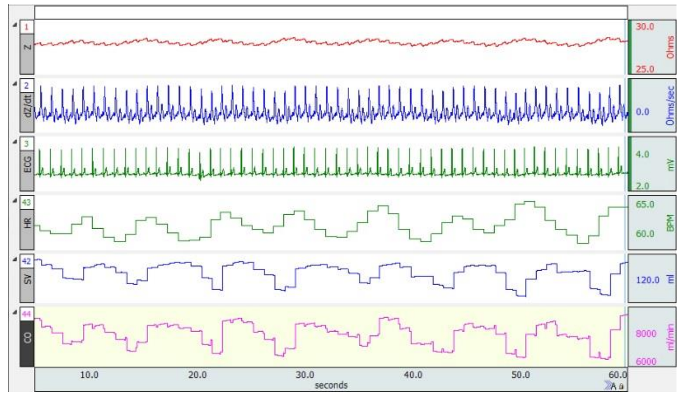
42 Aero Camino, Goleta, CA 93117
Tel (805) 685-0066 | Fax (805) 685-0067
info@biopac.com | **www.biopac.com**

Updated 03.28.19

BSL *PRO* Lesson H21: Impedance Cardiography



This BSL *PRO* Lesson describes how to setup the BSL System in order to record and measure <u>relative</u> differences in Cardiac Output and Stroke Volume using a noninvasive bioimpedance technique. When used with the MP36/35, ECG is also recorded.

Objectives:

1. Learn impedance cardiography techniques.
2. Measure the change in the following cardiovascular responses to postural changes (supine vs. standing):
   - Stroke Volume (SV)
   - Cardiac Output (CO)
   - Heart Rate (HR)
3. Examine how HR and SV interact to maintain CO.
4. Experiment with other ways to elicit cardiovascular responses, which is an excellent active learning exercise.

Equipment:

- Biopac Student Lab System:
  - MP36, MP35 or MP45 hardware
  - BSL 4.0.1 or greater software
- BSL *PRO* template file: “**H21_SS31LA.gtl”** (MP36/35) or **“H21_SS31LA_MP45.gtl”**
- BIOPAC Noninvasive Cardiac Output Sensor (SS31LA) which includes:
  - 4 x TouchProof “Y” Lead Adapter (CBL204)
  - 8 x Touchproof to Electrode Clip Lead (LEAD110)
- Disposable Paired Bioimpedance Electrodes (EL500), 4 per student
- Abrasive pads (ELPAD), 1 per student
- Electrode gel (GEL1)
- Cloth tape measure
- Floor mat
- To record ECG and Heart Rate (MP36 and MP35 only):
  - BIOPAC Electrode lead set (SS2L)
  - Disposable electrodes (EL503), 2 per student

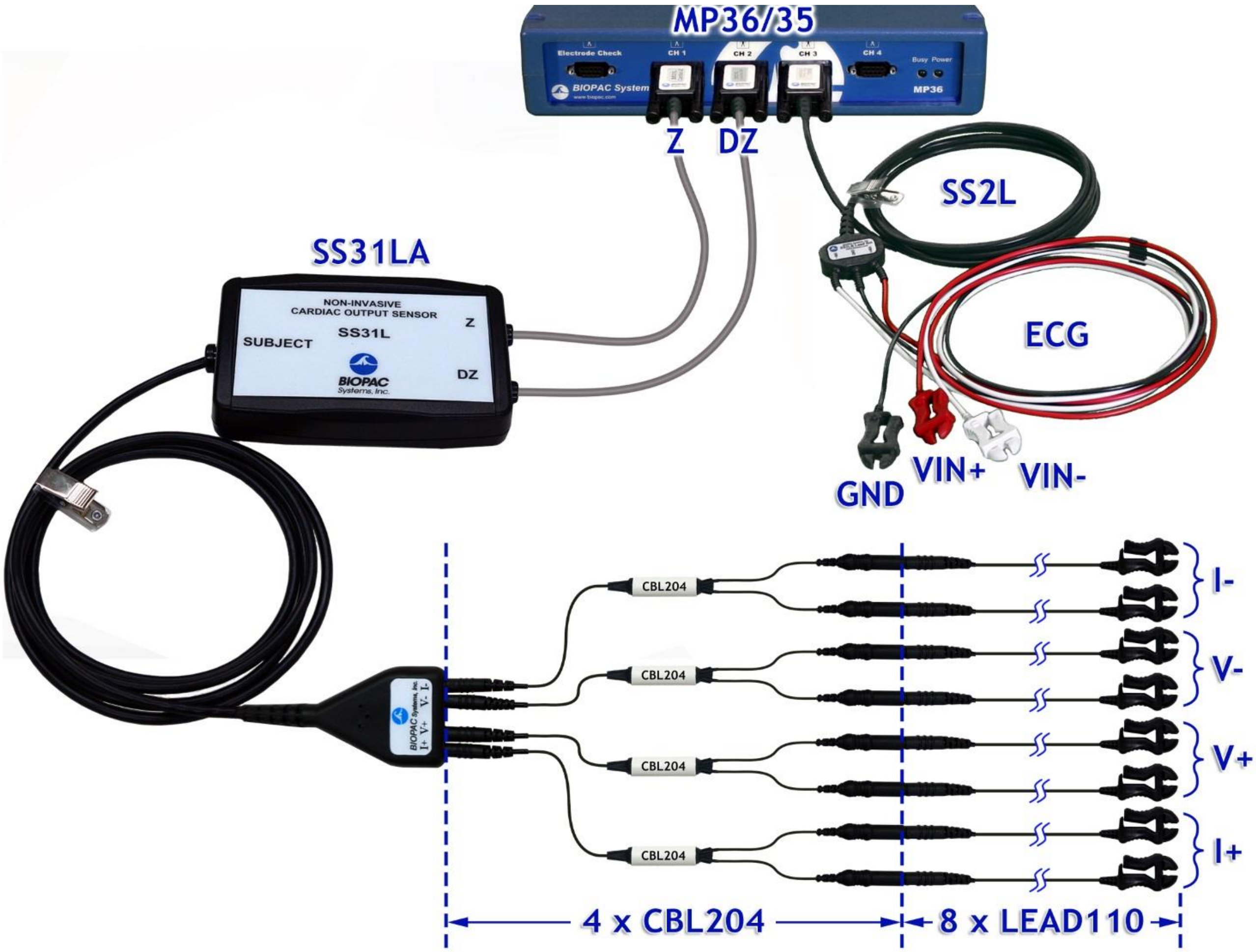


Figure 1

Figure 2

Background:

Cardiac Output as a Function of Stroke Volume and Heart Rate

The major purpose of the heart is to maintain an adequate flow of blood through the pulmonary and systemic circulations. The left ventricle and the right ventricle each pump approximately 68 to 100 mL of blood into their respective arterial systems with each heartbeat, or cardiac cycle as shown in Figure 3. The volume of blood ejected by one ventricle in a single beat is called **stroke volume** (**SV)**, and is simply the difference between the volume of blood in the ventricle at the end of diastole (**end-diastolic volume**, or **EDV**) and the volume of blood remaining in the ventricle at the end of systole (**end-systolic volume**, or **ESV**):

(1) SV = EDV – ESV

The sum of all stroke volumes ejected by a ventricle over a period of one minute is called **cardiac output**, or **CO**. Normally, right ventricular cardiac output is equal to left ventricular cardiac output. Cardiac output is calculated as the product of stroke volume, or the volume of blood ejected by the ventricle per beat, times the **heart rate** (**HR) -** number of beats per minute (BPM):

(2) CO = SV x **HR**

If we assume a resting adult SV of 70 mL and heart rate of 72 BPM, CO for either ventricle is calculated as:

(3) CO = **SV** x **HR** = 70 mL x 72 BPM = 5040 mL/min, or approximately **5 L/min**

An average CO for an adult at rest is approximately 5 to 6 L/min; however, this value can increase or decrease significantly in response to the changing needs of the body or in response to disease. By applying Equation 3, we can see that CO can be increased by increasing SV or HR or both; conversely, CO can be decreased by decreasing SV or HR or both. Reciprocal changes in SV and HR are observed under many conditions, resulting in the maintenance of stable CO.

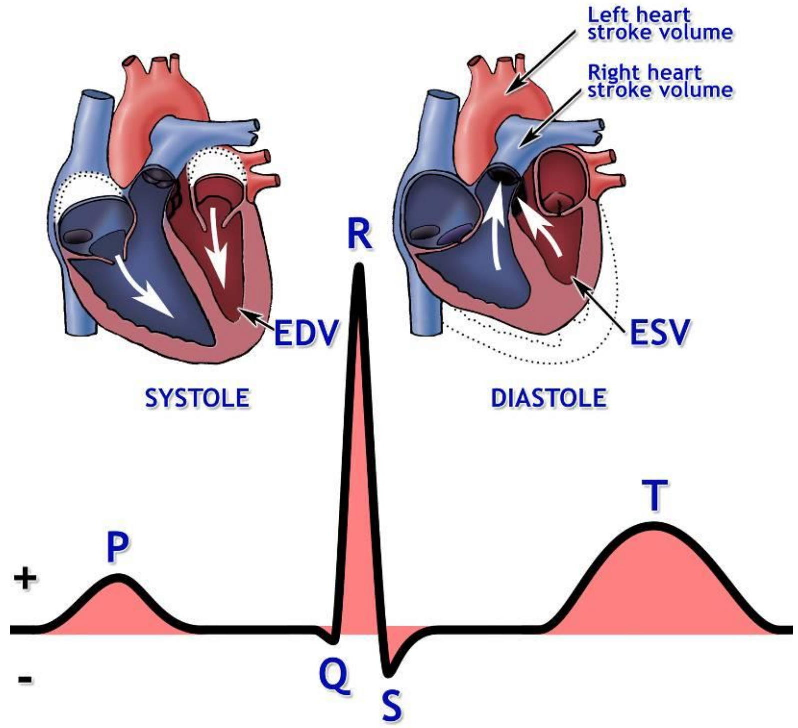


Figure 3

In dynamic physical exercise, for example, CO is increased to meet the increased metabolic needs of skeletal muscles. The increase in CO at the beginning of exercise, as well as throughout the duration of moderate exercise, is due to an increase in HR and an increase in SV. On the other hand, when the function of the heart is compromised by disease, as in cardiomyopathy, SV may be reduced due to decreased contractility of ventricular muscle. An autonomically mediated increase in heart rate may be initiated to minimize a subsequent decrease in CO so as to help maintain peripheral blood pressure and flow.

It is easier to understand normal and abnormal changes in cardiac output if we incorporate Equation 1 into Equation 2 as follows:

(4) CO = (EDV – ESV) x **HR**

EDV is determined by venous and atrial pressures and the venous return of blood to the heart. An increase in venous pressure increases venous return, thereby increasing EDV and CO. This occurs in dynamic physical exercise. EDV is also determined by ventricular compliance, or the ability of the ventricle to distend as it fills with blood. Some cardiac diseases render the wall of the ventricle less distensible (stiffer), thereby reducing EDV, SV, and CO. In these circumstances, maintenance of a relatively normal CO would require a reduction in ESV and/or an increase in HR.

ESV is determined, in part, by changes in peripheral vascular resistance (largely in the arterioles). A chronic increase in peripheral resistance tends to counter ventricular ejection, reducing SV and increasing ESV, as commonly seen in peripheral vascular diseases such as atherosclerosis and arteriosclerosis.

ESV is also determined by ventricular contractility, the ability of the ventricular myocardium to generate the compression force needed for adequate ejection of blood. An increase in ventricular contractility tends to reduce ESV thereby increasing SV and CO.

A physiological example of this effect is seen during dynamic physical exercise when ventricular contractility is increased by the actions of hormones and autonomic neurotransmitters. In cardiac disease where contractility has been compromised and the heart weakened, pharmaceuticals such as digitalis may be used to increase contractility, reduce ESV, and increase SV and CO.

Changes in EDV and ESV alter SV, which in turn may change CO. Changes in HR also change CO. Heart rate is governed by nervous and endocrine components of the autonomic nervous system. Factors that increase HR include decreases in parasympathetic and increases in sympathetic nervous system activity, which may occur during emotional stress such as anxiety or anticipation, and physical stress, including that associated with exercise or with acute or chronic pain. Changes in HR also occur normally as a result of autonomic reflexes that adjust blood pressure and blood flow.

Cardiac Output as Related to Mean Arterial Pressure and Peripheral Resistance

The left ventricle pumps blood through a closed circuit of blood vessels that collectively comprise the systemic circulation. Systemic blood returns to the right atrium to complete the circuit. Blood flows progressively from the beginning of the circuit to the end of the circuit because the pressure creating the flow is highest at the beginning of the circuit and least at the end of the circuit, and because the resistance opposing the flow is not great enough to stop it. The relation between flow, pressure, and resistance is:

$$\text{(5)} \quad \text{Flow} = \text{Pressure} \div \text{Resistance}$$

Accordingly, blood pressure plays a critical role in maintaining adequate blood flow throughout the body to meet metabolic demands. Cardiac output interacts with systemic vascular resistance to regulate mean arterial blood pressure (MAP), as indicated in Equation 6:

$$\text{(6)} \quad \text{Cardiac Output (CO)} \times \text{Systemic Vascular Resistance (SVR)} = \text{Mean Arterial Pressure (MAP)}$$

Where: CO is the blood flow (in mL/min) pumped by the heart, SVR is the resistance (in dyne-sec/cm^5) against which the left ventricle must pump to eject stroke volume, and MAP (in mmHg) is the mean arterial blood pressure that pushes blood through the circuit.

From Equation 6, an increase in CO and/or an increase in SVR will increase MAP. Likewise, if SVR falls, then CO must rise to maintain adequate MAP. On the other hand, if SVR increases (as with widespread arteriolar vasoconstriction, or in atherosclerosis or other peripheral vascular disease), then CO may decrease to maintain MAP within normal homeostatic limits.

Mean arterial pressure can be approximated using indirect blood pressure measurement and one of the following formulas:

$$\text{(7)} \quad \text{Mean Arterial Pressure} = 1/3 \text{ Pulse Pressure} + \text{Diastolic Pressure}$$

Where: Pulse pressure is the mathematical difference between systolic and diastolic pressures.

Rearranging the formula:

$$\text{(8)} \quad \text{Mean Arterial Pressure} = \frac{\text{Systolic Pressure} + (2 \times \text{Diastolic Pressure})}{3}$$

Systemic vascular resistance (also known as total peripheral resistance) is computed by dividing the MAP by the CO.

How can Cardiac Output be determined?

Cardiac output can be directly measured using invasive thermodilution techniques (CO-TD) and a pulmonary arterial catheter (PAC); obviously not a procedure that can be performed in the lab. Left ventricular CO can also be estimated using a noninvasive technique called **Impedance Cardiography (ICG)**, which provides an approximation of SV. If SV and HR are known, then based on Equation 2, CO can be determined.

Principles of Impedance Cardiography (ICG)

Ohm's Law defines the relationship between voltage and current in an electrical circuit.

$$\text{(9)} \quad V = I \times R$$

Where: V = Voltage, I = current, *and* R = Resistance

When working with alternating current (AC) circuits, the AC analog to Ohm's law is:

$$(10) \quad V = I \times Z$$

Where: Z is the **Impedance** of the circuit and V and I are the Root Mean Square (RMS) values of the voltage and current.

In AC circuits, V, I and Z possess both magnitude and phase. The term **bioimpedance**, or **bioelectrical impedance** may also be used when referring to the impedance of a living organism.

ICG systems induce a constant magnitude, alternating current (**I**) through the thorax via electrodes as shown in Figure 4. A separate set of electrodes monitor the voltage (**V**) developed across the thorax. Because the magnitude of I is constant, V will vary in direct proportion to Z.

The applied current flows through the immediate surrounding volume of the thorax which includes skin, skeletal muscle, the lungs, the heart and blood. Because blood is a conductor, the changes in blood volume during a cardiac cycle produce a measurable change in thoracic impedance. Researchers have empirically derived equations for estimating left ventricular SV based on thoracic impedance, with a widely used equation being that developed by Kubicek et al. (1966):

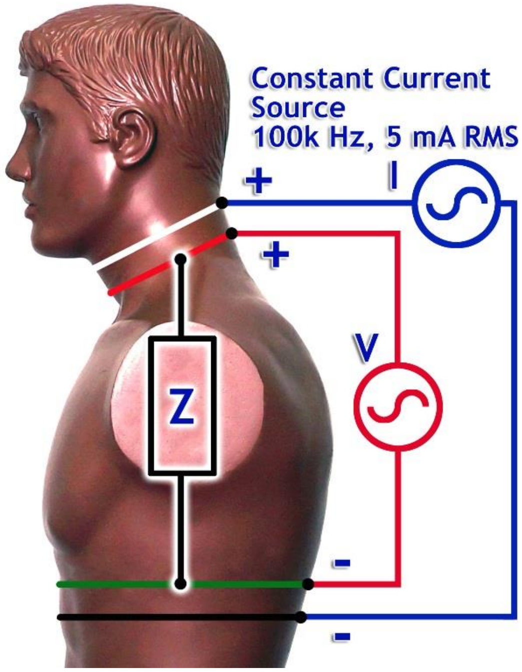


Figure 4

$$(11) \quad SV = rho \times LVET \times (dZ/dt\ Max) \times (L/Zo)^2$$

Where: SV = Stroke volume (ml)

rho = Resistivity of blood (Ohms·cm) which is assumed to be a constant 135 Ohms·cm (Quail, Traugott, Porges, & White, 1981).

L = Length or distance between inner band electrodes (cm)

Z_0 = Basal Thoracic Impedance (Ohms)

LVET = Left Ventricular Ejection Time (sec)

dZ/dt Max = Absolute value of the cyclic peak of the derivative of Z_0 (Ohms/sec)

Notes:

- *IMPORTANT* Impedance Cardiography (ICG) is an indirect measurement of stroke volume (SV). Studies have been performed to correlate ICG to SV, using thermodilution via catheter to the heart and have found that accuracy improves when variables such as height, weight, waist circumference, age and sex are factored into the SV equation. In this lesson, the ICG measurement is only faithful to the Kubicek derivation (Equation 11). Accordingly, this ICG measure is best interpreted as a relative indication of SV, versus an absolute measurement of SV. Even so, as a relative measure, ICG can provide a clear indication of important physiological processes associated with homeostasis and hemodynamic changes.
- Most of the literature in psychophysiology and many areas of physiology (e.g., exercise physiology) focus on the left ventricle because it pumps the blood that serves the metabolic needs of the striated musculature and thus subserves behavior, exercise, etc. Moreover, in the case of ICG, the left ventricle is the focus because the dZ/dt signal primarily reflects left ventricular ejection into the aorta. There is very little influence from the right ventricle in the ICG signal.
- LVET varies inversely with heart rate under a broad range of circumstances. During the lesson recordings, LVET is set to 1.0 seconds in the SV equation, which is outside the expected range. After all recordings are complete (prior to data analysis), SV and CO data will be rescaled, for each recording segment, based on a single measurement of LVET within each segment. Because the default value of LVET is 1.0 second, scaling SV and CO is accomplished by multiplying the data by the measured values of LVET. Although this method does not account for all LVET variation, it produces useful results without overcomplicating the lesson procedure.
- Rho may vary slightly with changes in hematocrit and red cell orientation, but that variation has largely been ignored because of the inconvenience of having to draw blood to measure it (defeats the non-invasive advantage of ICG over some other methods).

Ideas for eliciting cardiovascular responses

The first part of this lesson examines cardiovascular responses to postural changes (supine vs. standing). The student may then perform other experiments that may elicit cardiovascular responses. Because the ICG measurements are sensitive to motion and muscle artifact, the recordings should always take place with the Subject relaxed and still. For example, if examining cardiovascular changes with exercise, it is suggested to perform two recordings; one seated, pre-exercise, and one seated, post exercise. In both cases, during the recordings, the Subject is seated and relaxed. Unclip the electrode leads prior to exercising, and then after exercising, quickly reconnect the electrodes and start the recording.

Physical maneuvers:

- Compare resting state to post moderate exercise.
- Supine position; legs horizontal vs. elevated.
- Dive reflex or mild forehead cold pressor (simulating part of the dive reflex).

Psychological tasks:

- Outwardly directed attention tasks including video games and reaction time tests.
- Solving complex math problems or vocal serial subtractions.
- Evoking anxiety or disgust by viewing disturbing images or videos.

See Appendix 2 for the kinds of cardiovascular responses that these different tasks are expected to elicit.

BSL System Setup

The BIOPAC SS31LA Noninvasive Cardiac Output Sensor provides a constant current source of 5 mA RMS at 100,000 Hz across two pairs of electrodes ("**I+**" and "**I-**") that are applied to the Subject. The SS31LA also measures the voltage across two other pairs of electrodes ("V+" and "V-"). The circuitry inside the SS31LA processes and outputs two signals to the MP unit; Z_0 and dZ/dt as shown in Table 1. If using the MP36/35 hardware, two spot electrodes will also be placed on the Subject to record ECG. Software calculation channels will then handle the processing of HR, SV and CO. The Channel setup is summarized in Table 1.

Label Reference	Channel	Signal Description	Units
Analog Channels			
Z (Z_0)	1	Basal thoracic impedance (from SS31LA)	Ohms
DZ (dZ/dt)	2	Derivative (Rate of change) in the thoracic impedance in a given beat (from SS31LA)	Ohms/sec
ECG	3	ECG Lead II	mV
Calculation Channels			
Z – 5 Hz L.P.	40	Low Pass filter of Z (Z_0) – which reduces noise artifact	Ohms
dZ/dt Max	41	Calculates the maximum value of dZ/dt within each cardiac cycle	Ohms/sec
Stroke Volume (**SV**)	42	Applies an expression equivalent to Equation 11	ml
Heart Rate (**HR**)	43	Calculates Heart Rate from ECG (MP36/35) or from dZ/dt (MP45)	BPM
Cardiac Output (**CO**)	44	Applies Equation 2	ml/min

Table 1

Notes:

- The eight-electrode configuration is based on Reference 3 at the bottom of Appendix 2.
- *On the SS31LA the label "Z" is equivalent to "Z_0" and the label "DZ" is equivalent to "dZ/dt."
- **If the MP45 is used, ECG electrodes are not used, and HR is determined from the dZ/dt signal.
- The polarity of the dZ/dt Max is shown inverted in the graph to adhere to ICG convention. The value that is applied to Equation 11 can be interpreted as the absolute value of dZ/dt Max.
- The user must manually enter L (cm) into calculation channel 42's expression which represents Equation 11.
- If MP35 or MP45 is used, the Input Values bar graph may not display automatically after opening the h21.gtl or h21_MP45.gtl graph templates. To launch it manually, go to the MP menu and enable "Show Input Values."

Impedance Cardiography Statistics

Zo	Base Thoracic Impedance	Males: 15-30 ohms, Females: 25-35 ohms
dZ/dt	Impedance Change	0.8 – 3.5 ohms/sec
SV	Stroke Volume	60-120 ml/beat
CO	Cardiac Output	4000-9000 ml/minute

Note: Z_0 generally runs less than 25.5 ohms in males and greater than 25.5 ohms in females, most likely because of added breast tissue and differences in tissue and fluid content.

Hardware Setup:

General Cable Connections

If using an MP36 or MP35, it should be turned OFF until after the cable and electrode connections are made. It is assumed that the MP unit is connected to the host computer and that BSL 4 software has been installed and is known to work with the MP unit.

1. The hardware must be connected to the MP input channels as follows:

Transducer	MP36/MP35 Input	MP45 Input
SS31LA – “**Z**”	CH1	CH1
SS31LA – “**DZ**”	CH2	CH2
Electrode Lead Set (**SS2L**)	CH3	Not Used

Table 2

Ready the Subject

2. Select a Subject who is willing and able to expose the electrode sites shown in Figure 7.

Determine Electrode Placement

3. For ICG electrode placement, imagine four rings around the neck and torso at the vertical location described in Table 3 and shown in Fig. 6. The electrodes will be placed at the intersection of these rings and the mid-axillary lines on the left and right side of the body (Fig. 7).
4. If recording ECG, refer to Table 4 and Fig. 9 for electrode placement.

   Note: The ECG ground (“GND” - black) electrode is not connected because ground reference is obtained through the SS31LA. As a precaution, place a piece of tape around the lead to prevent accidental contact with a grounded metal surface

ICG Electrodes	**Location on frontal Plane** (Figure 6)
V+	Close to the clavicles at the base of the neck.
I+	Approximately 3 cm above the “V+” electrode
V-	Transverse plane that intersects the Xiphoid Process
I-	Transverse plane approximately 3 cm below the “V-“ electrode

Table 3

Prepare Electrode Sites

5. Clean the skin in and around the electrode sites using soap and water or alcohol if needed. Make sure the skin is completely dry and then lightly abrade the skin using the ELPAD.

ECG Electrode	Color	Placement
VIN+	Red	Above left ankle
VIN-	White	Above right wrist
GND	Black	Not Connected

Table 4

Notes:

- Remove any necklace(s) as they can interfere with the ICG measurements.
- Remove any jewelry around the right wrist or left ankle as they can interfere with the ECG measurements.

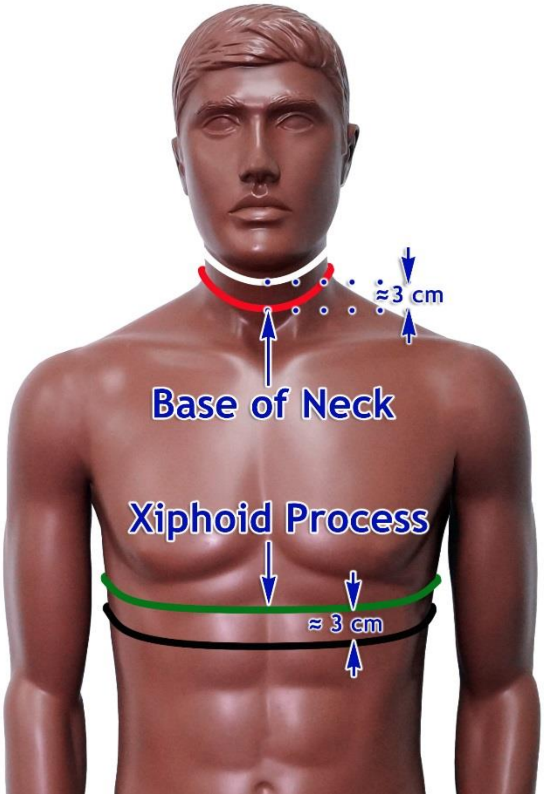


Figure 6

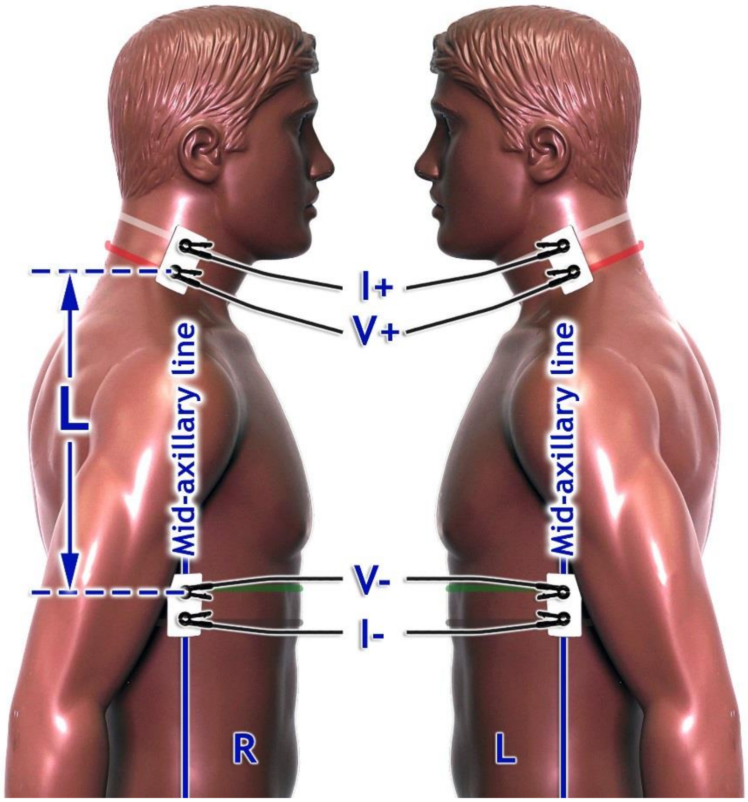


Figure 7

6. Using a cloth tape measure, determine the distance "L" in centimeters (cm) between the V+ electrodes and the V- electrodes as shown in Figure 7. Write this number down as it will be used in a later step. Note: 1 inch = 2.54 cm.

L = _________________ cm

Place Electrodes

7. After peeling off the adhesive backing, apply a drop of electrode gel (GEL1) to the center of each electrode (Figure 8).

Figure 8

8. Place the electrodes in the proper positions. For ICG (Fig. 7) use EL500 (or equivalent) electrodes. For ECG, use EL503 electrodes.

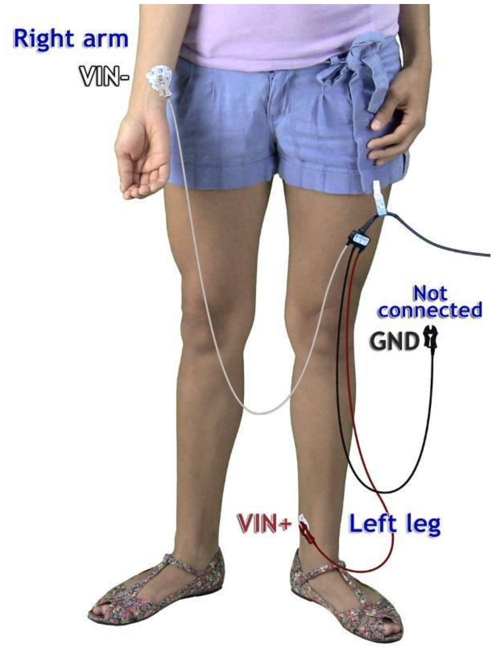


Figure 9

Position the Subject

9. Position the Subject in a Supine position. The Subject must be as comfortable as possible with their head supported (Fig. 10).

Attach Electrode Leads

10. Connect the eight ICG leads carefully following Figure 7. It is important that each lead pair (V+, I+, V-, I-) connect to the same location on the left and right sides.

Figure 10

Notes:

- Each lead pair connects to the same point on the SS31LA cable yoke, so there is no specific left or right lead.
- Organize the cables and leads and utilize the cable clips so that the Subject will be able to move from the supine to standing position without the leads excessively pulling on the electrodes.
- To minimize artifact, the Subject should be relaxed as possible, and should not move or talk during the recordings.

Turn ON the hardware

11. After all leads are connected to the electrodes, the MP36/35 may be turned ON. Turning ON the hardware after the connections are made minimizes the chance of instrumentation errors caused by Electrostatic Discharge (ESD).

Setup Software

Launch the BSL 4 software and from Startup dialog, choose the Create/Record a new experiment option, click Open Graph template from disk and then click OK. Navigate to the file, select it and click Open.

Calibration Procedure:

Calibration consists of modifying the SV equation (C3 expression) to account for "L" (cm) measured in Setup Step 6.

1. Navigate to the Stroke Volume (C3) calculation channel Expression dialog as follows (Figure 11):
   a. Depending on software version, select "Set up Data Acquisition" or "Set Up Channels…" from the MPxx menu.
   b. From the "Data Acquisition Settings" or "Channel Settings" dialog, select the **Calculation tab**.
   c. Select "C3" (Stroke Volume) by clicking on the line item, and then click the "Setup" button.
   d. Select the first line item, Stroke Volume (C3.0) in the "Metachannel setup" dialog and click "Setup Subchannel."

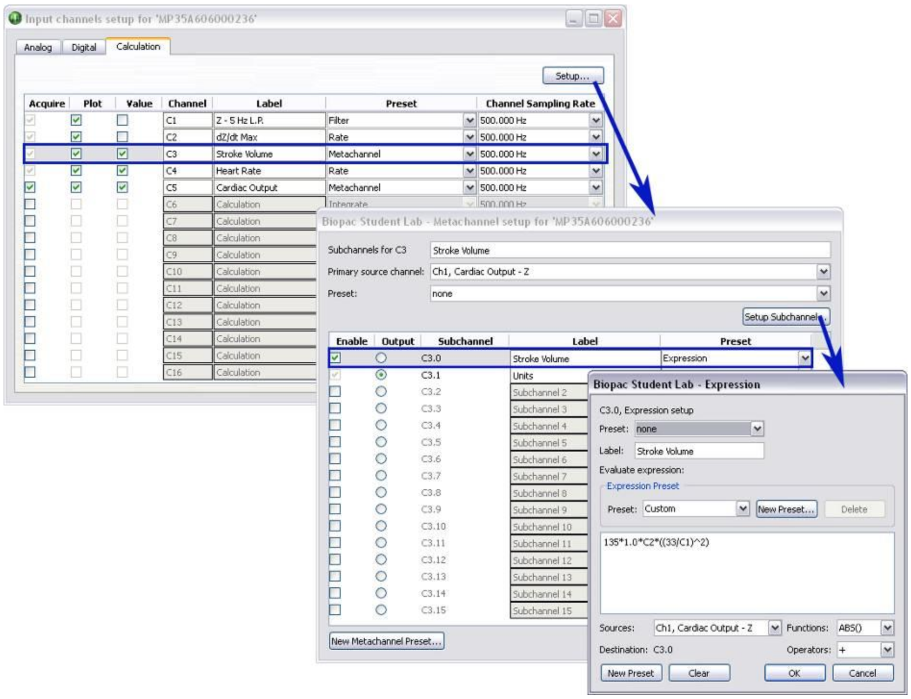


Figure 11

2. Change the Length (L) value (in cm) in the SV expression, as shown in Figure 12, to reflect that measured in Setup Step 6.
3. Click OK to close the Expression dialog, then close the other two channel setup dialogs.

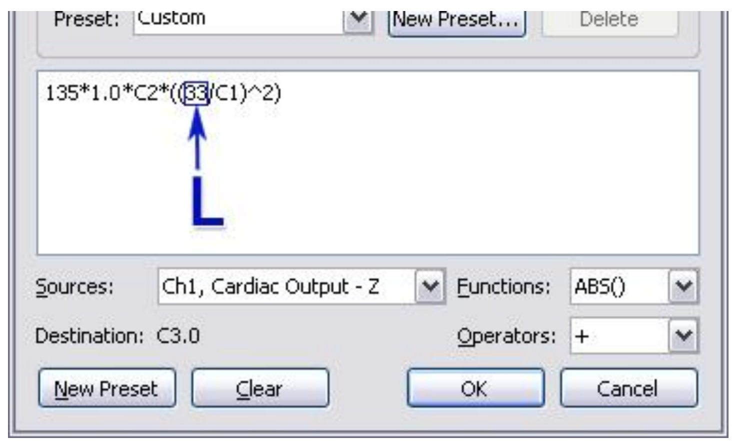


Figure 12

Recording Procedure:

You will perform two 60 second recordings; one with Subject in the supine position, and one with Subject in standing position. Optional recordings can then be performed.

1. The Subject is in a relaxed, supine, position (Figure 10).
2. Click **Start** to begin the recording.
3. Record for **60 seconds**, and then click **Stop**.
4. The Subject slowly moves to the standing position (Figure 13), being careful to prevent the electrode leads from pulling excessively on the electrodes.

   Note:
   - The Subject should try and relax the shoulders, arms, and hands as much as possible and should avoid any movement during the recording.
5. Click **Start** to begin the recording.
6. Record for **60 seconds**, and then click **Stop**.
7. Perform any additional recordings now.

Notes:
- ****Important**** SV and CO data are not yet valid because they do not take LVET into account.
- The ECG baseline may have an offset due to the signal from the Cardiac Output Module. This offset is not a problem as it does not affect the Heart Rate (HR) calculation (CH43).

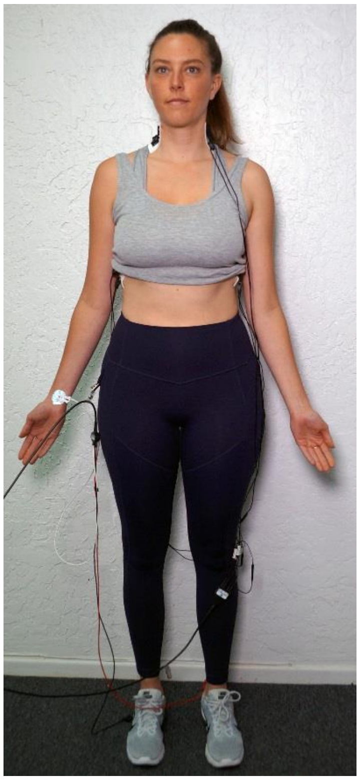


Figure 13

Rescaling SV and CO data to account for LVET:

This step requires familiarization with the measurement tools (see Appendix 1 for basic details).

LVET is set to 1.0 seconds in the default SV expression. Prior to data analysis, both SV and CO data must be rescaled, once for each recording segment, to account for changes in LVET.

1. View all the recorded data.
2. Zoom in on approximately four cardiac cycles within the first (Supine) recording segment.
3. Scroll, if necessary, to find a section dZ/dt data that contains little artifact.

   Note: Fig. 14 shows all channels hidden except CH 2 (dZ/dt) and CH 3 (ECG).
4. Use the "I" cursor to determine LVET as follows:
   a. Find the maximum dZ/dt peak within one cardiac cycle.
   b. Select an area that begins at the zero crossing (baseline) that is prior to (left of) the peak and ends at the minimum value after the peak.

Figure 14

The "Delta T" measurement will display the time of the selected area (LVET) which is typically between 200 and 400 milliseconds (ms). Convert the millisecond value to seconds (i.e. 200 ms = 0.2 seconds) and note this value in Table 6 (Analysis section) and in the Journal.

5. Zoom out to view all the data from the first recording segment.
6. If Stroke Volume (CH42) or Cardiac Output (CH44) were hidden, show them now.
7. Referencing the Append Event Markers (small diamonds), select all segment 1 data using the "I" cursor (Figure 15).
8. Activate the "Stroke Volume" channel (via channel button - CH42). Note that the vertical channel label will be darkened when the channel is active.
9. Select Transform > Waveform Math…
10. In the Waveform Math dialog, enter the LVET value (in seconds) obtained in Step 4 into the "K:" entry box. Make sure the rest of the dialog expression is setup exactly as shown in Figure 16.

    Notes:
    - DO NOT check "Transform entire wave"
    - Make sure the math operator is multiply ("*").
11. Click "OK" to perform the multiplication (scaling).
12. Activate the "Cardiac Output" channel (CH44).
13. Repeat Steps 9-11 referencing "CH44, Cardiac Output" and Figure 17.

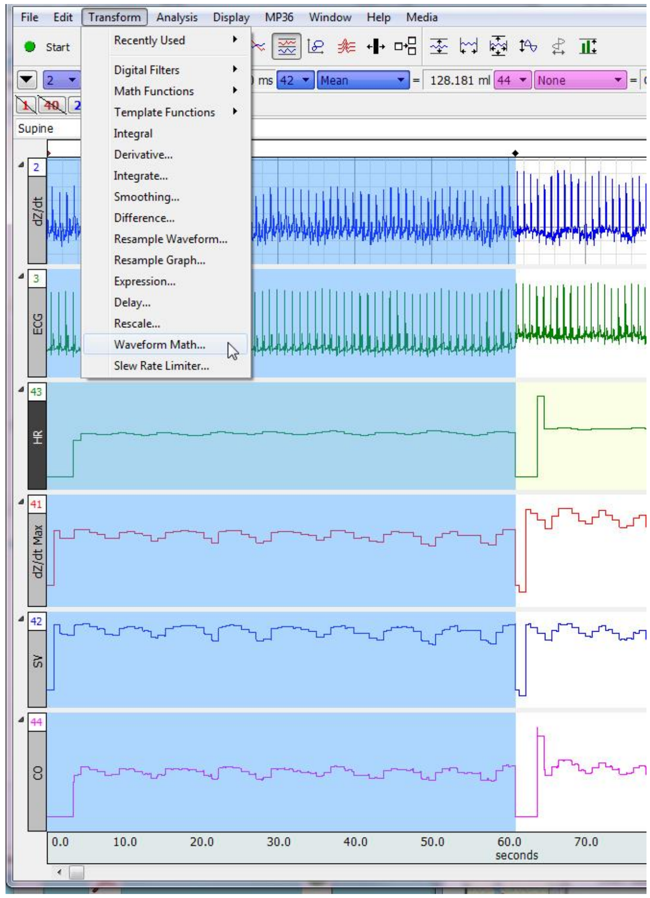


Figure 15

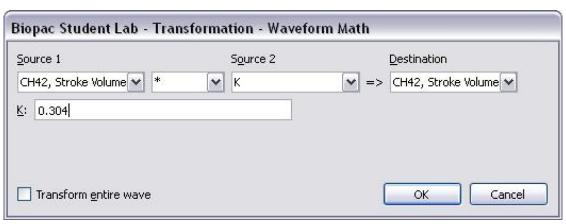


Figure 16

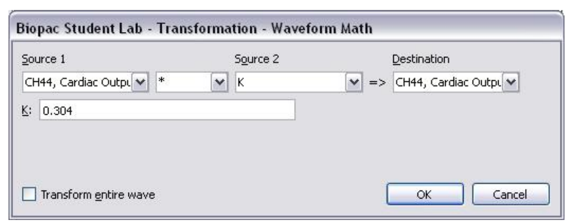


Figure 17

14. Zoom out to view all recorded data.
15. Zoom in on approximately four cardiac cycles within the second (Standing) recording segment.
16. Measure LVET from data in the <u>second</u> recording segment.
17. Select all data in the second segment and repeat Steps 8-13 to scale SV and CO.
18. Repeat these steps for any additional recording segments.

Done

To save the recorded data, choose: **File** menu > **Save As**… Enter a file name and then click **Save**.

Data Analysis:

Fill in the values for Table 6 based on measurements taken from data in each recording segment. The values for LVET were determined during Rescaling (Step 4).

Position/Task	**LVET** (sec) 2 Delta T	**SV** (ml) 42 Mean	**HR** (BPM) 43 Mean	**CO** (ml/min) 44 Mean
Supine				
Standing				

Table 6

Measurement examples:

1. Setup the graph to display all the recorded data.
2. Select an area of data within the <u>Supine</u> recording.

   Note:
   - The data selection should be at least 5 seconds long and must not contain any artifact in the dZ/dt, HR, or SV data.
3. Transfer the "Mean" measurements for SV (CH42), HR (CH43) and CO (CH44) into Table 6 and/or paste them into the Journal.

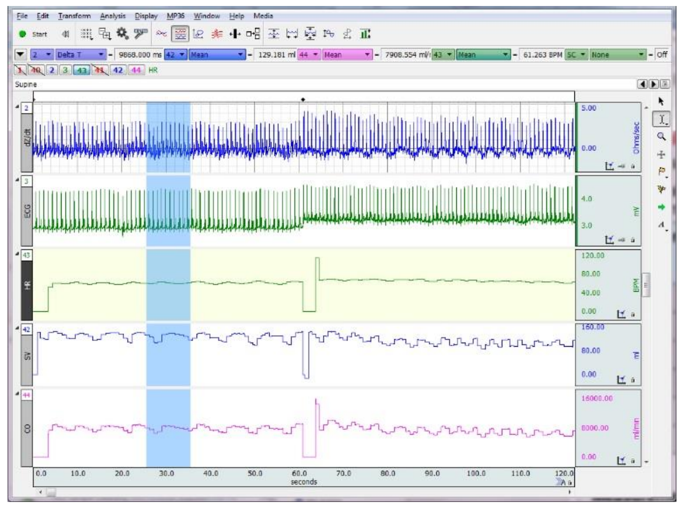


Figure 18

4. Select an area of data within the <u>Standing</u> recording as shown in Figure 19 and transfer the Mean measurements for SV, HR and CO into Table 5 and/or the Journal.
5. Repeat the measurement steps for all the recording segments.

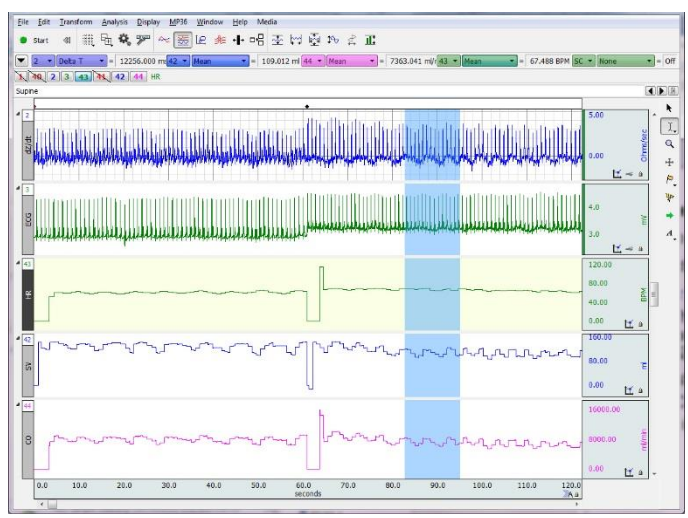


Figure 19

Questions:

How do your results compare to the expected results shown in Appendix 2?

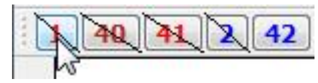
List possible reasons for the changes seen for each condition/task:

Appendix 1:

This section offers a quick overview of software essentials. For a full explanation of features, see the BSL *PRO* Tutorial or BSL *PRO* Manual.

Show/Hide channels:

Channel visibility can be toggled on and off by holding down the "Alt" key (Windows) or "option" key (Mac) and clicking on the Channel Box.



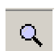
Autoscaling data:

Graph data can be autoscaled vertically and horizontally for enhanced viewing.

- To reset all vertical scales to the default template settings, select Display > Show Default Scales.
- Show All Data  toolbar button or Display > Show All Data adjusts vertical and horizontal scales to make all data visible.
- Autoscale vertically by using the  toolbar button or Display > Autoscale Waveforms to optimize the vertical display and allow closer examination of the waveform.
- Autoscale horizontally by using the  toolbar button or Display > Autoscale Horizontal to display the entire horizontal time scale in a single graph window.

Zooming in and out of data:

Use the Zoom tool to magnify portions of the waveform for a closer look.

- Zoom in by selecting the  toolbar icon and click/drag over the area of interest.
- To zoom back, use Ctrl – (minus) or "Display > Zoom Back."

Measurements:

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

Graph data measurements are taken by using the I-beam tool  to select an area of interest. The following basic measurements are used in this experiment:

Delta-T Shows the difference in time between the last and first sample of the selected area.

Mean Shows the mean amplitude value of data samples within the selected area.

BPM The Beats Per Minute measurement first calculates the difference in time between the beginning and end of the selected area (in seconds) and divides this value into 60 seconds/minute.
For example, if 1.5 seconds of data is selected, BPM = $\frac{60 \cancel{seconds} \ per \ Minute}{1.5 \cancel{seconds} \ per \ Beat} = 40$ BPM

Note*: When "SC" (Selected Channel) is assigned as the channel number, the measurement will apply to the active channel (channel button and channel label highlighted).

Appendix 2:

Expected cardiovascular responses to various maneuvers and tasks:

Physical maneuvers:

- Postural change from supine to standing:
  - Increase in HR
  - Decrease in SV
  - Variable change in CO, depending on changes in HR and SV
  - Increase in SVR
  - Increase in MAP, depending on change in CO and increases SVR
- Moderate exercise involving the legs (e.g., running or brisk walking in place):
  - Increase in HR
  - Increase or no change in SV
  - Increase in CO
  - Decrease in SVR
  - Increase in systolic but decrease in diastolic blood pressure, yielding a small increase in MAP

  Note: The pumping action of the legs increases venous return and SV. Exercise involving only the arms may be associated with increases in SVR and decreases in SV, especially if there is a substantial degree of isometric hand grip involved.
- Supine position with legs horizontal (relaxed) vs. elevated:
  - Slight increase or no change in HR
  - Increase in SV due to increase in venous return
  - Small increase in CO
  - No change or small decrease in SVR
  - No change or small increase in MAP
- Dive reflex or mild forehead cold pressor (simulating part of the dive reflex):
  - Decrease or increase in HR, depending on balance of dive reflex vs. cold pressor stimulation
  - Reciprocal change (increase or decrease) in SV to preserve CO
  - Little or no change in CO, depending on changes in HR and SV
  - Increase in SVR
  - Increase in MAP

Psychological tasks:

- Outwardly directed attention tasks, including video games and reaction time tests:
  - Decrease in HR with sensory intake (stimulus processing), but increase with response anticipation and execution
  - Reciprocal changes in SV
  - Variable change in CO, depending on changes in HR and SV
  - Increase in SVR
  - Increase in MAP
- Solving complex math problems and vocal serial subtractions (e.g., -7's starting with a 4-digit number):
  - Large increase in HR during first task minute, followed by a decline over ensuing minutes, but remaining elevated above resting baseline
  - Small or no change in SV
  - Increase in CO during first task minute, followed by a decline over ensuing minutes
  - Small changes in SVR
  - Increase in MAP

- Evoking anxiety or disgust by viewing disturbing images or videos:
  - Decrease in HR, especially for disgust
  - Small or no decrease in SV
  - Small decrease in CO
  - Small increase in SVR
  - Little change in MAP

Notes: In addition to postural change from supine to standing, the other recommended physical maneuvers to consider are (1) supine leg elevation, and (2) moderate dynamic exercise involving the legs (e.g., brisk walking in place).

Recommended psychological tasks are (1) vocal serial subtractions by steps of seven (starting from a 4-digit number; e.g., 1021) for three minutes (to show adaptation over time), and (2) playing a challenging video game for three minutes (again, allowing a demonstration of initial response and adaptation over time).

References for BSL *PRO* Lesson H21:

1. A. Sherwood, M. Allen, R. Kelsey, W. Lovallo and L. van Doornen, "Methodological Guidelines for Impedance Cardiography," Psychophysiology, vol. 27, 1990.
2. R. Kelsey, S. Ornduff and B. Alpert, "Reliability of Cardiovascular reactivity to stress: Internal Consistency," Psychophysiology, vol. 44, pp. 216-225, 2007.
3. Boomsma, De Vries, and Orlebeke. Comparison of Spot and Band Impedance Cardiogram Electrodes across Different Tasks, Psychophysiology.1989, Vol. 26, No. 6.

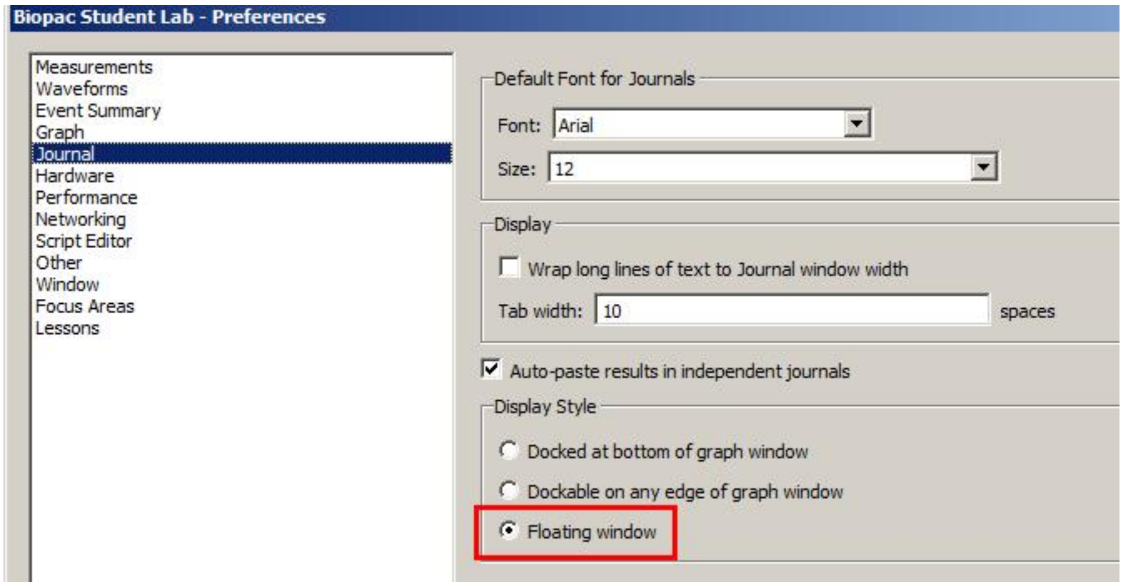
Appendix 3:

Enabling the "Floating window" Journal Display

BSL 4.1.2 and higher: In addition to the Help menu, lesson-specific *PRO* Lesson PDFs are also available in the lesson's Journal and viewable by clicking the Journal's "lesson procedure" tab. To enhance viewing of lesson PDFs from within the Journal, BIOPAC recommends changing the Journal display preference from the default "Docked at bottom of graph window" setting to "**Floating window**." This option allows for easy resizing and repositioning of the onscreen lesson Journal while allowing full access to the graph. "Floating window" also provides a higher resolution PDF display and positions any Output Control panels directly below the graph for easier viewing.

To change the Journal display to "Floating window":

1. In BSL *PRO*, choose "Display > Preferences" (or click the Preferences toolbar button.).
2. Highlight the "Journal" option in the Preferences window.
3. Under "Display Style," select "Floating window" and click OK.



4. The Journal will now appear in a separate window from the BSL graph. (It may appear behind the graph display. Drag the graph sideways and click the Journal window to bring it to the front.
5. Click the "lesson procedure" tab to view the PDF. Reposition and resize the Journal window as necessary. Toggle between Journal text (notes you've entered) and the lesson procedure PDF by clicking the "Journal" and "lesson procedure" tabs.