Exercise 4: Biopac Tutorial - Physiological Instrumentation

Understanding the methodology for obtaining physiological data is as important as understanding the physiological concepts themselves. This exercise is designed to familiarize you with the computer interfaced data acquisition unit called Biopac, equipment we will be using for many of our coming labs. Today, we will be using the physiological concepts we learned previously as an application for this technology. **BE SURE TO BRING THIS TUTORIAL FOR FUTURE REFERENCE TO ALL LABS THAT USE THE BIOPAC WORK STATIONS.**

Various physiological events can be measured by connecting a human subject to the computer using a device called a **transducer**. A transducer converts mechanical events into electrical signals. Each type of physiological event uses a different transducer. Today, we will be using a transducer called a **plethysmograph**, which detects pulse. Later on, we will be using other transducers, depending on the type of physiological activity we want to study. A transducer sends its electrical signal to the **Biopac MP35 Acquisition Unit**, otherwise known as the MP35 unit or the blue box, which **amplifies** and processes these electrical signals and displays them on the computer screen. The **Biopac Student Lab** software allows you to control how the electrical signals are displayed and to analyze the data you collect. Lab partners should take turns using the equipment so that everyone becomes familiar with using both the hardware and the software.

A **plethysmograph** responds to the surge of arterial blood that occurs in your fingertip due to the contraction of the heart. The photoelectric plethysmograph we will be using emits a beam of light that is then detected by a light sensor. The amount of light reflected back from your finger increases when ventricles contract and blood flow to the finger increases. This change in light is converted into an electrical signal that is plotted as a function of time on the computer display.

**Today’s Objectives**

1. Learn how to use the Biopac workstation.
2. Record pulse using a plethysmograph pulse transducer.
3. Compare the results of the aerobic step test, using manual versus computerized data collection.
Equipment List

√ Computer
√ Biopac MP35 Acquisition unit
√ Plethysmograph pulse transducer plugged into Ch. 2
√ Step stool
√ Metronome
√ Biopac Student Lesson L07 ECG & Pulse

Getting Started

The equipment for the day's experiment will usually be ready to go when you come into lab, but you should always double-check your equipment yourself before starting. Here is a checklist of the basic set-up when using the Biopac data acquisition units:

1. Check all your connections first:
   • The Biopac MP35 unit (blue box) is connected to the computer via a USB cable.
   • The AC adapter for the unit is plugged into the back of the blue box and the surge protector or electrical outlet.
   • The plethysmograph (SS4LA) is plugged into the front of the MP35 unit in Channel 2 (see Fig. 1).

Figure 1. Front panel of Biopac MP35 Acquisition Unit

Figure 2. BSL application icon
2. Turn the computer on BEFORE turning on the Biopac MP35 unit. The Power switch for the unit is on the back panel on the right. The down position is OFF. The up position is ON.

When the MP35 unit is initially turned on, two green lights on the right side of the front panel of the MP35 unit will light up. Do not launch the Biopac Student Lab application until the left "busy" light goes off. If you don't wait, the computer will not connect to the MP35 unit. If the busy light is flashing rather than steady, turn the MP35 unit off and on again. If the busy light does not go off after more than a minute, try turning the unit off and on again. If all else fails, ask for help from the instructor.

3. Launch the Biopac Student Lab software application. For Mac laptops, click on the Biopac Student Lab application icon (see Fig. 2) in the dock at the bottom of the screen (NOT the BSL PRO icon to the right).

For PCs, click on the “BSL Lessons 3.7” icon on the desktop (NOT the BSL PRO 3.7 icon).

4. A window will open asking you to choose a lesson. Select L07 ECG & Pulse and click OK. Type in a file name for your experiment. Use a name that distinguishes both your lab group and the exercise you are performing, like "Barbara's Pulse", not just "Pulse". Write down the name of your file here:

_________________________________________. Get into the habit of writing this information down every time you open a new file.

5. If you get an error message that the computer cannot find the hardware, check the USB cable connecting the MP35 unit to the computer, all other power cables, the ON/OFF switch, and make sure the power light is on and the busy light is off. For Macs, the error message will look like Fig. 3. For PCs, the error message will look like Fig. 4. Once the MP35 unit is properly connected to the computer, the error message should go away and the lesson should open.

![Figure 3. "Can't Find the Hardware" warning for Macs](image)
Figure 4. "Cannot Find the Hardware" warning for PCs

Recording A Pulse

1. When you enter a file name and click OK, the screen that opens will look like Figure 5:
The upper Data window displays two channels, one for recording an electrocardiogram, which we will not be doing, and one for recording the pulse. These channels are labeled on the left side of the window. The bottom Journal window displays instructions we will not be using either. Ignore both the top channel and bottom window in today's exercise. We will learn how to hide both of these windows once you have finished collecting your data.

2. To prepare your subject (lab partner), use the Velcro strap to attach the plethysmograph to the ventral surface (fingerprint side) of the index finger. It should be just snug enough to stay on the finger, but not so tight that it disrupts circulation (no purple finger tips!). The subject should rest her or his arm palm up on a table while sitting quietly. The hand should be relaxed.

**WARNING:** The plethysmograph is a fragile piece of equipment. All care should be taken to protect the detector window and the cord connections.

3. Click on the **Calibrate** button in the upper left corner of the screen. An error message will appear. Click **Ignore**.

   Any transducer must be calibrated before it can be used. The calibration process determines the minimum (baseline) and maximum reference points. If the peaks of your calibration recording seem small, software will correct the recording to fit the screen nicely. Do not move while the computer calibrates the plethysmograph.

4. If your subject moved during the calibration, you can redo it by clicking on **Redo Calibration**. If you got a recording of a steady pulse that looks like Figure 6, continue.

![Figure 6. Calibration trace](image)

5. Click the **Record** button to begin recording. You will get another error message; click **Ignore**. The recording of the pulse should appear, moving from left to right in the recording window. The recording is also referred to as a **trace**. The pulse trace is blue and the ECG trace (that you are ignoring) is a flat red line.
6. Experiment to see how moving your finger affects the recording. Click **Suspend** to stop recording and change the tightness of the strap. Click **Resume** to see how this affects the recording. Note that if the strap is too tight and blood can no longer flow into the finger, the pulse trace flattens. Click **Suspend** and readjust the plethysmograph to take a normal reading.

7. Continue recording for at least 20 – 30 seconds without moving until there is a good, steady pulse recording. Click **Suspend** to stop recording. If you want to record more, click **Resume**. Do NOT record more than a minute of data to avoid wasting memory space. If you want to erase your data and try again, click **Redo**. Your goal is to get at least six steady, uniform pulse beats in a row for analysis. When you are satisfied with your recording and are ready to analyze it, click **Done**.

8. When you click **Done**, you will be asked what you would like to do next. If another member of your group would like to record their pulse, select **Record from another Subject**. Otherwise, select **Analyze Current Data File** and click **OK**. If you want to analyze a previously recorded data file, choose **Analyze a Different Data File**. A finder window will open to the main Biopac folder. Select the **Data Files** folder, then your folder, then the file you want to analyze.

**NOTE:** If at any time you want to open a new file or go back to an old file, go to the Lessons menu. Choose the lesson to open a new file (for example, L07 ECG & Pulse) or go to the bottom of the menu and choose Review Saved Data.

### Navigating The Biopac Student Lab Software

The primary purpose of this exercise is to give you practice in collecting and analyzing data using the MP35 unit and Biopac Student Lab software. Take the time to familiarize yourself with the display tools and analysis functions. Becoming comfortable with the software is more important than calculating your heartbeat and getting to the end of the exercise. You will be needing these skills for future Biopac labs. Becoming proficient today will help you perform future exercises more smoothly and efficiently. The following steps are designed to help you manipulate the screen to optimize the viewing of your trace.

1. **Editing and Selection Tools:** There are three editing and selection tools, the Arrow, I-Beam, and Zoom. The icons to choose these tools are found in the bottom right corner of the data screen (see Figure 7).

   ![Editing and Selection Tools](image)

   *Figure 7. Editing and Selection Tools. From left to right: the Arrow, the I-Beam, and Zoom.*
The arrow is used to point and click, the I-Beam is used to highlight areas of the trace for analysis, and the zoom enlarges the trace.

2. To activate or hide a channel: Since we are only interested in the Pulse data we collected, we can hide the ECG channel and enlarge the Pulse channel. The Channel boxes are used to activate or hide the different channels and are found in the second row below the "Overlap" button in the upper left corner of your screen (for Macs, see Figure 8). In today's exercise, the Channel 1 box controls the ECG channel and the Channel 40 box controls the Pulse channel. Clicking on a channel box activates that channel so that editing and selection tools can be used on that trace. Values measured in an active channel will appear in the display windows found in the first row directly below the "Overlap" button. We will talk more about the display windows later.

![Image of analysis screen](image)

**Figure 8.** Upper left corner of analysis screen for Macs (left) and PCs (right). The square Channel boxes two rows below the "Overlap" button indicate the active channel. In the Mac example on the left, Channel 1 is inactive; the Channel 40 box has been selected (gray) and the Pulse Channel is the active channel. In the PC example on the right, Ch 1 has been hidden (X'ed out).

- Alternately click on the two channel boxes to see how the ECG and Pulse screens are activated. Note how the screen title running vertically on the left edge of the screen is highlighted when that channel is activated.
- Since we did not collect any ECG data, we do not need to keep Channel 1 on the screen. To hide this channel, Mac users hold down the option key and click on the Channel 1 icon. PC users hold down the Ctrl key and click on the Channel 1 icon. The channel box will have a slash through it when it is hidden (see the example on the right in Fig. 10). Hiding a channel does not prevent it from being an active channel. Displaying a channel does not make it an active channel unless the channel box is clicked. Be sure to leave the Pulse channel active once you hide the ECG channel.

3. Optimize the displayed channel: One of the most important things you need to learn how to do today is to optimize the way the trace is displayed so that your measurements can be as
accurate as possible. The trace will be easier to analyze if the Pulse channel is enlarged to fill the entire screen. To do this, close the journal window at the bottom of the screen:

- Mac users click on the red button in the upper left hand corner of the bottom window (see Figure 9).

Figure 9. Window control buttons. The red button (far left) will close the window. The yellow button (middle) will hide the window in the dock. The green button will maximize the window so that it fills the entire screen.

Be careful not to click on the red button of the data window at the top of the screen, as this will close your file. If this happens, click on the Lessons pull-down menu and choose Review Saved Data at the bottom of the list. Select the Data Files folder, then the folder you named, then the file you were working on (this is why you always write down your file names). Make the pulse channel fill the entire screen by clicking on the green button of the data window. Alternatively, click and drag the bottom right corner of the data window downward.

- PC users simply click on the upper border of the journal window and drag it down to the bottom of the screen.

4. Control the display of the X and Y axes: All of the data you collected will initially be displayed on a single screen, no matter how many minutes you recorded. The longer you record, the more squished together your pulses will appear and it can be difficult to place the cursor accurately when measuring your pulse rate. You will want to enlarge specific areas of your data for accurate analysis.

- Choose the zoom tool icon in the lower right hand corner of the screen. The zoom tool looks like a magnifying lens (see Fig. 7). Click and drag the zoom tool to draw a box around the specific area of the recording you would like to analyze. To undo the zoom, pull down the Display menu and select Zoom Back. There is also a Zoom Forward function to redo a zoom.

- You can also click the zoom tool anywhere on your trace to enlarge the entire display. The peaks will get higher and wider and some of the trace may be off screen; the scroll bar should now be blue. To adjust your trace so that the peaks and valleys are visible, pull down the Display menu and select Autoscale Waveforms. This automatically adjusts the Y-axis so that the highest and lowest points are on screen. If your pulses are still too squished
together, click on the trace again to zoom in further. Readjust the Y-axis by selecting **Autoscale Waveforms** again.

Note the **Autoscale Horizontal** function in the **Display** menu. This readjusts the X-axis so all the data you collected is once again displayed on the screen.

- Mac users can move to different locations along your trace by either clicking and dragging the blue scroll bar or by clicking the left and right arrows (see Fig. 10).

  ![Figure 10. Horizontal scroll bar and arrows from the lower right side of screen.](image)

- PC users have an analogous scroll bar at the bottom of the window.

- There is also a vertical scroll bar along the right edge of the screen. The vertical scroll bar can be used to reposition the trace on the screen if necessary.

5. Show or hide grids: Grid lines give you a visual reference point when looking at a trace. To add grid lines to your screen, simply click on the “Show Grid” button at the top of the window (see Fig. 11).

  ![Figure 11. Grid buttons at the top right corner of the screen](image)

To adjust the grid lines of the X-axis (time), click anywhere along the X-axis of the display. A dialog box will open (see Figure 12).
Enter the number of seconds you would like between grid lines for Major Division. Increments of 1, 2 or 5 seconds are usually appropriate. Click OK. The minor divisions cannot be adjusted.

- To adjust the grid lines of the Y-axis (mV), click anywhere along the Y-axis of the display. A similar dialog box will open. Look at the units of the Y-axis to determine the Major Divisions. If the maximum and minimum Y values are around 1 mV, then choose 0.1 or 0.2 mV increments for your grid divisions.

**Analyzing Your Data**

Now that you know how to adjust the display settings, practice using what you learned by calculating your subject's heart rate.

1. Display all the data you collected by pulling down the Display menu and choosing first **Autoscale Horizontal** and then **Autoscale Waveforms**. Your trace should be all squished together again. If the trace is too squished to distinguish the peaks (this means you have collected A LOT of data), use the zoom tool and the **Autoscale Waveforms** function to adjust your trace so that it can be more easily reviewed.

2. Select five pulse peaks that appear to be steady and regular and use the zoom tool to click and drag a box around those peaks. Be sure to include the lowest point before the first peak.
and the lowest point after the last peak. All five peaks should be displayed together now. See Fig. 13 for an example.

3. The I-Beam is used to highlight areas of the trace you want to measure. To highlight a region of your trace:

   • Click on the I-Beam icon in the bottom right corner of the screen (see Fig. 7). Highlight a pulse peak valley-to-valley by positioning the I-Beam at the lowest point of the trace in front of the pulse peak you want to measure; click and drag the I-Beam until the I-Beam is positioned at the lowest point of the next pulse peak; release the mouse. See Fig. 13 for an example of a highlighted peak.

![Figure 13. Screen shot of five pulse peaks with one peak highlighted.](image1)

![Figure 14. The measurement region is along the top of the data window and directly below the "Overlap" button. In this example, the channel select box is set to Channel 40, the measurement function box is set to Delta T (the highlighted time interval), and the reading in the result box is 0.815 sec.](image2)
4. Values that correspond to the highlighted areas appear in the result box in the measurement region found at the top of the screen (see Fig. 14). The measurement region will allow you to make up to five different measurements or calculations from the data you have highlighted. Use the following settings to calculate heart rate:

- The channel select boxes allows you to choose the channel you want to take your measurements from. Do not confuse the channel select box with the channel boxes directly below. We used the channel boxes previously to hide or activate a channel (see Fig. 8). The channel select boxes are in the row directly above the channel boxes. In today’s lab, all your measurements and calculations will be from Channel 40. Change the first two measurements from channel 1 to channel 40 by clicking on both the first and the second channel select boxes and choosing Ch40, Pulse from the pop-up menu. You can tell which channel your box is set to from both the label on the channel select box and from the color of the box. The box will match the color of the trace.

- The measurement function box allows you to choose the variable to be measured or the calculations you would like the computer to perform. Today we want to measure the time interval of each pulse beat, so choose Delta T from the middle of the pop-up menu (see Fig. 15). Note that Delta T is different from Delta at the top of the menu. Delta T measures the highlighted distance along the X-axis, while Delta measures the highlighted distance along the Y-axis.

- The Biopac software can also calculate heart rate based on the Delta T measurement, so set the second measurement function box to BPM (beats per minute). We won’t be using the other result boxes today.

5. Record the Delta T and the BPM for this first pulse beat in Table 1 on the next page, using whole numbers for the heart rate. This calculated heart rate is based on a single beat. Compare the calculated heart rate of several different pulse beats by highlighting three other pulse beats on your screen. Record this data in Table 1 as well. Do these values differ at all? How would you decide which value to use if there are differences?

- Since individual pulse beats can vary in length from beat to beat, calculating an average based on several beats is a more reliable way of measuring heart rate. Highlight all five pulse beats using the I-Beam. Delta T now represents the time of five pulses, not one, so the BPM calculation in the second results box is no longer correct. Use the formula below to calculate BPM based on five pulse beats:

\[
\text{Heart Rate (beats/min)} = \frac{\text{Number of beats} \times 60 \text{ sec.}}{\Delta T \times 1 \text{ min.}}
\]
How does the BPM averaged from five pulse beats compare to the BPM calculated from a single beat? How does this formula compare to the formula we used to calculate heart rate earlier in the semester?

<table>
<thead>
<tr>
<th>Table 1. Resting Pulse Data</th>
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<tbody>
<tr>
<td>Delta T (sec.)</td>
</tr>
<tr>
<td>Pulse beat #1</td>
</tr>
<tr>
<td>Pulse beat #2</td>
</tr>
<tr>
<td>Pulse beat #3</td>
</tr>
<tr>
<td>Pulse beat #4</td>
</tr>
<tr>
<td>*For 5 beats</td>
</tr>
</tbody>
</table>

*NOTE: The Biopac program will calculate BPM for a single beat, but you must do the calculation for BPM for 5 beats. Use the formula for Heart Rate on the previous page.

Aerobic Capacity Revisited

Earlier in the semester, we measured our pulse rates manually to estimate our aerobic capacity using the McArdle-Katch Bench Stepping Test. If possible have a member of your group who performed the Step Test previously repeat the Step Test using the plethysmograph to measure pulse. This will allow you to compare data collected both manually and using the MP35 unit. We will not be measuring recovery heart rate over time this week.

1. Attach the plethysmograph to the finger of the subject who will do the step test.
   **IMPORTANT:** The plethysmograph should not be wrapped tightly around the finger. It should be loose enough to slip off the finger without readjusting the velcro fastener, yet still give a good pulse reading during the calibration.
2. Open a new file by going to the Lessons menu and choosing L07 ECG & Pulse. Name your file, calibrate the plethysmograph and record the resting pulse of your subject for about 15 seconds to get a good baseline reading. Click Suspend to stop recording. Go back to the instructions for "Recording A Pulse" if you need a reminder for getting started. Slip the plethysmograph off the subject's finger without loosening the velcro fastener. No recordings will be made during exercise because the movement affects the recording.
3. Have your subject perform the Step Test:
• Set the metronome to 88 beats per minute for females or 96 beats per minute for males. You can turn off the sound of the metronome and use the flashing light to keep time if you prefer.

• Brace the step stool backwards against the wall to prevent it from slipping. Facing the back of the step stool, step up to the top step of the stool. Use the same four-step cadence you used last week (up right foot, up left foot, down right foot, down left foot) for a period of three minutes, stepping in time with the metronome. LISTEN CAREFULLY TO THE METRONOME TO MAINTAIN THE CORRECT PACE.

4. Immediately after 3 minutes of stepping, slip the plethysmograph back on the subject's finger and click Resume to begin recording the pulse while the subject stands quietly and rests their arm on the tabletop. It is crucial that the recording begin as soon as the individual stops exercising.

5. Record the pulse for about 30 seconds, the click Done. Select Analyze Current Data File and click OK.

Using Markers To Navigate Your Recording:

1. Markers are used to reference important events or locations in the data. The marker bar is the white bar located at the top of the screen just below the measurement region (see Fig. 16).

2. There are two types of markers:
   a. Append markers. These markers are automatically inserted when you begin a new recording. They appear as a black diamond above the text box and appear blue when active. The marker will always be identified by text. Ex: “seated and relaxed”.
   b. Event markers. These markers can be manually entered during a recording by pressing either the ESCAPE key (Macs) or F9 (PCs). They appear as inverted triangles below the marker text region and are yellow when active. You can manually add the text you wish in the text box above the inverted triangle by double clicking on a selected marker. Ex: “Robin's pulse post-run”.

   You can add an event marker after recording by clicking in the marker region with the selection tool (arrow). The new marker becomes the current active marker and you may label it by typing in the marker text box. To remove a marker, see the following section on the marker tool.

3. The marker tool allows you to navigate from marker to marker without tediously scrolling through your entire recording. The marker tool is located at the far right side of the marker bar. See Fig. 17 to see what it looks like.
Using the marker tool to find a specific marker in your data:

a. Click on the right pointing marker tool to reach the next marker to the right of the data section you are looking at.

b. Click on the left pointing marker tool to reach the previous marker to the left of the data section you are looking at.

c. Click on the downward pointing marker tool at the far right end of the marker region. This will generate a pop-up menu. Select the Find option. Enter the name of the marker (Ex. “Robin's pulse post-run”). Click Find next and the selected marker will light up on the screen. If you wish to see all markers and their labels listed, select Marker Manager. This will list all markers with their labels and time stamp.

To remove a marker, click on the marker to activate it, then open the marker tool pop-up menu, choose “Clear” and “Active Event Marker”.

Data Analysis

1. If necessary, adjust the trace so that pulse peaks can be easily measured. Scroll along the trace until the 15 second point is reached. This should be approximately where recording resumed after the Step Test was completed. The exact point when recording was resumed will have been marked by the diamond shaped marker found just below the measurement region at the top of the data window (see Fig. 18).

2. Use the zoom tool (see Fig. 8) to select five pulse peaks beginning at 5 seconds after the Step Test was completed. These pulse peaks may be irregular and jagged since the subject was recovering from exercise. If the peaks are difficult to distinguish, choose the closest peaks that are readable for analysis.

3. Use the I-Beam to highlight five pulse peaks and measure Delta T. If the valleys between pulse peaks are difficult to distinguish, the top of the peaks can be used instead. Be careful to correctly count the number of pulses that are highlighted. Calculate heart rate using the formula above.
4. Estimate maximal oxygen consumption rate (VO$_2$ max) using the following equations.

Females:

\[ \text{VO}_2 \text{ max} = 65.81 - (0.1847 \times \text{HR}) \]

Males:

\[ \text{VO}_2 \text{ max} = 111.33 - (0.42 \times \text{HR}) \]

Use the standards from Tables 2 or 3 from Exercise 2: Aerobic Capacity to determine fitness level based on estimated VO$_2$ max.

<table>
<thead>
<tr>
<th>Table 2. Aerobic Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta T (sec)</td>
</tr>
<tr>
<td>At rest</td>
</tr>
<tr>
<td>After exercise</td>
</tr>
<tr>
<td>VO$_2$ max in ml/kg/min (from formula)</td>
</tr>
<tr>
<td>VO$_2$ max from previous Step Test</td>
</tr>
</tbody>
</table>
Questions:

1. Define and describe the function of the following equipment: transducer, amplifier, plethysmograph.

2. How does the plethysmograph that you used detect pulse?

3. What should you do if you get a dialog box that says "I can't find the hardware."?

4. What is the purpose of calibrating a transducer?

5. What are the functions of the arrow, the I-Beam, and the zoom tools?

6. How do you adjust the X and Y axes in the data window (how do you adjust the way the trace is displayed)?

7. How do you choose the data you wish to view in the data window?

8. Where is the measurement region? Where is the channel select box, the measurement function box, and the result box and what are they used for?

9. How do you insert a marker into your trace, both while you are recording and if your recording has already been made? How do you use the marker tool?

10. Be able to calculate a heart rate from a trace using the formula provided.