

Experiment HS-6: Ventilation and Oxygen Saturation Levels, Part 1

Equipment Required

PC or Mac Computer

IXTA, USB cable, IXTA power supply

SP-304 Spirometer

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

iWire-PO2-100 Pulse Oximeter

BNC-BNC cable

Male-Male DIN8 cable

NOTE – the iWire PO2 sensor must be plugged into the IXTA prior to turning it on.

Pulse Oximeter and Spirometer Setup

1. Locate the A-FH-300 flow head and the airflow tubing and the iWire-PO2-100 pulse oximeter and its cable.



Figure HS-6-S1: The FH-300 flow head and the airflow tubing.

2. Firmly push the two air flow tubes onto the two outlets on the flow head.
3. Carefully connect the other ends of the two air flow tubes into the Channel A1 input of the IXTA. Connect the red port to the red connector on the tubing.
4. Plug the iWire PO2 sensor into the iWire 1 port on the front of the IXTA.
5. Clip the photoplethysmograph sensor over the end of the subject's middle finger. An embossed diagram on the sensor indicates the position of the finger within the clip. The indicator light on the pulse oximeter amplifier will stop blinking when the sensor is working properly.



Figure HS-6-S2: The PO2-100D pulse oximeter.



Figure HS-6-S3: A PO2-100D pulse oximeter and the flow head connected to the internal spirometer of the IXTA unit. NOTE – the iWire-PO2-100 will be plugged into the iWire 1 port on the front of the IXTA.

Warning: The photoplethymograph sensor passes two wavelengths of light through the subject's fingernail. For proper recording, the subject's fingernail should not be covered with nail polish, artificial nails, or any coating, clear or otherwise.

Preparations Before Recording

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 his or her lips around the outside of the opening of the flow head, or 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. Air that passes through the nose causes errors in the lung volume values.
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.
 - 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.

Units Conversion for the iWirePO2-100 Pulse Oximeter

The software has programmed the PO2 sensor to work properly.

Experiment HS-6: Ventilation and Oxygen Saturation Levels, Part 1

Exercise 1: Oxygen Saturation Level While Breathing at Rest

Aim: To determine the effect of breathing on the oxygen saturation level in the blood of a subject at rest.

Approximate Time: 20 minutes

Procedure

1. Instruct the subject to:
 - Sit quietly and become accustomed to breathing through the spirometer flow head.
 - Make sure the subject breathes through the red port side of the 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 his or her mouth and hold it at mouth level in a position that prevents a breath from moving through the flow head.

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

2. Type **Rest** in the Mark box. Click the mark button to attach the comment to the data.
3. Click the AutoScale All button. Notice the slowly moving wave on the Lung Volume channel. Record five to six breaths, which normally takes about forty-five seconds to record.
4. Click Stop to halt recording. Your data may look like the image below.
5. Select Save in the File menu.

Data Analysis

1. Scroll through the recording and find the section of data recorded when the subject was breathing while resting.
2. Use the Display Time icons to adjust the Display Time of the Main window to show 30 seconds of breathing that are free of artifacts on the Main window.
3. Click AutoScale All.

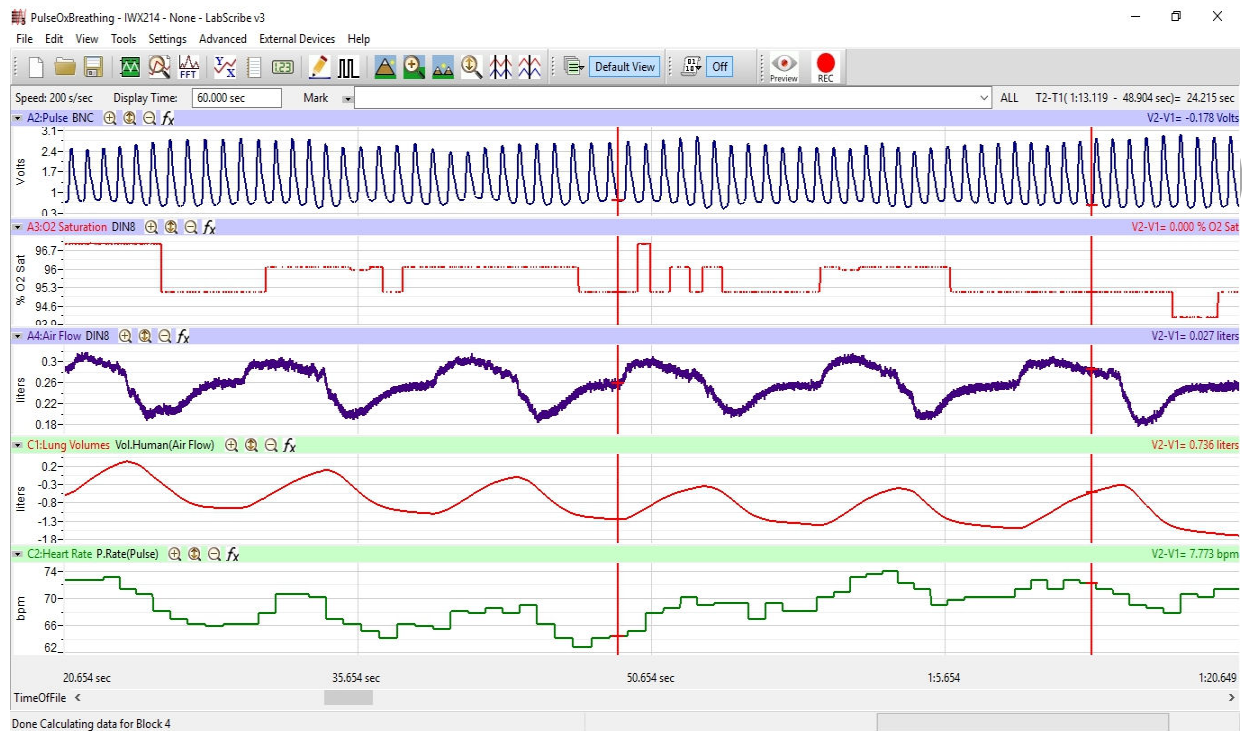


Figure HS-6-L1: Pulse, oxygen saturation level, air flow, lung volumes, and heart rate during breathing at rest, displayed on the Main window.

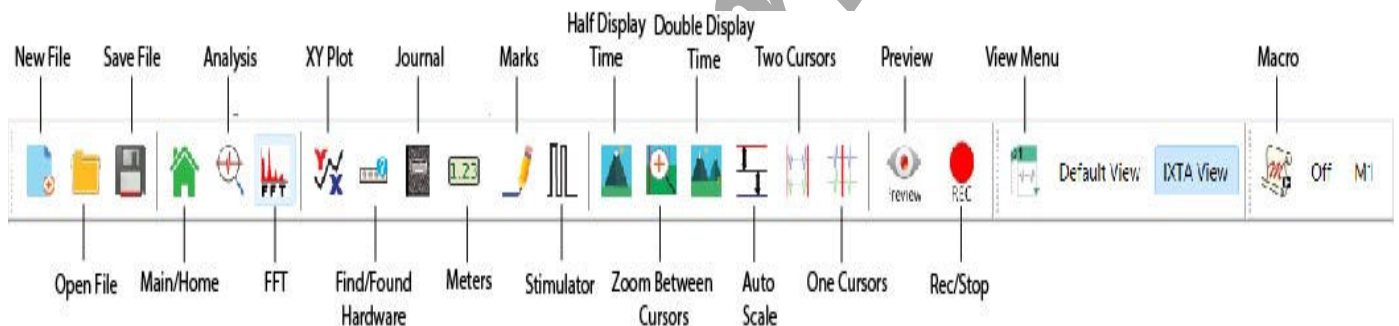


Figure HS-6-L2: The LabScribe toolbar.

4. 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. 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.
- 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.

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

5. Click on the Analysis icon to transfer the data to the Analysis window.
6. Look at the Function Table that is above the uppermost channel displayed in the Analysis window. The mathematical functions, Max, Min, Max-Min, Mean, and T2-T1 should appear on the Functions Table at the top of the Analysis window. Values for Max, Min, Max-Min, Mean, and T2-T1 on each channel are seen in the table across the top margin of each channel.
7. Once the cursors are placed in the correct positions for determining the saturation levels and heart rate, the values of the parameters in the Function Table 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 the parameters from the recording to the Journal. To use these functions:
9. Place the cursors at the locations used to measure the oxygen saturation levels and the heart rate in each breath.
10. Transfer the names of the mathematical functions used to determine the values to the Journal using the Add Title to Journal function on the pull-down menu of any channel.
11. On the Lung Volume channel, use the mouse to place a cursor at the beginning of the inhalation of the first breath being measured. Place the second cursor at the end of the exhalation of the same breath. Measure the following levels and rates.
 - Maximum Oxygen Saturation Level, the value for Max on the O2 Saturation channel.
 - Minimum Oxygen Saturation Level, the value for Min on the O2 Saturation channel.
 - Mean Oxygen Saturation Level, the value for Mean on the O2 Saturation channel.
 - Maximum Heart Rate, the value for Max on the Heart Rate channel.
 - Minimum Heart Rate, the value for Min on the Heart Rate channel.
 - Mean Heart Rate, the value for Mean on the Heart Rate channel.

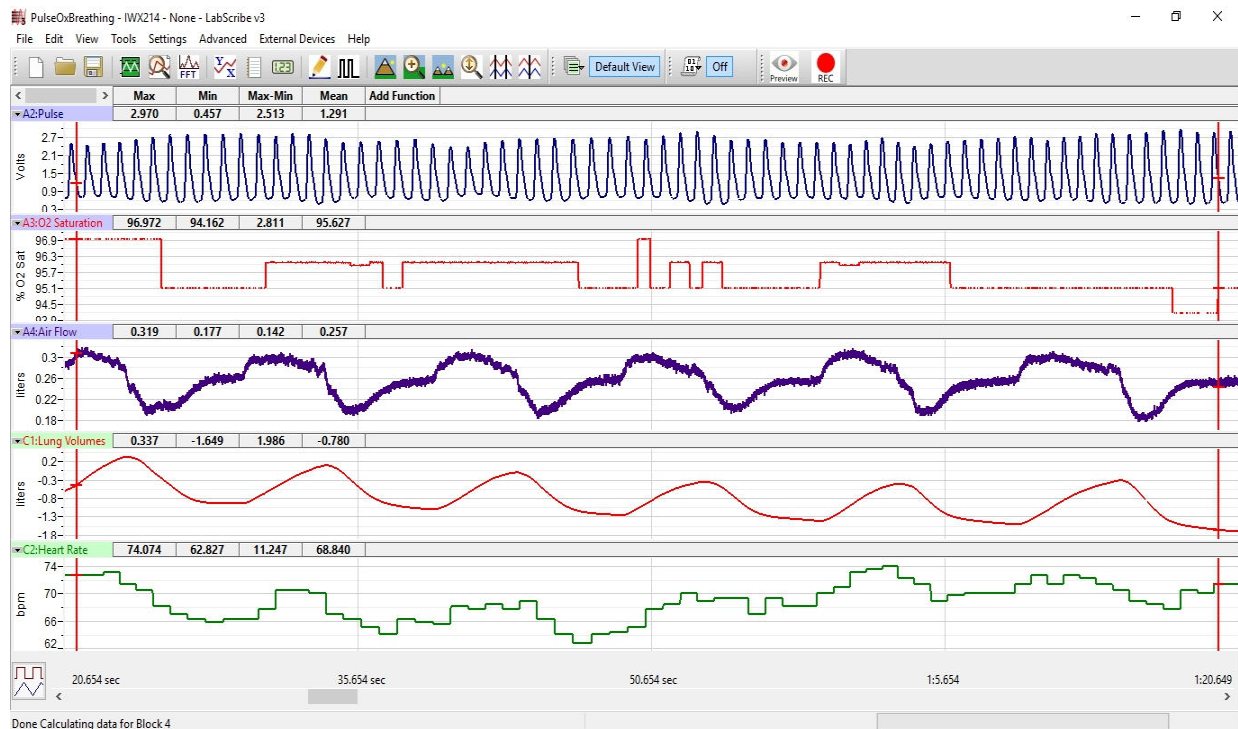


Figure HS-6-L3: Pulse, oxygen saturation level, air flow, lung volumes, and heart rate of a resting subject displayed in the Analysis window.

12. Record the values in the Journal using the one of the techniques described in Steps 7 or 8, and in Table 1.
13. Repeat Steps 8 through 10 for two additional breath cycles.
14. Average the values obtained for each parameter and enter the means in the Journal and Table 1.

Questions

1. Does the subject's oxygen saturation level change in response to inhalation or exhalation?
2. Does the oxygen saturation level change during a normal breath? By how much?
3. Is there any significant difference in the mean oxygen saturation levels among the three breaths?

Table HS-6-L1: Oxygen Saturation Levels during Breathing at Rest.

Subject	%O ₂ Saturation			Heart Rate (BPM)		
	Min	Max	Mean	Min	Max	Mean
Breath 1						
Breath 2						
Breath 3						
Mean						

Exercise 2: Oxygen Saturation during Apnea

Aim: To measure the effect of apnea on the subject's oxygen saturation level.

Approximate Time: 20 minutes

Procedure

1. The subject should sit quietly and breath normally before this exercise begins. The subject should already be accustomed to breathing through a flow head.
2. 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 his or her breath as long as possible.
 - When the subject resumes breathing, he or she should continue to breath through the flow head until the breathing pattern is back to normal.
3. Click Record. After waiting ten seconds for the Lung Volume channel to zero, have the subject place the flow head in his or her mouth and begin breathing.
4. Type **Rest** in the Mark box and then click the mark button.
5. Click the AutoScale All button. Notice the slowly moving wave on the Lung Volume channel. Record three breaths, which normally takes about twenty seconds to record. Type **Apnea** in the Mark box.
6. Click the mark button as the subject inhales as deeply as possible. After reaching his or her maximum inhalation, the subject should hold his or her breath for as long as possible.
7. While the subject is holding his or her breath, type **ResumeBreathing** in the Mark box. Click the mark button to mark the recording when the subject resumes breathing.

8. The subject should continue to breathe through the spirometer until his or her breathing returns to normal.
9. Click Stop to halt recording. Your data should look like the image below.
10. Select Save in the File menu.

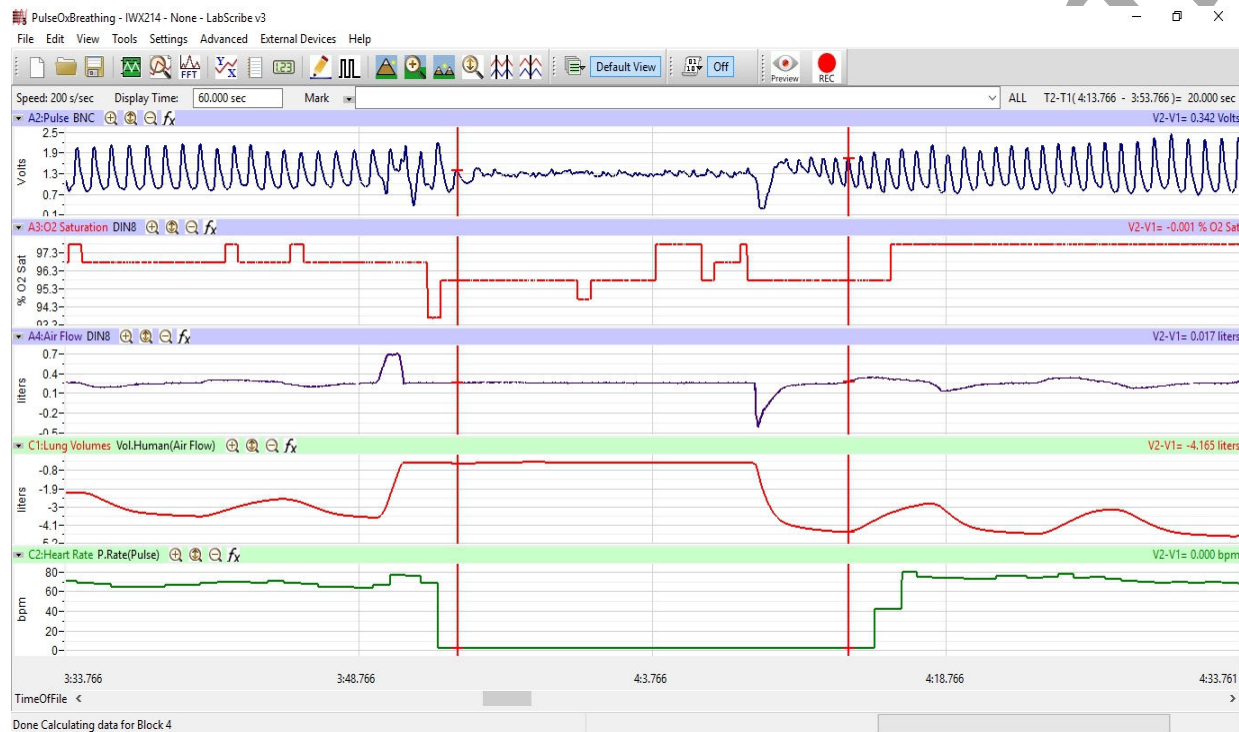


Figure HS-6-L4: Pulse, oxygen saturation level, air flow, lung volumes, and heart rate before, during and after apnea, displayed in the Main window.

Data Analysis

1. Scroll to the recording of the subject's breathing before, during and after apnea 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 normal breath before apnea, the period of apnea, and a couple of normal breaths after apnea in the Main window.
3. Click AutoScale All.
4. Click on the Analysis icon.
5. On the Lung Volume channel, use the mouse to place a cursor at the beginning of the maximum inhalation that precedes apnea. Place the second cursor at the beginning of the first normal breath that follows apnea. Measure the following levels and rates.
 - Maximum Oxygen Saturation Level, the value for Max on the O2 Saturation channel.
 - Minimum Oxygen Saturation Level, the value for Min on the O2 Saturation channel.

- Change(Δ) in Oxygen Saturation Level, the value for Max-Min on the O2 Saturation channel.
- Maximum Heart Rate, the value for Max on the Heart Rate channel.
- Minimum Heart Rate, the value for Min on the Heart Rate channel.
- Change(Δ) in Heart Rate, the value for Max-Min on the Heart Rate channel.

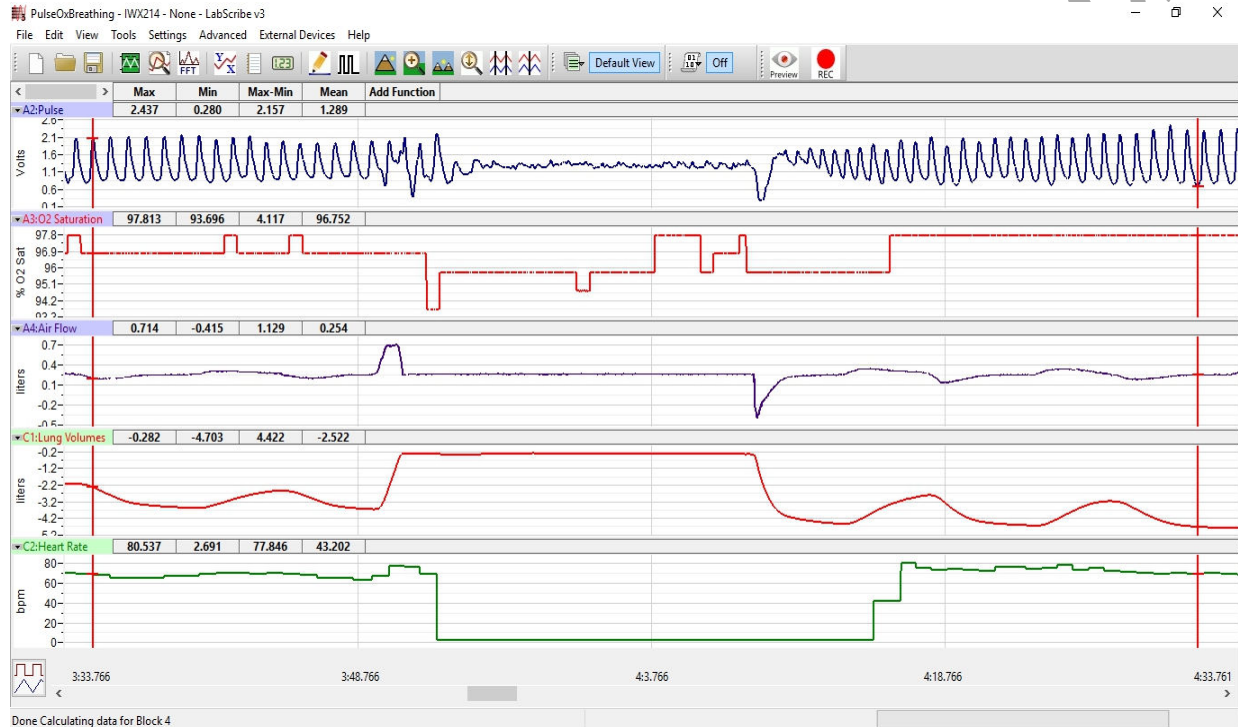


Figure HS-6-L5: Pulse, oxygen saturation level, air flow, lung volumes, and heart rate before, during and after apnea, displayed in the Analysis window.

- Record the values in the Journal using the one of the techniques described in Exercise 1, and in Table 2.
- Measure the following parameters and record their values in the Journal:
 - Response Time to Apnea. Place one cursor at the beginning of the maximal inhalation that precedes apnea, and the second cursor at the first change in the oxygen saturation level during apnea. The value for the T2-T1 function is the response time to apnea. Record the values in the Journal.
 - Recovery Time from Apnea. Place one cursor at the end of apnea, when the subject starts to exhale, and the second cursor at the return of the oxygen saturation level to normal. The value for the T2-T1 function is the recovery time from apnea. Record the values in the Journal.
- Click the Save button to save the file.

Table HS-6-L2: Oxygen Saturation Levels and Heart Rate during Rest, Apnea, Hyperventilation, Valsalva Maneuver, and Chest Expansion.

Breathing	%O ₂ Saturation			Heart Rate (BPM)		
	Max	Min	Δ	Max	Min	Δ
Resting						
Apnea						
Hyperventilation						
Valsalva						
Chest Expansion						

Questions

1. How does the oxygen saturation level during normal breathing compare to oxygen saturation level at the end of apnea? What causes the oxygen saturation levels to change?
2. How does the Response Time to Apnea compare to the Recovery Time from Apnea?
3. How does the heart rate during normal breathing compare to the heart rate at the end of apnea?

Exercise 3: Hyperventilation and Oxygen Saturation Levels

Aim: To measure the effect of hyperventilation on the subject's oxygen saturation level.

Approximate Time: 20 minutes

Procedure

1. The subject should prepare for the exercises just like the subjects in Exercises 1 and 2:
2. 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.
 - The subject should hyperventilate by breathing as quickly and as deeply as possible for 15-20 seconds.
 - After the hyperventilation period, the subject resumes breathing normally.
3. Click Record. After waiting ten seconds have the subject place the flow head in his or her mouth and begin breathing.
4. Type **Rest** in the Mark box and then click the mark button.
5. Click the AutoScale All button. Record five normal breaths. Type **Hyperventilate** in the Mark box.

- Click the mark button as the subject inhales and exhales as quickly and as deeply as possible.
- While the subject is hyperventilating, type **Normal** in the Mark box. Click the mark button to mark the recording when the subject returns to breathing normally.
- Click Stop to halt recording. Your data should look like image below.
- Select Save in the File menu.

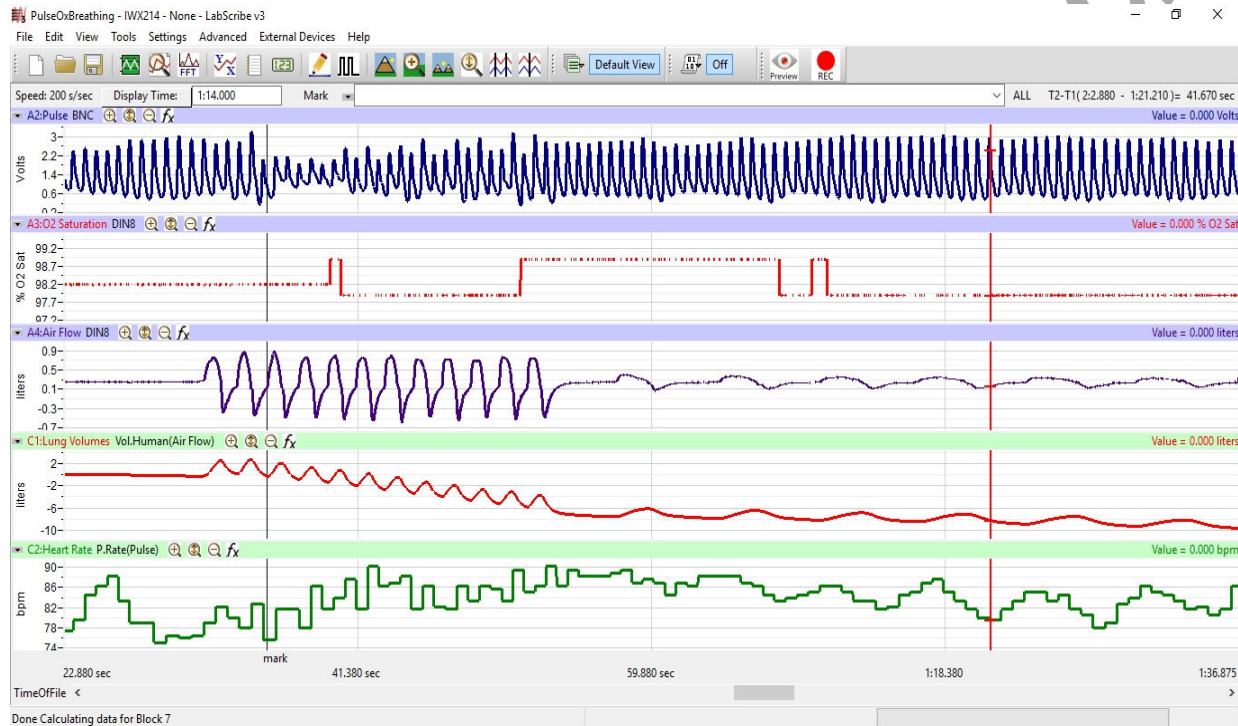


Figure HS-6-L6: Pulse, oxygen saturation level, air flow, lung volumes, and heart rate before, during and after hyperventilation, displayed in the Main window.

Data Analysis

- Scroll to the recording of the subject's breathing before, during and after hyperventilation that is displayed in the Main window.
- Use the same techniques described in Exercise 2 to adjust the width of data to include the normal breath before hyperventilation, the period of hyperventilation, and a few normal breaths after hyperventilation in the Main window.
- Click AutoScale All
- Click on the Analysis icon.
- On the Lung Volume channel, use the mouse to place a cursor at the beginning of the first deep breath of hyperventilation. Place the second cursor at the point where the oxygen saturation level after hyperventilation returns to normal. Measure the following levels and rates.

- Maximum Oxygen Saturation Level, the value for Max on the O2 Saturation channel.
- Minimum Oxygen Saturation Level, the value for Min on the O2 Saturation channel.
- Change(Δ) in Oxygen Saturation Level, the value for Mean on the O2 Saturation channel.
- Maximum Heart Rate, the value for Max on the Heart Rate channel.
- Minimum Heart Rate, the value for Min on the Heart Rate channel.
- Change (Δ) in Heart Rate, the value for Mean on the Heart Rate channel.

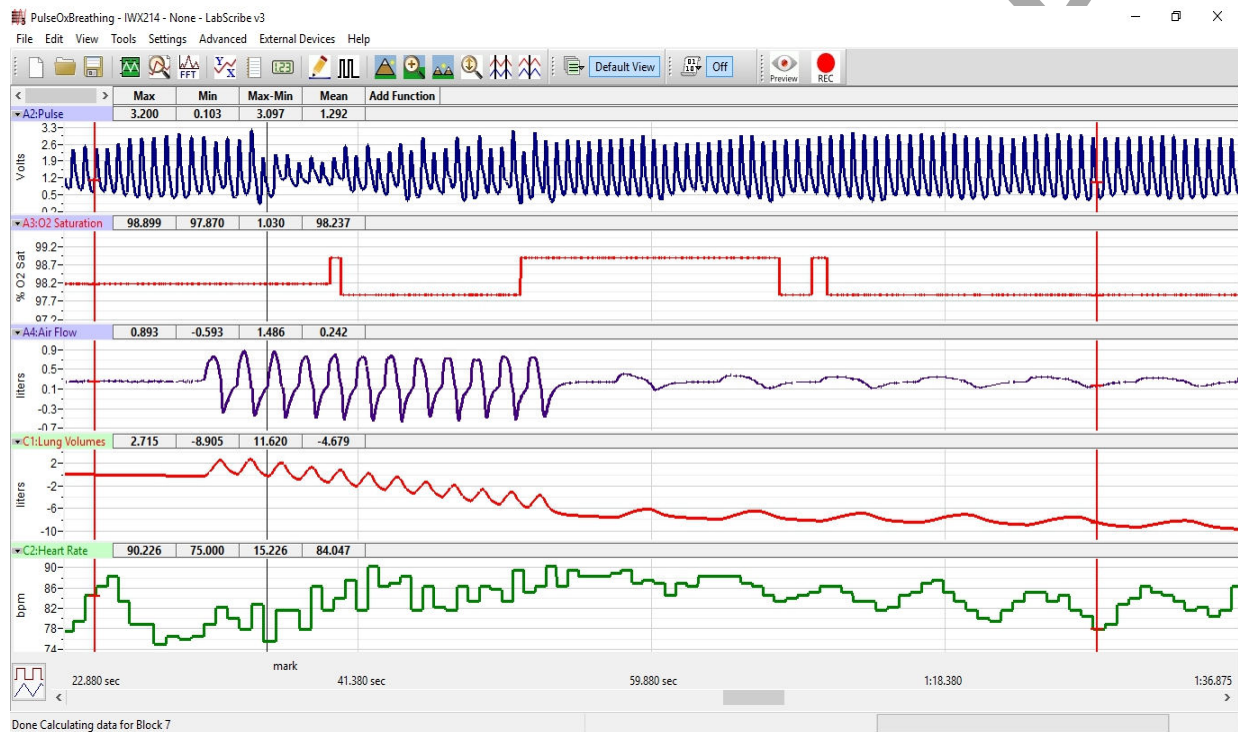


Figure HS-6-L7: Pulse, oxygen saturation level, air flow, lung volumes, and heart rate before, during and after hyperventilation, displayed in the Analysis window.

- Record the values in the Journal and in Table 2.
- Measure the following parameters and record their values in the Journal:
 - Response Time in Hyperventilation. Place one cursor at the beginning of the first depth breath in hyperventilation, and the second cursor at the first change in the oxygen saturation level during hyperventilation. The value for the T2-T1 function is the response time to hyperventilation. Record the values in the Journal.
 - Recovery Time from Hyperventilation. Place one cursor at the end of hyperventilation, when the subject returns to normal breathing, and the second cursor at the return of the oxygen saturation level to normal. The value for the T2-T1 function is the recovery time from hyperventilation. Record the values in the Journal.

8. Select Save in the File menu.

Questions

1. How does the oxygen saturation level during normal breathing compare to oxygen saturation level during hyperventilation? What causes the oxygen saturation levels to change?
2. How does the Response Time to Hyperventilation compare to the Recovery Time from Hyperventilation?
3. How does the heart rate during normal breathing compare to the heart rate at the end of hyperventilation?

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

Exercise 4: Valsalva Maneuver and Oxygen Saturation Levels

Aim: To measure the effect of chest compression by the muscles involved in exhalation on oxygen saturation levels. In this exercise, air is not allowed to exit the lungs.

Approximate Time: 20 minutes

Procedure

1. This exercise is performed without using a spirometer. The subject should breathe normally before performing the Valsalva maneuver.
2. Click on the Record button to record the subject's heart rate and oxygen saturation level while resting. **Rest** in the Mark box. Click the mark button.
3. Click AutoScale All. Type **Valsalva** in the Mark box.
4. Click the mark button as the subject:
 - inhales deeply.
 - closes the mouth and pinches the nose to prevent the flow of air from the lungs
 - raises the diaphragm and compresses the rib cage as if blowing up a balloon
 - performs this procedure for as long as possible before returning to breathing normally
5. Type **Normal** in the Mark box. Click the mark button as the subject returns to breathing normally.
6. Click Stop to halt recording. Select Save in the File menu.

Data Analysis

1. Scroll to the recording of the subject's breathing before, during and after the Valsalva Maneuver that is displayed in the Main window.

2. Use the same techniques described in Exercises 2 and 3 to adjust the width of data to include the normal breath before the maneuver, the period of maneuver, and a few normal breaths after maneuver in the Main window.
3. Click AutoScale All.
4. Click on the Analysis icon.

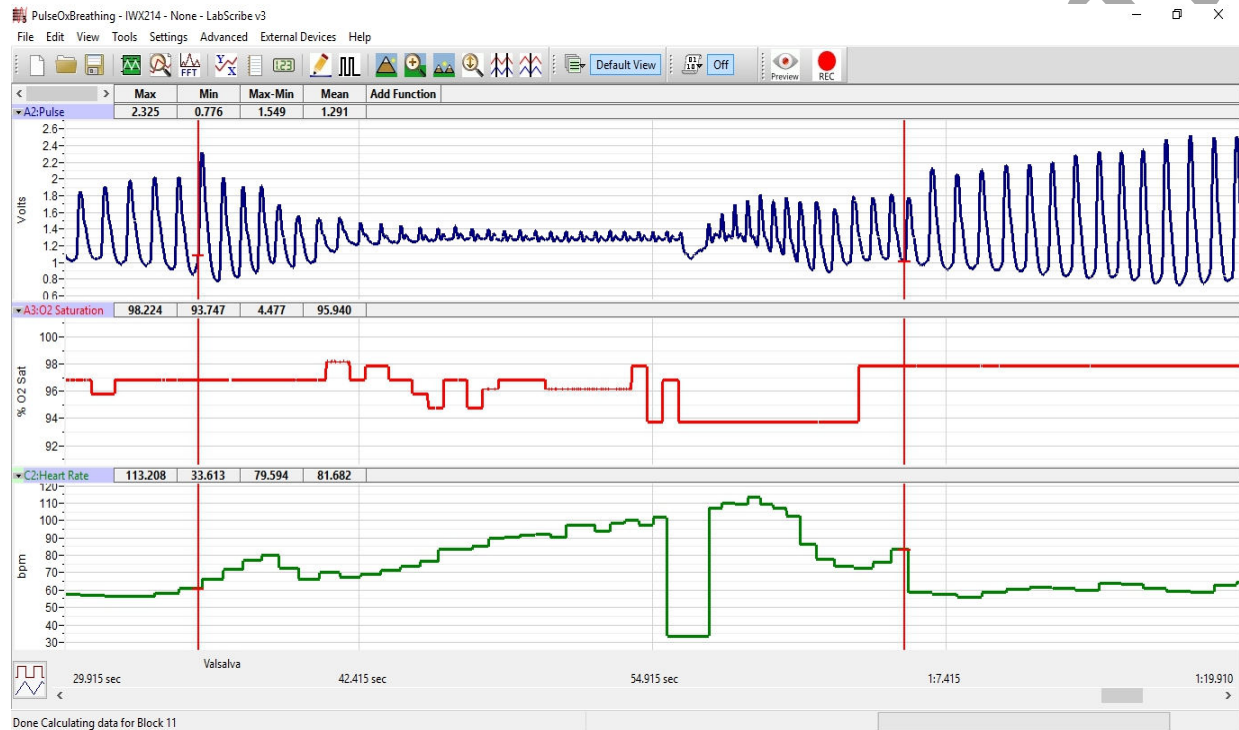


Figure HS-6-L8: Pulse, oxygen saturation level, and heart rate before, during and after a Valsalva maneuver, displayed in the Analysis window.

5. Use the mouse to click on and drag
6. On the Lung Volume channel, use the mouse to place a cursor on the mark that indicates the start of the Valsalva maneuver. Place the second cursor at the point where the oxygen saturation level after Valsalva maneuver returns to normal. Measure the same values as in the previous exercise.
7. Record the values in the Journal and in Table 2.
8. Select Save in the File menu.

Questions

1. How does the change in oxygen saturation level during the Valsalva maneuver compare to the change in oxygen saturation level during apnea?
2. How does the change in oxygen saturation level during the Valsalva maneuver compare to the change in oxygen saturation level during hyperventilation?

3. How does the change in heart rate during the Valsalva maneuver compare to the change in heart rate during apnea and during hyperventilation?

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

Exercise 5: Chest Expansion and Oxygen Saturation Levels

Aim: To measure the effect of chest expansion by the muscles involved in inhalation on oxygen saturation levels. In this exercise, air is not allowed to enter the lungs.

Approximate Time: 20 minutes

Procedure

1. This exercise is performed without using a spirometer. The subject should breath normally before performing the chest expansion.
2. Click on the Record button to record the subject's heart rate and oxygen saturation level while resting. Type **Rest** in the Mark box. Click the mark button.
3. Click the AutoScale buttons on the all the channels. Type **Chest Expansion** in the Mark box.
4. Click the mark button as the subject:
 - closes the mouth and pinches the nose to prevent the flow of air into the lungs.
 - lowers the diaphragm and expands the rib cage as if inhaling deeply.
 - performs this procedure for as long as possible.
5. Type **Normal** in the Mark box. Click the mark button as the subject returns to breathing normally.
6. Click Stop to halt recording.
7. Select Save in the File menu.

Data Analysis

1. Scroll to the recording of the subject's breathing before, during and after the chest expansion that is displayed in the Main window.
2. Use the same techniques used in Exercises 3 and 4 to measure and record the oxygen saturation levels and heart rates before, during, and after chest expansion.
3. Record the values in Table 2.

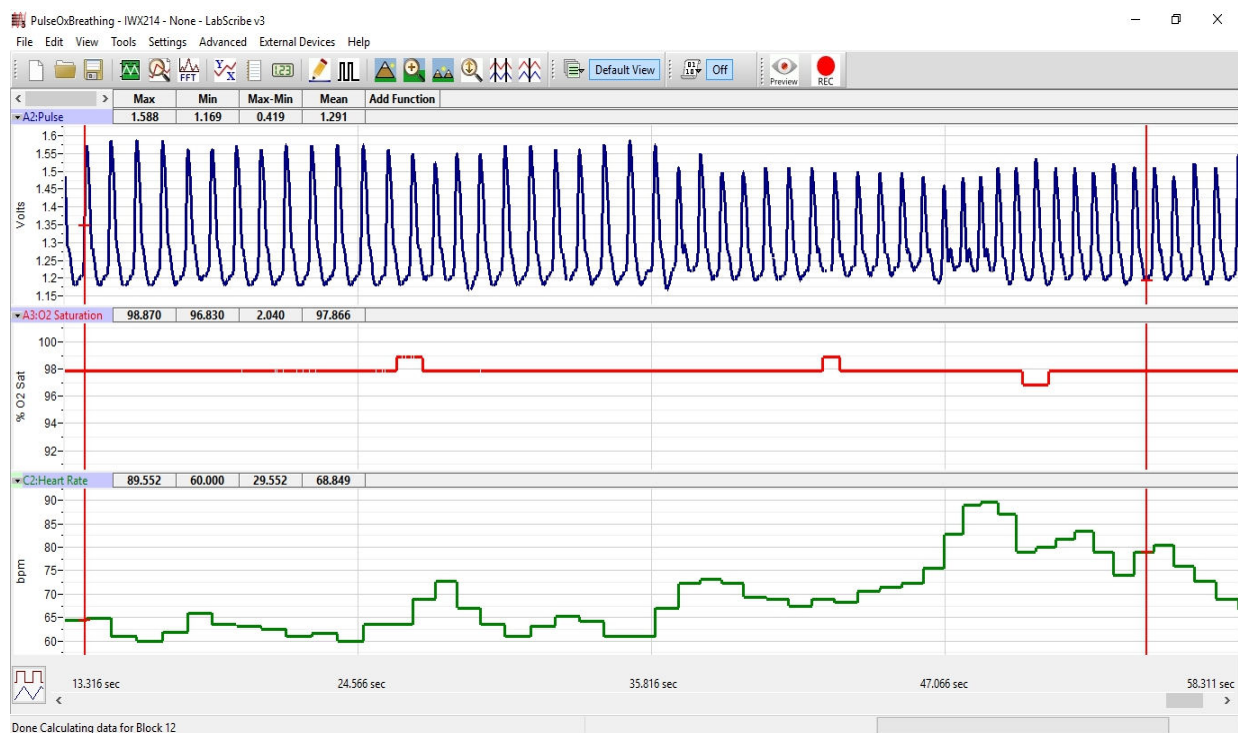


Figure HS-6-L9: Pulse, oxygen saturation level, and heart rate before, during, and after chest expansion, displayed on the Analysis window.

Questions

1. How does the change in oxygen saturation level during chest expansion compare to the changes in oxygen saturation level during apnea? Hyperventilation? Valsalva Maneuver?
2. How does the change in heart rate during the chest expansion compare to the change in heart rate during apnea? Hyperventilation? Valsalva Maneuver?