

## Cardiovascular Effects of Exercise

This basic experiment allows students to see how exercise affects the ECG and the finger pulse.



Written by staff of ADInstruments.

### Introduction

In this laboratory session you will record the electrocardiogram (ECG) and the finger pulse from a healthy volunteer, and compare the recordings made when the volunteer is at rest and immediately after exercise.

### Background

The arterial system functions as a pressure reservoir. Blood enters via the heart and exits 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 can control the distribution of blood to the various organs in the body. The distribution of blood that flows to a particular organ is influenced by local conditions. If there are cells that require more arterial blood, due to a decline in pH or oxygen levels or an increase in carbon dioxide levels, smooth muscle sphincters open to permit blood into particular capillary beds.

The distribution of blood to a particular organ when a subject is at rest may be very different from that seen during exercise. For example, the blood flow to the skin and the gut decreases during exercise, while blood flow to the skeletal muscles increases dramatically. Furthermore, the amount of blood flowing around the circulatory system (the cardiac output) may be increased to many times its resting value.

### Required Equipment

A Computer system  
Chart software, version 5.0 or later  
PowerLab (with built-in Bio Amp or PowerLab and Bio Amp front-end)  
Five-lead Shielded Bio Amp Cable & snap-connect Lead Wires  
Three reusable clamp electrodes or disposable adhesive electrodes  
Electrode cream (for use with the clamp electrodes)  
Alcohol swabs (70% ethanol on cotton wool or paper tissue); optional  
Ballpoint pen  
Abrasive pads/gel  
Finger pulse transducer  
Hand dynamometer or a rubber squeeze-ball (e.g. a tennis ball)

### Procedures

#### Warning

This experiment involves exercise and an elevation of heart rate: volunteers should not have a history of cardiovascular or respiratory problems.

#### Subject preparation

1. The student volunteering for the experiment should remove any watch, jewelry and so on from their wrists and ankles.

2. Connect the BNC plug from the finger pulse transducer's cable to the BNC socket for Input 2. Rotate the connecting ring of the transducer plug clockwise until it locks (Figure 1).

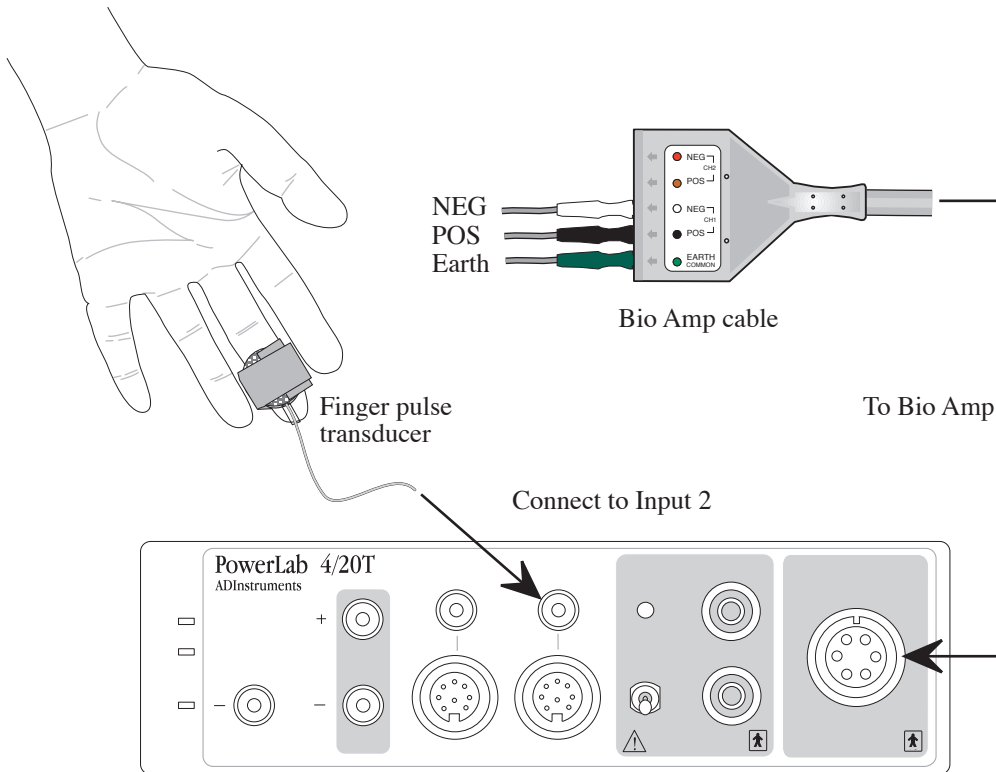


Figure 1. Setup of equipment for this experiment, showing the connections to the PowerLab

3. Place the pressure pad of the finger pulse transducer against the distal segment (the tip) of the middle finger of either hand of the volunteer. Use the Velcro strap to attach it firmly - neither loose nor tight.
4. Plug the Bio Amp cable into the Bio Amp socket.
5. Attach the rectangular ends of the lead wires to the Earth, CH1 NEG and CH1 POS connections on the Bio Amp cable.
6. If alcohol swabs are available, firmly swab the skin with them in each area where electrodes will be placed
7. Using a pen, mark each area with a small cross. Lightly abrade the skin at these areas with an abrasive pad. This decreases the electrical resistance of the outer layer of skin and ensures good electrical contact.
8. If you are using the reusable clamp electrodes, apply a small amount of electrode cream to the electrodes, attach the electrodes to the subject as described below and connect the electrodes to the leads.
9. If you are using the disposable electrodes (which have electrode gel on them already), attach the electrodes to the subject as described below, and connect the electrodes to the leads.

10. Ensure the volunteer is relaxed and sits as still as possible to minimize any signal from movement.
11. Have the volunteer place their hands in their lap for all ECG measurements.

### Attaching the ECG electrodes

**Standard connection:** attach the positive electrode to the left wrist, the negative to the right wrist, and the ground to the right leg. If after looking at the signal in the Bio Amplifier dialog box during the first exercise you find that this does not produce a good signal, you can use the alternative method shown (Figure 2).

**Alternative connection:** attach the positive electrode to the left upper arm, the negative to the right upper arm and the ground to either wrist (Figure 2). NOTE: Do not place the electrodes over the major muscles of the upper arm because muscle activity interferes with the signal recorded from the heart. Attach the electrodes on the outer side of the arm, midway between the elbow and the shoulder.

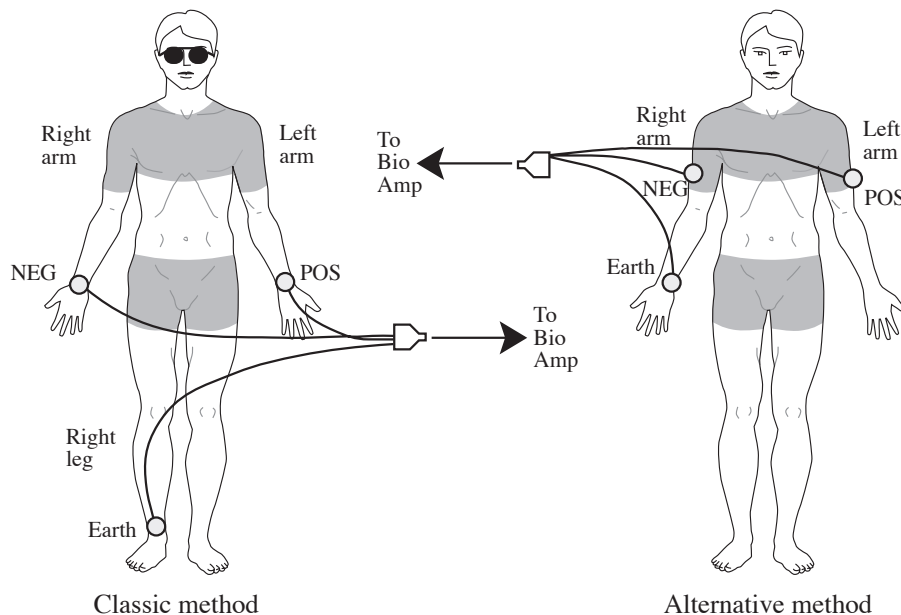


Figure 2. Attaching ECG electrodes; two alternative methods.

### Software setup and calibration

**Note:** To set up recording for this experiment, you load a settings file from the Experiments Gallery. If your tutor has made other arrangements, for instance, the Experiments Gallery does not contain the required settings file, or you have to set up the file manually, then follow their instructions. Otherwise continue.

1. Locate Chart on your computer and start the program. If the Experiments Gallery dialog box does not appear in front of the Chart window, choose the "Experiments Gallery..." command from the File menu.
2. In the Experiments Gallery dialog box, select "Cardiovascular Effects of Exercise" in the left-hand list. Select "ECG & Pulse Settings" in the right-hand list, and click the Open button to apply those settings.
3. After a short time, the Chart window on the computer screen should be set up for the experiment. Channel 1 should be named "Vol. Pulse", Channel 2 "Blood Flow" and Channel 3 "ECG".

**Note:** Channel 2 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 2 is displayed on Channel 1 and illustrates the change in finger pulp volume over time.

**You are now ready to begin the exercises.**

### Exercise 1: ECG and volume pulse at rest

#### Objectives

In this part of the lab, you will measure the ECG and volume pulse from a resting volunteer.

#### Procedure

Everything should be set up as described in the general notes above. Ask the volunteer to remain as relaxed and still as possible, to minimize any signal from movement. The Bio Amp cable comes with a clip that can be used to gather and hold the cable and leads to help keep them still.

1. Choose **Bio Amplifier** from the Channel 3 (ECG) Channel Function pop-up menu. Observe the signal that appears in the dialog box.

**Note:** If the ECG cannot be seen, check that all three electrodes are correctly attached. If the signal is noisy and indistinct, make sure that the volunteer is relaxed; consider using the alternative attachment positions shown in Figure 2. If necessary, adjust the value in the Range pop-up menu of the dialog box so that the signal occupies about a half to two thirds of the vertical axis.

2. Click OK to return to the Chart window.
3. Choose the Input Amplifier... command from the Channel 2 (Blood Flow) Channel Function pop-up menu. Adjust the **Range** so that the signal occupies about a half to two thirds of full scale when the volunteer has both hands in their lap.
4. Click OK to return to the Chart window.
5. Click Start, and record for ten seconds; add a **comment** to your trace called "Resting ECG and finger pulse".
6. Click Stop to end your recording.
7. If you are saving your files, choose Save from the File menu to save the recording. Keep the file open for the next exercise.

### Exercise 2: ECG and volume pulse after exercise

#### Objectives

In this part of the laboratory, you will measure the ECG and volume pulse in a volunteer at intervals after exercise, analyze the resultant signals, and compare them with the same volunteer's resting ECG and volume pulse.

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### Procedure

1. Disconnect the Bio Amp cable and the finger pulse transducer from the PowerLab. Check that the ECG leads are not tangled; the volunteer should gather them up and hold them.
2. The volunteer should now exercise for at least two minutes: for example, two minutes of step-up exercise, or running up four flights of stairs.

**Note:** Remember that the ECG leads are still attached to the electrodes, so the volunteer should exercise carefully (so as not to break the leads or move the electrodes), but vigorously enough to elevate their heart rate.

3. Immediately after exercise, reconnect the Bio Amp cable and the finger pulse transducer to the PowerLab while the volunteer sits down and relaxes.
4. Click Start, and record for two minutes or until the heart and breathing rate have returned to normal. During this time, enter a **comment** called "Recovery" in your trace.
5. Click Stop to end your recording.
6. If you are saving your files, choose Save from the File menu to save the recording.

### Exercise 3: Volume pulse after hand exercise

#### Objectives

In this part of the laboratory, you will measure changes in the finger pulse in a volunteer at intervals after hand exercise, analyze the resultant signals, and compare them with the same volunteer's resting finger pulse.

#### Procedure

1. Disconnect the ECG leads from the volunteer. (The finger pulse transducer should remain connected.)
2. If you are saving your files, choose Save from the File menu to save the recording for Exercises 1 and 2.
3. From the File menu, choose "Experiments Gallery", and open the settings file called "Hand Exercise Settings".
4. Ask the volunteer to remain still and relaxed. Click the Start button and record for 20 seconds; during this time, enter a **comment** called "Resting."
5. Click the Stop button.
6. Have the volunteer grasp the hand dynamometer (or rubber squeeze-ball) in the palm of their hand to which the finger pulse transducer is attached, and then rhythmically squeeze it for a few minutes until their forearm muscles fatigue.
7. Stop exercising.
8. Click Start.

9. Record for two minutes or until the amplitude of the finger pulse signal has attained a reasonably constant level for one minute; during this time, enter a **comment** called "Recovery from hand exercise."
10. Click Stop.
11. If you are saving your files, choose Save from the File menu to save the recording.

## Analysis

### Exercises 1 and 2

1. **Select** a short part of the resting ECG trace, containing three cardiac cycles.
2. Open the **Zoom window** using the Chart Toolbar menu. Your trace should resemble Figure 3.

**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 "P-Q" interval, but P-R is the traditional nomenclature.

3. Use the Marker and Waveform Cursor to make the following time measurements from the displayed waveform, as shown in Figure 3.
  - P-R time interval
  - QRS duration
  - S-T time interval
  - T-P time interval
  - R-R time interval
4. Calculate the heart rate from the R-R interval.
5. Repeat the above measurements using the first "good" ECG traces immediately 30 seconds and 60 seconds after exercise.
6. Record your data in Table 1 of your Data Notebook.

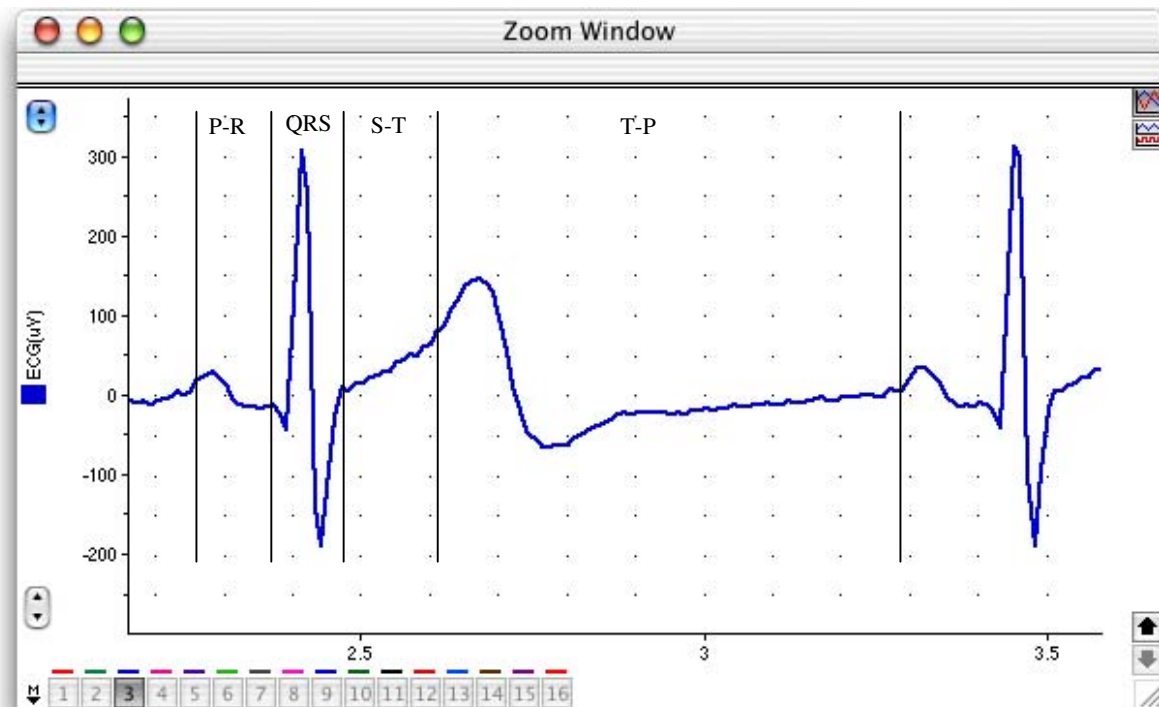


Figure 3. Zoom window view of an ECG recorded from an individual at rest: the various intervals are shown.

### Exercise 3

1. Look at the "Vol. Pulse" trace recorded immediately after exercise.
2. Calculate the subjects' heart rate from the pulse data before exercise.
3. Using the pulse data, calculate heart rate 10, 30, 60 and 120 seconds after exercise.
4. **Select** three pulse beats from before exercise from the "Vol. Pulse" trace.
5. Open the **Zoom window**.
6. Place the **Marker** on the baseline of the waveform.
7. Use the **Waveform Cursor** to determine the amplitude of a pulse beat.
8. Determine the average amplitude of three pulse beats.
9. Repeat steps 4-8 for your post-exercise data at the 10, 30, 60 and 120-second time-points.
10. Fill out Table 2 in your Data Notebook.

# Data Notebook

**Table 1. Results table for Exercises 1 and 2.**

Measurement	ECG while resting	ECG after exercise		
		0 seconds	30 seconds	60 Seconds
P-R interval				
QRS duration				
S-T interval				
T-P interval				
R-R interval				
Heart rate				

**Table 2. Results from Exercise 3.**

Time	Heart Rate (beats per minute)	Average Pulse Amplitude (mV)
Resting		
10 seconds post-exercise		
30 seconds post-exercise		
60 seconds post-exercise		
120 seconds post-exercise		



## Study Questions

### Exercises 1 and 2

1. What happened to the R-R interval and the heart rate after exercise?
2. Note that the R-R interval consists of the sum of QRS, S-T, T-P and P-R. Which of these become shorter when the heart rate increased?
3. How is heart rate controlled by nerves?
4. Immediately after exercise, was the amplitude of the pulse smaller or larger than in the resting period?
5. What happened to the pulse amplitude during recovery from exercise?
6. During exercise, blood flow in the skin and finger pulp is usually reduced by sympathetic vasoconstrictor nerve activity. After exercise, however, skin and finger blood flow may be increased. Why is the blood flow to extremities reduced during exercise? Why does it increase to higher than normal levels during recovery? What other factors may influence the supply of blood to the skin and fingers during and after exercise?

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7. Changes in the cardiovascular system are only some of a number of changes that occur in the body during and after exercise. What other physical changes did you observe in the volunteer?

### Exercise 3

8. Immediately after hand exercise, was the amplitude of the pulse smaller or larger than in the resting period?
9. What happened to the pulse amplitude during recovery from hand exercise?
10. The muscles active during hand exercise are mainly in the forearm, with a few small muscles in the hand. Would you expect blood flow to these muscles to increase during exercise?
11. The muscle mass in one forearm is very much less than the muscle mass in the legs. During hand exercise, would there be a great need for the body to redirect blood flow away from the gut and skin?
12. There are no muscles in the distal segment of the fingers. Would you expect the increased muscle blood flow in exercise to affect the finger blood flow?

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