Cardiovascular Effects of Exercise

In this experiment, you will record an electrocardiogram, or ECG, and finger pulse from a healthy volunteer. You will then compare the ECG and pulse recordings when the volunteer is at rest and immediately after exercise.

Background

Cardiac function

The volume of blood that the heart ejects into the circulation each minute is called the cardiac output (CO). It is the product of how much blood is being pumped by the heart each time the heart contracts (Stroke Volume) and how fast the heart is going (Heart Rate). This means Cardiac Output can be described as the heart rate (beats/min) (HR) and the stroke volume (liters/beat) (SV) (i.e., the volume of blood ejected during each beat). In humans, CO = HR x SV = 70 x 0.07 ≈ 5.0 liters/min.

The mammalian nervous system controls HR via the autonomic nerves. Stimulation of sympathetic nerves increases the rate. Stimulation of the parasympathetic nerve supplying the heart, the vagus nerve, decreases the rate. At rest, the vagal effect predominates (vagal tone), and the heart beats more slowly than it would in the absence of any autonomic activity. During exercise, vagal activity diminishes and sympathetic activity increases. This, together with increased levels of circulating adrenaline, results in increased heart rate.

Stroke volume at rest can vary considerably between people. Very fit people have a high Stroke Volume. It explains why fit people have low resting Heart Rate. Think of how this relates to CO = HR x SV. It is influenced by a variety of factors including the volume of blood returning to the heart (venous return), sympathetic nerve activity and levels of circulating adrenaline. At first, during exercise, these factors all increase, and SV is thus increased. However, there is a problem! If you increase heart rate there is a big reduction in the time we have to fill our ventricles between each beat (diastole). Once the level of exercise exceeds about 50% of the individual's capacity, there is little if any further increase in SV. Only increasing HR can then increase CO further.

The heart rate in an adult human can rarely exceed about 180 beats/min. It follows, therefore, that a very fit athlete with a resting heart rate of 40 beats/min has a much greater capacity to increase CO than does a less fit individual with a resting heart rate of 90 beats/min.

In a fit athlete, CO before exercise = 5 L, HR = 40 beats/min, then SV = 0.125 L. In a less fit individual, CO before exercise = 5 L, HR = 90 beats/min, SV = 0.055 L. Suppose both now do strenuous exercise, raising their heart rates to 160 beats/min. Assume that SV in both has increased by 1.5 times (athlete: 0.125 L increased to 0.188 L, less fit individual: 0.055 L increased to 0.083 L).

That means the CO of our trained athlete has increased from 5 L/min at rest to 160 x 0.188 = 30 L/min, while the CO of our less fit individual has gone from 5 L/min to 160 x 0.083 = 13.3 L/min!
**Electrical activity of the heart during exercise**

An increase in heart rate corresponds to a shortening of the cardiac cycle (RR interval decreases).

**Control of the arterial system**

The arterial system functions as a pressure reservoir. Blood enters via the heart and exits to the venous system through the capillaries. Signals from the autonomic nervous system control the tone of smooth muscle sphincters around the arterioles. In this way, the autonomic nervous system controls the distribution of blood to the various organs in the body.

![Diagram showing changes in organ blood flow between rest and exercise.](image)

The distribution of blood that flows to a particular organ is influenced by local conditions. If cells require more arterial blood—due to, say, a decline in pH or oxygen levels, or an increase in carbon dioxide levels—smooth muscle sphincters open to permit blood to enter the particular capillary beds.

The distribution of blood to an organ when a person is at rest may be very different from that seen during exercise. For example, the blood flows to the gut and kidneys, which together normally account for about 50% of the resting blood flow, decrease appreciably during exercise, whereas blood flow to the exercising skeletal muscles increases dramatically.
Required Equipment

• LabChart software
• PowerLab Data Acquisition Unit
• 5 Lead Shielded Bio Amp Cable
• Shielded Lead Wires (3 Snap-on)
• Disposable ECG Electrodes
• Abrasive Gel or Pad
• Alcohol Swabs
• Finger Pulse Transducer
• Gauze or cotton ball (or similar material)
• Ballpoint pen

Procedure

⚠️ This experiment involves exercise and an elevation of heart rate. The volunteer should not have a history of cardiovascular or respiratory problems. If the volunteer feels major discomfort during the exercise, discontinue the exercise and consult your instructor.

Note: If the volunteer cannot continue the experiment and a new volunteer is chosen, you need to restart the experiment from the beginning.

Equipment Setup and Electrode Attachment

1. Make sure the PowerLab is turned off and the USB cable is connected to the computer.

2. Connect the Finger Pulse Transducer to Input 1 on the front panel of the PowerLab and the 5 Lead Shielded Bio Amp Cable to the Bio Amp Connector on the front panel (Figure 2). The hardware needs to be connected before you open the settings file.

Figure 2. Equipment Setup for PowerLab 26T
3. Place the pressure pad of the Finger Pulse Transducer on the tip of the middle finger of either hand of the volunteer. Use the Velcro strap to attach it firmly but without cutting off circulation.

- If the strap is too loose, the signal will be weak, intermittent, or noisy. If the strap is too tight, blood flow to the finger will be reduced causing a weak signal and discomfort. You may need to adjust the strap in the next stage of the exercise.

4. Make sure the Finger Pulse Transducer is not resting on any surface. The volunteer should keep their palm facing upward to prevent the Finger Pulse Transducer from touching a surface.

5. Attach the Shielded Lead Wires to the Bio Amp Cable. Channel 1 positive will lead to the left forearm, Channel 1 negative will lead to the right forearm, and the Earth will lead to the right ankle. Attach the Disposable Electrodes to the end of the wires. Refer to Figure 3 for proper placement, but do not attach them to the volunteer. Follow the color scheme on the Bio Amp Cable.

6. Remove any jewelry from the volunteer’s hands, arms, and right leg. Use the ballpoint pen to mark small crosses on the skin on the forearms and right ankle area. Use Figure 3 as a guide. Abrade the skin with Abrasive Gel or Pad. This is important as abrasion helps reduce the skin’s resistance. After abrasion, clean the area with an Alcohol Swab to remove the dead skin cells. Wait for the skin to dry, and stick the Disposable Electrodes to the skin (Figure 3).

**Note:** Do not place the electrodes over the major muscles because muscle activity interferes with the signal recorded from the heart.

7. Check that all three electrodes are properly connected to the volunteer and the Bio Amp Cable before proceeding. Turn on the PowerLab.

*Figure 3. Electrode Placement*
Exercise 1: ECG and Blood Volume Pulse during Rest

In this exercise, you will record the electrocardiogram and blood volume pulse while the volunteer is at rest.

1. Launch LabChart and open the settings file “ECG & Pulse Settings” from the Experiments tab in the Welcome Center. It will be located in the folder for this experiment.

Note: Channel 1 is the raw signal from the Finger Pulse Transducer and is an indication of the net rate of blood flow into the finger pulp. The time integral of Channel 1 is displayed in Channel 2 and illustrates the change in finger pulp blood volume over time. You will be using Channel 2 for your analysis.

2. Have the volunteer sit in a relaxed position facing away from the monitor. Make sure they are in a position in which they can stay throughout the exercise.

3. Select Bio Amp from the Channel 3 Channel Function pop-up menu. Observe the signal (Figure 4) and adjust the range in the dialog so that the maximal electrical response occupies about one half to two-thirds of the full scale.

![Figure 4. Bio Amp Dialog](image)

Note: If the ECG cannot be seen, check that all three electrodes are attached correctly. If the signal is noisy and indistinct, you may want to use an alternative electrode placement. Connect the positive electrode to the left upper arm, negative electrode to the right upper arm, and Earth to the right wrist. Remember to avoid the major muscles of the arm.

4. Start recording. Remind the volunteer to remain relaxed and as still as possible. Make sure the volunteer is still facing away from the monitor. Add a comment with “resting ECG.”

5. Record the baseline values for one minute. Stop recording, and save your data. Do not close the file. Keep the electrodes attached as you will need to use the same volunteer in the next exercise.
Exercise 2: ECG and Blood Volume Pulse after Exercise

In this exercise, you will record the electrocardiogram and blood volume pulse of the volunteer periodically after exercise. These values will be compared to those taken while the volunteer was at rest.

1. Disconnect the Shielded Bio Amp Cable and the Finger Pulse Transducer from the PowerLab. Leave the electrodes and transducer attached to the volunteer. Make sure the leads are not tangled; hand them to the volunteer to hold.

2. Have the volunteer exercise for at least two minutes. Your instructor will have more information about the type of exercise you can do in your laboratory, but examples include running up and down stairs, running in place, and stepping up and down on a footstool.

Note: Remember the ECG leads are still attached to the electrodes. The volunteer should exercise carefully to prevent breaking the equipment but vigorously enough to elevate heart rate.

3. Immediately after exercise, reconnect the Bio Amp Cable and Finger Pulse Transducer to the PowerLab while the volunteer sits down and relaxes.

4. Using the same file as before, Start recording as soon as possible. Record for two minutes or until the heart and respiratory rates have returned to normal. During this time, add a comment with “recovery.”

5. Save your data when you are finished recording.

Analysis

Exercise 1: ECG and Blood Volume Pulse during Rest

1. Examine the data in the Chart View. Autoscale, if necessary. Select a small part of the resting “ECG” data trace, containing the cardiac cycle, and examine it in Zoom View. The cardiac cycle is shown in Figure 5. In your Zoom View window, you want to have more than one cycle visible.
2. Use the **Marker** and **Waveform Cursor** to make the following measurements of the cardiac cycle:

- P-R interval
- QRS duration
- S-T interval
- T-P interval
- R-R interval

**Note:** The P-R interval is the time from the start of the P wave to the start of the QRS complex. A more logical name would be the P-Q interval, but P-R interval is the traditional nomenclature.

3. Calculate the heart rate from the R-R interval. Follow the steps below:
   a) \[ HR = \frac{1}{\text{cycle length}}, \] where cycle length is the R-R interval
      - For example, if R-R interval = 800 ms:
   b) \[ HR = \frac{1}{800 \, \text{ms}}, \text{ and } 800 \, \text{ms} / 1000 = 0.8 \, \text{s} \]
   c) \[ HR = \frac{1}{0.8} \, \text{s} \]
   d) \[ HR = 1.25 \, \text{beats/s} \]
   e) \[ HR = 1.25 \, \text{beats/s} \times 60 \, \text{s} = 75 \, \text{BPM} \]

4. Enter these values in Table 1 of the Data Notebook.

**Question:**
Based on this data that you just collected and knowledge from your lectures what do you predict will change in the ECG and why.
Exercise 2: ECG and Blood Volume Pulse after Exercise

1. Repeat the Analysis for Exercise 1, using data from when the volunteer was at rest.

2. Repeat the measurements using the “ECG” data trace at 10 and 60 seconds after exercise.

3. Enter these values in Table 1 of the Data Notebook.

Data Notebook

Table 1. Cardiac Cycle during Rest and After Exercise

<table>
<thead>
<tr>
<th></th>
<th>ECG During Rest</th>
<th>ECG After Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0 seconds</td>
</tr>
<tr>
<td>P-R Time Interval</td>
<td></td>
<td></td>
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<tr>
<td>QRS Duration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-T Time Interval</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-P Time Interval</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-R Time Interval</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart Rate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Blood Volume Pulse before and after Exercise

<table>
<thead>
<tr>
<th></th>
<th>Heart Rate (BPM)</th>
<th>Mean Pulse Amplitude (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 s Post-exercise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 s Post-exercise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 s Post-exercise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>120 s Post-exercise</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Study Questions

1. In the space below, draw a bar graph showing the P-R time interval, S-T time interval, T-P time interval, and R-R time interval from when the volunteer was at rest, then 30 seconds after exercise, and 60 seconds after exercise. (8 marks)
2. In the space below, draw a bar graph showing the mean pulse beat amplitudes while the volunteer was at rest, 10 seconds after exercise, 30 seconds after exercise, 60 seconds after exercise. (3 marks)
3. What happened to the R-R interval and heart rate after exercise? (2 marks)
4. What happened to the T-P interval during exercise? Outline what this means for ventricular filling time. (4 marks)
5. Now that we have done the calculations for R-R interval and T-P interval can you explain why people who have cardiac arrhythmia’s often don’t have symptoms until they begin to exercise? (4 marks)
6. Immediately after exercise was the amplitude of the pulse smaller or larger than during the resting period? Why was the pressure pulse bigger / smaller? (4 marks)
7. When we are exercising there is more blood in our arterial circulation. Where did this blood come from and how did it get there? (4 marks)
8. Summarise the cardiac and vascular changes that are occurring during exercise. Your answer should include a description of heart rate, stroke volume, blood flow to tissues and blood pressure. (6 marks)