Experiment HS-4: Lung Volumes and Heart Rate

Equipment Required

PC or Mac Computer

IXTA, USB cable, IXTA power supply

A-FH-300L Spirometer flow head and plastic tubes

A-SRK Student Respiratory kit

PPG-320 Pulse plethysmograph

Spirometer and Pulse Plethysmograph Setup

1. Locate the A-FH-300L flow head, the airflow tubing, and the PPG-320 pulse plethysmograph.

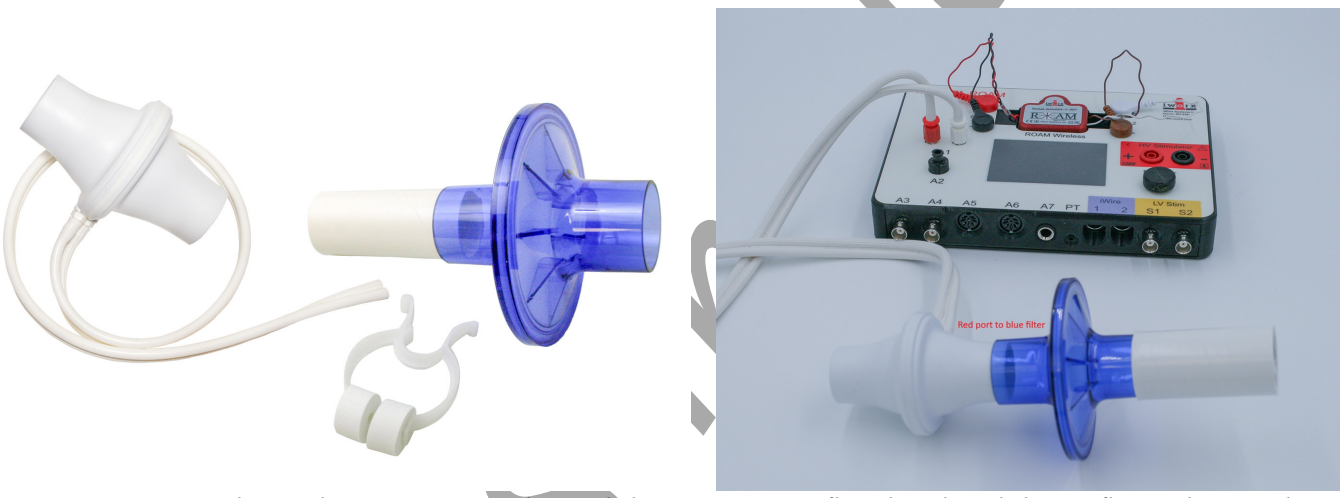

Figure HS-4-S1: The student respiratory kit and the A-FH-300L flow head and the airflow tubing. The blue filter will attach to the flow head.

2. Firmly push the two air flow tubes onto the two outlets on the A-FH-300L flow head. Carefully connect the other ends of the two air flow tubes into the Channel A1 input of the TA, and connect the pulse sensor to the PT port.
3. Place the plethysmograph on the volar surface (where the fingerprints are located) of the distal segment of the subject's middle finger or thumb, and wrap the Velcro^{tm} strap around the end of the finger to attach the unit firmly in place.

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Figure HS-4-S3: A PPG-320 pulse plethysmograph and the 300 L flow head connected to the TA unit.

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Before Starting

1. Please read the procedures for each exercise completely before beginning the experiment. You should have a good understanding of how to perform these exercises before making recordings.
2. The spirometer will monitor breathing from a subject. It is important that the subject is healthy and has no history of respiratory or cardiovascular problems.
3. The outlets on the flow head should always be in the upright position to avoid problems with condensation developing in the airflow tubes.
4. To reduce turbulence, the subject should place their lips around the cardboard mouthpiece attached to the flow head.
5. Use a nose-clip to prevent air from entering or leaving the nose as the subject is breathing. If not using the nose clip, hold your nose and breathe only through your mouth.
6. Check the calibration of your spirometer on the Lung Volumes channel:
    - Click on the words Vol.Human (Air Flow), that are next to the title of the Lung Volumes channel, to open the computed function pull-down menu.
    - Select Setup Function from this pull-down menu to open the Spirometer Calibration Dialog window.

- Check that the internal spirometer is being used by making sure the Type of Spirometer is the IXTA.
- Make sure the reset time is set to “No Reset”, and the first 10 seconds of the recording are used to zero the baseline of the Lung Volumes channel.
- Enter 37 for temperature of exhaled air.
- Click OK.

7. Allow the IXTA to warm up for 10 minutes before recording for the first time.
8. Make sure the subject is breathing through the red port side of the flow head.

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Experiment HS-4: Lung Volumes and Heart Rate

Exercise 1: Heart Rate While Breathing at Rest

Aim: To determine the effect of breathing while at rest on the subject's heart rate and the change in heart rate during respiratory sinus arrhythmia (RSA).

Approximate Time: 30 minutes

Procedure

1. Instruct the subject to:
    - Sit quietly and become accustomed to breathing through the spirometer flow head.
    - Breathe normally before any recordings are made.
    - Hold the flow head so that its outlets are pointed up.
    - Remove the flow head from their mouth and hold it at mouth level in a position that prevents a breath from moving through the flow head.
2. Type **Resting** in the Mark box.

> ***Note: The LabScribe software will zero the Lung Volumes channel during the first ten seconds of recording. No air should be moving through the flow head during this time.***

3. Click on the Record button. After waiting at least ten seconds for the Lung Volumes channel to zero, have the subject place the flow head in their mouth and begin breathing. Click the mark button to mark the recording.
4. Click the AutoScale All button. Notice the slowly moving wave on the Lung Volumes channel. Record five breaths, which normally takes about forty-five seconds to record.
5. Click Stop to halt recording. Your data may look like Figure HS-4-L1.
6. Select Save As in the File menu, type a name for the file. Click on the Save button to save the data file.

Data Analysis

1. Scroll to the recording of the subject's breathing and heart rate while at rest. Use the Display Time icons to adjust the Display Time of the Main window to show all 5 complete breathing cycles on the Main window.

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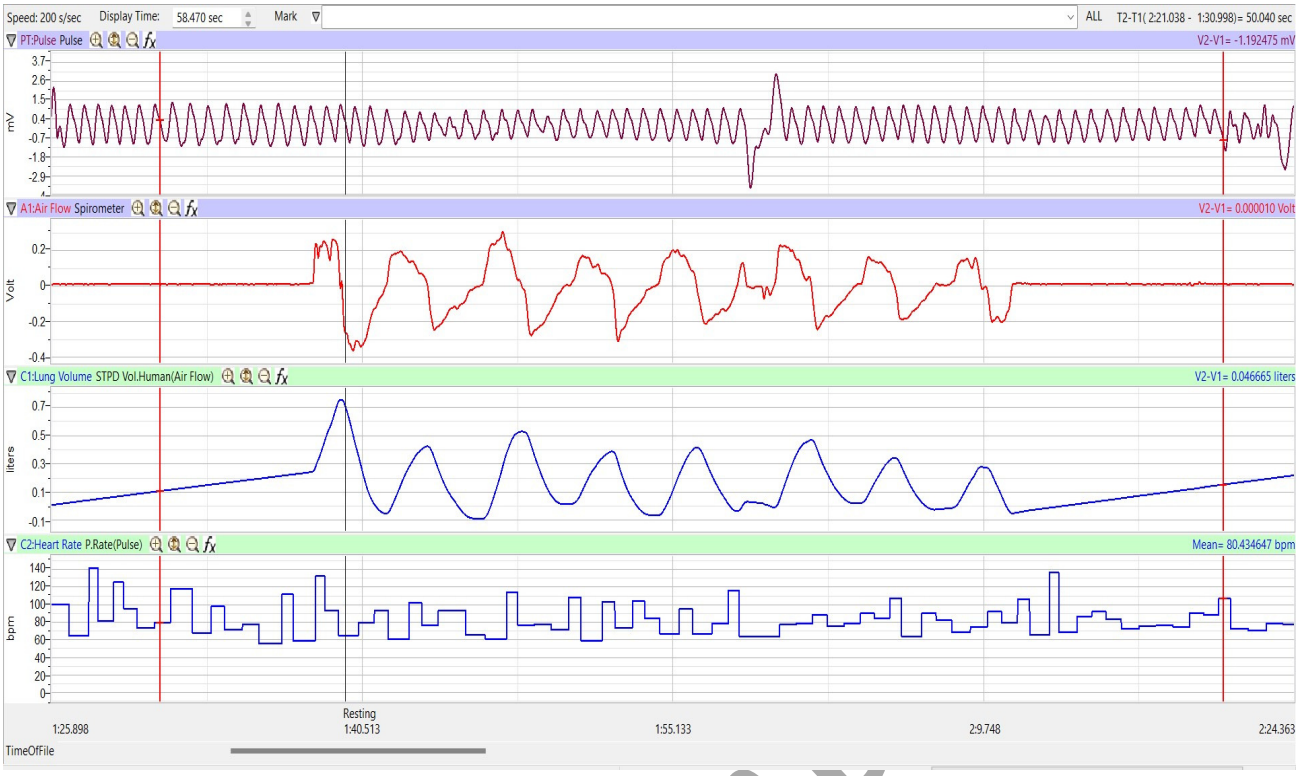

Figure HS-4-L1: Pulse, air flow, lung volumes, and heart rate during breathing at rest, displayed on the Main window. An upward deflection on the Lung Volumes channel indicates inhalation.

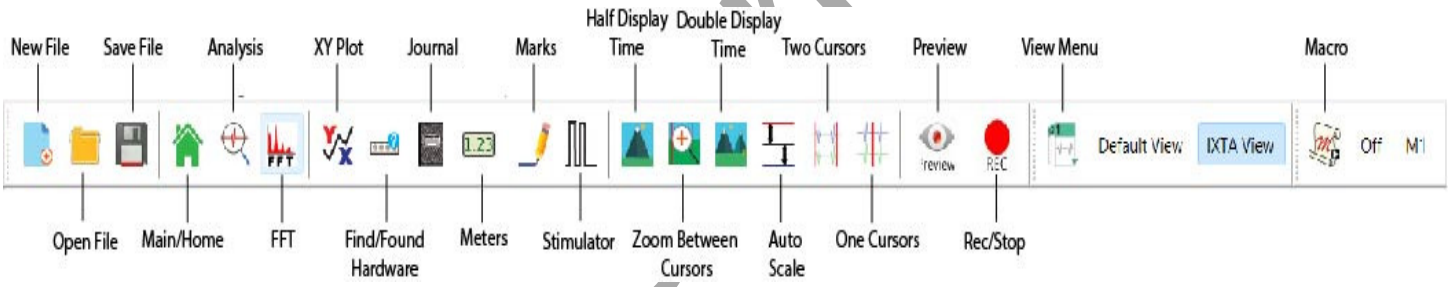

Figure HS-4-L2: The LabScribe toolbar.

3. Click on the Analysis window icon.
4. Look at the Function Table that is above the uppermost channel displayed in the Analysis window. The mathematical functions, Max-Min, Max, Min, and Mean, should appear in this table. Values for these four parameters on each channel are seen in the table across the top margin of each channel.
5. Use the mouse to click on and drag one cursor to the trough before the first breath cycle displayed on the Lung Volumes channel, and the other cursor to the trough before the second breath cycle.
6. The values for the following parameters on a breath cycle are determined when the cursors are placed at the two positions described in Step 4:

- **Tidal Volume (TV)**, which is the value for Max-Min on the Volume Channel.
- **Minimum Heart Rate**, which is the value for Min on the Heart Rate channel.
- **Maximum Heart Rate**, which is the value for Max on the Heart Rate channel.
- **Respiratory Sinus Arrhythmia (RSA) Prominence** or the difference between the minimum and maximum heart rates during a breath cycle, which is the value for Max-Min on the Heart Rate channel.
- **Mean Heart Rate**, which is the value for Mean on the Heart Rate channel.

7. Once the cursors are placed in the correct positions for determining the tidal volume and heart rate during inhalation and exhalation, the values for these parameters can be recorded in the on-line notebook of LabScribe by typing their names and values directly into the Journal.
8. The functions in the channel pull-down menus of the Analysis window can also be used to enter the names and values of these parameters from the recording to the Journal. To use these functions:
    - Place the cursors at the locations used to measure the tidal volume and heart rates during the breath cycle.
    - Transfer the names of the mathematical functions used to determine the volumes and rates to the Journal using the Add Title to Journal function in the Lung Volumes Channel pull-down menu.
    - Transfer the values for the volumes and rates to the Journal using the Add All Data to Journal function in the Lung Volumes Channel pull-down menu.
9. Record the values in the Journal using one of the techniques described in Step 8.
10. Repeat the measurements of tidal volume, maximum and minimum and mean heart rate, and RSA prominence on the 4 other cycles.
11. Average the five values obtained for each rate and the tidal volume. Enter the means in a table in the Journal. You can open and close the Journal by clicking on its icon on the LabScribe toolbar.
12. Record the means for the tidal volume and heart rates in Table 1.

Questions

1. The RSA prominence is the difference in the heart rates (HR) before and after inhalation. What is the average RSA prominence of the subject?
2. What percentage of the pre-inhalation heart rate is the RSA prominence?
3. How does the RSA prominence of this subject compare to subjects from other groups in class?

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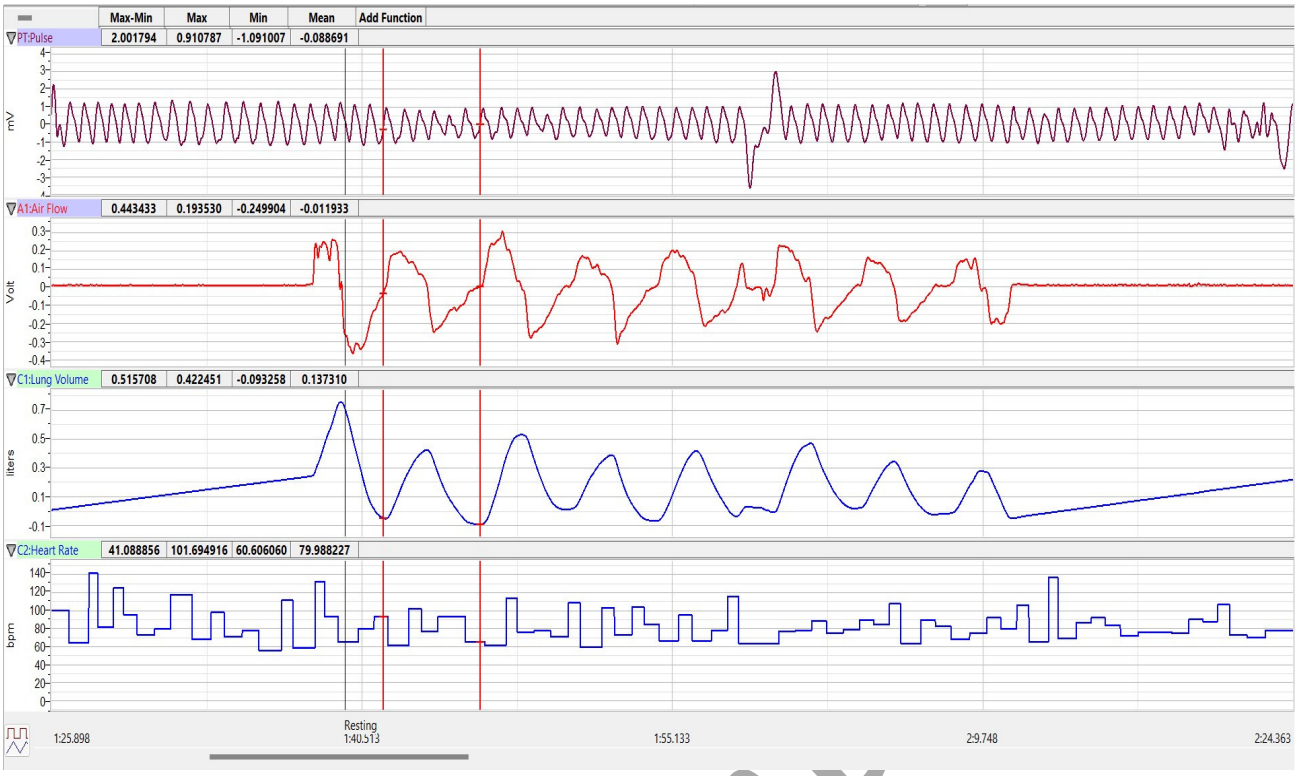

Figure HS-4-L3: The heart rate and breathing rates of a subject performing abdominal breathing while resting, displayed in the Analysis window.

Table HS-4-L1:Heart Rate Variation during Breathing at Rest.

Subject	Heart Rate (BPM)				Tidal Volume (mls)
_____	Min	Max	RSA	Mean	
Breath 1					
Breath 2					
Breath 3					
Mean					

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Exercise 2: Heart Rate during Apnea

Aim: To measure the effect of apnea, after a maximum inhalation, on the subject's heart rate.

Approximate Time: 15 minutes

Procedure

1. The subject should sit quietly and breathe normally before this exercise begins. The subject should already be accustomed to breathing through a flow head.
2. Remind the subject of the following:
    - Hold the flow head with its outlets pointed up.
    - Before the recording begins, the subject should remove the flow head from their mouth, and hold it at mouth level in a position that prevents air from moving through the flow head.
    - After the recording begins, wait at least 10 seconds before putting the flow head in their mouth.

    REMINDER: The LabScribe software will zero the Lung Volumes channel during the first ten seconds of recording. No air should be moving through the flow head during this time.

3. Before the recording begins, instruct the subject about the breathing pattern for this exercise:
    - After the 10 second calibration period, the subject should take 5 normal breaths through the flow head.
    - Then, the subject will take a deep inhalation and hold their breath as long as possible.
    - When the subject resumes breathing, they should continue to breathe through the flow head until the breathing pattern is back to normal.
4. Type **Resting** in the Mark box.
5. Click on the Record button. After waiting at least ten seconds for the Lung Volumes channel to zero, have the subject place the flow head in their mouth and begin breathing normally. Click the mark button.
6. Click the AutoScale All button. Notice the slowly moving wave on the Lung Volumes channel. Record five breaths, which normally takes about forty-five seconds to record.
7. Type **Apnea** in the Mark box.
8. Click the mark button as the subject inhales as deeply as possible. After reaching their maximum inhalation volume, the subject should hold their breath as long as possible.

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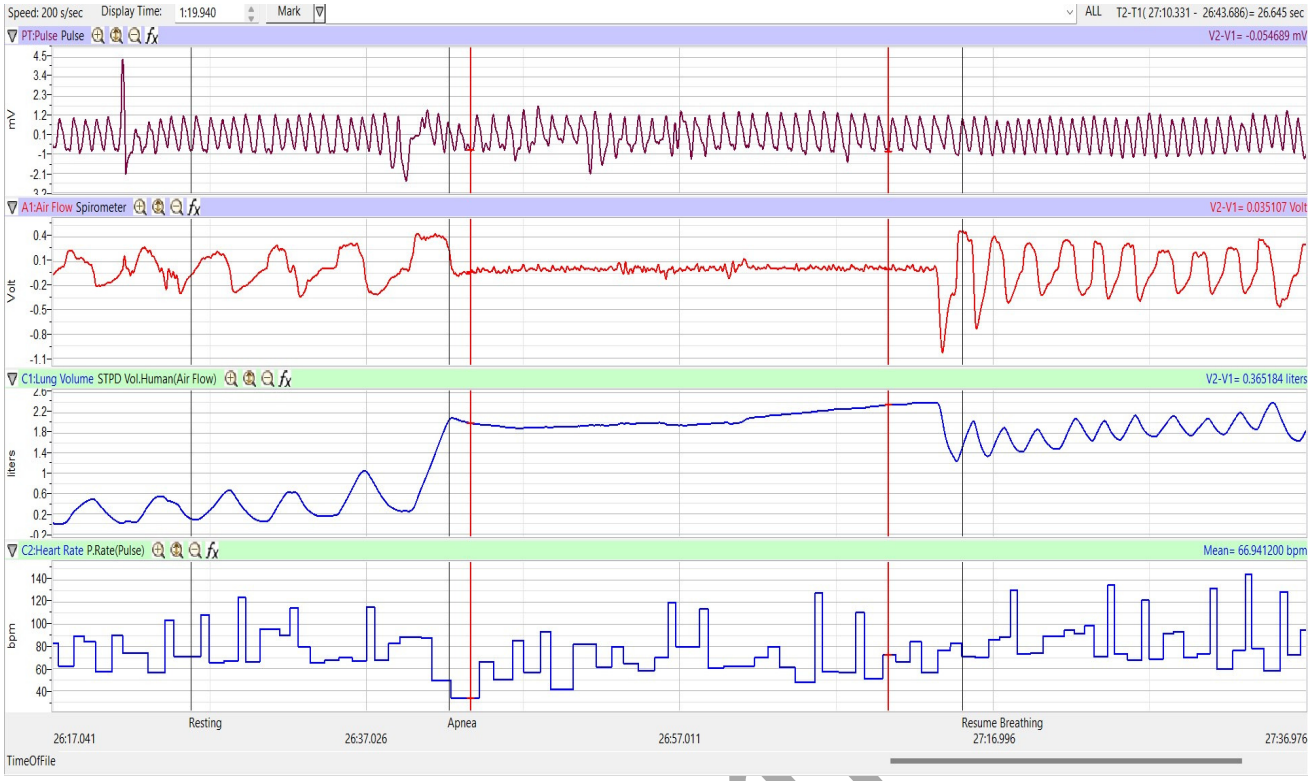

Figure HS-4-L4: Pulse, air flow, lung volumes, and heart rate before, during and after apnea, displayed in the Main window.

9. While the subject is holding their breath, type **Resume Breathing** in the Mark box. Click the mark button to mark the recording when the subject resumes breathing.
10. The subject should continue to breathe through the spirometer until their breathing returns to normal.
11. Click Stop to halt recording. Your data should look like the HS-4-L4 above..
12. Select Save in the File menu.

Data Analysis

1. Scroll to the recording of the subject's breathing before, during and after holding their breath so that it is displayed in the Main window. Use the Display Time icons to adjust the Display Time of the Main window to show the breathing from before to after apnea.
3. Click on the Analysis window icon.
4. The functions used to analyze this data are the same as the ones used in Exercise 1 and programmed by the settings file.
5. Use the mouse to click on and drag a cursor to the trough, on the Lung Volumes channel, that precedes the three normal breaths taken by the subject before the deep inhalation. The second cursor goes on the trough after the third normal breath.

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6. The values for the following parameters during breathing at rest are determined when the cursors are placed at the two positions described in Step 7:
    - **Maximum Heart Rate - Breathing at Rest**, which is the value for Max on the Heart Rate channel.
    - **Minimum Heart Rate - Breathing at Rest**, which is the value for Min on the Heart Rate channel.
    - **RSA Prominence (Max-Min) Heart Rate-Breathing at Rest**, which is the value for Max-Min on the Heart Rate channel.
    - **Mean Heart Rate - Breathing at Rest,** which is the value for Mean on the Heart Rate channel.

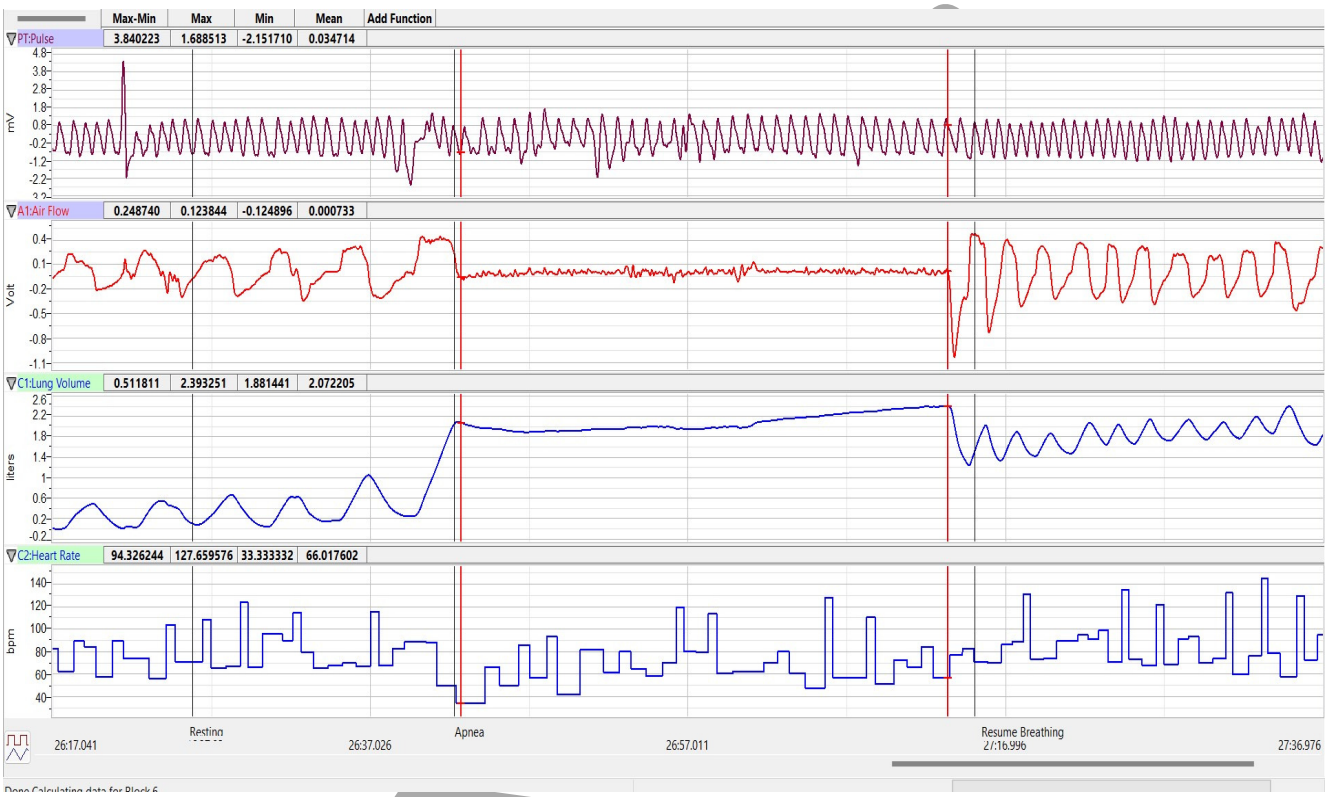

Figure HS-4-L5: Pulse, air flow, lung volume, and heart rate before, during and after apnea, displayed in the Analysis window. The cursors are positioned to measure the volume and rates during apnea.

9. Record the values in the Journal using one of the techniques described in Exercise 1. Record the volume and heart rates in Table 2.
10. On the Lung Volumes channel use the mouse to click on and drag a cursor to the trough that precedes the subject's deep inhalation. The second cursor goes at the end of the subject's exhalation after apnea.

Work Lab

11. The values for the following rates during apnea are determined when the cursors are placed at the two positions described in Step 6:
    - **Inspiratory Capacity (IC)**, which is the sum of the Tidal Volume (TV) and Inspiratory Reserve Volume (IRV) and which is the value for Max-Min on the Lung Volumes Channel.
    - **Maximum Heart Rate - Apnea**, which is the value for Max on the Heart Rate channel.
    - **Minimum Heart Rate - Apnea**, which is the value for Min on the Heart Rate channel.
    - **RSA Prominence (Max-Min) Heart Rate-Apnea**, which is the value for Max-Min on the Heart Rate channel.
    - **Mean Heart Rate - Apnea**, which is the value for Mean on the Heart Rate channel.
12. Record the values in the Journal as described in Exercise 1. Record the heart rates in Table 2.
13. Use the mouse to click on and drag a cursor to the trough, on the Lung Volumes channel, that precedes the first breath taken by the subject after apnea. The second cursor goes on the trough after the first normal breath following apnea.
14. The values for the following parameters during the recovery to normal breathing are determined when the cursors are placed at the two positions described in Step 13:
    - **Maximum Heart Rate - Return to Normal**, which is the value for Max on the Heart Rate channel.
    - **Minimum Heart Rate – Return to Normal**, which is the value for Min on the Heart Rate channel.
    - **RSA Prominence (Max-Min) Heart Rate-Return to Normal**, which is the value for Max-Min on the Heart Rate channel.
    - **Mean Heart Rate - Return to Normal,** which is the value for Mean on the Heart Rate channel.
15. Record the values in the Journal using one of the techniques described in Exercise 1. Record the heart rates in the table.

Questions

1. How does the change in heart rate during deep inhalation compare to the change in heart rate during normal inhalation?
2. How does the change in heart rate during deep inhalation compare to the change in heart rate during apnea?
3. How does the change in heart rate during normal breathing compare to the change in heart rate during the recovery from apnea?
4. Which type of breathing reached a higher maximum heart rate: normal breathing, deep inhalation, apnea, or recovery from apnea?

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Table HS-4-L2: Heart Rate Variation before, during, and after Apnea.

Subject	Heart Rate (BPM)			
Deep Inhalation Volume: ____ Liters	Max	Min	RSA	Mean
Breathing at Rest				
Deep Inhalation				
Apnea				
Return to Normal				

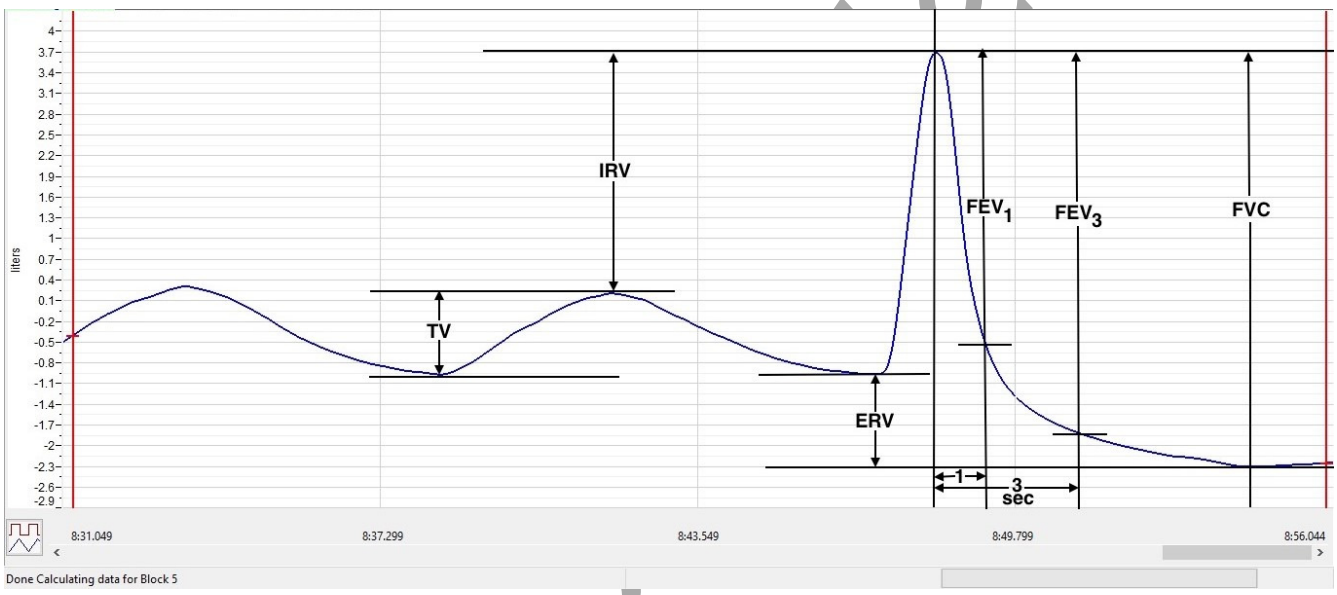

Figure HS-4-L6: Long Volumes labeled for placing cursors in the correct locations.

Exercise 3: Sub-Maximal Inhalation Volumes and Heart Rate

Aim: To measure the effect of inhalation volumes that are higher than the Tidal Volume (TV), but less than the Inspiratory Capacity (IC), on the subject's heart rate.

Approximate Time: 20 minutes

Procedure

1. Repeat Exercise 1 on the same subject using an inhalation volume that is between the Tidal Volume (TV) and the Inspiratory Capacity (IC).

Note: *Remember that the Inspiratory Capacity (IC) is equal to the sum of the Tidal Volume (TV) and the Inspiratory Reserve Volume (IRV).*

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2. To aid the subject in determining an inhalation level that is between the tidal volume (TV) and the inspiratory capacity (IC), allow the subject to observe their recording on the computer screen. While watching the computer monitor, the subject can control their depth of breathing.
3. Record at least three breath cycles at each of three different inhalation levels that are fractions of the Inspiratory Capacity (IC). You data should look like Figure HS-4-L6.

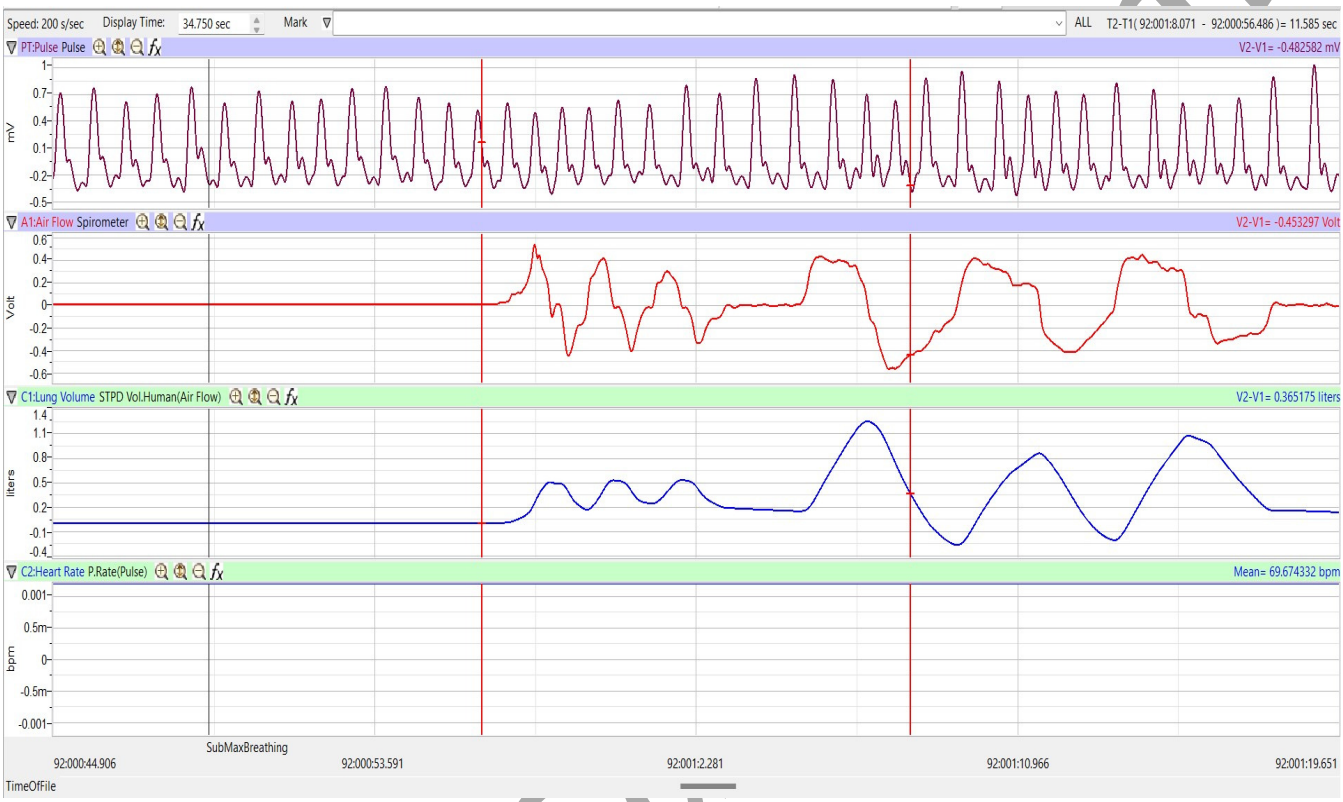

Figure HS-4-L7: Pulse, air flow, lung volumes, and heart rate during breaths of various depths displayed in the Main window.

Data Analysis

1. Use the same techniques used in Exercise 1 to measure the inhalation volumes and heart rates from the three breath cycles recorded at each of three different levels of submaximal inhalation.
2. Use the same techniques to record the values for the parameters in the Journal and the means for each level of inhalation in Table 3.

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Questions

1. How does the change in heart rate during a submaximal inhalation compare to the change in heart rate during normal inhalation?
2. How does the change in heart rate during a submaximal inhalation compare to the change in heart rate during deep inhalation (IC)?

Work Sub

3. Is there a linear relationship between inhalation volume heart rate. Use a sheet of graph paper or a graphing program to plot the heart rate as a function of inhalation volume?

Table HS-4-L3: Heart Rate Variation with a Sub-Maximal Inhalation Volumes.

	Heart Rate (BPM)				Mean Inhalation Volume (mls)
	Min	Max	D Heart Rate	Mean	
Level 1 Mean					
Level 2 Mean					
Level 3 Mean					

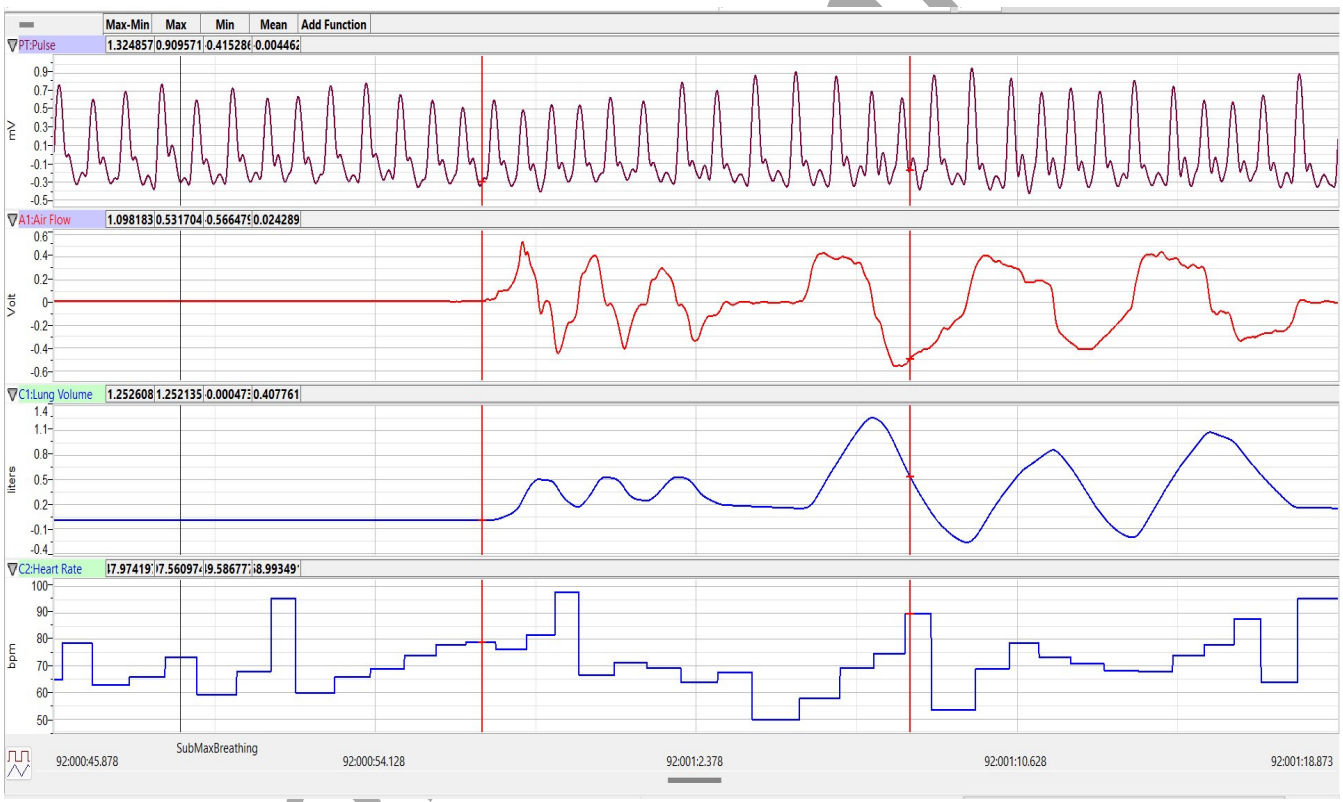

Figure HS-4-L7: Pulse, air flow, lung volumes, and heart rate during submaximal breaths, displayed in the Analysis window.

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