Homeostasis and Autonomic Reflexes

One of the homeostatic mechanisms of the human body serves to maintain a fairly constant blood pressure. Major determinants of blood pressure are heart rate, amount of blood pumped with each beat (*stroke volume*), and the resistance of the arterial system that is receiving the blood. Heart rate is influenced by *baroreceptors*, special sensors in tissues in the aortic arch and carotid arteries, which consist of nerve endings that respond to stretching (see Figure 1). An increase or decrease in stretch sends signals to the medulla in the brain which in turn acts on the heart through the vagus nerve, completing what is called a *feedback loop*. Sudden increase in pressure in the heart or carotid arteries causes an increase in stretch of the baroreceptor sensors and results in a decrease in heart rate. Sudden lowering of pressure causes the opposite effect. This feedback loop enables us to function as blood pressure changes with body position and external forces such as gravity.

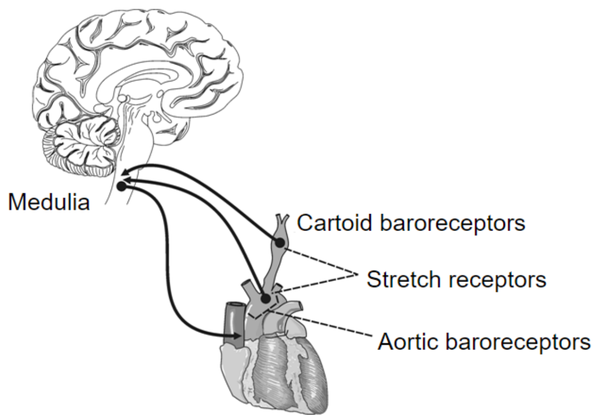

Figure 1

Most people have experienced a sensation of dizziness after standing abruptly from a seated or squatting position. This effect can be seen in healthy individuals, but it is accentuated in the elderly and in certain conditions such as dehydration and Parkinson's disease. In these cases, the increase in heart rate may be significant but is still not able to make up for an insufficiency of the other two contributors to blood pressure (i.e., low blood volume or poor regulation of the resistance of the arterial system by the sympathetic nervous system).

One of the first tests performed by doctors on patients who complain of dizziness is to check the blood pressure and pulse with the patient lying down and then standing. A drop in blood pressure of 20 points or an increase in heart rate of 20 points with standing is considered significant. This condition is called *orthostatic hypotension*.

In this experiment, you will observe a subject's heart rate response to 1) suddenly squatting from a standing position and 2) suddenly standing from a squatting position. In the former, there is a rapid increase in venous return to the heart as veins in the leg muscles are compressed. This causes a sudden increase in stroke volume and pressure sensed by the baroreceptors. In the latter, there is a sudden reduction in venous return to the heart because of "pooling" of blood in the legs. This results in a decrease in stroke volume and pressure.

OBJECTIVES

- Observe heart rate response to sudden squatting.
- Observe heart rate response to sudden standing from a squatting position.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Wireless Heart Rate **or** Go Wireless Exercise Heart Rate
saline solution in dropper bottle (only for use with Go Wireless Exercise Heart Rate)

PROCEDURE

Select one person from your lab group to be the subject. **Important**: Do not attempt this experiment if you suffer from knee pain or dizzy spells. Inform your instructor of any possible health problems that might be exacerbated if you participate in this exercise.

1. Launch Graphical Analysis. Connect your Go Wireless Heart Rate or Go Wireless Exercise Heart Rate to your Chromebook, computer, or mobile device. **Note**: The sensor will only be seen by the application when the sensor is in contact with the subject's skin.
2. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings.
   b. Change end collection to 400 s.
   c. Click or tap Done.
3. Have the subject stand quietly with the sensor in the correct position (in the hands for Go Wireless Heart Rate or around the chest in contact with the skin for Go Wireless Exercise Heart Rate). Click or tap Collect to start data collection. Obtain 30 s of graphed data as a baseline heart rate for the standing position.
4. After at least 30 s of stable baseline data have been collected, instruct the subject to rapidly lower themselves into a squatting position. Maintain this position until heart rate returns to the initial baseline rate.
5. After obtaining 10–20 s of stable heart rate values, instruct the subject to rise rapidly to a standing position. Continue to record data until the baseline heart rate has been achieved, or until the end of the run. Data will be collected for 400 s.
6. Determine the baseline heart rate.
   a. Select the area of the graph where the resting heart rate is displayed.
   b. Click or tap Graph Tools, ⩘, and choose View Statistics.
   c. Record the mean heart rate, rounded to the nearest whole number, in Table 1.
   d. Dismiss the Statistics box.

7. Determine the maximum heart rate over the entire data-collection period.
    a. Click or tap Graph Tools, , and choose View Statistics.
    b. Record the maximum heart rate in Table 1.
    c. Dismiss the Statistics box.

8. Determine the baroreceptor response time for squatting.
    a. Click or tap the data point that represents the heart rate immediately prior to squatting.
    b. Record the time component of this data point.
    c. Click or tap the point that represents the maximum or minimum heart rate (first peak or valley) that follows squatting.
    d. Record the time component of this point.
    e. Determine the difference between the two time values, Δx, and record this value in Table 2 (to the nearest whole number) as Response time 1: Squatting.

9. Repeat Step 8 for the following regions:
    a. From the maximum or minimum heart rate following squatting to the beginning of a new stable heart rate. Record the Δx value (time) in Table 2 as Recovery time 1.
    b. The region just prior to standing and the maximum heart rate after standing. Record the Δx value (time) in Table 2 as Response time 2: Standing.
    c. The region between the maximum heart rate after standing and the point at which the heart rate has re-stabilized (i.e., is stable for at least 40 s). Record the Δx value (time) in Table 2 as Recovery time 2.

DATA

Table 1		
Baseline heart rate (bpm)	Minimum heart rate (bpm)	Maximum heart rate (bpm)

Table 2				
	Baroreceptor response time 1: Squatting (s)	Recovery time 1 (s)	Baroreceptor response time 2: Standing (s)	Recovery time 2 (s)
Initial time				
Final time				
Total time				

DATA ANALYSIS

1. How much and in which direction (increase or decrease) did the heart rate change as a result of
   a. squatting?
   b. standing?

2. Changing the heart rate is only one of a variety of homeostatic mechanisms that maintain a fairly constant blood pressure during changes in body position. The sympathetic nervous system helps by adjusting peripheral resistance in the arterial system. As this occurs the heart rate is able to normalize again. Compare the duration of the initial direction of heart rate change after standing to the recovery time. What does your data tell you about the relative speed of the change in peripheral vascular resistance as compared to that of the heart rate response?

3. Dizziness may result from low blood pressure and can occur in patients who take medicines that impair the ability of the heart to increase its rate. Given what you have learned from your data, which daily activities would be most likely to cause dizziness in people who take these medications?

4. Using your knowledge of heart rate response to a decrease in blood volume returning to the heart, suggest a way to evaluate (without the use of medical equipment) whether significant blood loss has occurred in an accident victim.

5. The majority of astronauts who are in a microgravity environment for several weeks will experience orthostatic hypotension and dizziness on return to Earth. What are possible mechanisms for this?