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).

Procedure

1. Instruct the subject to:
    - Sit quietly and become accustomed to breathing through the spirometer flowhead.
    - Breath normally before any recordings are made.
    - Hold the flowhead so that its outlets are pointed up.
    - Remove the flowhead from his or her mouth and hold it at mouth level in a position that prevents a breath from moving through the flowhead.
1. Type <Subject's Name> Breathing at Rest in the Mark box that is to the right of the Mark button.

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.*

2. Click on the Record button. After waiting ten seconds for the Lung Volumes channel to zero, have the subject place the flowhead in his or her mouth and begin breathing. Press the Enter key on the keyboard to mark the recording.
3. Click the AutoScale buttons of the Air Flow and Lung Volumes channels. Notice the slowly moving wave on the Lung Volumes channel. Record five breaths, which normally takes about forty-five seconds to record.
4. Click Stop to halt recording. Your data may look like Figure HS-4-L1.
5. Select Save As in the File menu, type a name for the file. Choose a destination on the computer in which to save the file, like your lab group folder). Designate the file type as *.iwxdata. 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. Display four adjacent breathing cycles that are free of artifacts in the Main window.
2. Use the Display Time icons to adjust the Display Time of the Main window to show the four complete breathing cycles on the Main window. The four adjacent breathing cycles can also be selected by:

- Placing the cursors on either side of a group of four complete breathing cycles; and
- Clicking the Zoom between Cursors button on the LabScribe toolbar (Figure HS-4-L2) to expand the four selected breathing cycles to the width of the Main window.

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.

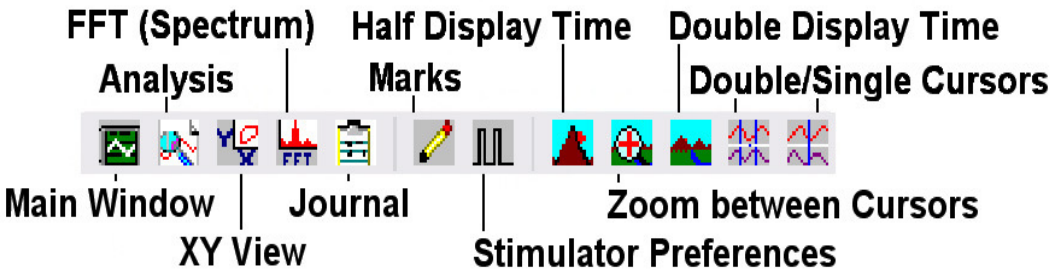

Figure HS-4-L2: The LabScribe toolbar.

3. Click on the Analysis window icon in the toolbar or select Analysis from the Windows menu to transfer the data displayed in the Main window to the Analysis window (Figure HS-4-L3).
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. Sections of the data displayed on the Heart Rate channel may be calculated incorrectly if pulses on the raw data (Pulse) channel have low amplitudes. These pulses with low amplitudes might not be identified by the rate function on the Heart Rate channel and used in the calculation of the subject's heart rate. Pulses used in the rate calculation can be properly identified by either adjusting the position of the trace on the Pulse channel or adjusting the position of the threshold, a parameter in the rate function dialogue window which identifies the pulses to be counted in the rate calculation.

    - To raise the level of the trace on the Pulse channel, use the mouse to click on and drag the trace higher on the screen. If the pulse trace is moved up by the proper amount, the peaks of the missed pulse will intersect the invisible threshold level set by the rate function dialogue window. The pulses or waves that used to be missed in the rate calculation will now be included in the calculation. On the Heart Rate channel, the revised plot of the rate calculation will be displayed automatically. If the rate is still not displayed properly, the pulse trace can be moved up again.

Note: *Setting the proper threshold level also prevents small artifacts in the data from being counted as pulse waves.*

    - To adjust the level of the threshold parameter for the Heart Rate channel, click on the Channel Function/Mode area to the right of the Channel Title on the Heart Rate channel. Select Setup from the menu to open the rate function dialogue window. Change the level of the threshold: by typing a new value in the box; or, by clicking on the up or down arrows on the right side of the box; or, by clicking on and sliding the threshold line, that is displayed on the graph of the pulse data at the bottom of the dialogue window, up or down.

6. There may be section of data on the Lung Volumes channel where the baseline is sloped. The sloping occurs when the temperature inside the spirometer increases while the subject breathes through the unit. Ultimately, the change in temperature inside the spirometer affects the computed function on the Lung Volumes channel that initially sets the baseline of that channel to zero.

    - The easiest way to flatten the slope of the baseline on the Lung Volumes channel is to increase the length of time used to set that baseline. When more data points are used to establish the baseline, the slope of the baseline will get closer to zero and become easier to use as a point of reference for measuring lung volumes.
    - To increase the length of the recording used in setting the baseline on the Lung Volumes channel, click on the Channel Function/Mode area to the right of the Channel Title on the Lung Volumes channel. Select Setup from the menu to open the Spirometer Calibration dialogue window. Change the amount of time used to set the slope of the baseline on the Lung Volumes channel from 5 seconds to the length of the largest block of recorded data. For example, if a subject's respiration was recorded in data blocks that are between 30 and 90 seconds long, set the length of time used in setting the baseline to 60 seconds.

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. 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 (Figure HS-4-L3).
10. The values for the following parameters on a breath cycle are determined when the cursors are placed at the two positions described in Step 9:
    - 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.
11. Record the values in the Journal using one of the techniques described in Steps 7 or 8.
12. Repeat the measurements of tidal volume, maximum and minimum and mean heart rate, and RSA prominence on two additional normal breath cycles.
13. Average the three 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 (Figure HS-4-L2).
14. Record the means for the tidal volume and heart rates in Table HS-4-L1.

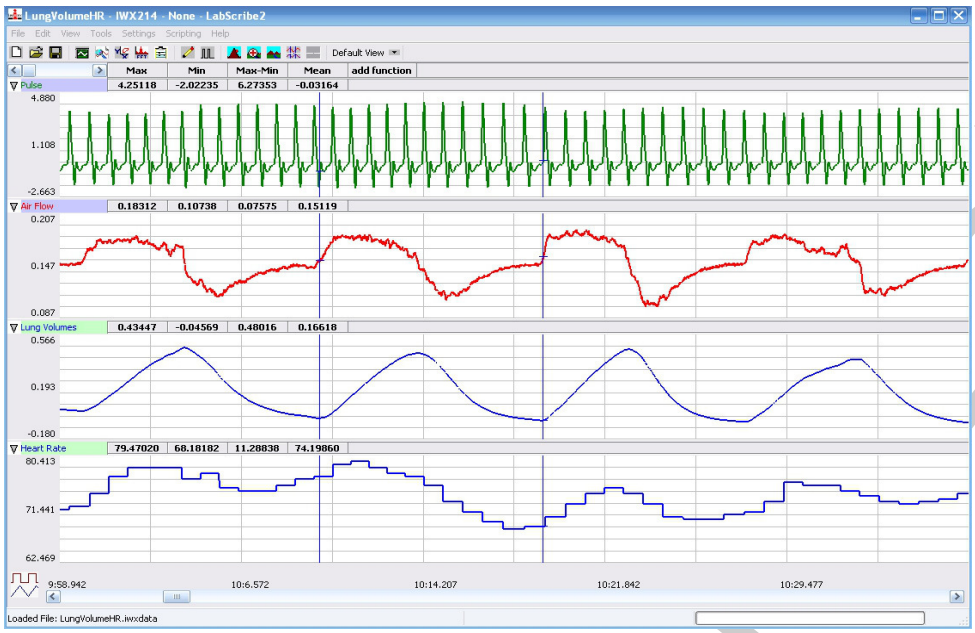

Figure HS-4-L3: The heart rate and breathing rates of a subject performing abdominal breathing while resting, displayed in the Analysis window.

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 (Table HS-4-L1)?
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?

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

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

Exercise 2: Heart Rate during Apnea

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

Procedure

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

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. Before the recording begins, instruct the subject about the breathing pattern for this exercise:
    - After the 10 second calibration period, the subject should take 2 or 3 normal breaths through the flowhead.
    - Then, the subject will take a deep inhalation and hold his or her breath as long as possible.
    - When the subject resumes breathing, he or she should continue to breath through the flowhead until the breathing pattern is back to normal.
4. Type <Subject's Name> Breathing at Rest in the Mark box that is to the right of the Mark button.
5. Click on the Record button. After waiting ten seconds for the Lung Volumes channel to zero, have the subject place the flowhead in his or her mouth and begin breathing normally. Press the Enter key on the keyboard.
6. Click the AutoScale buttons of the Air Flow and Lung Volumes channels. Notice the slowly moving wave on the Lung Volumes channel. Record three breaths, which normally takes about twenty seconds to record. Type Apnea in the Mark box

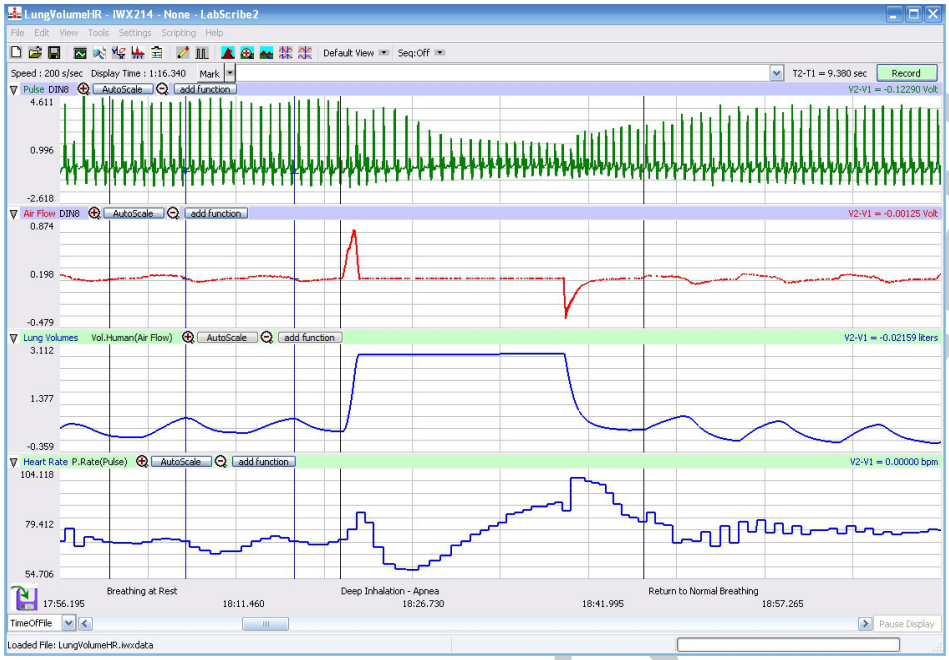

Figure HS-4-L4: Pulse, air flow, lung volumes, and heart rate before, during and after apnea, displayed in the Main window.

7. Press the Enter key on the keyboard as the subject inhales as deeply as possible. After reaching his or her maximum inhalation volume, the subject should hold his or her breath a long as possible.
8. While the subject is holding his or her breath, type Resume Breathing in the Mark box. Press the Enter key on the keyboard to mark the recording when the subject resumes breathing.
9. The subject should continue to breath through the spirometer until his or her breathing returns to normal.
10. Click Stop to halt recording. Your data should look like Figure HS-4-L4.
11. Select Save in the File menu.

Data Analysis

1. Scroll to the recording of the subject's breathing before, during and after holding his or her breath that is displayed in the Main window.
2. Use the Display Time icons to adjust the Display Time of the Main window to show the breathing from before to after apnea on the Main window. This segment of the data can also be selected by:
    - Placing the cursors on either side of the selected data; and
    - Clicking the Zoom between Cursors button on the LabScribe toolbar to expand the selected to the width of the Main window.
3. Click on the Analysis window icon in the toolbar or select Analysis from the Windows menu to transfer the data displayed in the Main window to the Analysis window (Figure HS-4-L5).

4. The functions used to analysis this data are the same as the ones used in Exercise 1 and programmed by the settings file.
5. Minimize the heights of the Pulse and Air Flow channels and maximize the heights of the traces on the Lung Volumes and Heart Rate channels as it was done in Exercise 1.
6. Use one of the techniques described in Exercise 1 to record the volume and heart rates in the Journal.
7. 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.
8. 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.
    - Difference (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.

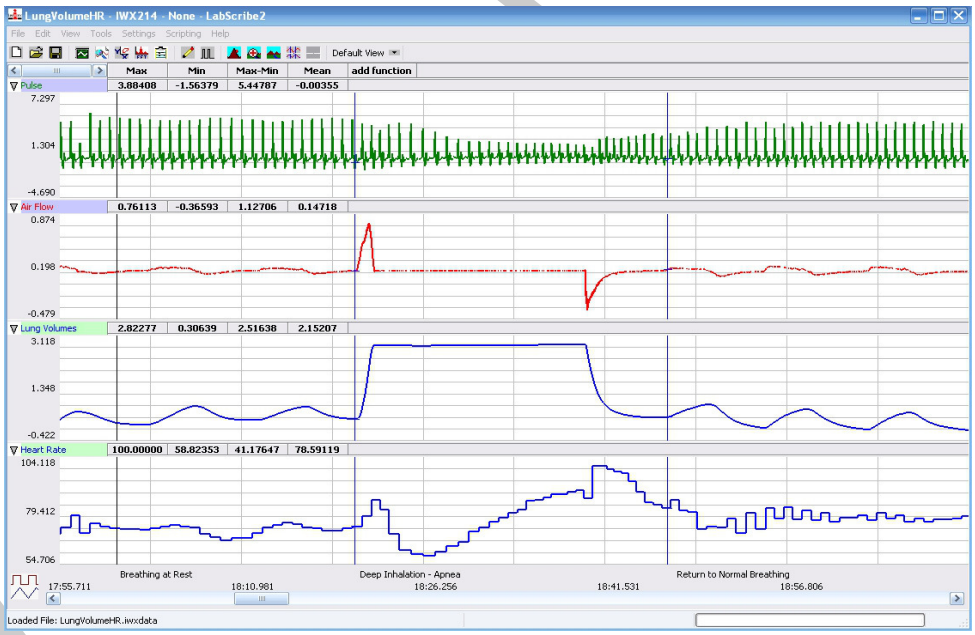

Figure HS-4-L5: Pulse, air flow, lung volume, and heart rate before, during and after apnea, displayed in the Analysis window. The cursors are positioned to measure the volume and rates during apnea.

9. Record the values in the Journal using one of the techniques described in Exercise 1. Record the volume and heart rates in TableHS-4-L2.

10. Use the mouse to click on and drag a cursor to the trough, on the Lung Volumes channel, that precedes the subject's deep inhalation. The second cursor goes at the end of the subject's exhalation after apnea (Figure HS-4-L5).
11. The values for the following rates during apnea are determined when the cursors are placed at the two positions described in Step 10:
    - 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.
    - Difference (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 using one of the techniques described in Exercise 1. Record the heart rates in Table HS-4-L2.
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 - Recovery to Normal, which is the value for Max on the Heart Rate channel.
    - Minimum Heart Rate - Recovery to Normal, which is the value for Min on the Heart Rate channel.
    - Difference (Max-Min) Heart Rate-Recovery to Normal, which is the value for Max-Min on the Heart Rate channel.
    - Mean Heart Rate - Recovery 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.

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

Subject	Heart Rate (BPM)			
Deep Inhalation Volume: ____ Liters	Min	Max	D Heart Rate	Mean
Deep Inhalation				
Apnea				
Return to Normal				

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?

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.

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).*

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 his or her recording on the computer screen. While watching the computer monitor, the subject can control his or her depth of breathing.
3. Record at least three breath cycles at each of two different inhalation levels that are fractions of the Inspiratory Capacity (IC). You data should look like Figure HS-4-L6.

Figure HS-4-L6: 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 three breath cycles recorded at each of two different levels of submaximal inhalation (Figure HS-4-L7).
2. Use the same techniques to record the values for the parameters in the Journal and the means for each level of inhalation on Table HS-4-L3.

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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					

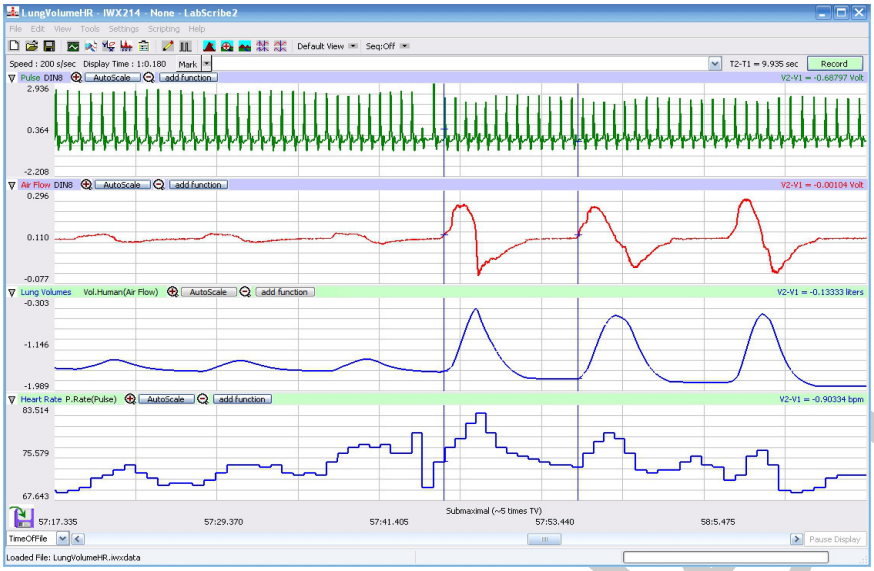

Figure HS-4-L7: Pulse, air flow, lung volumes, and heart rate during submaximal breaths, displayed in the Analysis window.

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)?
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?

Exercise 4: "Inhalation" without Air Exchange

Aim: To measure the effect of chest expansion caused by the muscles involved in inhalation without allowing air to enter the lungs.

Warning: No one with any cardiovascular diseases should be a subject in this exercise!

Procedure

1. Repeat Exercise 2 with the same subject, but without using a spirometer.
2. The subject should breath normally without breathing through a spirometer.
3. After the subject exhales normally, he or she closes his or her mouth and pinches off his or her nose.
4. With the flow of air into the lungs blocked, the subject lowers his or her diaphragm and expands his or her ribcage as if he or she were taking a deep breath. The subject should perform this

procedure for as long as possible before returning to breathing normally

5. Even though no air is exchanged, the subject's heart rate should change.

Data Analysis

1. Use the same techniques used in Exercise 2 to determine the subject's heart rates before, during, and after the blocked inhalation (Figure HS-4-L8).
2. Use the same techniques to record the values for the parameters in the Journal and on Table HS-4-L4.

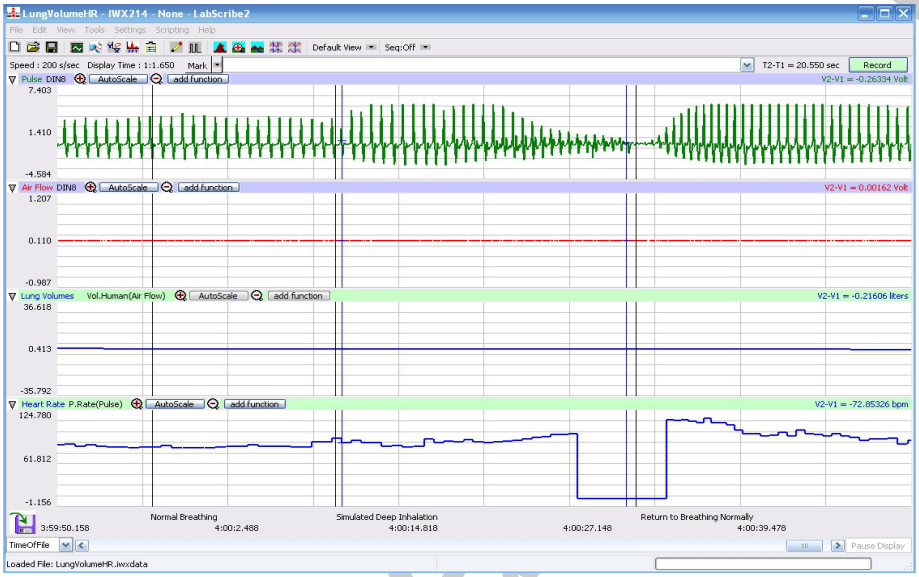

Figure HS-4-L8: Pulse and heart rate before, during and after inhalation was blocked, displayed on the Analysis window.

Table HS-4-L4: Heart Rate Variation with Inhalation Blocked.

	Heart Rate (BPM)			
	Min	Max	D Heart Rate	Mean
Normal Breathing				
Simulated Deep Breathing				
Return to Normal				

Questions

1. How does the change in heart rate during deep inhalation/apnea compare to the change in heart rate during the blocked inhalation?

2. Is the blocked inhalation able to create the same level of negative pressure in the thoracic cavity as deep inhalation?

Exercise 5: "Exhalation" without Air Exchange - Valsalva Maneuver

Aim: To measure the effect of chest compression caused by the muscles involved in exhalation without allowing air to exit the lungs.

Warning: No one with any cardiovascular diseases should be a subject in this exercise!

Procedure

1. Repeat Exercise 4 without using a spirometer.
2. The subject should breath normally without breathing through a spirometer.
3. After the subject inhales deeply, he or she closes his or her mouth and pinches off his or her nose.
4. With the flow of air out of the lungs blocked, the subject raises his or her diaphragm and compresses his or her rib cage as if he or she were blowing up a balloon. The subject should perform this procedure for as long as possible before returning to breathing normally
5. Even though no air is exchanged, the subject's heart rate should change.

Data Analysis

1. Use the same techniques used in Exercise 2 to determine the subject's heart rates before, during, and after the blocked exhalation.
2. Use the same techniques to record the values for the parameters in the Journal and on Table HS-4-L5.

Table HS-4-L5: Heart Rate Variation with Exhalation Blocked.

	Heart Rate (BPM)			
	Min	Max	D Heart Rate	Mean
Normal Breathing				
Simulated Exhalation				
Return to Normal				

Questions

1. How does the change in heart rate during deep inhalation/apnea compare to the change in heart rate during the blocked exhalation?
2. How does the change in heart rate during blocked inhalation compare to the change in heart rate during the blocked exhalation?