Cardiovascular Function in Humans

Introduction

The purpose of this lab is to measure various aspects of cardiovascular physiology, and to explore the regulation of the cardiovascular system during exercise.

Notes:
Each group will collect its own data and will contribute to the class data set for Exercises 1 and 2. Only one member from each pair should perform these resting measurements. This individual will provide their age, sex and weight (in kg) to the class data. Two groups (i.e. groups of 4 people) will work together in Exercise 3, from which one member will be the subject that performs the bicycle exercise. Subjects should wear loose, comfortable clothing, suitable for exercising. **Students with cardiovascular difficulties, those who are ill or are on any medication should NOT take part as subjects. However they should co-ordinate and monitor the experiments.**

You will need a watch or cellphone with a timer during this lab. Your TA will provide you with the class data but you must bring a USB key to save your work.

Exercise 1: Electrocardiogram (ECG) at Rest

In this exercise we will be recording the ECG, which is a record of voltage differences across the body, caused by the propagation of electrical signals across the heart during the cardiac cycle. Subjects should be in a prone, comfortable position during recording.

1. Wipe both wrists and the right ankle with an alcohol swab before attaching the electrodes.

2. Attach the red electrode to the right wrist, the black electrode to the left wrist and the green electrode to the right ankle.

3. Click the LabScribe2 icon and answer "OK" in the box that appears. Pull down the **Settings** menu. Select the **Heart Rate-ECG-Peripheral Blood Flow** settings file.

4. Instruct the subject to be still and breathe normally, press **Record**.

5. Record sufficiently long to obtain at least five beats, press **Stop**. Note the time on the record.

6. Export an image of your best ECG to include in your lab report. Refer to the introductory lab if you need help with this step.

7. Calculate the subject's heart rate (in beats/min) and enter the value on the class data sheet.

8. Save your ECG file.

Exercise 2: Arterial Blood Pressure at Rest

In this exercise, you will be measuring arterial blood pressure using digital sphygmomanometers. There will also be a manometric sphygmomanometer in the lab room for you to gain experience with the manometric technique. The manometric technique best illustrates the principles of blood pressure measurement. You may also listen for the characteristic Korotkoff sounds when you use the digital equipment if you place a stethoscope over the brachial artery while the blood pressure is being measured.

Digital Technique:

1. The subject should lie prone on their back, quietly, and should not look at the display. Place the compression cuff of the sphygmomanometer on the upper arm so that the cuff is at the same level as the heart.

2. Inflate the cuff to a pressure of about 180mm Hg. Place the inflation bulb on the table. Ensure the subject does not move or talk. The cuff will automatically deflate at a fixed rate. When the cycle is completed, values will be displayed on the monitor. The first value is the systolic pressure while the second value is the diastolic pressure. Shortly afterward, the heart rate will be displayed. Record all three values. Push the valve button to deflate and remove the cuff from the arm. If you were unsuccessful in obtaining a reading, try inflating the cuff to a higher pressure than previously and repeat the procedure.

DO NOT KEEP THE CUFF ON FOR MORE THAN 3 MINUTES AT A TIME. ALLOW THE ARM AT LEAST 2 MINUTES "REST" BETWEEN MEASUREMENTS.

3. Make 2-3 measurements on each subject to determine the most representative values. Calculate mean arterial pressure (MAP) and pulse pressure (PP) using these formulas:

Pulse Pressure = Systolic Pressure – Diastolic Pressure

$$\text{Mean Arterial Pressure} = \frac{\text{Systolic Pressure} + (2 \times \text{Diastolic Pressure})}{3}$$

Manometric Technique:

1. Place the bell of the stethoscope tightly over the brachial artery on the inside of the arm at a position about 10 cm above the point of the elbow. If you are not certain of the placement, feel for the brachial pulse first.

2. Inflate the cuff to a pressure of 180mm Hg and then deflate slowly and evenly (approximately 10mm Hg every 5 seconds). Note the exact pressure at which the "thud" sound is first heard. This is the systolic pressure.

3. Continue deflating the cuff at the same rate until the sounds can be clearly heard and getting louder. Record the heart rate by timing the thuds. Continue deflating the cuff until all sound has just disappeared. Record the exact point. This is the diastolic pressure.

Note: For those individuals who also had an ECG measurement recorded, the prone heart rate measured by ECG will be tabulated separately from the heart rate tabulated by sphygmomanometry.

Exercise 3: Cardiovascular Changes During Exercise

1. The subject should lie prone on the bench. Attach the pulse plethysmograph to the volar surface of the subject's finger (refer to the introductory lab if you need to familiarize yourself with the equipment). Open a new **Heart Rate-ECG-Peripheral Blood Flow** settings file.

2. Have the subject **relax, lying down in a horizontal position for 2 minutes**, staying as calm as possible, breathing deeply with eyes closed.

3. Press **Record** and type "Resting" into the comment box next to the **Mark** button, press **Enter**. **Record for 30 seconds** then press **Stop**. This will be used to determine the control heart rate at rest.

4. Seat the subject on the stationary bicycle, keeping the plethysmograph on the finger (you can unplug the plethysmograph from the iWorx unit if necessary, just remember to plug it back in). Place the cuff of the digital sphygmomanometer loosely on the opposite arm. In order to obtain a good recording from the finger pulse plethysmograph, it is important that the subject NOT grasp the bicycle handle. ~~Simply~~ the subject should place his~~/her~~ hand on his~~/her~~ lap and remain still while recording the pulse, avoiding any movement that will disturb the pulse measurement, and hold the bike handle with the other arm (the one with the digital sphygmomanometer).

Have the subject **relax on the bike in this position for at least three minutes**, ready to begin pedaling, but **DO NOT** inform the subject of when you will start recording.

5. Press **Record** while the subject continues sitting quietly. Type "Sitting" into the comment box next to the **Mark** button and press **Enter**. **Record for at least 2 minutes**, or longer if necessary until a stable, calm, heart rate is reached, taking note of any changes in heart rate over time. During the recording, measure and record the subject's blood pressure and heart rate using the digital sphygmomanometer. After the measurement, deflate the pressure cuff but leave it in place on the arm. Press **Stop**.

6. Press **Record**. Type "Exercise" into the comment box next to the **Mark** button and press **Enter**. Start the exercise test by adjusting the tension control to level 5. Start pedaling at 80-100 rpm (a speed of roughly 25-30 km/h), at which time type "Start" into the comment box next to the **Mark** button and press **Enter**. **Begin timing the subject**. Note that you will get better data for your lab report if the subject exercises at a moderate exercise intensity that is not too easy (so you can increase the tension control if necessary), but it should not be too hard because the subject will need to maintain pedaling at this speed and power output for the full ten minutes.

7. You will need to quantify heart rate every 2 minutes during exercise. To do so, the subject must briefly stop pedaling and relax the hand on their lap and record the pulse to get at least 5-10 good beats. Measure and record blood pressure and heart rate using the digital sphygmomanometer while briefly stopping after 4 and 10 minutes of exercise (the subject can continue pedaling during the blood pressure measurement).

8. Remain sitting on the bike, without pedaling, after the final heart rate and blood pressure measurement at 10 minutes. Type "Recovery" into the comment box next to the **Mark** button

and press **Enter**. Place the hand with the plethysmograph on your lap and record the pulse continuously for 10 minutes. The subject must sit quietly on the bike for the **ENTIRE** recovery period. Measure and record the blood pressure and heart rate using the digital sphygmomanometer after roughly 4 and 10 minutes of recovery. Press **Stop**.

9. Analyze your data. Use the pulse trace to obtain measurements of heart rate at rest while lying down, sitting quietly on the bike before exercise, every two minutes during exercise, and every two minutes during recovery from exercise.

Questions for Analysis

1. Label the various waveforms in the ECG (P wave, QRS complex, and T wave; as described in lecture) you recorded in Exercise 1. What are the electrical events that underlie each of these waveforms? What is the largest contributor to the time delay between the P wave and the QRS complex, and why is this delay important?

2. Analyze the class data for resting heart rate and resting blood pressure to determine if there are any patterns associated with sex, age, or body weight. If so, what are the possible explanations?

3. What are the origins of Korotkoff sounds and the reason for their disappearance in Exercise 2?

4. Describe what causes the pulse measured by the finger plethysmograph in Exercise 3. How is it related to the pulse pressure?

5. How did the heart rate measured lying down differ from the heart rate measured while sitting quietly on the bike in Exercise 3? What is the physiological explanation for these results?

6. Plot the changes in heart rate and blood pressure versus time before, during, and after bicycle exercise in Exercise 3. Why are the changes in heart rate and blood pressure important during exercise? What are the probable mechanisms responsible for these changes? Which factor (changes in heart rate or changes in stroke volume) is the more important contributor to increasing cardiac output during exercise?

7. Does heart rate return to resting levels immediately after exercise? Does it remain elevated, and if so, for how long does it remain elevated? What is the physiological explanation for these results?