Lesson 16

BLOOD PRESSURE

- Indirect measurement
- Ventricular Systole & Diastole
- Korotkoff sounds
- Mean Arterial pressure
I. INTRODUCTION

In this lesson, you will record your blood pressure, which is comprised of two numbers: systolic pressure (the force of blood in your arteries as the heart contracts and pushes it out) and diastolic pressure (the force of your blood between heartbeats). Understanding circulation will help you understand and accurately measure your blood pressure.

Circulating blood provides a transportation and communication system between the body’s cells and serves to maintain a relatively stable internal environment for optimum cellular activity. Blood circulates because the heart pumps it through a closed circuit of blood vessels (Fig. 16.1 and 16.2).

Blood flow through the heart and the blood vessels is unidirectional, flowing into the heart from the pulmonary and systemic veins, and out of the heart into pulmonary and systemic arteries.

Blood flow through the chambers of the heart is unidirectional because of the action of four valves inside the heart (see fig. 16.3) that normally prevent retrograde or backward flow during the cardiac cycle (one heartbeat).

- **The right atrioventricular valve** (tricuspid) and the **left atrioventricular valve** (bicuspid or mitral) prevent the backward flow of blood from the ventricles into the atria.
- **The pulmonary semilunar valve** and the **aortic semilunar valve** prevent the backward flow of blood from arteries into the ventricles.

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**Figure 16.1**

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**Figure 16.2**

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**Figure 16.3**
Lesson 16: Blood Pressure

The left and right ventricles are the primary pumping chambers of the heart. During relaxation of the ventricles (**ventricular diastole**) the atrioventricular valves open and the semilunar valves close, allowing the ventricles to fill with blood. During contraction of the ventricles (**ventricular systole**) the atrioventricular valves close and the semilunar valves open, allowing the ventricles to eject blood into the arteries.

As the heart works at pumping blood, the ventricles relax and fill with blood, then contract and eject blood, then repeat the cycle of filling and ejecting. Due to the nature of the cardiac cycle the ejection of blood by the ventricles into the arteries is not continuous. Therefore, both blood pressure and blood flow in the arteries is **pulsatile**, increasing during ventricular systole and decreasing during ventricular diastole.

Figure 16.4 represents a graphic recording of changes in systemic arterial blood pressure measured directly by inserting a small catheter into an artery and attaching the catheter to a pressure measuring and recording device.

![Figure 16.4](image)

**Systolic pressure** is the highest arterial pressure reached during ventricular systole. The normal range of systolic pressures for a resting adult is 100 - 139 mm Hg.

**Diastolic pressure** is the lowest arterial pressure reached during ventricular diastole. The normal range of diastolic pressures for a resting adult is 60 - 89 mm Hg.

The mathematical difference between systolic pressure and diastolic pressure is called **pulse pressure**. Pulse pressure is directly related to stroke volume of the heart and inversely related to heart rate and peripheral resistance.

For example, when the volume of blood ejected per beat (called **stroke volume**) increases at the beginning of exercise, systolic pressure increases more than diastolic pressure, resulting in an increase in pulse pressure.

In the systemic circuit (refer back to Fig. 16.2), blood flows out of the left ventricle into systemic arteries and then serially through arterioles, capillaries, venules, and veins before returning to the heart to be pumped through the pulmonary circuit. Flow through a closed circuit such as the systemic circuit is determined by the pressure energy causing the flow, and the resistance to flow offered by the blood vessel walls (friction) and the internal viscosity of the blood.

The relationship between flow (F), pressure (P) causing the flow and resistance (R) to the flow is expressed as:

\[ F = \frac{P}{R} \]

Flow is expressed as liters/min., pressure is expressed as **mm Hg (torr)**, and resistance is expressed as peripheral resistance units.
The pressure \( P \) is neither systolic nor diastolic but rather a pressure in between the two, called **mean arterial pressure** (MAP). Mean arterial pressure converts a pulsatile pressure (systolic/diastolic) into a continuous pressure that determines the average rate of blood flow from the beginning of the circuit (left ventricle) to the end of the circuit (right atrium).

During the cardiac cycle, or one heartbeat, the ventricle spends more time in diastole than it spends in systole. As a result, mean arterial pressure is not the mathematical average of systolic and diastolic pressure but rather an approximation of the geometric mean. Mean Arterial Pressure (MAP) can be calculated using either of the following equations:

\[
\text{MAP} = \frac{\text{pulse pressure}}{3} + \text{diastolic pressure}
\]

**OR**

\[
\text{MAP} = \frac{(\text{systolic pressure} + 2 \times \text{diastolic pressure})}{3}
\]

If systolic pressure were 120 mm Hg and diastolic pressure were 60 mm Hg, then the mean arterial pressure would be 80 mmHg, as calculated below:

\[
\text{MAP} = \frac{60}{3} + 60 = 20 + 60 = 80 \text{ mmHg}
\]

**OR**

\[
\text{MAP} = \frac{(120 + 2 \times 60)}{3} = \frac{(120 + 120)}{3} = \frac{240}{3} = 80 \text{ mmHg}
\]

**IMPORTANT CONCEPT!**

Systemic arterial blood pressure is commonly measured with **indirect** methods because direct methods of measurement are invasive and neither practical nor convenient for routine use. It is important to recognize the limitations of indirect measurement:

- Indirect methods can only give an **approximation** of the actual blood pressure.
- Indirect methods may be influenced by the person taking the measurement—for example, the person may not be able to hear the sound changes accurately.
- Indirect methods can be influenced by the quality and calibration of the equipment being used.

The most common indirect method of measuring systemic arterial blood pressure involves the use of a stethoscope or microphone and a sphygmomanometer. This is referred to as an **auscultatory** method, which simply means diagnostic monitoring (via stethoscope) of the sounds made by internal organs.

The sounds detected during blood pressure measurement are referred to as **Korotkoff Sounds** and were first identified by Russian surgeon Nicolai Sergeivich Korotkov in 1905.

Arterial pressure is determined by placing an inflatable rubber cuff, attached to a pressure gauge, around the arm, inflating it to collapse the underlying artery, and listening over the vessel below the cuff with a stethoscope or microphone (Fig. 16.5).
Sound is created by the turbulent flow of blood through the compressed vessel. When cuff pressure exceeds systolic arterial pressure, the artery is collapsed, blood flow through it ceases, and no sound is produced. As cuff pressure is slowly reduced, blood flow through the artery begins when cuff pressure falls just below systolic arterial pressure.

At this point, a sharp tapping sound (the first sound of Korotkoff) may be heard with the stethoscope or microphone over the artery. The cuff pressure when this sound is first heard is taken as an approximation of systolic pressure.

As cuff pressure is further reduced, the sounds increase in intensity (and may resemble swishing), then suddenly become muffled (the second sound of Korotkoff) at the level of diastolic pressure, then disappear. Sounds disappear when the vessel is no longer compressed by the pressure cuff and normal non-turbulent blood flow resumes.

Since it is easier to determine when the sound disappears than when it becomes muffled, and since only a few millimeters of mercury pressure differential exist between the two, the disappearance of sound is commonly used as an indicator of diastolic pressure.

Figure 16.6 is a graphic display that summarizes this concept. The diagram shows the relationship in time between the ECG waveform, the Korotkoff sounds (as heard through the stethoscope), the cuff pressure, the blood pressure pulse waveform (at the arm), and the condition of the brachial artery under the cuff. The pulse waveform represents the brachial pressure in the artery above the cuff. The shaded area of the Aortic pressure wave represents the blood flow that can pass below the cuff as soon as the aortic pressure exceeds the cuff pressure.
One concept that can be examined in this lesson is the timing of the Korotkoff sounds with respect to the ECG waveform. The sounds appear at about the time of the T-wave. This sound occurs approximately near the time of peak pressure (systole), which, if measured at the heart, would occur immediately after the R-wave. However, there is a delay due to the time it takes the pressure wave to reach the arm, so the sounds are shifted in time with respect to the R-wave. Although the ECG wave will vary based on the experimental condition (i.e., pre-exercise, post-exercise), the relationship of the P-wave to the sound should be a consistent interval within each condition. Using this fact, you will be able to distinguish actual Korotkoff sounds from extraneous noise.

- In some cases (such as when a Subject has hypertension) you may notice what is called an “auscultatory gap.” This occurs when you hear sound at a higher cuff pressure, but it fades out as the pressure is decreased, and then reappears at a still lower pressure. This may require an alternate method of blood pressure measurement, using a strictly palpatory technique.

By convention, blood pressures determined by indirect methods are expressed in the form of a ratio: systolic pressure/diastolic pressure. For example, if systolic pressure was measured as 135 mm Hg and diastolic pressure was measured as 80 mm Hg, systemic arterial blood pressure would be expressed as 135/80, and pulse pressure would be 55 mm Hg. If the sound became muffled at 85 mm Hg and disappeared at 80 mm Hg, the systemic arterial blood pressure would be expressed as 135/85-80.

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**A note about your BP reading from this lab**

There are many factors that influence blood pressure measurement, such as: genetics, age, body weight, state of physical activity, level of salt, caffeine or other drugs in the system, monitor’s hearing, etc.

The Journal of the American Medical Association published the following blood pressure classification data (Table 16.1) from the Seventh Report of the National High Blood Pressure Education Program’s Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7):

<table>
<thead>
<tr>
<th>BP Classification</th>
<th>Systolic mmHg</th>
<th>Diastolic mmHg</th>
<th>Lifestyle Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&lt; 120</td>
<td>&lt; 80</td>
<td>Encourage</td>
</tr>
<tr>
<td>Prehypertension</td>
<td>120-139</td>
<td>80-89</td>
<td>Yes</td>
</tr>
<tr>
<td>Stage 1 hypertension</td>
<td>140-159</td>
<td>90-99</td>
<td>Yes</td>
</tr>
<tr>
<td>Stage 2 hypertension</td>
<td>≥ 160</td>
<td>≥ 100</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Note:* Diagnosis of high blood pressure is based on the average of two or more readings taken at each of two or more visits after initial screening. Unusually low readings should be evaluated for clinical significance.

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Table 16.1 JNC 7 Blood Pressure Classifications

If your blood pressure as determined from this lesson is “high,” you should not be too concerned. A mistake may have been made in the measurement, or there may be other factors affecting your system that resulted in a temporarily high reading.

If you are concerned about it, please consult your doctor. Do not try to diagnose or treat yourself based on the laboratory blood pressure readings.
Lesson 16: Blood Pressure

Please review the following procedure before you come into the lab so recording can proceed quickly.

**Blood Pressure Measurement**

The following is a review of the basic clinical blood pressure measurement procedure using the sphygmomanometer and stethoscope, with an explanation of the logic behind each step.

As discussed earlier, this is an indirect blood pressure measurement. It can be fairly accurate if performed exactly as described, but will nonetheless provide only an approximation of the absolute blood pressure.

It is important that you try to minimize errors by following the measurement procedure as detailed, and it is also important that you realize it is impossible to eliminate all errors.

*Note:* The actual procedure used in this lesson will have a few additional steps since you will be simultaneously recording the parameters.

<table>
<thead>
<tr>
<th>Basic measurement step</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Select the proper size cuff for your Subject.</td>
<td>The BIOPAC sphygmomanometer cuff is designed for arms with a circumference from 25.4 cm (10 inches) to 40.6 cm (16 inches). This is the standard adult range, and is marked on the cuff to make sure you fall within it. If this cuff does not fit your Subject, you should use another Subject for this lesson so the readings are accurate. Cuffs come in several sizes and it is important that you select the right size cuff for the Subject’s arm because if the cuff is too large you may get incorrect low readings, and if it is too small you may get incorrect high readings.</td>
</tr>
<tr>
<td>2. Make sure all the air in the sphygmomanometer cuff is expelled before use.</td>
<td>If air is left in the cuff you may get a false high reading because an excessive amount of pressure will be required to occlude the brachial artery.</td>
</tr>
<tr>
<td>3. Close the valve.</td>
<td>You need to minimize the effects of gravity. Arm above heart level can give false low readings, and arm below heart level can give false high readings.</td>
</tr>
<tr>
<td>4. Position the Subject’s arm at heart level.</td>
<td>The cuff pressure must be applied directly to the artery, which requires the bladder inside the cuff to be in the proper position.</td>
</tr>
<tr>
<td>5. Place the cuff so that the “Artery” label is over the Subject’s brachial artery (with the arrow on the label facing down).</td>
<td>The cuff edge should be high enough to avoid covering any part of the stethoscope diaphragm. This is to minimize any extraneous noise cause by the cuff rubbing against the diaphragm.</td>
</tr>
<tr>
<td>6. Position the cuff such that the lower edge of the cuff is 1.5 to 2 inches above the antecubital fossa (inner aspect of elbow).</td>
<td></td>
</tr>
<tr>
<td>7. Wrap the cuff evenly and snugly around the Subject’s arm and allow the Velcro® to hold it in place.</td>
<td>A loose cuff can give a false high reading because of the increased pressure required to occlude the brachial artery.</td>
</tr>
<tr>
<td></td>
<td>After it is snugly in place, you may wish to inflate the cuff slightly (10-20 mmHg) so that it will stay in place.</td>
</tr>
<tr>
<td>Step we will use:</td>
<td>Reason</td>
</tr>
<tr>
<td>------------------</td>
<td>--------</td>
</tr>
<tr>
<td>8. Make sure all the rubber tubing and cables of both the sphygmomanometer cuff and stethoscope are not tangled or pinched.</td>
<td>Any tubing on the sphygmomanometer that is pinched can cause false pressure reading and if the stethoscope tubing is pinched, it can greatly reduce the loudness of the Korotkoff sounds.</td>
</tr>
<tr>
<td>9. Position the sphygmomanometer pressure dial indicator such that you can read the face of the dial straight on.</td>
<td>Reading the dial at an angle can cause inaccurate readings due to parallax error.</td>
</tr>
<tr>
<td></td>
<td>- The dial indicator can be clipped to the strap sewn into the cuff above the “Artery” label.</td>
</tr>
<tr>
<td>Notes for the following steps:</td>
<td>Besides causing pain for the Subject, an overinflated cuff may produce a vasospasm, which can cause incorrect pressure readings.</td>
</tr>
<tr>
<td></td>
<td>- Besides discomfort for the Subject (which can elevate blood pressure), occlusion of blood caused by the cuff creates venous congestion in the forearm. The blood must be allowed to drain or it can lead to incorrect pressure readings. For the same reason, it important to wait at least one (1) minute between successive blood pressure measurements.</td>
</tr>
<tr>
<td>a) It is important to not inflate the cuff higher than is needed.</td>
<td></td>
</tr>
<tr>
<td>b) It is important to not leave the cuff at a high pressure for an extended period of time.</td>
<td></td>
</tr>
<tr>
<td>10. Palpate the brachial artery between the antecubital fossa and the lower edge of the cuff to find where the pulse is best felt.</td>
<td>The stethoscope diaphragm needs to be placed over the brachial artery where the Korotkoff sounds are best heard.</td>
</tr>
<tr>
<td></td>
<td>- Use your first and second fingers to feel the pulsation of the brachial artery on the inside of your elbow.</td>
</tr>
<tr>
<td></td>
<td>- During the actual lesson, you can note this position by marking the spot with a washable felt pen.</td>
</tr>
<tr>
<td>Alternate technique:</td>
<td></td>
</tr>
<tr>
<td>10. Inflate the cuff to 110 mmHg and place the stethoscope diaphragm over the brachial artery between the antecubital fossa and the lower edge of the cuff and move it around to find the place where the sounds are best heard.</td>
<td>This alternate procedure can result in optimal placement of the stethoscope diaphragm, but it can take longer to find. As noted above, it is not safe to inflate the cuff for a long period of time, so this technique is not used in the lesson because when you add the steps required to perform the recording, it simply takes too long.</td>
</tr>
<tr>
<td>11. Inflate the cuff to 160 mmHg.</td>
<td>If cuff is not inflated high enough, true systolic pressure may be missed.</td>
</tr>
<tr>
<td></td>
<td>- Pump the cuff rapidly then release to reduce distal vasculatory engorgement.</td>
</tr>
<tr>
<td></td>
<td>- It is assumed that the majority of Subjects in the physiology lab will have systolic pressures below this pressure.</td>
</tr>
<tr>
<td>Reason</td>
<td></td>
</tr>
<tr>
<td>If cuff is not inflated high enough, true systolic pressure may be missed.</td>
<td></td>
</tr>
<tr>
<td>This technique has the advantage of being quick and easy, and for reasons discussed above, it is preferable to minimize the amount of time the cuff is at high pressure. The disadvantage of this technique is that it uses more pressure than most Subjects probably need, and (in rare cases) it may miss the point of diastolic pressure. However, because a simultaneous recording</td>
<td></td>
</tr>
</tbody>
</table>
### Alternate technique:

11. Either by listening through the stethoscope, or by palpating the radial artery (on flexor surface of wrist), inflate the cuff 20 to 30 mmHg above the point at which the sounds or pulse disappear. This technique makes sure the cuff pressure does not go excessively high.

12. Place the stethoscope in the correct position. Do not push down excessively on it and try to maintain a constant pressure against the skin. Excessive pressure could distort the artery and give incorrect pressure indications (usually gives a diastolic pressure reading that is too low). Also, excessive pressure can cause the stethoscope to rub on the Subject’s skin, which may generate extraneous noise.

13. Release the pressure at a rate of 2 to 3 mmHg/second. Deflating too slowly produces venous congestion, which can give false high diastolic pressure readings. Deflating too rapidly leads to inaccuracies because the actual point of systolic or diastolic pressure could lie between heartbeats. The slower the heart rate, the more inaccurate the reading.

14. Note the pressure at which the Korotkoff sounds first appear (systolic). This sound indicates the pressure closest to the systolic pressure.

15. Continue to listen and note the pressure when the sounds completely disappear (diastolic). This pressure is close to the point of diastolic pressure. Note: The point at which the sounds become muffled is closer to the diastolic pressure but since it’s easier to detect the disappearance of sound—and the difference between the two is small—we will use the point of disappearance of sound.

16. Deflate the cuff as rapidly as possible after all the sounds disappear. This will minimize patient discomfort and reduce venous congestion.

When evaluating a patient or Subject, you will normally take their blood pressure at different points in time and/or under different circumstances (at rest vs. after exercise, etc.) to see how the blood pressure changes. With this in mind, it becomes important that your technique is consistent every time you do it. If two people use different techniques, they may get slightly different readings, but the difference (or delta) — which can be the more important factor — will be very consistent for each person.
II. EXPERIMENTAL OBJECTIVES

1. To use an auscultatory method for an indirect determination of systemic arterial systolic and diastolic blood pressures and to correlate the appearance and disappearance of vascular sound with systolic and diastolic pressures respectively.

2. To measure, record, and compare systemic arterial blood pressure in the right arm and the left arm of the same Subject under identical conditions.

3. To measure, record, and compare systemic arterial blood pressures in the same Subject under different experimental conditions of rest and exercise.

4. To compute and compare pulse pressure and mean arterial pressure under different experimental conditions of rest and exercise.

5. To compute the pulse pressure wave velocity by measuring the time between the R-wave of the ECG and the Korotkoff sounds.

III. MATERIALS

- BIOPAC Blood Pressure Cuff (SS19L)
- BIOPAC Stethoscope (SS30L)
- BIOPAC electrode lead set (SS2L)
- BIOPAC disposable vinyl electrodes (EL503), 3 electrodes per Subject
- BIOPAC electrode gel (GEL1)
- BIOPAC abrasive pad (ELPAD)
- Rubbing alcohol and swab (to clean stethoscope earpieces and stethoscope diaphragm)
- Tape measure (for pulse speed calculation)
- Optional: washable felt pen (to mark stethoscope placement on arm)
- Computer system
- Biopac Student Lab 3.7
- BIOPAC data acquisition unit (MP36, MP35, or MP30 with cable and power)
### IV. EXPERIMENTAL METHODS

For further explanation, use the online support options under the Help Menu.

#### A. SET UP

<table>
<thead>
<tr>
<th>FAST TRACK Set Up</th>
<th><strong>DETAILLED EXPLANATION OF SET UP STEPS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Select your lab group.</td>
<td><strong>Lab Group Requirements:</strong></td>
</tr>
<tr>
<td><strong>CAUTION!</strong></td>
<td>You should work in a group of at least 3 people. One person will be the <strong>Subject</strong>, one (the <strong>Recorder</strong>)) will operate the computer, and another person (the <strong>Director</strong>) will perform the blood pressure measurement.</td>
</tr>
<tr>
<td><strong>Subject</strong> selected must not have had or now have any disorder, hypertension, heart surgery, stroke, or any history of cardiovascular degeneration.</td>
<td>The <strong>Subject</strong> must meet the qualifications listed to the left.</td>
</tr>
<tr>
<td><strong>Subject</strong> must not have consumed caffeine, smoked, or performed heavy exercise within one hour of the recording.</td>
<td>The <strong>Recorder</strong> is responsible for starting and stopping the recording, and adding markers to the recording. Only the <strong>Recorder</strong> should look at the computer screen.</td>
</tr>
<tr>
<td><strong>Subject</strong> must meet the qualifications listed to the left.</td>
<td>The <strong>Director</strong> should perform the measurement normally, without regard to the recording aspect, but should call out the points of systolic and diastolic pressure so that the <strong>Recorder</strong> can add the markers to the data recording.</td>
</tr>
<tr>
<td>2. Turn the computer <strong>ON</strong>.</td>
<td>The name of the lesson file should be the <strong>Director</strong>’s name.</td>
</tr>
<tr>
<td>3. Make sure the BIOPAC MP3X unit is turned <strong>OFF</strong>.</td>
<td>The desktop should appear on the monitor. If it does not appear, ask the laboratory instructor for assistance.</td>
</tr>
</tbody>
</table>
| 4. Plug the equipment in as follows (Fig. 16.7): | ![Figure 16.7](image)
- BP Cuff (**SS19L**) — **CH 1**
- Stethoscope (**SS30L**) — **CH 3**
- Electrode lead set (**SS2L**) — **CH 4**
| 5. Turn the MP3X Data Acquisition Unit **ON**. | Blood Pressure Cuff (**SS19L**) plugs into CHannel 1
- Stethoscope (**SS30L**) plugs into CHannel 3
- Electrode Lead Set (**SS2L**) plugs into CHannel 4 |
| 6. Clean the stethoscope earpieces and diaphragm. | Before using the stethoscope, clean each earpiece with rubbing alcohol and allow it to dry completely. You should also clean the surface of the stethoscope diaphragm (the part that comes in contact with the skin) for each new **Subject**. |

Set Up continues…
7. Place three electrodes on the Subject as shown. Fig 16.8.
   - There is an alternate placement shown on page 13 which may not be practical in every lab group, but will yield the best data.

8. Attach the electrode lead set (SS2L) to the electrodes as shown, paying close attention to the lead colors (Fig. 16.9).

The standard electrode placement is shown in Fig. 16.8 below.

It is important that you follow the electrode procedure below to obtain an optimal ECG recording:

a) Abrade the surface of the skin at the points of electrode placement (see following figure) in about a 2” diameter. Do not use alcohol to clean the skin. Alcohol will dry the skin and prevent good electrical contact with the electrode.

b) Peel off an electrode using the tab. Try not to touch the adhesive.

c) Place a drop of GEL1 electrode gel onto the small sponge of the electrode (without allowing any gel to get on the adhesive).

d) Attach the electrodes to the skin in the positions shown (over the previously abraded areas).

![Figure 16.8 Standard Electrode placement](image)

![Figure 16.9 Standard electrode lead attachment](image)

Each of the pinch connectors on the end of the electrode cable needs to be attached to a specific electrode. The electrode cables are each a different color and you should follow the figure provided to ensure that you connect each cable to the proper electrode.

The pinch connectors work like a small clothespin, but will only latch onto the nipple of the electrode from one side of the connector.

Position the electrode cables such that they are not pulling on the electrodes. Connect the electrode cable clip (where the cable meets the three individual colored wires) to a convenient location (can be on the Subject’s clothes). This will relieve cable strain.
9. Open the cuff valve and roll the cuff in on itself, then press to flatten and close the valve. This will release all pressure from the cuff.

10. Start the Biopac Student Lab Program.

11. Choose Lesson 16 (L16-Bp-1).

12. Type in the Director’s filename. Use a unique identifier. The file name should be the Director’s identifier (the one performing the blood pressure measurement vs. the Subject).

13. Click OK. This ends the Set Up procedure.

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An alternate electrode placement is shown below. This placement will yield the best results but may not be practical in your lab.

Figure 16.10 Alternate electrode lead attachment
## B. CALIBRATION

The Calibration procedure establishes the hardware’s internal parameters (such as gain, offset, and scaling) and is critical for optimum performance. **Pay close attention to the Calibration procedure.**

<table>
<thead>
<tr>
<th>FAST TRACK Calibration</th>
<th>DETAILED EXPLANATION OF CALIBRATION STEPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Double check the electrodes and stethoscope, and make sure the <strong>Subject</strong> is relaxed and sitting down. <strong>Note that cuff is not on Subject during calibration.</strong></td>
<td>Make sure the electrodes adhere securely to the skin. If they are being pulled up, you will not get a good ECG signal. The <strong>Subject</strong> must be relaxed during the calibration procedure so that the muscle (EMG) signal does not corrupt the ECG signal.</td>
</tr>
<tr>
<td>2. <strong>Click Calibrate.</strong></td>
<td>The <strong>Calibrate</strong> button is in the upper left corner of the Setup window. This will start the calibration recording.</td>
</tr>
<tr>
<td>3. <strong>Director</strong> should inflate the cuff to 100 mmHg and then tell the <strong>Recorder</strong> that he/she is ready.</td>
<td>Pump the bulb to inflate the cuff until the gauge reads 100 mmHg. (You may need to pump 10 to 12 times to establish enough pressure in the cuff for a gauge reading.)</td>
</tr>
<tr>
<td>4. <strong>Recorder</strong> should click <strong>OK.</strong></td>
<td>Follow the prompt:</td>
</tr>
<tr>
<td>5. <strong>Director</strong> should deflate the cuff to 40 mmHg and then tell the <strong>Recorder</strong> that he/she is ready.</td>
<td>(Do not worry if you are not exactly at 40mmHg. But it is important to try to keep the pressure constant.)</td>
</tr>
<tr>
<td>6. <strong>Recorder</strong> should click <strong>OK.</strong></td>
<td><strong>Recorder</strong> should wait until the <strong>Director</strong> gives the go ahead.</td>
</tr>
<tr>
<td>7. <strong>Recorder</strong> should read the prompt to <strong>Director</strong> and click <strong>OK.</strong></td>
<td>Use the pressure release valve to deflate the cuff pressure to 40 mmHg.</td>
</tr>
<tr>
<td>8. <strong>Director</strong> should tap the stethoscope diaphragm twice.</td>
<td>Follow the prompt:</td>
</tr>
<tr>
<td>9. Wait for the calibration to stop.</td>
<td>(Do not worry if you are not exactly at 40mmHg. But it is important to try to keep the pressure constant.)</td>
</tr>
<tr>
<td>Calibration continues…</td>
<td><strong>Recorder</strong> should wait until the <strong>Director</strong> gives the go ahead.</td>
</tr>
<tr>
<td></td>
<td>When you click <strong>OK</strong> the calibration recording will begin.</td>
</tr>
<tr>
<td></td>
<td><strong>After</strong> the calibration recording begins, lightly tap the stethoscope diaphragm twice.</td>
</tr>
<tr>
<td></td>
<td>The calibration recording stops automatically after 8 seconds.</td>
</tr>
</tbody>
</table>
10. **Check** the calibration data:

- If similar, proceed to Data Recording.
- If different, **Redo Calibration**.

**END OF CALIBRATION**

Your calibration recording should resemble Fig. 16.11.

![Figure 16.11](image)

The pressure waveform should be riding at about 40 mmHg and should not decline during the calibration recording.

- If your data resembles Fig. 16.11, proceed to the Data Recording section.
- If the pressure waveform declines or if the data shows any large spikes, jitter, or large baseline drifts, make sure the valve is fully closed (clockwise) and check the hose connections on the cuff to make sure they are tight, then click **Redo** and repeat the entire calibration.
- If the ECG waveform is excessively noisy and the **Subject** was completely relaxed, and if the ECG baseline drifts excessively, then one or more of the electrodes are not making good electrical contact with the skin. Review Setup Steps 7-8 (page 12) and make sure that the electrode has not peeled up.

**Practice pressure release**

To obtain accurate measurements, it is important that the cuff pressure is released at a rate of 2-3 mmHg per second. You are encouraged to practice pressure release several times before proceeding to the recording segment. To practice, you’ll need a watch or clock with a second hand. The following steps will help you develop a consistent pressure release technique:

a) Open the cuff valve and roll the cuff in on itself, then press to flatten and close the valve.
   - This will release all pressure from the cuff.

b) Pump the cuff bulb until the pressure dial reads 160 mmHg.

c) Tell the timer when you are ready, and slowly turn the valve counter-clockwise to begin releasing the cuff pressure.
   - Open the valve slowly so that you don’t have a large pressure drop, and try to maintain an even release.
   - To keep the release rate constant, you may need to open the valve more as the cuff pressure diminishes.

d) When pressure is at 100 mmHg, say “Stop” and ask the timer how long that took.
   - It should take you about 20-30 seconds to drop 60 mmHg.

e) Repeat as necessary until you can release cuff pressure at 2-3 mmHg per second.
C. RECORDING LESSON DATA

FAST TRACK Recording

1. Prepare for the recording.

   **CAUTION!**
   Do not inflate the cuff higher than is needed. Never leave the cuff at high pressure (more than 120 mmHg) for more than 1 minute.

2. Review the Blood Pressure measurement procedure provided in the Introduction (page 7).

3. Make sure all the air in the sphygmomanometer cuff is expelled and close the pressure release valve.

4. Place the cuff on the Subject’s left arm so that the “Artery” label is over the brachial artery (with the arrow on the label facing down).

5. Position the cuff such that the lower edge of the cuff is 1.5 to 2 inches above the antecubital fossa (inner aspect of elbow).

Recording continues…

**DETAILED EXPLANATION OF RECORDING STEPS**

This lesson records blood pressure and heart sounds in a total of eight segments. Three channels of data will be displayed during the recording: ECG, Stethoscope, and Pressure.

**Hints for obtaining optimal data:**

a) **Subject** must not have consumed caffeine or smoked within one hour of the recording and should relax for a few minutes before recording begins.

b) The **Subject** should never hold up his/her own arm or flex the bicep muscle. The arm must be in a relaxed state to minimize EMG artifact.

c) **Subject’s** clothing should not interfere with electrodes during the recording; **Subject** may need to lift his/her top during the recording.

d) The **Director** should find an arrangement that makes it easy to inflate and deflate the cuff while viewing the pressure dial indicator.

e) **Director** must not leave the cuff at a high pressure for an extended period of time.

f) Earpieces of the stethoscope should not be too tight.

g) Apply the electrodes at least 5 minutes before exercising. Sweating tends to affect the adhesion of the electrodes to the skin.

h) The room should be quiet so you can easily hear the sounds through the stethoscope.

It is hoped that you will review the procedure before you come into the lab, so that you may go through the recordings more quickly. The lesson will carefully guide you through all the steps, but it important to review the core part of the measurement. In the real clinical setting you will probably not be simultaneously recording the data.

Turn the release valve fully counter-clockwise and roll the cuff up while squeezing it. Turn the pressure release valve fully clockwise.

There is an “Artery” label (with arrow) that is sewn into the cuff.

The first recording is done on the **Subject’s** left arm.

The cuff edge should be high enough to avoid covering any part of the stethoscope diaphragm.
6. Wrap the cuff evenly and snugly on the Subject’s arm (Fig. 16.12). The Velcro® wrap should hold the cuff in place, but you may wish to inflate the cuff slightly (10-20 mmHg) so that it will stay in place.

7. Position the sphygmomanometer pressure dial so you can read the face of the dial straight on. A strap sewn into the cuff above the “Artery” label allows the dial indicator to be clipped in if desired.

8. Check that the tubing and cables are not tangled or pinched. Make sure none of the rubber tubing and cables of the sphygmomanometer cuff or the stethoscope are tangled or pinched.

9. Position the Subject’s arm at heart level (Fig. 16.13). Find a position that is comfortable for the Director and the Subject. Director may hold up the Subject’s arm, or Subject may rest his/her arm on the lab table.

Note: Director should hold the pump bulb as shown, with both fingers on the release valve so it can be easily turned.

Recording continues…
10. Palpate the brachial artery between the antecubital fossa and the lower edge of the cuff to find where the pulse is best felt.
   - Use your first and second finger.
   - Subject may make a fist to help locate pulse, but should relax arm for the recording.

11. Mark this spot with a washable felt pen.

12. Make sure the “Artery” label of the cuff is aligned with the pulse point.

13. Place the stethoscope in the correct position and apply firm but not excessive contact pressure.

Use your first (index) and second (middle) fingers to feel the pulsation of the brachial artery on the inside of the elbow. This can be tricky, but after a few tries you should get the hang of it. It may help if the Subject makes a fist while you are trying to locate the pulse.

Once you have located the pulse, mark the spot by tracing along the edge of the top and bottom of the stethoscope diaphragm, so you can use it for the other recording segments.

You need to press firmly enough to establish good contact sound, but you shouldn’t be pressing too hard into the Subject’s arm.

Problems you may encounter:

a) You can’t hear the Korotkoff sounds.
   With some people, it is just difficult to hear the Korotkoff sounds off of their arm. This does not mean that anything is wrong with the person’s physical state, so do not alarm them — it’s just a fact of life. If this is the case, wait one minute and repeat the measurement using a slightly different position for the stethoscope diaphragm and/or using the other arm.
   Another possibility is that your hearing is not acute enough to detect the sounds, but the recording is picking them up, which for the purposes of this lesson is ok. In a real clinical setting, if you could not hear the sounds, you would need to try a strictly palpatory method to get the reading. For this lab, since you probably have a time constraint, you might just switch Subjects.

b) You hear an auscultatory gap.
   Wait at least 1 minute, then try the measurement again. If this second reading fails, then use the palpatory method with the brachial or radial artery while inflating the cuff and note the point where the pulse is no longer felt. This value will be the Subject’s approximate systolic pressure value. The diastolic value should be found the normal way (disappearance of all sounds). The recording will not be accurate, but it will allow you to finish the lessons and answer the questions.

Recording continues…
Segment 1 — Left arm, sitting up

14. **Recorder** should click on **Record** when **Director** is ready.

15. **Director** should inflate the cuff to 160 mmHg and say when ready.

**CAUTION!**

Do not leave the cuff at this pressure for more than 1 minute.

16. **Recorder** should click **OK**.

17. **Director** should release the pressure at a rate of 2 to 3 mmHg/second and call out when the Korotkoff sounds first appear (systolic).

**Recorder** insert an event marker.

∇ Systolic

18. **Director** should continue to listen and call out when the pressure sounds completely disappear (diastolic).

**Recorder** insert an event marker and click **Suspend**.

∇ Diastolic

19. **Director** should deflate the cuff as rapidly as possible after all the sounds disappear.

20. Review the data on the screen (Fig.16.14).

⁻ If **correct**, go to Step 21.

⁻ If **incorrect**, **Redo**.

When you click **Record**, the recording will begin and an append marker labeled “First recording with cuff on left arm, while sitting up and relaxed” will automatically be inserted.

The majority of **Subjects** in the physiology lab will have systolic pressures below this pressure. Pump the cuff rapidly then release to reduce distal vasculatory engorgement.

The first sound (which may resemble a sharp tapping) indicates the pressure closest to the **systolic pressure**.

To insert an event marker, press the **F9** key. Enter a marker label. Markers and labels can be edited after recording.

This pressure is close to the point of **diastolic pressure**.

If sound diminishes but never disappears, note diastolic at the point sound diminishes.

To insert an event marker, press the **F9** key. Enter a marker label. Markers and labels can be edited after recording.

This will minimize patient discomfort and reduce venous congestion. Note: Some noise from the rapidly deflating cuff may be recorded on the stethoscope channel. This is normal.

Figure 16.14 After first recording segment

The **Pressure wave** should be a decreasing slope.

The **sound wave** (in the **Stethoscope** channel) should show the appearance of the Korotkoff sounds, with little noise before or after. If you see little sounds recorded, the stethoscope was probably not placed well and you should redo the recording. The **ECG wave** should not have too much noise in it.
**Segment 2 — Left arm, sitting up**

21. **Recorder** should click **Resume**.

22. **Director** should inflate the cuff to the pressure of Korotkoff sound detection and say when ready.

23. **Recorder** should click **OK**.

24. **Director** should release the pressure at a rate of 2 to 3 mmHg/second and call out when systolic and then diastolic are detected.

   **Recorder** should insert event markers and then click **Suspend**.

   ![Systolic](image1)  
   ![Diastolic](image2)

25. **Director** should deflate the cuff as rapidly as possible after all the sounds disappear.

26. Review the data on the screen.
   - If correct, go to Step 27.
   - If incorrect, **Redo**.

**Segment 3 — Right arm, sitting up**

27. Switch the cuff to the **Subject’s** right arm.

28. **Recorder** should click **Resume**.

29. **Director** returns the cuff pressure to the level of Korotkoff sounds and says when all is ready.

   - **Subject** remains relaxed and seated with arm at heart level.

30. **Recorder** clicks **OK**.

31. **Director** should release the cuff pressure at 2-3 mmHg/second and call out when systolic and then diastolic sounds are detected.

   **Recorder** should insert event markers and then click **Suspend**.

   ![Systolic](image3)  
   ![Diastolic](image4)

32. **Director** should deflate the cuff as rapidly as possible after all the sounds disappear.

   **Recording continues…**

A dialog box is generated instructing the **Director** to inflate the cuff.

When you click **OK**, the recording will continue and an append marker labeled “Second recording with cuff on left arm, while sitting up and relaxed” will automatically be inserted.

To insert an event marker, press the **F9** key. Enter a marker label. Markers and labels can be edited after recording.

Click **Suspend** after diastolic is detected.

If sound diminishes but never disappears, note diastolic at the point sound diminishes.

This will minimize patient discomfort and reduce venous congestion. Note: Some noise from the rapidly deflating cuff may be recorded on the stethoscope channel at this point. This is normal.

See the data sample on page 19 for comparison.

Follow the previously detailed cuff placement guidelines and prepare for recording (see Steps 3-13).

A dialog box is generated instructing the **Director** to inflate the cuff.

When you click **OK**, the recording will continue and an append marker labeled “First recording with cuff on right arm, while sitting up and relaxed” will automatically be inserted.

To insert an event marker, press the **F9** key. Enter a marker label. Markers and labels can be edited after recording.

Click **Suspend** after diastolic is detected.

If sound diminishes but never disappears, note diastolic at the point sound diminishes.

This will minimize patient discomfort and reduce venous congestion. Note: Some noise from the rapidly deflating cuff may be recorded on the stethoscope channel at this point. This is normal.
33. Review the data on the screen.
   ➢ If correct, go to Step 34.
   ➢ If incorrect, Redo.

See the data sample on page 19 for comparison.

Segment 4 — Right arm, sitting up

34. **Recorder** should click **Resume**.

35. **Director** should return the cuff pressure to the level of Korotkoff sounds and say when ready.
   ➢ **Subject** is sitting up.

A dialog box is generated instructing the **Director** to inflate the cuff.

36. **Recorder** should click **OK**.

37. **Director** should release the cuff pressure at 2-3 mmHg/second and call out when **systolic** and then **diastolic** sounds are detected.

   **Recorder** should insert event markers and then click **Suspend**.

   ✓ **Systolic**
   ✓ **Diastolic**

To insert an event marker, press the **F9** key. Enter a marker label. Markers and labels can be edited after recording.

38. **Director** should deflate the cuff as rapidly as possible after all the sounds disappear.

Click **Suspend** after diastolic is detected.

If sound diminishes but never disappears, note diastolic at the point sound diminishes.

Recording continues…

39. Review the data on the screen.
   ➢ If correct, go to Step 40.
   ➢ If incorrect, Redo.

See the data sample on page 19 for comparison.

Segment 5 — Right arm, lying down

40. **Subject** should lie down and relax.

A dialog box is generated instructing the **Director** to inflate the cuff.

41. **Recorder** should click **Resume**.

42. **Director** should return the cuff pressure to the level of Korotkoff sounds and say when ready.

43. **Recorder** should click **OK**.

44. **Director** should release the cuff pressure at 2-3 mmHg/second and call out when **systolic** and then **diastolic** sounds are detected.

   **Recorder** should insert event markers and then click **Suspend**.

   ✓ **Systolic**
   ✓ **Diastolic**

This will minimize patient discomfort and reduce venous congestion. Note: Some noise from the rapidly deflating cuff may be recorded on the stethoscope channel at this point. This is normal.

To insert an event marker, press the **F9** key. Enter a marker label. Markers and labels can be edited after recording.

Click **Suspend** after diastolic is detected.

If sound diminishes but never disappears, note diastolic at the point sound diminishes.
45. **Director** should deflate the cuff as rapidly as possible after all the sounds disappear.

46. Review the data on the screen.
   - If **correct**, go to Step 47.
   - If **incorrect**, **Redo**.

   **Segment 6 — Right arm, lying down**

47. **Recorder** should click **Resume**.

48. **Director** should return the cuff pressure to the level of Korotkoff sounds and say when ready.

49. **Recorder** should click **OK**.

50. **Director** should release the cuff pressure at 2-3 mmHg/second and call out when systolic and then diastolic sounds are detected.

   **Recorder** should insert event markers and then click **Suspend**.

   ▼ Systolic
   ▼ Diastolic

51. **Director** should deflate the cuff as rapidly as possible after all the sounds disappear.

52. Review the data on the screen.
   - If **correct**, go to Step 53.
   - If **incorrect**, **Redo**.

   **Segment 7 — Right arm, after exercise**

53. Disconnect the electrode lead cables from the **Subject** and confirm the **Subject** can safely exercise.

   **CAUTION**!
   **Subject** selected must not have had or now have any disorder, hypertension, heart surgery, stroke, or any history of cardiovascular degeneration.

   **Subject** must not have consumed caffeine, smoked, or performed heavy exercise within one hour of the recording.

   **Recording continues…**

This will minimize patient discomfort and reduce venous congestion. Note: Some noise from the rapidly deflating cuff may be recorded on the stethoscope channel at this point. This is normal.

See the data sample on page 19 for comparison.

**Subject** should continue to lie down and relax.

A dialog box is generated instructing the **Director** to inflate the cuff.

When you click **OK**, the recording will continue and an append marker labeled “Second recording with cuff on right arm, while lying down and relaxed” will automatically be inserted.

To insert an event marker, press the **F9** key. Enter a marker label. Markers and labels can be edited after recording.

Click **Suspend** after diastolic is detected.

If sound diminishes but never disappears, note diastolic at the point sound diminishes.

This will minimize patient discomfort and reduce venous congestion. Note: Some noise from the rapidly deflating cuff may be recorded on the stethoscope channel at this point. This is normal.

See the data sample on page 19 for comparison.

Remove the electrode lead cables prior to exercise.

Confirm that the **Subject** meets has no history of disorders and meets the requirements listed to the left before performing any exercise.
54. **Subject** should exercise to elevate heart rate to a moderate level and then sit to recover.

55. Reconnect electrode lead cables.

56. **Recorder** should click **Resume**.

57. **Director** should return the cuff pressure to the level of Korotkoff sounds and say when ready.

58. **Recorder** should click **OK**.

59. **Director** should release the cuff pressure at 2-3 mmHg/second and call out when **systolic** and then **diastolic** sounds are detected.

   **Recorder** should insert event markers and then click **Suspend**.

   ✓ **Systolic**
   
   ✓ **Diastolic**

60. **Director** should deflate the cuff as rapidly as possible after all the sounds disappear.

61. Review the data on the screen.
   - If correct, go to Step 62.
   - If incorrect, **Redo**.

   **Segment 8 — Right arm, after exercise**

62. If **Subject**’s heart rate has declined significantly, repeat exercise to elevate to a moderate level and then have the **Subject** sit to recover from the exercise.

63. **Recorder** should click **Resume**.

64. **Director** should return the cuff pressure to the level of Korotkoff sounds and say when ready.

65. **Recorder** should click **OK**.

66. **Director** should release the cuff pressure at 2-3 mmHg/second and call out when **systolic** and then **diastolic** sounds are detected.

   **Recorder** should insert event markers and then click **Suspend**.

   ✓ **Systolic**
   
   ✓ **Diastolic**

   Recording continues...

**Subject** should do 50 push-ups or run in place for 5-minutes to elevate the heart rate to a moderate level.

Check electrode adhesion and reconnect cables after exercise.

A dialog box is generated instructing the **Director** to inflate the cuff.

When you click **OK**, the recording will continue. An append marker “First recording with cuff on right arm, while sitting and recovering from exercise” will automatically be inserted.

To insert an event marker, press the **F9** key. Enter a marker label. Markers and labels can be edited after recording.

Click **Suspend** after diastolic is detected.

If sound diminishes but never disappears, note diastolic at the point sound diminishes.

This will minimize patient discomfort and reduce venous congestion. Some noise from the rapidly deflating cuff may be recorded on stethoscope channel at this point. This is normal.

See the data sample on page 19 for comparison.

67. **Segment 9 — Right arm, after exercise**

68. If **Subject**’s heart rate has declined significantly, repeat exercise to elevate to a moderate level and then have the **Subject** sit to recover from the exercise.

69. **Recorder** should click **Resume**.

70. **Director** should return the cuff pressure to the level of Korotkoff sounds and say when ready.

71. **Recorder** should click **OK**.

72. **Director** should release the cuff pressure at 2-3 mmHg/second and call out when **systolic** and then **diastolic** sounds are detected.

   **Recorder** should insert event markers and then click **Suspend**.

   ✓ **Systolic**
   
   ✓ **Diastolic**

   Recording continues...

Remove the electrode lead cables prior to exercise, then check electrode adhesion and reconnect cables after exercise.

A dialog box is generated instructing the **Director** to inflate the cuff.

When you click **OK**, the recording will continue. An append marker “Second recording with cuff on right arm, while sitting and recovering from exercise” will automatically be inserted.

To insert an event marker, press the **F9** key. Enter a marker label. Markers and labels can be edited after recording.

Click **Suspend** after diastolic is detected.

If sound diminishes but never disappears, note diastolic at the point sound diminishes.
67. **Director** should deflate the cuff as rapidly as possible after all the sounds disappear.

68. Review the data on the screen.
   - If correct, go to Step 69.
   - If incorrect, **Redo**.

69. Click **Done** and then **Yes**.

   This will minimize patient discomfort and reduce venous congestion. Note: Some noise from the rapidly deflating cuff may be recorded on the stethoscope channel. This is normal.

   See the data sample on page 19 for comparison.

70. Remove the electrodes and transducers.

   Click **Done** to end all lesson recordings. After you press **Done**, a prompt asking you to confirm that you are finished with all blood pressure recordings will appear.

   Click **Yes** and the blood pressure data will be written to the data file.

   After you click **Yes**, a pop-up window with options will appear. Make your choice, and continue as directed.

   If choosing the “Record from another Subject” option:
   - Repeat Set Up Steps 6-9 for new **Subject** and continue the entire lesson from Set Up Step 11.
   - Each **Subject** will need to use a unique file name.

   Remove the electrode cable pinch connectors, and peel off the electrodes. Throw out the electrodes and wash any residue from the skin. The electrodes may leave a slight ring on the skin for a few hours. This is normal, and will disappear.
V. DATA ANALYSIS

FAST TRACK Data Analysis

1. Enter the **Review Saved Data** mode and choose the correct file.

   Note Channel Number (CH) designations:

<table>
<thead>
<tr>
<th>Channel</th>
<th>Displays</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH 1</td>
<td>Cuff Pressure</td>
<td>mmHg</td>
</tr>
<tr>
<td>CH 3</td>
<td>Stethoscope</td>
<td>milliVolts</td>
</tr>
<tr>
<td>CH 4</td>
<td>ECG Lead II</td>
<td>milliVolts</td>
</tr>
</tbody>
</table>

2. Setup your display window for optimal viewing of the first recording segment.

3. Set up the measurement boxes as follows:

<table>
<thead>
<tr>
<th>Channel</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH 1</td>
<td>Value</td>
</tr>
<tr>
<td>CH 1</td>
<td>BPM</td>
</tr>
<tr>
<td>CH 1</td>
<td>ΔT</td>
</tr>
</tbody>
</table>

**Detailed Explanation of Data Analysis Steps**

This segment is the period from the first append marker (at Time Zero) to the next append marker.

The following tools help you adjust the data window:

- Autoscale horizontal
- Zoom Previous
- Autoscale waveforms
- Horizontal (Time) Scroll Bar
- Zoom Tool
- Vertical (Amplitude) Scroll Bar

The measurement boxes are above the marker region in the data window. Each measurement has three sections: channel number, measurement type, and result. The first two sections are pull-down menus that are activated when you click on them.

The following is a brief description of the measurements.

- **Value**: displays the amplitude value for the channel at the point selected by the I-beam cursor. If a single point is selected, the value is for that point, if an area is selected, the value is the endpoint of the selected area.

- **BPM**: Beats Per Minute first calculates the difference in time between the end and beginning of the area selected by the I-Beam tool (same as ΔT), and then divides this value into 60 seconds/minute.

- **ΔT**: The Delta Time measurement is the difference in time between the end and beginning of the selected area.

The “selected area” is the area selected by the I-Beam tool (including the endpoints).
4. Using the I-Beam cursor, select the point that corresponds to the first event marker (Fig. 16.16).

Complete the Data Report table with the requested measurements.

A — value measurements
(one measurement for each segment)

This is the event marker that was entered manually when the Director detected the systolic pressure point.

![Figure 16.16](image)

Note: In Figure 16.16, the value measurement represents cuff pressure at the selected point and the BPM measurement is not giving an accurate reading because only one point is selected with the I-beam cursor.

5. Select the point that corresponds to the first sound the stethoscope detected. (Fig. 16.17).

A — value measurements
(one measurement for each segment)

Note that to help distinguish a Korotkoff sound from other noise, you should note that the proper sound appears at a point in time corresponding to the T-wave of the ECG cycle. This can be of great assistance in determining the beginning and ending of sounds.

![Figure 16.17](image)

6. Select the point that corresponds to the second event marker (Fig. 16.18).

B
(one measurement for each segment)

This is the event marker that was entered manually when the Director detected the diastolic pressure point.

![Figure 16.18](image)

Data Analysis continues...
7. Select the point that corresponds to the end of the Korotkoff sounds (diastolic pressure) as recorded by the stethoscope (Fig. 16.19). This is the last sound detected by the stethoscope.

\[ B \]
(one measurement for each segment)

To help distinguish a Korotkoff sound from other noise, you should note that the proper sound will appear at a point in time corresponding to the T-wave of the ECG cycle.

---

8. Looking at the ECG complexes in the region between the systolic and diastolic pressure, select an area from one R-wave to the next R-wave (Fig. 16.20).

Note the reading for BPM and then repeat this measurement on two successive R-waves.

\[ C \]
(one measurement for each segment)

Note: BPM changes on a beat-by-beat cycle, so for the most accurate measurement you should take BPM (R-R) measurements on 3 successive R-waves and find the average BPM.

---

9. Zoom in on one of the ECG complexes in the time between systolic and diastolic pressure.

---

10. Using the I-beam cursor, select the area from the peak of the R-wave to the beginning of the sound detected by the stethoscope (Fig. 16.21).

Note the \( \Delta T \) measurement.

\[ E \]

---

Data Analysis continues…
11. Zoom out and locate the next recording segment.

12. Repeat Steps 4-11 for each recording segment to complete the Data Report with measurements from all 8 recording segments.

13. Save or print the data file.

14. Exit the program.

END OF DATA ANALYSIS

You can use the marker tools to find the start of each segment. Each segment begins at its labeled append marker and ends at the next append marker.

This lesson had eight recording segments (unless modified for your lab session). Segments are identified by their append markers.

You may save the data to a drive, save notes that are in the journal, or print the data file.

END OF LESSON 16

Complete the Lesson 16 Data Report that follows.
Blood Pressure

- Indirect measurement
- Ventricular Systole & Diastole
- Korotkoff sounds
- Mean Arterial pressure

DATA REPORT

Student’s Name: ____________________________
Lab Section: _______________________________
Date: ________________________________

I. Data and Calculations

Subject Profile

Name ____________________________  Height ____________________________
Age ____________________________  Weight ____________________________
Gender: Male / Female  Time of day ____________________________

A. Systolic Measurements

Complete Table 16.2 with the systolic measurements for all eight data segments. Note the pressure measurement at two different times: a) at the marker insertion point where the Director signaled the systolic point during recording, and b) where the first sound was detected with the stethoscope. Calculate the deltas between the trials for each condition and between the Marker and Stethoscope pressure measurements for each segment.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Trial</th>
<th>At Marker Insertion</th>
<th>Marker Average (calculate)</th>
<th>When first sound detected</th>
<th>Sound Average (calculate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left arm, sitting up</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right arm, sitting up</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right arm, lying down</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right arm, after exercise</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
B. Diastolic Measurements

Complete Table 16.3 with the diastolic measurements from each of the eight data segments. Note the pressure measurement at two different times: a) at the marker insertion point when the Director signaled the diastolic point during recording, and b) where the sound disappeared. Calculate the deltas between the trials for condition and between the marker and the stethoscope measurements for each segment.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Trial</th>
<th>At Marker Insertion</th>
<th>Marker Average (calculate)</th>
<th>When first sound detected</th>
<th>Sound Average (calculate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left arm, sitting up</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right arm, sitting up</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right arm, lying down</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right arm, after exercise</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C. BPM Measurements

Complete Table 16.4 with the BPM measurements from three cycles of each of the eight data segments and calculate the mean BPM for each segment.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Trial</th>
<th>Cycle</th>
<th>Calculate the Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left arm, sitting up</td>
<td>1</td>
<td>1</td>
<td>of Cycles 1-3 of Trial 1-2 means</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Right arm, sitting up</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Right arm, lying down</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Right arm, after exercise</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
D. Summary of Mean Blood Pressure Data

Complete Table 16.5 with the average from sound data from tables 16.2 and 16.3 and then calculate the mean Arterial Pressure (MAP) and the pulse pressure.

\[
\text{MAP} = \frac{\text{pulse pressure}}{3} + \text{diastolic pressure} \quad \text{OR} \quad \text{MAP} = \frac{(\text{systolic pressure} + 2 \text{ diastolic pressure})}{3}
\]

Pulse pressure = Systolic pressure – Diastolic pressure

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>SYSTOLE</th>
<th>DIASTOLE</th>
<th>BPM</th>
<th>Calculations:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Table 16.2 Sound Average</td>
<td>Table 16.3 Sound Average</td>
<td>Table 16.4</td>
<td>MAP</td>
</tr>
<tr>
<td>Left arm, sitting up</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right arm, sitting up</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right arm, lying down</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right arm, after exercise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

E. Timing of Korotkoff Sounds

Complete Table 16.6 with the ΔT for each condition, and calculate the means.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Trial</th>
<th>Timing of Sounds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ΔT [CH1]</td>
<td>Mean (calc)</td>
</tr>
<tr>
<td>Left arm, sitting up</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Right arm, sitting up</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Right arm, lying down</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Right arm, after exercise</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

F. Calculation of Pulse Speed

Complete the calculation using Segment 1 data (left arm, sitting up).

<table>
<thead>
<tr>
<th>Distance</th>
<th>Distance between Subject’s sternum and right shoulder?</th>
<th>cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distance between Subject’s right shoulder and antecubital fossa?</td>
<td>cm</td>
</tr>
<tr>
<td></td>
<td>Total distance?</td>
<td>cm</td>
</tr>
<tr>
<td>Time</td>
<td>Time between R-wave and first Korotkoff sound?</td>
<td>secs</td>
</tr>
<tr>
<td>Speed</td>
<td>Speed = distance/time = ______ cm / ______ sec</td>
<td>cm/sec</td>
</tr>
</tbody>
</table>
II. Questions:

1. Note the difference in systolic pressure value between when the sound actually began, was detected by the stethoscope transducer, and was recorded, and the time when the observer first heard the sound and pressed the marker button. (Example: 141 mmHg – 135 mmHg = 6 mmHg). What factors could account for this difference? Would the observed difference be the same if measured by another observer? Explain your answer.

2. a) Does your systolic and/or diastolic arterial pressure change as your heart rate increases?

b) How does this change affect your Pulse Pressure?

c) How would you expect the systolic, diastolic and pulse pressures to change in a normal healthy individual as their heart rate increases?

3. Give three sources of error in the indirect method of determining systemic arterial blood pressure.

4. Use an equation that relates flow, pressure, and resistance to define mean arterial pressure:
5. Blood flow (liters per min.) through the pulmonary circuit equals blood flow through the systemic circuit, but pulmonary resistance to flow is 5 times less than the systemic resistance to flow. Using the equation in Question 4, show that mean pulmonary pressure is 5 times less than mean systemic pressure.

6. Define the first and second sounds of Korotkoff. Which sound is used to approximate systolic pressure and which sound is used to approximate diastolic pressure?

7. Why is mean arterial pressure not equal to (systolic pressure – diastolic pressure)/2?

8. Define pulse pressure. Explain, in terms of changes in systolic and diastolic pressures, why pulse pressure increases during exercise.

9. Give one reason why blood pressure in the left arm may be different than blood pressure in the right arm of a Subject at rest.

10. Name an artery other than the brachial that could be used for an indirect measurement of blood pressure and explain your choice.