Cardiovascular Effects of Exercise

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

Written by staff of ADInstruments.

Background

Cardiac function

The volume of blood that the heart ejects into the circulation each minute, the cardiac output (CO), is the product of 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 epinephrine, results in increased heart rate.

Stroke volume at rest is appreciably higher in very fit individuals. 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 epinephrine. At first, during exercise, these factors all increase, and SV is thus increased. However, the increase in HR also decreases ventricular filling time and thus limits the capacity for increased SV. Although initially SV may increase up to 1.5 fold, 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).

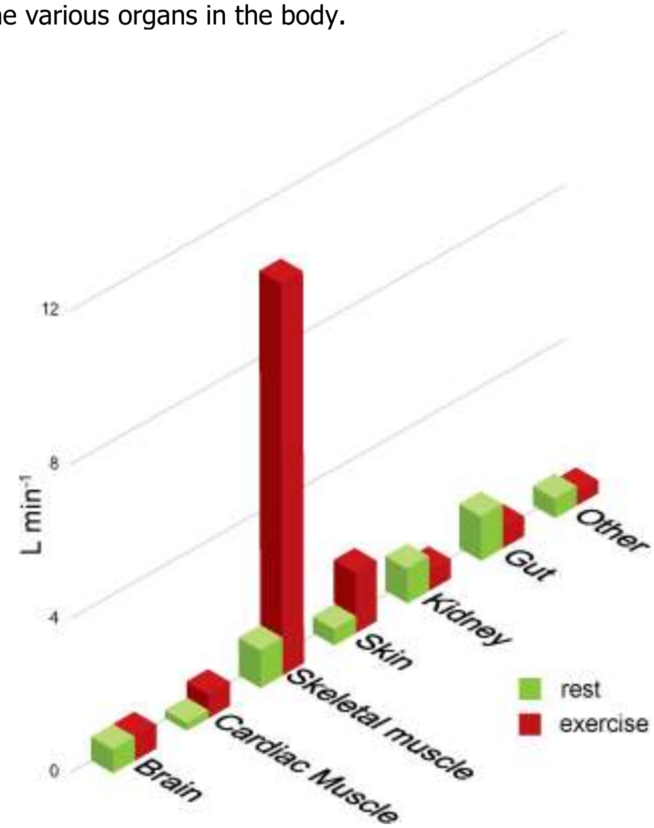
That means the CO of our trained athlete has increased from 5 L/min at rest to 160 x 0.188 = 30 L/min, while the CO of our less fit individual has gone from 5 L/min to 13.3 L/min! To match our athlete's CO, the resting SV of the less fit individual would have had to increase by about 6-fold; an impossibility!

Electrical activity of the heart during exercise

An increase in heart rate corresponds to a shortening of the cardiac cycle (RR interval decreases). Most of this shortening occurs in the TP interval. The QT interval also shortens, but only slightly.

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.



Changes in organ blood flow between rest and exercise.

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
- Hand Dynamometer (or other squeezable object)
- 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.

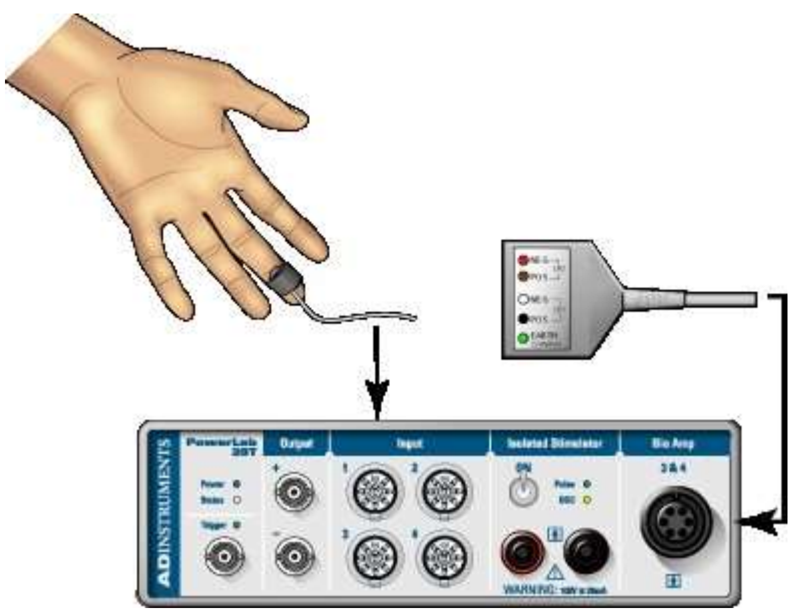


Figure 2. Equipment Setup for PowerLab 26T

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.

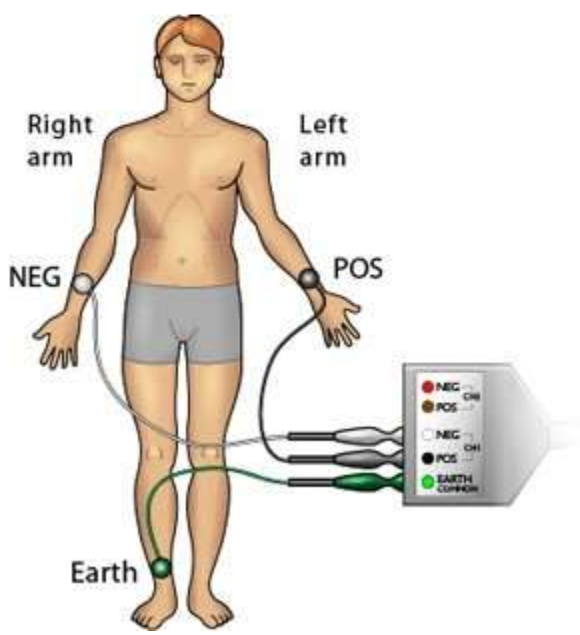


Figure 3. Electrode Placement

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.

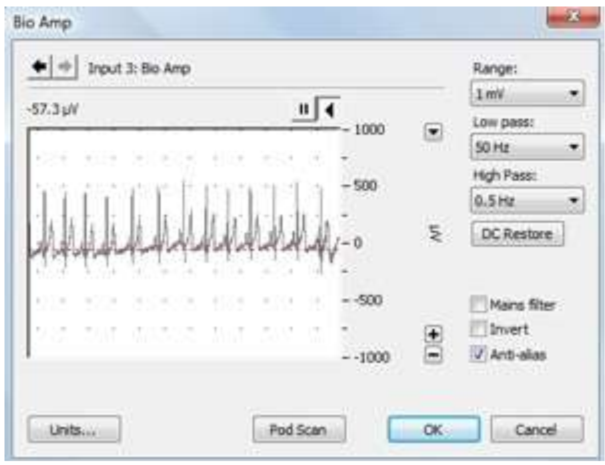


Figure 4. Bio Amp Dialog

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.

Exercise 3: Blood Volume Pulse after Hand Exercise

In this exercise, you will measure changes in blood volume pulse at periodical intervals after hand exercise.

1. Disconnect the Shielded Bio Amp Cable from the PowerLab and Shielded Lead Wires from the volunteer. Leave the Finger Pulse Transducer connected to the PowerLab and the volunteer.

2. Open the settings file "Hand Exercise Settings" from the **Experiments** tab in the **Welcome Center**. It will be located in the folder for this experiment. Make sure the data from Exercise 2 is saved.

3. Have the volunteer relax and face away from the monitor. **Start** recording. If you do not see a good pulse signal in Channel 1, you will need to adjust the range of the channel. Add a **comment** with "rest," and record baseline pulse for 30 seconds.

4. **Stop** recording. Have the volunteer grasp the Hand Dynamometer (or squeezable object provided by your instructor) in the palm of the hand to which the Finger Pulse Transducer is attached. Have the volunteer rhythmically squeeze it for at least three minutes until the forearm muscles fatigue.

5. Stop exercising. **Start** recording immediately. Record for two minutes or until the amplitude of the finger pulse signal remains reasonably constant for one minute. During this time, add a **comment** with "recovery."

6. 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.

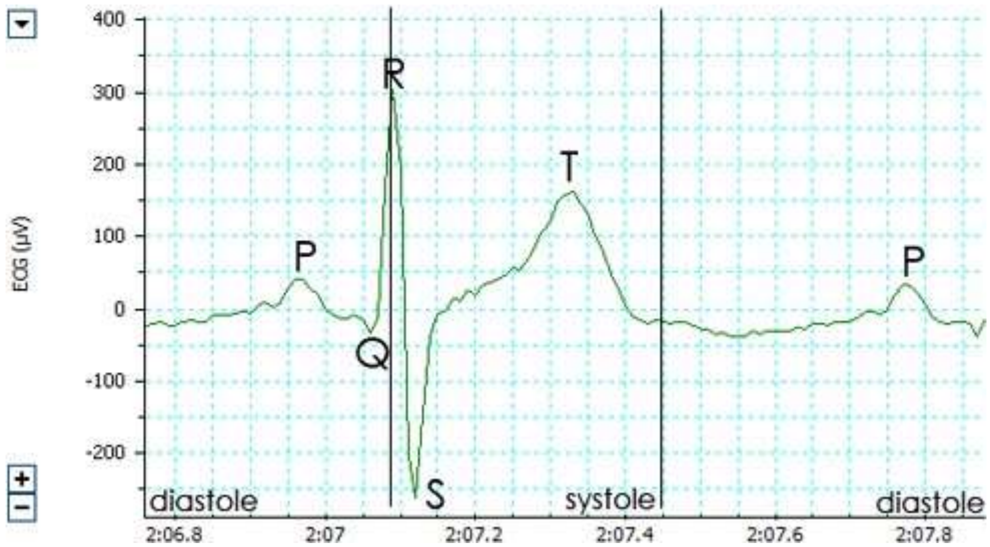


Figure 5. Cardiac Cycle of an Electrocardiogram

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 = 1 / cycle length, where cycle length is the R-R interval
      - For example, if R-R interval = 800 ms:

   b) HR = 1 / 800 ms, and 800 ms / 1000 = 0.8 s
   c) HR = 1 / 0.8 s
   d) HR = 1.25 beats/s
   e) HR = 1.25 beats/s x 60 s = 75 BPM

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

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.

Exercise 3: Blood Volume Pulse after Hand Exercise

1. Examine the data in the Chart View. **Autoscale**, if necessary.

2. Using the "Volume Pulse" data trace, calculate the volunteer's heart rate while the volunteer is at rest. Then calculate heart rate 10, 30, 60, and 120 seconds after exercise.

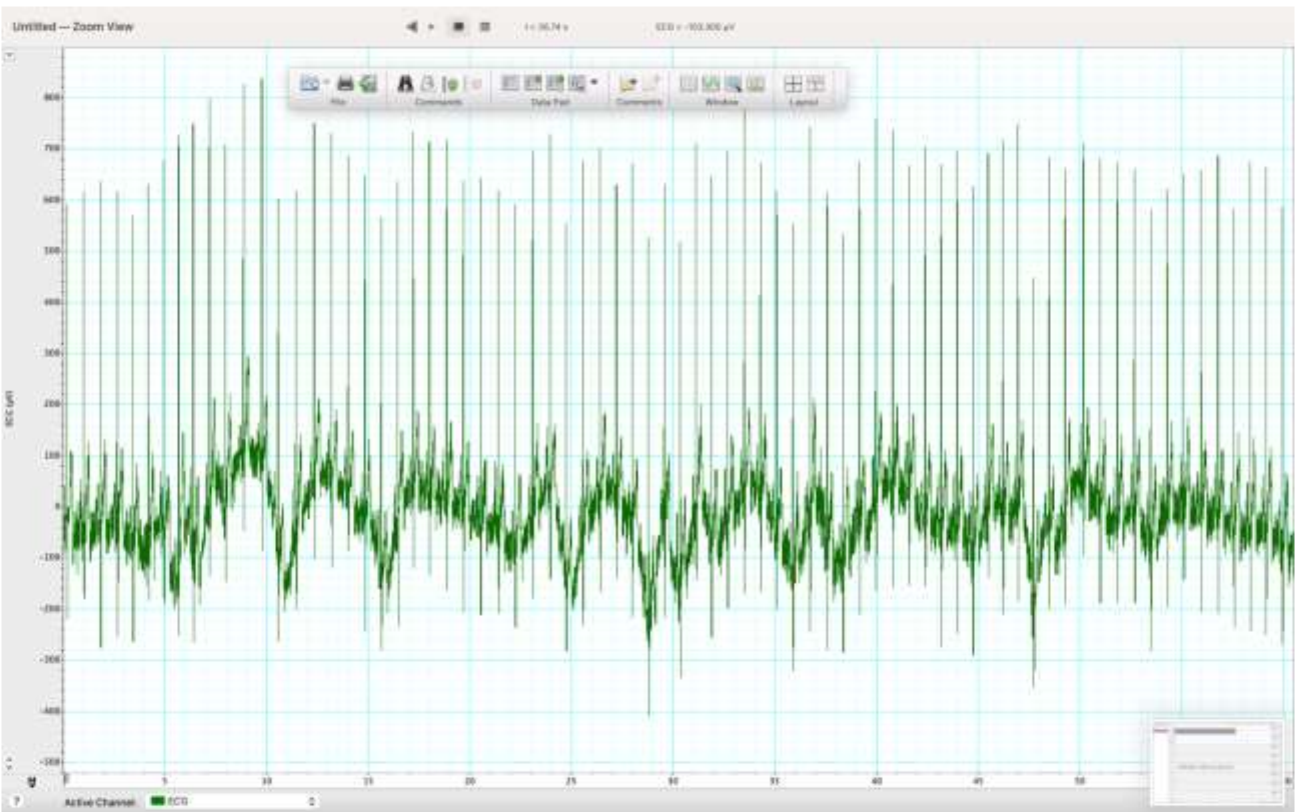
3. Select a small part of the "Volume Pulse" data trace, containing three pulse beats, while the volunteer is at rest and examine it in **Zoom View**.

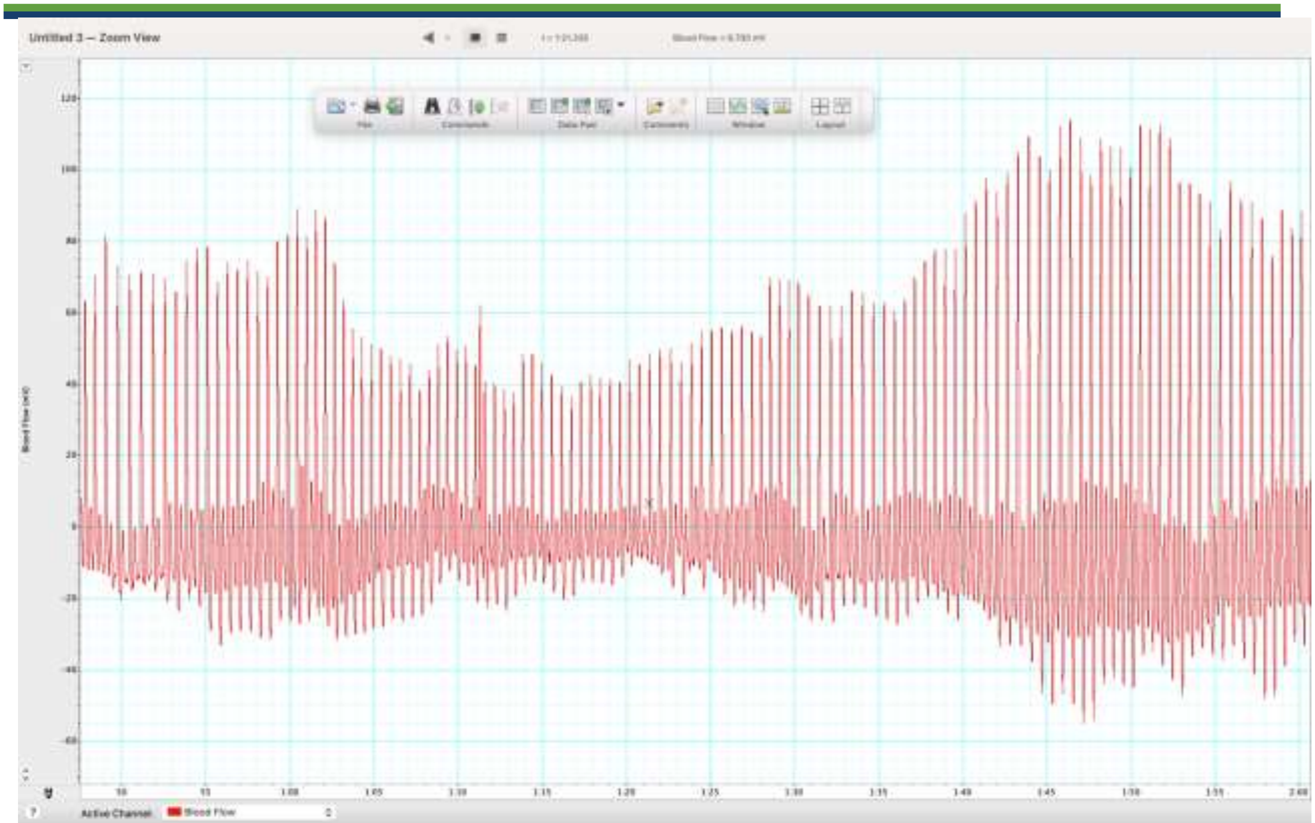
4. In Zoom View, use the **Marker** and **Waveform Cursor** to determine the amplitude of one of the pulse beats. Place the Marker on the baseline of the waveform and the Waveform Cursor on the peak. Repeat this for the other two pulse beats, and calculate the mean amplitude.

5. Repeat steps 3-4 for your post-exercise data at the 10, 30, 60, and 120-second intervals.

6. Enter these values in Table 2 of the Data Notebook.

Data Notebook





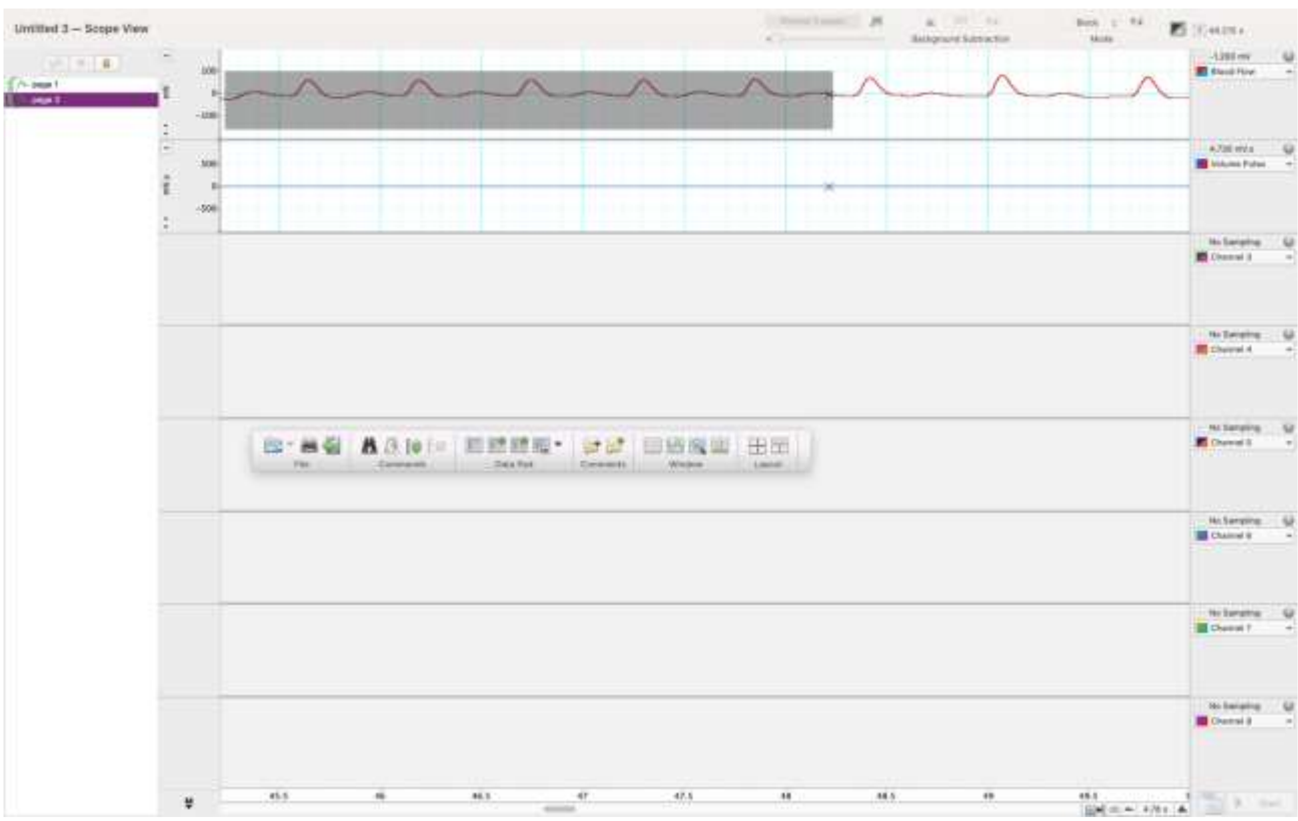


Table 1. Cardiac Cycle during Rest and After Exercise

	ECG During Rest	ECG After Exercise		
		0 seconds	30 seconds	60 seconds
P-R Time Interval	0.20	0.12	0.15	0.18
QRS Duration	0.1	0.08	0.09	0.1
S-T Time Interval	0.08	0.05	0.06	0.08
T-P Time Interval	0.2	0.12	0.19	0.2
R-R Time Interval	1.2	0.6	0.8	1.0
Heart Rate	80bpm	120bpm	100bpm	90bpm

Table 2. Blood Volume Pulse after Hand Exercise

	Heart Rate (BPM)	Mean Pulse Amplitude (mV)
Rest	80bpm	10
10 s Post-exercise	110bpm	20
30 s Post-exercise	100bpm	15
60 s Post-exercise	90bpm	12
120 s Post-exercise	86bpm	10

Study Questions

1. **How is heart rate controlled by the nervous system?**

The sympathetic nervous system (SNS) releases the hormones (catecholamines – epinephrine and norepinephrine) to accelerate the heart rate. The parasympathetic nervous system (PNS) releases the hormone acetylcholine to slow the heart rate

2. **What happened to the R-R interval and heart rate after exercise?**

Exercise increases heart rate when corresponds to a shortening of a cardiac cycle.

Thus **the RR interval decreases after exercise**

3. **Immediately after exercise (Exercise 2), was the amplitude of the pulse smaller or larger than during the resting period?**

It has been reported that **the rising velocity of the pulse ascending curve is related to peripheral resistance, which is reduced because of the exercise muscle vasodilatation during exercise** [22]. Therefore, the pulse peak time reduces with increasing exercise loads

4. Immediately after hand exercise (Exercise 3), was the amplitude of the pulse smaller or larger than during the resting period?

- Since heart rate and therefore pulse reflect the overall requirements of the circulation, a little local

exercise will not affect the rate to any significant extent.

- The amplitude was smaller (decreased).

5. What happened to the blood volume pulse amplitude during recovery from hand exercise?

The pulse amplitude is smaller after exercise and **slowly increases** during

recovery. This decrease reflects the vasoconstriction in the fingers as blood is

shunted to exercising muscles. After two

minutes recovery, the pulse amplitude should be the same or higher than resting levels

6. Calculate cardiac output for an athlete with HR = 40 BPM and SV = 0.125 L.

Measuring Cardiac Output

Cardiac Output = Stroke Volume * Heart Rate, which is written **CO = SV * HR**.

Remember, there are two variables that are used to determine the cardiac output.

Those are the stroke volume and heart rate

CO = 40*0.125 = 5 Liters/Min

Blood Pressure

In this experiment, you will become familiar with auscultation (listening to the sounds of the body) and the measurement of blood pressure using a stethoscope, Blood Pressure Cuff, and Sphygmomanometer. You will also assess changes in peripheral circulation and the effects of cuff location.

Written by staff of ADInstruments.

Background

The pressure in the arteries varies during the cardiac cycle. The ventricles contract to push blood into the arterial system and then relax to fill with blood before pumping once more. This intermittent ejection of blood into the arteries is balanced by a constant loss of blood from the arterial system through the capillaries. When the heart pushes blood into the arteries there is a sudden increase in pressure, which slowly declines until the heart contracts again. Blood pressure is at its highest immediately after the ventricle contracts (systolic pressure) and at its lowest immediately prior to the pumping of blood into the arteries (diastolic pressure). Systolic and diastolic pressures can be measured by inserting a small catheter into an artery and attaching the catheter to a pressure gauge. Such a direct measurement might be accurate, but is invasive and often inconvenient and impractical. Simpler estimates of blood pressure can be made with acceptable accuracy using noninvasive, indirect methods.

The modern era of blood pressure measurement started with the introduction of the mercury sphygmomanometer by Scipione Riva-Rocci (1863-1937) in 1896. Blood pressure is estimated using a stethoscope and a blood pressure cuff connected to a mercury sphygmomanometer. The cuff is placed on the upper arm and inflated to stop arterial blood flow to the arm from the brachial artery; the high pressure in the cuff collapses the artery. The pressure in the cuff is then released slowly. When the cuff pressure begins to fall below the systolic pressure in the artery, blood begins to flow to the arm through the partially collapsed artery. This flow is turbulent rather than streamlined and generates sounds called Korotkoff sounds, which can be heard through the stethoscope. When blood flow is first heard, the cuff pressure approximates systolic pressure. As the cuff pressure continues to decrease and the artery regains its normal diameter, flow becomes streamlined and the sounds become muffled and then disappear. The cuff pressure at the point of the sound muffling approximates diastolic pressure, but as the disappearance of sound is easier to detect than muffling, and since the two occur within a few millimeters of mercury pressure, the disappearance of sound is commonly used the determine diastolic pressure.

An alternative method makes use of a simple finger pulse transducer connected to the computer. The cuff is inflated to a pressure that obliterates the finger pulse. As the cuff pressure is released, the finger pulse returns and the pressure at which it reappears is a measure of the arterial systolic pressure.

It is conventional to reference all arterial blood pressure measurements to the position of the heart. There are differences in pressure with the arm held in different positions. In a column of blood, a difference in height of one meter corresponds to a pressure difference of 10.3 kPa, or 77 mmHg. Due to hydrostatic pressure of a column of blood, any measurements made below the heart will be greater in pressure and any made above the heart will be lower in pressure than measurements made at heart level.

Required Equipment

- LabChart software
- PowerLab Data Acquisition Unit
- Finger Pulse Transducer
- Blood Pressure Cuff
- Sphygmomanometer
- Stethoscope
- Cardio Microphone
- DIN to DIN smart adapter to connect the Cardio Microphone to input 3 (without the smart adapter, the Cardio Microphone will be treated as a Bio Amp which is not appropriate for this experiment).

⚠ **This procedure involves stopping blood flow to the arm. Make sure you are confident with the operation of the sphygmomanometer, especially the pressure relief valve, before beginning. While mild discomfort is normal, stop inflation and release the pressure immediately if the volunteer experiences acute pain.**

Procedure

Section 1: Techniques for Measuring Blood Pressure

Exercise 1: Auscultation of Blood Pressure

In this exercise, you will measure blood pressure using the traditional method of auscultation. The PowerLab is not required in this exercise.

1. In order to perform the experiment correctly, you need to become familiar with the use of the stethoscope. Refer to Figure 1. Make sure the bell of the stethoscope is active. Lightly tap on the bell. If no sound is clearly heard, rotate the bell 180° on its endpiece.

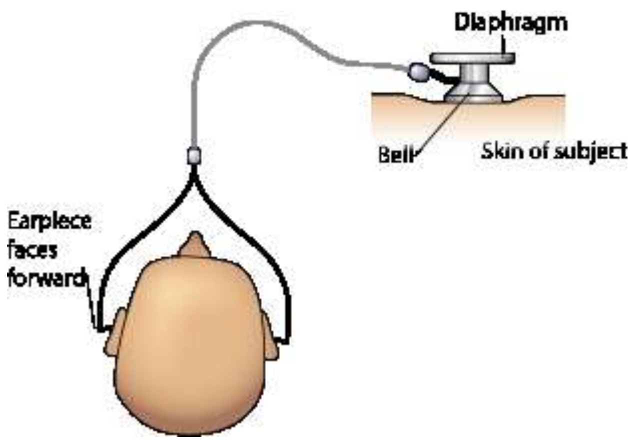


Figure 1. Stethoscope Placement

2. Place the Blood Pressure Cuff around the upper portion of either arm of the volunteer, between the elbow and shoulder (Figure 2).

3. Place the bell of the stethoscope over the brachial artery, as shown in Figure 2. The artery lies medial to the biceps tendon, just above the elbow crease.

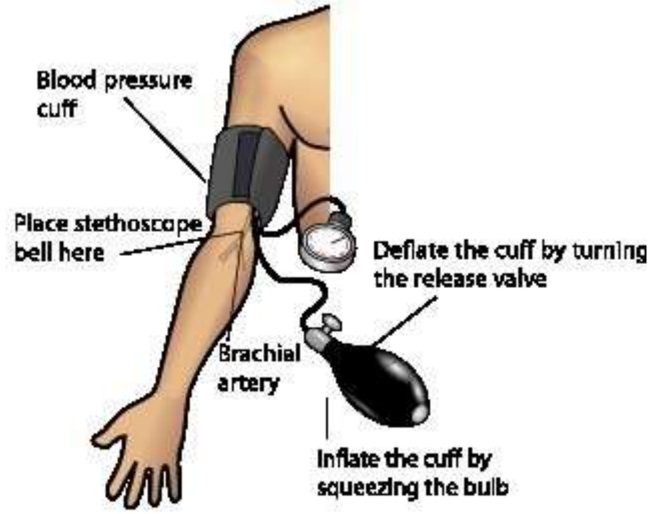


Figure 2. Placement of the Blood Pressure Cuff and Stethoscope

4. Inflate the cuff until the pressure reaches approximately 180 mmHg. Do **not** inflate the cuff past this point.

5. Slowly reduce the pressure approximately 1 to 2 mmHg per second while listening through the stethoscope for Korotkoff sounds. Note the pressure at which sharp, tapping sounds are first heard. This is the systolic pressure (Figure 3).

6. Continue slowly reducing the pressure. The pressure at the cessation of sound is the diastolic pressure (Figure 3). Record the volunteer's blood pressure in Table 1 of the Data Notebook.

Note: Completely deflate the Blood Pressure Cuff once diastolic pressure is determined. Do not leave it partially inflated or inflated for a long period of time. Leave the cuff and stethoscope positioned on the volunteer.

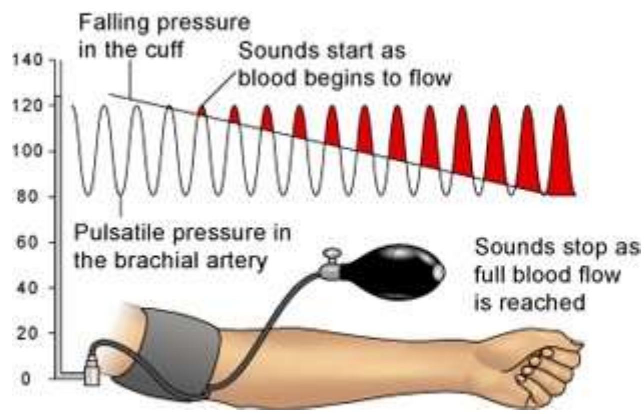


Figure 3. Graphical Representation of Auscultation

7. Wait at least two minutes for the volunteer to recover and repeat steps 4 to 6. Record the volunteer's blood pressure in Table 1 of the Data Notebook. Repeat two additional times on the same volunteer, following the same procedure.

8. Leave the Blood Pressure Cuff fully deflated on the volunteer's arm.

Equipment Setup

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

2. Connect the Pressure Transducer to Input 1 on the front panel of the PowerLab (Figure 4).

3. Connect the Finger Pulse Transducer to Input 2 on the front panel of the PowerLab (Figure 4).

4. Connect the Cardio Microphone to Input 3 on the front panel of the PowerLab (Figure 4). Note you will not use the microphone this exercise but it must be connected to the PowerLab before you open the settings file for this exercise. You will use the microphone in exercise 3.

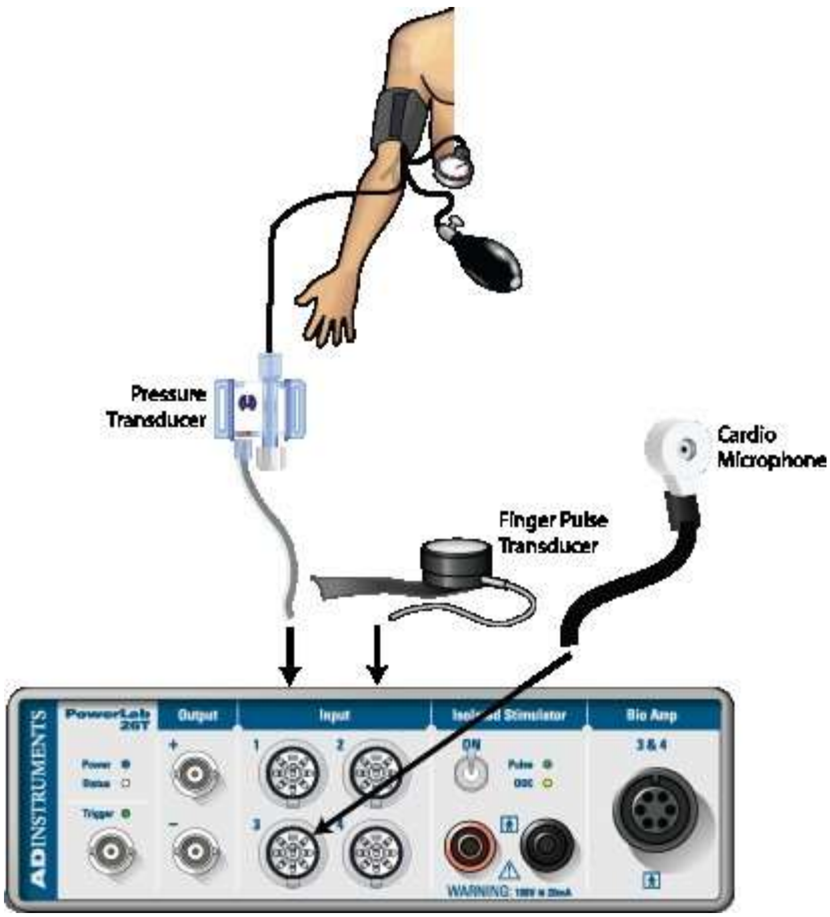


Figure 4. Equipment Setup for PowerLab 26T

5. Place the pressure pad of the Finger Pulse Transducer on the tip of the middle finger of the hand with the Blood Pressure Cuff attached. 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.

6. Have the volunteer face away from the monitor, sit comfortably, and relax. Make sure the Finger Pulse Transducer is not resting on any surface. The volunteer's hands should be in his/her lap and the leg should support the wrist, allowing the fingers to hang freely. Tell the volunteer not to move during the recording.

Exercise 2: Blood Pressure and Pulse

In this exercise, you will observe the changes in blood flow while measuring blood pressure. You will then determine if pulse measurement can be used to replace the stethoscope.

1. Launch LabChart and open the settings file "Blood Pressure Settings" from the **Experiments** tab in the **Welcome Center**. It will be located in the folder for this experiment.

2. Make sure the volunteer is still relaxed with the Finger Pulse Transducer free from any surface. If the volunteer feels any discomfort, re-adjust the transducer before continuing with the experiment.

3. Go to **Input Amplifier** in the Channel 2 Channel Function pop-up menu. Adjust the Range in the dialog so that the signal occupies about one half to two-thirds of the full scale (Figure 5). Channel 2 shows the raw signal from the Finger Pulse Transducer, which indicates the net rate of blood flow into the finger pulp.

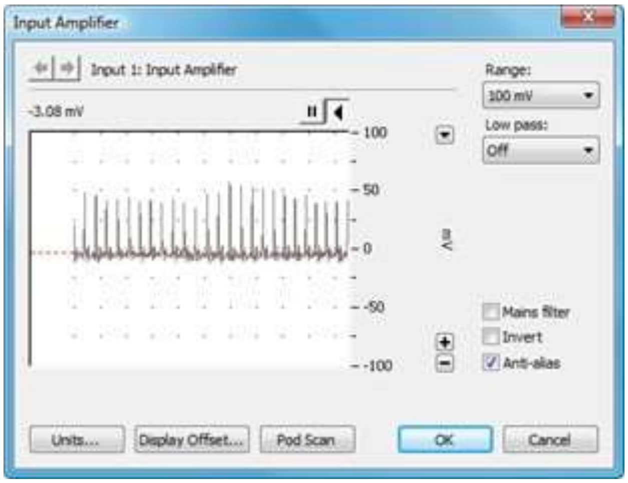


Figure 5. Input Amplifier Dialog

4. Make sure you can inflate the Blood Pressure Cuff without disturbing the volunteer's hand. Adjust any of the equipment now, if necessary.

5. **Start** recording. Enter a **comment** with "exercise 2," and continue recording for 10 seconds.

6. Inflate the Blood Pressure Cuff until the pressure is approximately 180 mmHg. Note that the pressure signal increases and the pulse signal disappears (Figure 6). While one group member is inflating the cuff, have another group member prepare a comment with "systolic."

7. Listening with the stethoscope for the Korotkoff sounds as you did in exercise 1, slowly deflate the cuff. When the Korotkoff sounds are first heard through the stethoscope, press the Return/Enter key to add the **comment**. Have a group member prepare a comment with "diastolic."

8. Continue releasing the pressure. When diastolic pressure is reached (cessation of sound), press the Return/Enter key to add the **comment**. Completely deflate the cuff. **Stop** recording.

9. Save your data, but do not close the file. Leave the Finger Pulse Transducer on the volunteer's finger.

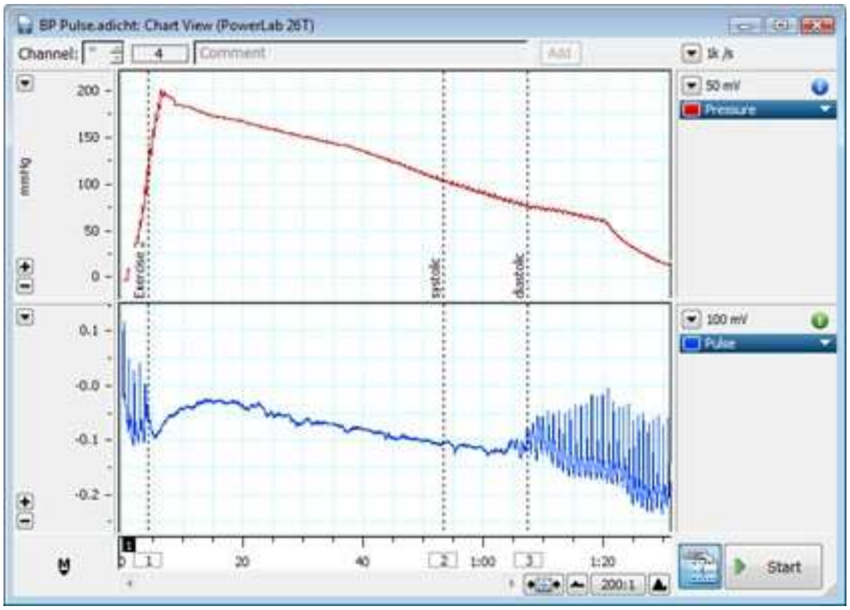


Figure 6. Sample Blood Flow Waveform

Exercise 3: Blood Pressure and Arterial Sounds

In this exercise, you will record arterial sounds while measuring blood pressure. You will use a cardio microphone instead of a stethoscope. You will then compare the pulse measurement with the cardio microphone recording and determine if a cardio microphone could be used to replace the stethoscope.

Note. If you opened the settings file "Blood Pressure Settings" before the Cardio Microphone was connected to input 3 of the PowerLab the range for Channel 3 will be need to be set to 100 mV.

1. Make sure the volunteer is still relaxed with the Finger Pulse Transducer free from any surface. If the volunteer feels any discomfort, re-adjust the transducer before continuing with the experiment.
2. Place the Cardio Microphone over the brachial artery as you did with the bell of the stethoscope. Secure the microphone in place.
3. Make sure you can inflate the Blood Pressure Cuff without disturbing the volunteer's hand or the microphone. Adjust any of the equipment now, if necessary.
4. **Start** recording. Enter a **comment** with "exercise 3," and continue recording for 10 seconds.
5. Inflate the Blood Pressure Cuff until the pressure is approximately 180 mmHg.
6. Slowly reduce the pressure in the cuff as you did in exercises 1 and 2. Once the pressure has gone below 50 mmHg deflate the cuff completely. **Stop** recording.
7. Examine your cardio microphone recording. It should look similar to Figure 7.
8. Save your data and close the file. The cardio microphone can be removed from the volunteer's arm. Leave the Finger Pulse Transducer on the volunteer's finger.

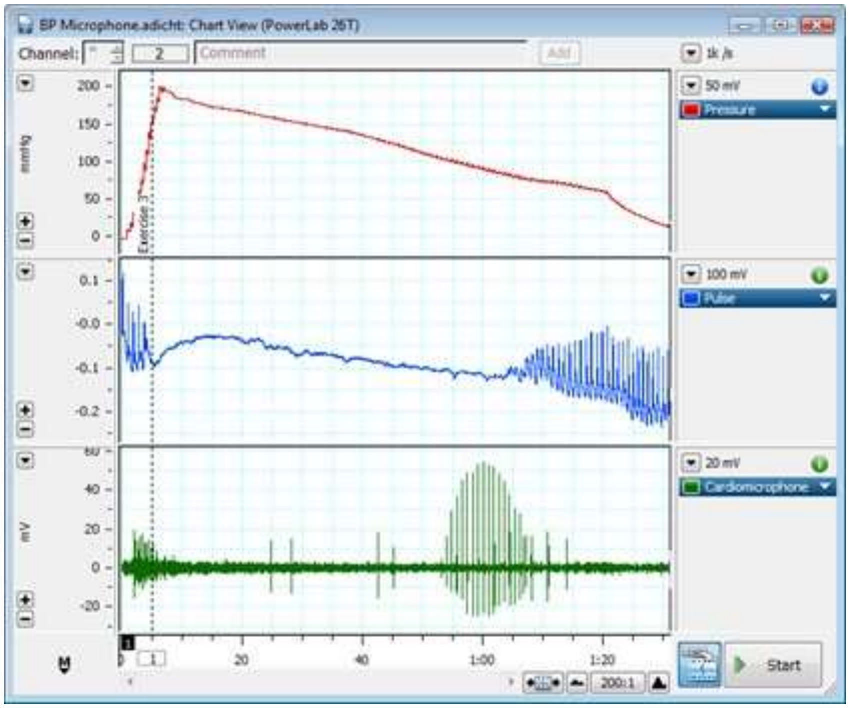


Figure 7. Cardio Microphone Recording of Arterial Sound During Blood Pressure Measurement

Section 2: Effects of Cuff Positioning on Blood Pressure

Exercise 4: Measuring Systolic Pressure in the Upper Arm

In this exercise, you will measure systolic blood pressure in the upper arm. Open the settings file "Blood Pressure Limbs Settings" from the **Experiments** tab in the **Welcome Center**. It will be located in the folder for this experiment.

1. Make sure the volunteer is in the same relaxed position as the previous exercises with the Finger Pulse Transducer free from any surface. If the volunteer feels any discomfort, re-adjust the transducer before continuing with the experiment.

2. Go to **Input Amplifier** in the Channel 2 Channel Function pop-up menu. Adjust the Range in the dialog so that the signal occupies about one half to two-thirds of the full scale. Channel 2 shows the raw signal from the Finger Pulse Transducer, which indicates the net rate of blood flow into the finger pulp.

3. **Start** recording, and add a **comment** with "exercise 4."

4. Inflate the Blood Pressure Cuff to 180 mmHg. Note the increase in pressure signal recorded on Channel 1. The pressure value should correspond to the sphygmomanometer pressure gauge.

5. Slowly deflate the cuff as before until the pressure has dropped to 60 mmHg. Once the pressure has reached 60 mmHg, completely deflate the Blood Pressure Cuff and **Stop** recording. Save the file, and keep it open.

Exercise 5: Measuring Systolic Pressure in the Forearm

In this exercise, you will measure systolic blood pressure in the forearm and compare it to the measurement taken from the upper arm. The same procedure will be followed.

1. Move the Blood Pressure Cuff from the upper arm to the forearm. It will need to be adjusted to achieve a snug fit. Have the volunteer relax and hang the arm with the cuff by his/her side. Make sure the elbow is not bent and the Finger Pulse Transducer hanging freely. Make sure you will not move the volunteer's hand when inflating the cuff.

2. **Start** recording, and add a **comment** with "exercise 5."

3. Inflate the Blood Pressure Cuff to 180 mmHg.

4. Slowly deflate the cuff as before until the pressure has dropped to 60 mmHg. Once the pressure has reached 60 mmHg, completely deflate the Blood Pressure Cuff and **Stop** recording. Save the file, and keep it open.

Exercise 6: Measuring Systolic Pressure in the Leg

In this exercise, you will measure systolic blood pressure in the leg and compare it to the measurements taken from the upper arm and forearm. This exercise is a variation from Exercises 4 and 5 as the volunteer will be sitting and standing.

1. Have the volunteer sit down and remove his/her left shoe and sock. Place the Finger Pulse Transducer on the tip of the left big toe of the volunteer. Adjust the strap as before, when placing it on the finger. Make sure the volunteer does not rest the Finger Pulse Transducer against the ground.

Note: The volunteer must not stand or put weight on the Finger Pulse Transducer. This will damage the transducer and give incorrect pulse signals.

2. Wrap the Blood Pressure Cuff around the calf of the volunteer's left leg. Make sure you achieve a snug fit. Have the volunteer relax.

3. **Start** recording, and add a **comment** with "exercise 6, sitting."

4. Inflate the Blood Pressure Cuff to 180 mmHg.

5. Slowly deflate the cuff as before until the pressure has dropped to 60 mmHg. Once the pressure has reached 60 mmHg, completely deflate the Blood Pressure Cuff and **Stop** recording. Save the file, and keep it open.

6. Wait at least two minutes for the volunteer to recover. When ready, have the volunteer stand.

7. **Start** recording, and add a **comment** with "exercise 6, standing."

8. Inflate the Blood Pressure Cuff to 180 mmHg.

9. Slowly deflate the cuff as before until the pressure has dropped to 60 mmHg. Once the pressure has reached 60 mmHg, completely deflate the Blood Pressure Cuff and **Stop** recording. Save the file.

Analysis

Exercise 1: Auscultation of Blood Pressure

1. Record the systolic and diastolic blood pressures from all four trials in Table 1 of the Data Notebook.

2. Calculate the mean blood pressure and enter it in Table 1.

Exercise 2: Blood Pressure and Pulse

1. Examine the data in the Chart View and **Autoscale**, if necessary. Use the **View Buttons** to change the compression of the data trace so the entire exercise can be viewed at once.

2. Use the **Marker** and **Waveform Cursor** to measure the systolic and diastolic pressures, based on the comments. Place the Marker on the baseline pressure (i.e., before you inflated the cuff) and move the Waveform cursor to the systolic and diastolic comments. Enter the pressure values in Table 2 of the Data Notebook.

Exercise 3: Blood Pressure and Arterial Sounds

1. Examine the data in the Chart View and **Autoscale**, if necessary. Use the **View Buttons** to change the compression of the data trace so the entire exercise can be viewed at once.

2. The Cardio Microphone channel displays the Korotkoff sounds as spikes. These spikes can be used to determine systolic and diastolic pressure. The first spike following the reduction in cuff pressure represents the systolic pressure. The last spike in the series represents the diastolic pressure. Use the **Marker** and **Waveform Cursor** to measure the systolic and diastolic pressures, based on the Korotkoff sounds. Enter the pressure values in Table 3 of the Data Notebook.

Exercise 4: Measuring Systolic Pressure in the Upper Arm

1. Examine the data in the Chart View. Use the **Marker** and **Waveform Cursor** to measure the systolic blood pressure from the data trace. The systolic blood pressure occurs when you can see blood flow in the Chart View. You may need to **Autoscale** the data trace. Record the result in Table 4 of the Data Notebook.

Exercise 5: Measuring Systolic Pressure in the Forearm

1. Examine the data in the Chart View. Use the **Marker** and **Waveform Cursor** to measure the systolic blood pressure from the data trace. The systolic blood pressure occurs when you can see blood flow in the Chart View. You may need to **Autoscale** the data trace. Record the result in Table 4 of the Data Notebook.

Exercise 6: Measuring Systolic Pressure in the Leg

1. Examine the data in the Chart View. Use the **Marker** and **Waveform Cursor** to measure the systolic blood pressure from the data trace. The systolic blood pressure occurs when you can see blood flow in the Chart View. You may need to **Autoscale** the data trace. Record the result in Table 4 of the Data Notebook.

Data Notebook

Table 1. Auscultation

	Systolic Pressure (mmHg)	Diastolic Pressure (mmHg)
Trial 1	120	80
Trial 2	115	75
Trial 3	110	75
Trial 4	110	90
Mean	113.75	80

Table 2. Blood Pressure and Pulse

	Systolic Pressure (mmHg)	Diastolic Pressure (mmHg)
Pressure Value	112	76

Table 3. Blood Pressure and Cardio Microphone

	Systolic Pressure (mmHg)	Diastolic Pressure (mmHg)
Pressure Value	113	80

Table 4. Systolic Blood Pressure Measured at Different Body Parts

	Systolic Pressure (mmHg)
Upper Arm	115
Forearm	114
Leg, sitting	113
Leg, standing	115

Study Questions

1. What are some possible sources of error or variation in using auscultation to record blood pressure?

There can be a lot of variations that can cause error when we use auscultation to record blood pressure for example the blood cuff can be loose or so tight or the person who is listening to the voice may not hear properly.

2. **Does the point of the first Korotkoff sound in Exercise 2 correspond with the first appearance of blood flow (pulse signal)?**

yes it does but it has a little delay so the blood can reach to our finger but exept for that te Korotkoff sound corresponds to first pulse signal.

3. **Does the point at which diastolic pressure is heard through the stethoscope in Exercise 2 correspond with anything in particular in the pulse signal?**

yes, the pulse signals go back to normal comparing to pressured state and signals are very similar to normal condition.

4. **Does the appearance and disappearance of the Korotkoff sounds in Exercise 3 correspond with anything in the pulse signal?**

yes appearance of Korotkoff sound correspond to systolic pressure and disappearance of Korotkoff sound corresponds to diastolic pressure.

5. **From your results in exercises 1-3 comment on whether the technology used in exercises 2 and 3 can replace the stethoscope in determining systolic and diastolic blood pressure.**

Yes auscultation devices can be replaced with stethoscope if we get the sound signal and tap signal well and process it in aright way so we can find systolic and diastolic pressure in the pressure range

6. In Exercise 4, are the values for systolic blood pressure close to the values obtained in Exercises 1 and 2? Explain your results.

yes they are close to values in exercise 1,2 because the are of measuring are very close and they both measure the same pressure.

7. Is there any significant difference in systolic blood pressure obtained from the upper arm compared to that obtained from the forearm?

no there isn't any significant difference in systolic blood pressure in upper arm an forearm.

8. Compare the systolic blood pressure obtained from the leg when the volunteer was sitting and standing.

there isn't any significant difference but when the volunteer was standing the systolic blood pressure was higher comparing to sitting position.

Roles :

Mahdi Siami :
Managing the experiment, working with labchart and saving data, writing notes, writing report part blood pressure

AliAkabr Mahmoodzadeh :
Subject, writing report part ECG

Alireza Zargaran :

Helping subject to prepare, connecting wires and making the instruments stable and inflating blood pressure cuff