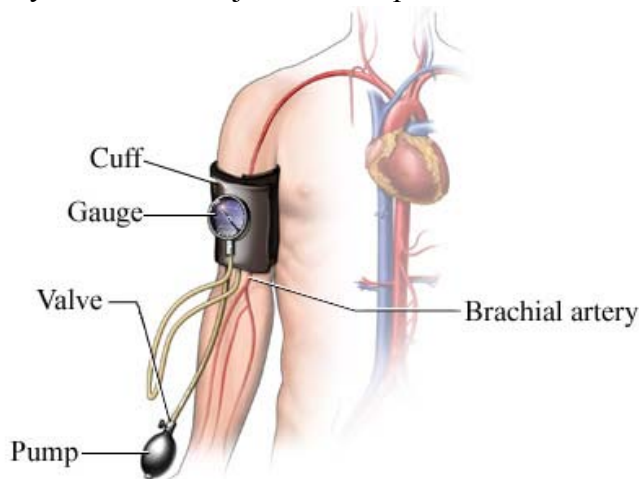


Image from: <http://www.health.com>