Richard Pflanzer, Ph.D.
Associate Professor Emeritus
Indiana University School of Medicine
Purdue University School of Science

William McMullen
Vice President, BIOPAC Systems, Inc.

II. EXPERIMENTAL OBJECTIVES

1) To become familiar with the principle of plethysmography and its usefulness in qualitatively assessing peripheral changes in blood volume.
2) To observe and record changes in peripheral blood volume and pressure pulse under a variety of both experimental and physiological conditions.
3) To determine the approximate speed of the pressure pulse wave traveling between the heart and the finger.
4) To illustrate the electrical activity associated with normal cardiac activity and how it relates to the flow of blood throughout the body.

III. MATERIALS

- BIOPAC Electrode Lead Set (SS2L)
- BIOPAC Disposable Electrodes (EL503,) 3 electrodes per subject
- BIOPAC Pulse Transducer (SS4LA or SS4L)
- Ruler or Measuring Tape
- Ice water or warm water in plastic bucket
- BIOPAC electrode gel (GEL1) and abrasive pad (ELPAD) *or* skin cleanser
- Biopac Student Lab System: BSL 4 software, MP36 or MP35 hardware
- Computer System (Windows 8, 7, Vista, XP, Mac OS X 10.5 – 10.8)

IV. EXPERIMENTAL METHODS

A. SETUP

FAST TRACK Setup

1. Turn the computer **ON**.
2. If the MP36/35 unit is on, turn it **OFF**.
3. **Plug the equipment in** as follows:

   Electrode Lead Set (SS2L) — CH 1

   Pulse Transducer (SS4LA) or

   Pulse Transducer (SS4L) — CH 2
4. Turn **ON** the MP36/35 unit.
5. Clean and abrade skin.
6. Attach three electrodes on the **Subject** (Fig. 7.3).

Setup continues…

Detailed Explanation of Setup Steps

Fig. 7.2 MP connections

If the skin is oily, clean electrode sites with soap and water or alcohol before abrading.

If electrode is dry, apply a drop of gel.

Remove any jewelry on or near the electrode sites.

Fig. 7.3

- One electrode on the medial surface of the left leg, just above the ankle bone.
- One electrode on the medial surface of the right leg, just above the ankle bone.
- One electrode on the right anterior forearm just above the wrist (same side of arm as the palm of hand.)

Note: For optimal electrode contact, place electrodes on skin at least five minutes before start of Calibration.

7. Clip the Electrode Lead Set (SS2L) to the electrodes, following the color code (Fig. 7.4).
   - RED = LEFT ankle
   - WHITE = RIGHT wrist
   - BLACK = RIGHT ankle

Fig. 7.4

Setup continues…

8. Clean the window of the pulse transducer.

This will prevent any oil or dirt on the window from interfering with the signal. Use a soft cloth, Q-tip, or other non-abrasive material to wipe it clean.

9. Put pulse transducer sensor on tip of **RIGHT** index finger (Fig. 7.5) wrap Velcro snugly around finger, but not too tightly.

The transducer should be snug, but not so much that blood circulation is cut off—it's a fine line between snug and too tight.

Fig. 7.5 Sensor position on RIGHT hand

10. **Subject** gets in proper seating position, facing away from monitor and adjusts the leads and cables (Fig. 7.6).

The cables should have enough slack to not pull on the electrodes or the transducer when hands are in lap, and must be positioned to allow unrestricted movement when right hand is raised above the head.

Connect the electrode cable clip to a convenient location on Subject's clothes.

11. Start the Biopac Student Lab Program.

Start Biopac Student Lab by double-clicking the Desktop shortcut.

12. Choose lesson **"L07 – ECG & Pulse"** and click **OK**.
13. Type in a unique **filename** and Click **OK**.

No two people can have the same filename, so use a unique identifier, such as **Subject's** nickname or student ID#.

A folder will be created using the filename. This same filename can be used in other lessons to place the **Subject's** data in a common folder.

14. Set Preferences.
    - Choose File > **Lesson Preferences**.
    - Select an option.
    - Select the desired setting and click **OK**.

This lesson has optional Preferences for data and display while recording. Per your Lab Instructor's guidelines, you may set:

Grids: Show or hide gridlines

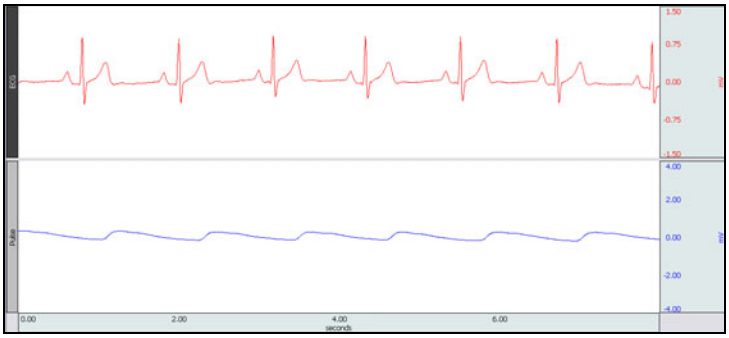
Heart Rate Data: Calculate and display Heart Rate data.

Lesson Recordings: Specific recordings may be omitted based on instructor preferences.

END OF SETUP

B. CALIBRATION

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

FAST TRACK Calibration	Detailed Explanation of Calibration Steps
1. **Subject** is seated relaxed and still, facing away from monitor (Fig. 7.6).	 **Fig. 7.6 Proper seating position for Calibration and Lesson** **Subject** must be seated in a chair, arms at side of body and knees flexed with feet supported.
2. Click **Calibrate**.	**Subject** must remain relaxed and as still throughout calibration to minimize baseline shift and EMG artifact.
3. **Wait** for Calibration to stop.	Calibration lasts eight seconds.
4. Verify recording resembles the example data. • If similar, click **Continue** and proceed to Data Recording. • If necessary, click **Redo Calibration**.	There should be a recognizable ECG waveform with a baseline at or near 0 mV, little EMG artifact and no large baseline drift. The lower channel should display a visible pulsatile waveform.  **Fig. 7.7 Example Calibration data** If recording does not resemble the Example Data ▪ If the data is noisy or flatline, check all connections to the MP unit. ▪ If the ECG displays baseline drift or excessive EMG artifact: o Verify electrodes are making good contact with the skin and that the leads are not pulling on the electrodes. o Make sure Subject is in a relaxed position ▪ If the Pulse Signal is not present, change the position or tightness of the transducer. Some **Subjects** may not produce a good pulse signal and it may be necessary to use a different **Subject**.
END OF CALIBRATION	

C. DATA RECORDING

FAST TRACK Recording

1. **Subject** is seated and relaxed, arms supported, breathing normally, facing away from monitor.
   - **Review** recording steps.

Seated and relaxed

2. Click **Record**.
3. Record for **15 seconds**.
4. Click **Suspend**.
5. Verify that recording resembles the example data.
   - If <u>similar</u>, click **Continue** and proceed to the next recording.
   - If necessary, click **Redo**.
   - If all required recordings have been completed, click **Done**.

Recording continues…

Detailed Explanation of Recording Steps

Three conditions will be recorded*: Arm relaxed, hand in hot or cold water, and hand held up.

***IMPORTANT**

This procedure assumes that all lesson recordings are enabled in Lesson Preferences, which may not be the case for your lab. Always match the recording title to the recording reference in the journal and disregard any references to excluded recordings.

Hints for obtaining optimal data:

To minimize muscle (EMG) artifact and baseline drift:

- **Subject** must be relaxed.
- Make sure electrodes do not peel up and that the cables and leads do not pull on the electrodes or transducer.

Subject remains seated and relaxed.

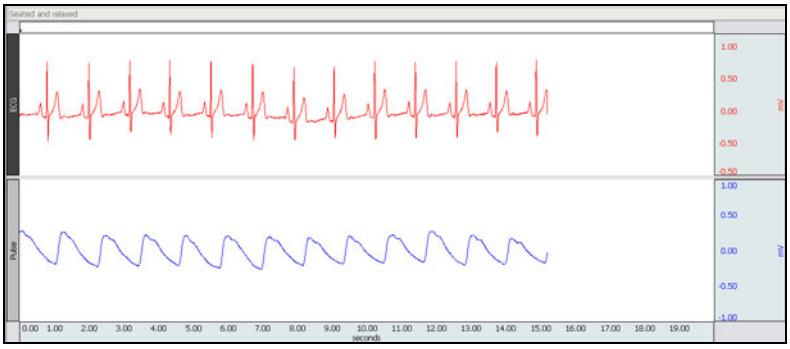


Fig. 7.8 Example Seated and relaxed data

The data description is the same as outlined in Step 4 of the Calibration procedure.

Click **Redo** and repeat Steps 2 – 5 if necessary. Note that once **Redo** is clicked, the most recent recording will be erased.

Seated, left hand in water

6. **Subject** remains seated and relaxed, facing away from monitor.
   - **Review** recording steps.
7. Put **Subject's** left (non-recording) hand into a plastic bucket filled with water (Fig. 7.9).

WARNING
The container for the water must not be metal, as this poses the potential danger of bypassing the electrical isolation of the MP unit.

Warm water should be approximately 40° C (104 deg F,) cold water approximately 20° C (68 deg. F.)

Fig. 7.9 Positioning

8. Once **Subject** is still, click **Record**.

In order to capture the heart rate and pulse variation, click Record as quickly as possible after **Subject's** hand is in water and they are still.

9. Record for 30 seconds.

Subject remains seated, relaxed with left hand in water.

10. Click **Suspend**.
11. **Subject** removes hand from water.
12. Verify recording resembles the example data.
    - If similar, click **Continue** and proceed to the next recording.

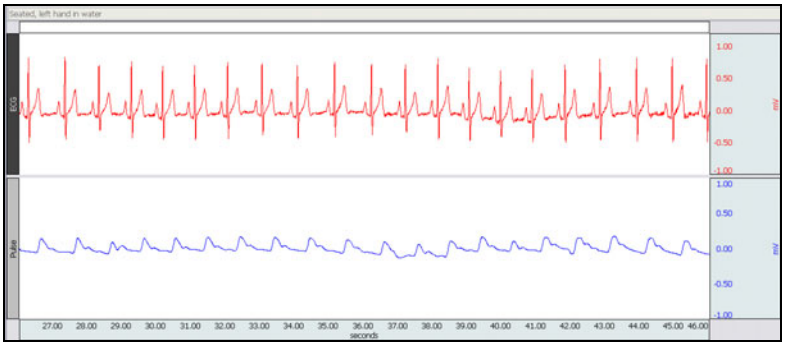


Fig. 7.10 Example Left hand in water data

- If necessary, click **Redo**.
- If all required recordings have been completed, click **Done**.

The data description is similar to that outlined in Step 4 of the Calibration procedure; however the pulse signal will most likely have a different amplitude and shape.

Click **Redo** and repeat recording if necessary. Note that if cold water was used; wait for the **Subject's** hand to return to normal temperature before repeating Steps 7 – 12. Once **Redo** is clicked, the most recent recording will be erased.

Recording continues…

Seated, right hand above head

13. **Subject** remains seated, relaxed, facing away from monitor.
    - If cold water was used, wait for **Subject's** hand to return to normal temperature before continuing.
    - **Subject** raises right hand above head, arm extended, pulse transducer attached (Fig. 7.11).
    - **Review** recording steps.

Fig. 7.11

Adjust any leads or cables that are pulling on the electrodes or transducer.

14. Click **Record.**

Subject remains seated with right arm extended above head.

15. Record for 60 seconds.

16. Click **Suspend**.

17. Verify recording resembles the example data.
    - If similar, click **Continue** to proceed to the optional recording section, or **Done** to finish the lesson.

There could be more EMG artifact in the ECG recording and there could be more baseline drift than in previous recordings. The pulse recording will vary greatly between **Subjects**; some displaying greater pulse amplitude and some less.

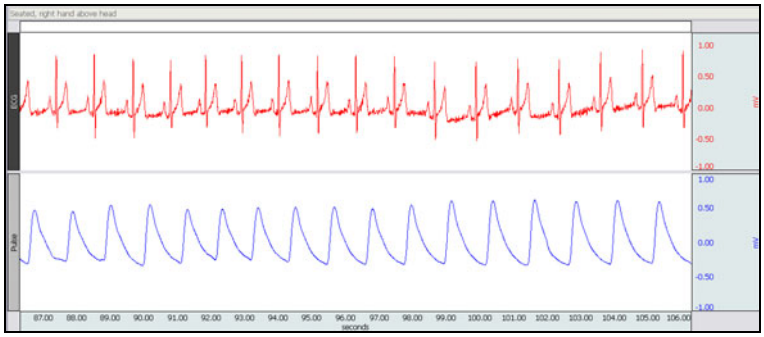


Fig. 7.12 Example Hand raised above head data

- If necessary, click **Redo**.

The data might be different for the reasons detailed in Step 4 of the Calibration procedure.

Click **Redo** and repeat Steps 13 – 17 if necessary. Note that once **Redo** is clicked, the most recent recording will be erased.

Recording continues…

OPTIONAL ACTIVE LEARNING PORTION

With this lesson you may record additional data by clicking **Continue** following the last recording. Design an experiment to test or verify a scientific principle(s) related to topics covered in this lesson. Although you are limited to this lesson's channel assignments, the electrodes or transducers may be moved to different locations on the **Subject**.

Design Your Experiment

Use a separate sheet to detail your experiment design, and be sure to address these main points:

A. ***Hypothesis***

Describe the scientific principle to be tested or verified.

B. ***Materials***

List the materials you will use to complete your investigation.

C. ***Method***

Describe the experimental procedure—be sure to number each step to make it easy to follow during recording.

Run Your Experiment

D. ***Set Up***

Set up the equipment and prepare the subject for your experiment.

E. ***Record***

Use the **Continue**, **Record** and **Suspend** buttons to record as much data as necessary for your experiment.

Click **Done** when you have completed all of the recordings required for your experiment.

Analyze Your Experiment

F. Set measurements relevant to your experiment and record the results in a Data Report.

18. After clicking **Done**, choose an option and click **OK**.

If choosing the **Record from another Subject** option:

- Repeat Setup Steps 5 – 10, and then proceed to Calibration.

19. Remove the electrodes and the transducer.

Remove the electrode cable pinch connectors and peel off all electrodes. Discard the electrodes (BIOPAC electrodes are not reusable.) Wash the electrode gel residue from the skin, using soap and water. The electrodes may leave a slight ring on the skin for a few hours which is quite normal.

END OF RECORDING

V. DATA ANALYSIS

FAST TRACK DATA ANALYSIS

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

   - Note Channel Number (CH) designations:

Channel	*Displays*
CH 1	**ECG**
CH 40	**Pulse**

   - Note measurement box settings:

Channel	*Measurement*
CH 1	**Delta T** (time interval)
CH 1	**BPM** (rate)
CH 1	**P-P**
CH 40	**P-P**

2. **Zoom** in on a small section of the "**Seated and relaxed**" data.
3. Using the **I-Beam** cursor, select the area between two successive R waves (one cardiac cycle).

   A

4. Repeat the above measurements for each of the data recordings.

   A

Data Analysis continues…

DETAILED EXPLANATION OF DATA ANALYSIS STEPS

If entering **Review Saved Data** mode from the Startup dialog or lessons menu, make sure to choose the correct file.

The data window should resemble Fig. 7.13.

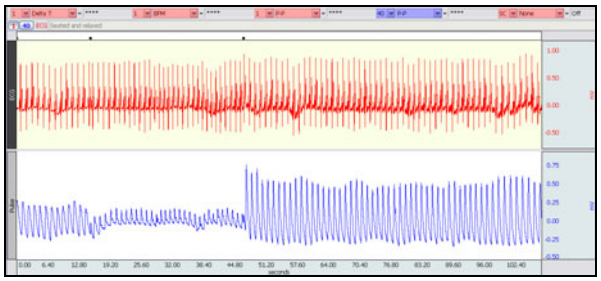


Fig. 7.13 Example data

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.

Brief definition of measurements:

Delta T: Displays the amount of time in the selected area (the difference in time between the endpoints of the selected area.)

BPM: The **B**eats **P**er **M**inute measurement first calculates the difference in time between the beginning and end of the selected area (seconds/beat,) and divides this value into 60 seconds/minute.

P-P (Peak-to-Peak)**:** Subtracts the minimum value from the maximum value found in the selected area.

The "selected area" is the area selected by the I-Beam (including endpoints.)

Note: The append event markers ◆ mark the beginning of each recording. Click on (activate) the event marker to display its label.

Useful tools for changing view:

Display menu: Autoscale Horizontal, Autoscale Waveforms, Zoom Back, Zoom Forward

Scroll Bars: Time (Horizontal); Amplitude (Vertical)

Cursor Tools: Zoom Tool

Buttons: Overlap, Split, Show Grid, Hide Grid, -, +

Hide/Show Channel: "Alt + click" (Windows) or "Option + click" (Mac) the channel number box to toggle channel display.

Be sure to zoom in far enough so that you can easily measure the intervals between peaks, approximately 4 cardiac cycles.

Try to go from R wave peak to R wave peak as precisely as possible (Fig. 7.14).

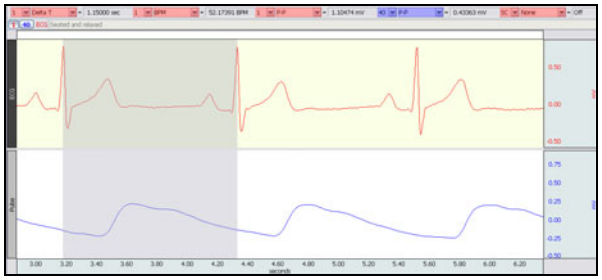


Fig. 7.14 R-R interval selected

5. Using the **I-Beam** cursor, select the area between two successive pulse peaks (one cardiac cycle).

   A

6. Repeat the above measurements for each of the data recordings.

   A

7. Select individual pulse peaks for each recording and determine their amplitudes.

   B

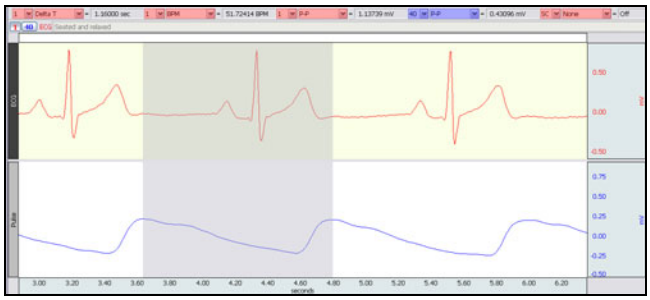


Fig. 7.15 Area between two successive pulse peaks

Use the **P-P** (CH 40) measurements.

Note: It is best to take measurements on data immediately following the start of the recording (after marker) because the body's homeostatic regulation of blood pressure and volume occurs quickly. The increase or decrease in your results will be dependent on the timing of your data relative to the speed of physiological adjustments.

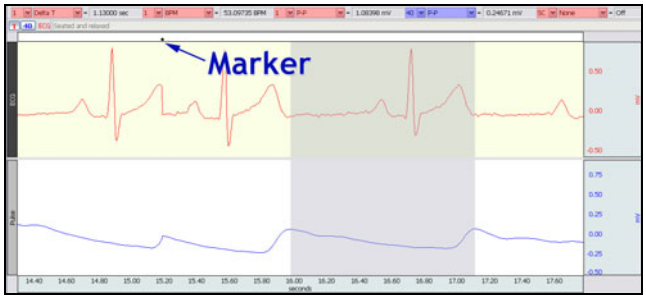


Fig. 7.16 Selection for amplitude measurements

8. Using the I-Beam cursor, select the interval between the R-wave and pulse peak.

   C

Record two time intervals (**Delta T;)** one from "Seated and Relaxed" data and "Seated, right hand above head" data.

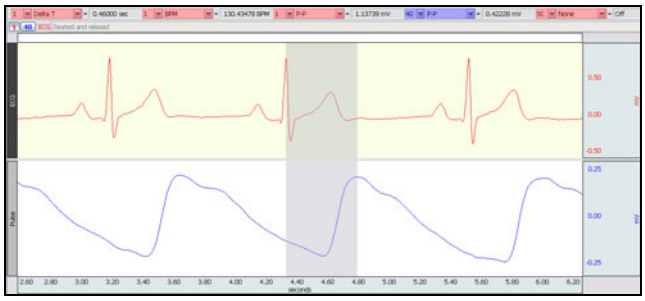


Fig. 7.17 R-wave to next pulse peak

9. Answer the questions at the end of the Data Report.
10. **Save** or **Print** the data file.
11. **Quit** the program.

END OF DATA ANALYSIS

An electronically editable **Data Report** can be found in the journal (following the lesson summary,) or immediately following this Data Analysis section. Your instructor will recommend the preferred format for your lab.

END OF LESSON 7

Complete the Lesson 7 Data Report that follows.

ECG & PULSE

- *Mechanical Action of the Heart, Peripheral Pressure Pulse, and Plethysmography*

DATA REPORT

Student's Name: _____

Lab Section: _____

Date: _____

I. Data and Calculations

Subject Profile

Name:_____ Height:_____

Age:_____ Gender: Male / Female Weight:_____

A. Comparison of ECG with Pulse Plethysmogram

Complete Table 7.1 with data from three cycles from each acquired recording and calculate the Means.

Table 7.1

Condition	Selected Area	Measurement	Cycle I	Cycle 2	Cycle 3	Mean
Arm Relaxed	R-R Interval	**DeltaT** CH 1				
	Heart Rate	**BPM** CH 1				
	Pulse Interval	**DeltaT** CH 1				
	Pulse Rate	**BPM** CH 1				
Temp. Change	R-R Interval	**DeltaT** CH 1				
	Heart Rate	**BPM** CH 1				
	Pulse Interval	**DeltaT** CH 1				
	Pulse Rate	**BPM** CH 1				
Arm Up	R-R Interval	**DeltaT** CH 1				
	Heart Rate	**BPM** CH 1				
	Pulse Interval	**DeltaT** CH 1				
	Pulse Rate	**BPM** CH 1				

B. Relative Volume Changes

Complete Table 7.2 with data from each acquired recording.

Table 7.2

Measurement	Arm Resting	Temperature	Arm Up
QRS Amplitude CH1 P-P			
Relative Pulse Amplitude (mV) CH 40 P-P			

C. **Calculation of Pulse Speed**

Distance between Subject's sternum and shoulder? _____cm

Distance between Subject's shoulder and fingertip? _____cm

Total distance? _____cm

Data from 'Arm relaxed' recording of the recording (measure with I-Beam)

Time between R-wave and Pulse peak? _____secs

Speed?_____cm/sec

Data from 'Arm up' recording of the recording (measure with I-Beam)

Time between R-wave and Pulse peak? _____secs

Speed?_____cm/sec

II. Questions

D. Referring to data in table 7.1, are the values of heart rate and pulse rate similar for each condition? Yes / No

Explain why the values might differ or be similar.

_____

_____

_____

E. Referring to Table 7.2 data, how much did the amplitude of the QRS complex change between conditions?

Extreme temp – Arm Resting? _____ mV

Arm up – Arm Resting? _____ mV

F. Referring to Table 7.2 data, how much did the pulse amplitude change between arm positions?

Extreme temp – Arm Resting? _____ mV

Arm up – Arm Resting? _____ mV

G. Referring to Table 7.2 data, does the amplitude of the QRS complex change with the pulse amplitudes? Why or why not?

_____

_____

_____

H. Describe one mechanism that causes changes in blood volume to your fingertip.

_____

_____

_____

I. Referring to data from section C of this report, how would you explain the difference in speed, if any?

_____

_____

_____

J. Which components of the cardiac cycle (atrial systole and diastole, ventricular systole and diastole) are discernible in the pulse tracing?

_____

_____

_____

K. Would you expect the calculated pulse wave velocities of other students to be very close if not the same as yours? Why or why not?

L. Explain any amplitude or frequency changes that occurred with arm position.

III. OPTIONAL Active Learning Portion

A. ***Hypothesis***

B. ***Materials***

C. ***Method***

D. ***Set Up***

E. ***Experimental Results***

End of Lesson 7 Data Report