Experiment HS-8: Restrictive and Obstructive Airway Diseases

This lab was written in conjunction with Dr. Debra Mullikin-Kilpatrick of Boston College.

Equipment Required

PC or Mac Computer

IXTA, USB cable, IXTA power supply

A-FH-300 Spirometer flow head and plastic tubes

Black Restrictive flow head coverings

3ft Smooth interior tubing (35mm I.D.) - cut into lengths of 6”, 8”, 10” and 12”

Drinking straws

Packing or Duct Tape

Spirometer Setup

1. Locate the A-FH-300 flow head and the airflow tubing in the iWorx kit. Firmly push the two air flow tubes onto the two outlets on the A-FH-300 flow head.
2. 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.

Note: It is important that the students who participate in the breathing exercises are healthy and do not have any of the characteristic diseases stated in the Background. There is a chance that students can become light-headed, so it is important to follow the directions carefully.

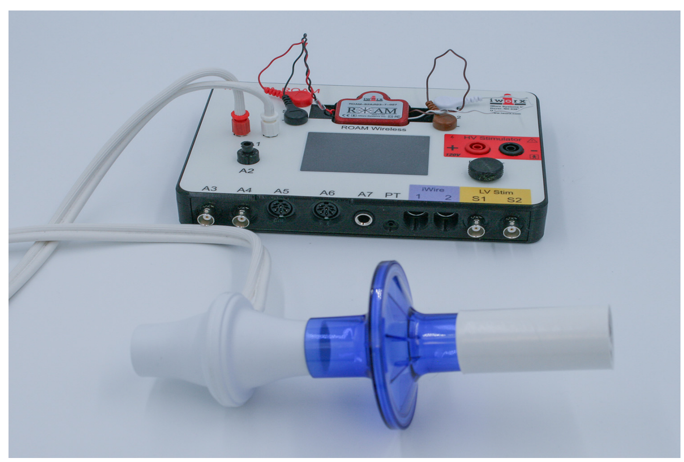

Figure HS-8-1: The A-FH-300 flow head and the airflow tubing, student respiratory kit with the spiro cap.

Figure HS-8-2: The flow head connected to the internal spirometer of the IXTA unit.

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 the breathing from a subject.
3. On the flow head, the outlets connected to the airflow tubing should always be pointed up to avoid problems with condensation developing within the tubing.
4. To reduce turbulence within the flow head, place a disposable cardboard mouthpiece over the opening of 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 is not included in the volume measurements and causes errors in these 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

- Check that the internal spirometer is being used is the IXTA and the flow head is 300L.
- 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.

Connecting the Restrictive Flow Head Covers:

Follow the images below for attaching the Restrictive Flow Head covers for use in Exercise 2 of the lab.

Figure HS-8-3: The 5 different size flow head caps for Restrictive experiment.

Figure HS-8-4: Flow head and cap.

Figure HS-8-5: Flow head with cap attached.

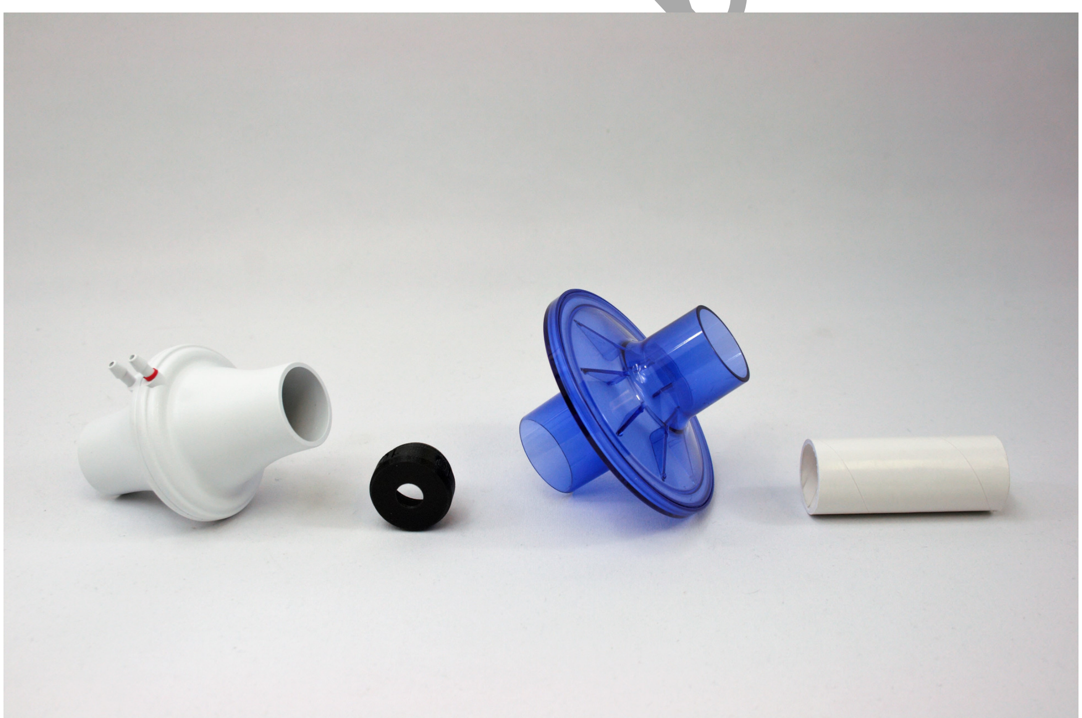

Figure HS-8-6: Flow head, cap, bacterial filter and cardboard mouthpiece.

Figure HS-8-7: Full assembly of the flow head for the Restrictive portion of the lab.

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Exercise 1: Normal Breathing While Resting

Aim: To measure breathing parameters in a healthy, resting subject.

Approximate Time: 30 minutes

There will be no restriction on the flow head during Exercise 1

Procedure

1. **PRACTICE** – There will be no recording actually done during this time:

   Instruct the subject to:

   - Sit quietly and become accustomed to breathing through the spirometer flow head.
   - Make sure to breathe through the red port side of the flow head.
   - Breathe normally before any recordings are made.
   - Hold the flow head so that the small outlet ports are pointed up.
   - Remove the flow head from their mouth and hold it at the mouth level in a position that prevents a breath from moving through the flow head.

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. Once done practicing, type **Resting** in the Mark box.
3. Click on the Record button. After waiting 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 button. Notice the slowly moving wave on the Lung Volume channel.
5. Record breathing using this method:
   - Have the subject record ten normal breaths, which normally takes about forty-five to sixty seconds.
   - After the ten breaths have been recorded, coach the subject to take in a very large inhale to fill the lungs completely.
   - After reaching their maximum inhalation volume, the subject should exhale as quickly and as completely as possible. Have the subject exhale completely, bending over to help force the air out of the lungs. The subject should try to exhale for at least 3 seconds to create a flat baseline.
   - Have the subject return to breathing normally.

6. Repeat Step 5, three (3) times. The recording should have a cycle of ten breaths, big in/out, ten breaths, big in/out, ten breaths, big in/out, ten breaths.
7. Click Stop to halt recording. Your data should look like Figure HS-8-L1.

Note: This breathing pattern is important and will be used throughout the lab exercises. If, at any time, the subject gets light headed during these exercises, remove the flow head and have the subject sit, relax and breath normally.

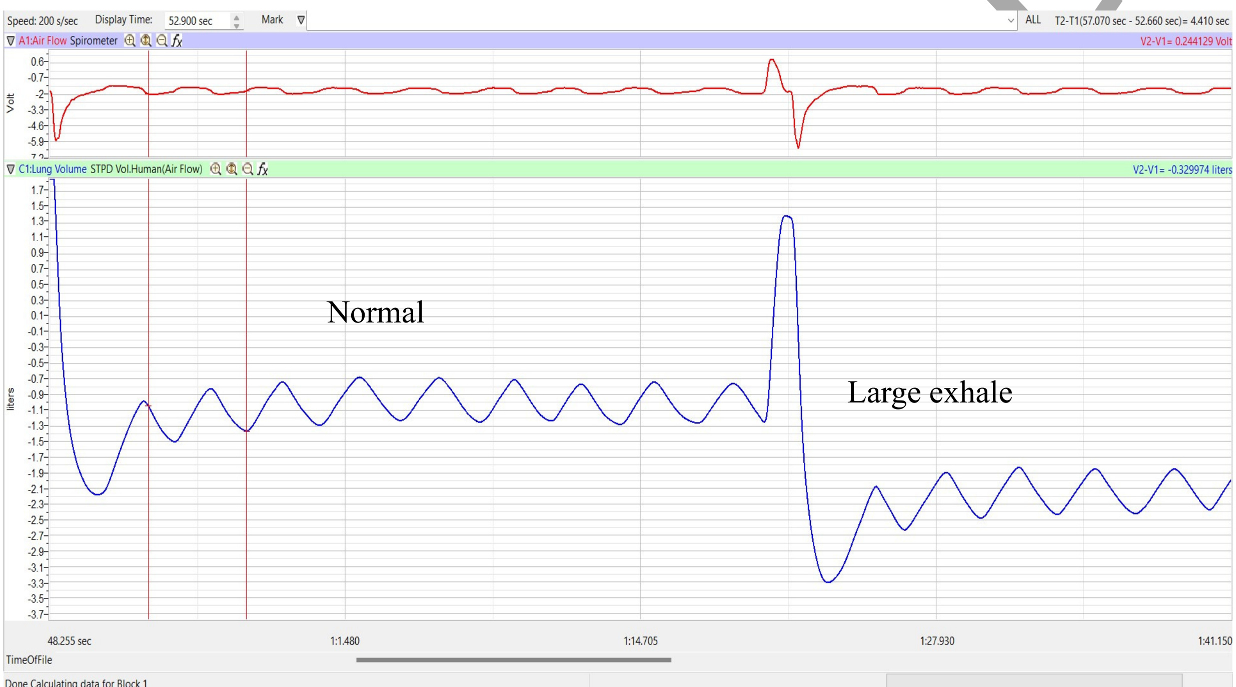


Figure HS-8-L1: Air flow and lung volumes of the normal and forced breathing of a subject at rest.

7. 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-Normal Breathing at Rest

1. Scroll through the recording and find the section of data recorded from the first cycle when the subject was breathing while resting.
2. Use the Display Time icons to adjust the Display Time of the Main window to show the full set of data for one complete section –10 breaths and the full in/out breath and a few normal breaths.
3. Click on the Analysis window icon in the toolbar to transfer the data displayed in the Main window to the Analysis window.

4. Look at the Function Table that is above the uppermost channel displayed in the Analysis window. The mathematical functions, V2-V1, Max_dv/dt, Min_dv/dt, and T2-T1 should appear in this table. Values for V2-V1, Max_dv/dt, Min_dv/dt, and T2-T1 on each channel are seen in the table across the top margin of each channel.

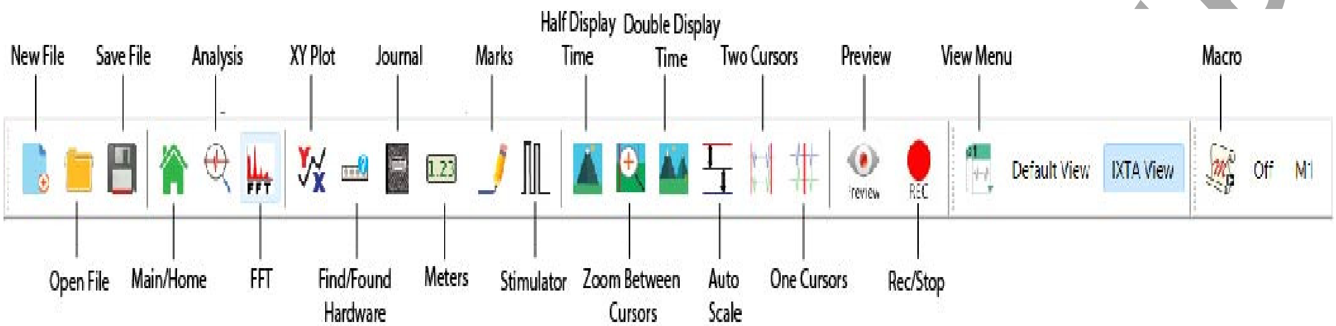


Figure HS-8-L2: The LabScribe toolbar.

5. Minimize the height of the Air Flow channel by clicking on the border between the channels and dragging the Lung Volumes channel upward. This will expand the Lung Volumes channel while making the Air Flow channel smaller.

6. On the Lung Volumes channel, use the mouse to click on and drag the cursors to specific points on the recording to measure the following volumes:

   - **Tidal Volume (TV)**, which is the volume of air inhaled or exhaled during a normal breathing cycle. Place one cursor in the trough prior to inhalation, and the second cursor on the peak of the cycle. The value for the V2-V1 function on the Lung Volumes channel is the tidal volume.

   - **Maximum Inspiratory Flow Rate**, which is the maximum rate of air movement during inhalation. Leave the cursors in the same positions used to measure the tidal volume. The value for the Max_dv/dt function on the Lung Volumes channel is the maximum inspiratory flow rate of that breath cycle.

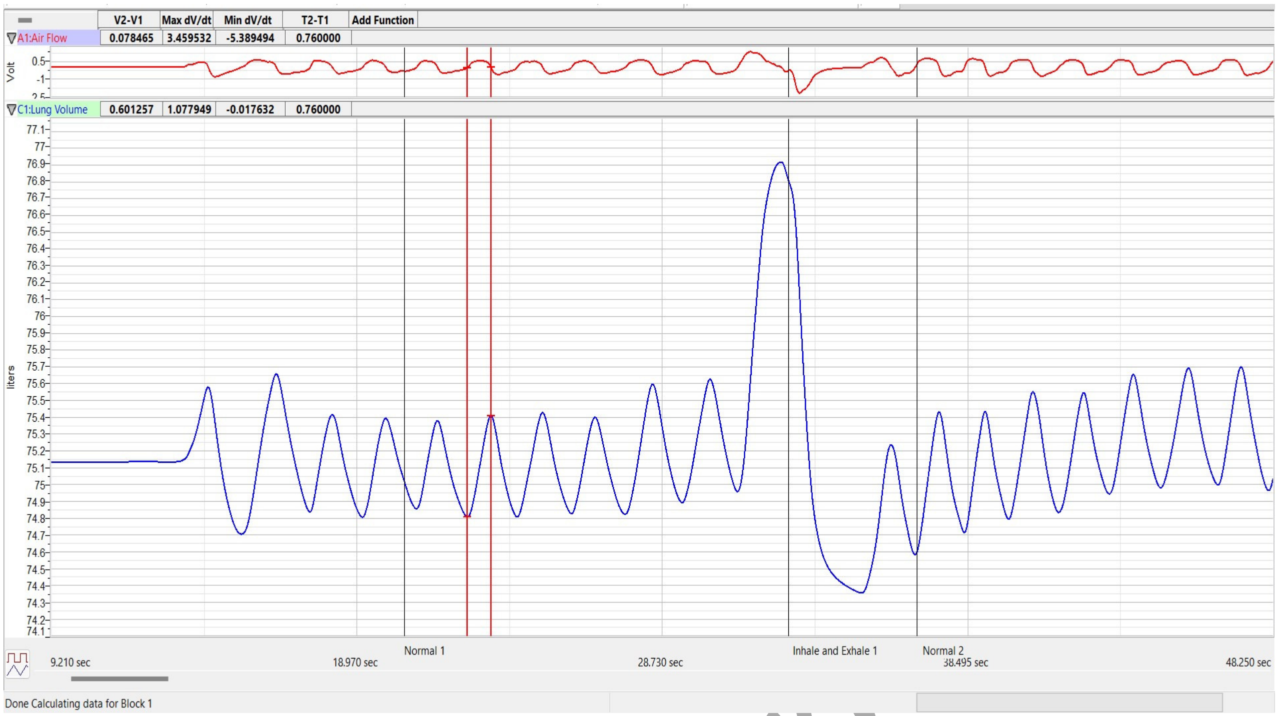
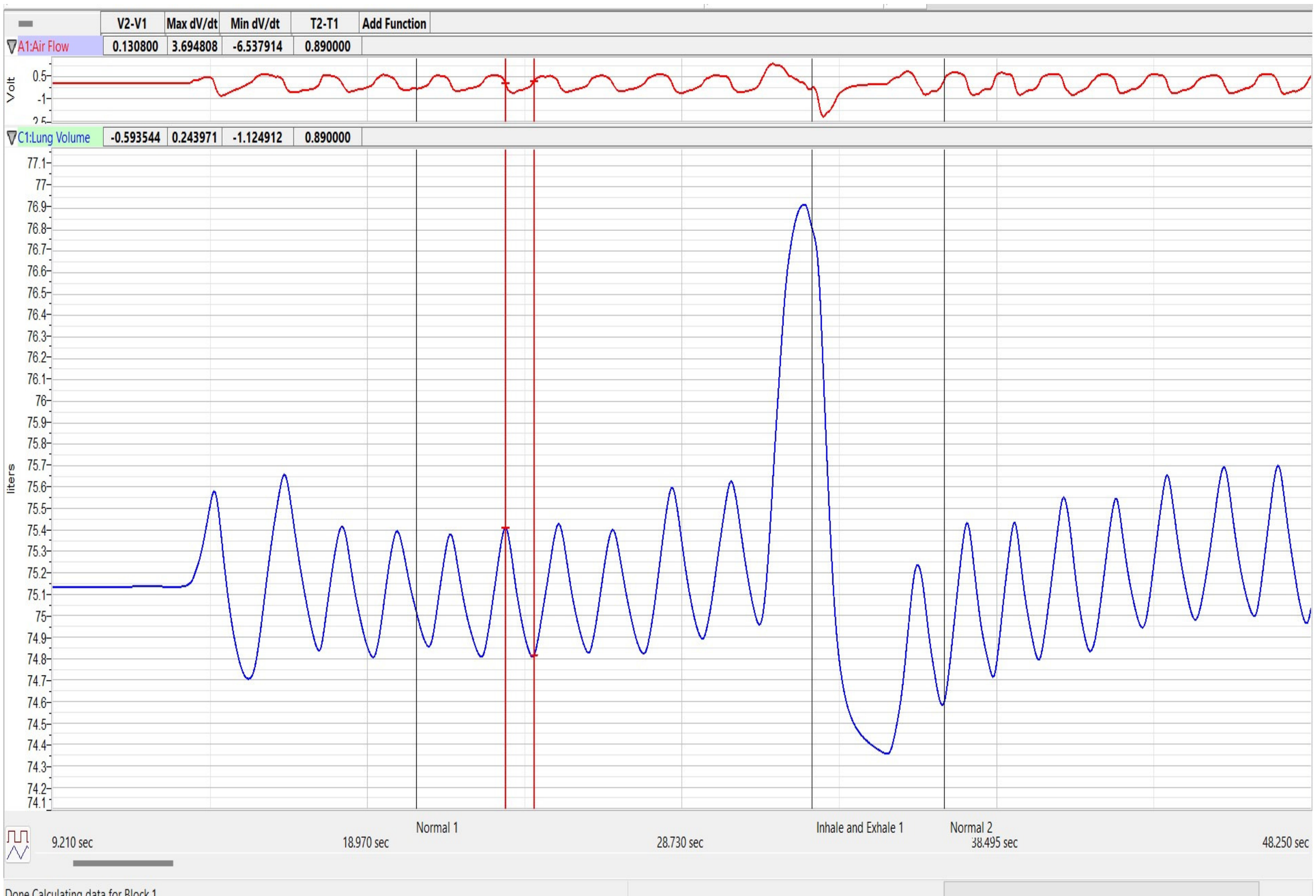


Figure HS-8-3: Breathing pattern of a subject at rest, displayed on the Lung Volumes channel in the Analysis window. The cursors are positioned on the trough and the peak of the breath cycle to measure the tidal volume (TV) with V2-V1 and the maximum inspiratory flow rate with Max_dv/dt.

- **Maximum Expiratory Flow Rate**, which is the maximum rate of air movement during exhalation. Place one cursor on the peak of the breath cycle, and the second cursor in the trough to the right of that peak. The value for the Min_dv/dt function on the Lung Volumes channel is the maximum expiratory flow rate of that breath cycle. This function is used since the exhalation portion of the breath cycle has a negative slope.



igure HS-8-L4: Breathing pattern of a subject at rest, displayed on the Lung Volumes channel in the Analysis window. The cursors are positioned on the peak of the breath cycle and the trough of the succeeding cycle to measure the maximum expiratory flow rate with Min_dv/dt.

- **Breath Period**, which is the duration of each breathing cycle. Place one cursor on a peak of a breath cycle, and the second cursor on the peak of an adjacent cycle. The value for T2-T1 on the Lung Volumes channel is the period of that breath cycle.

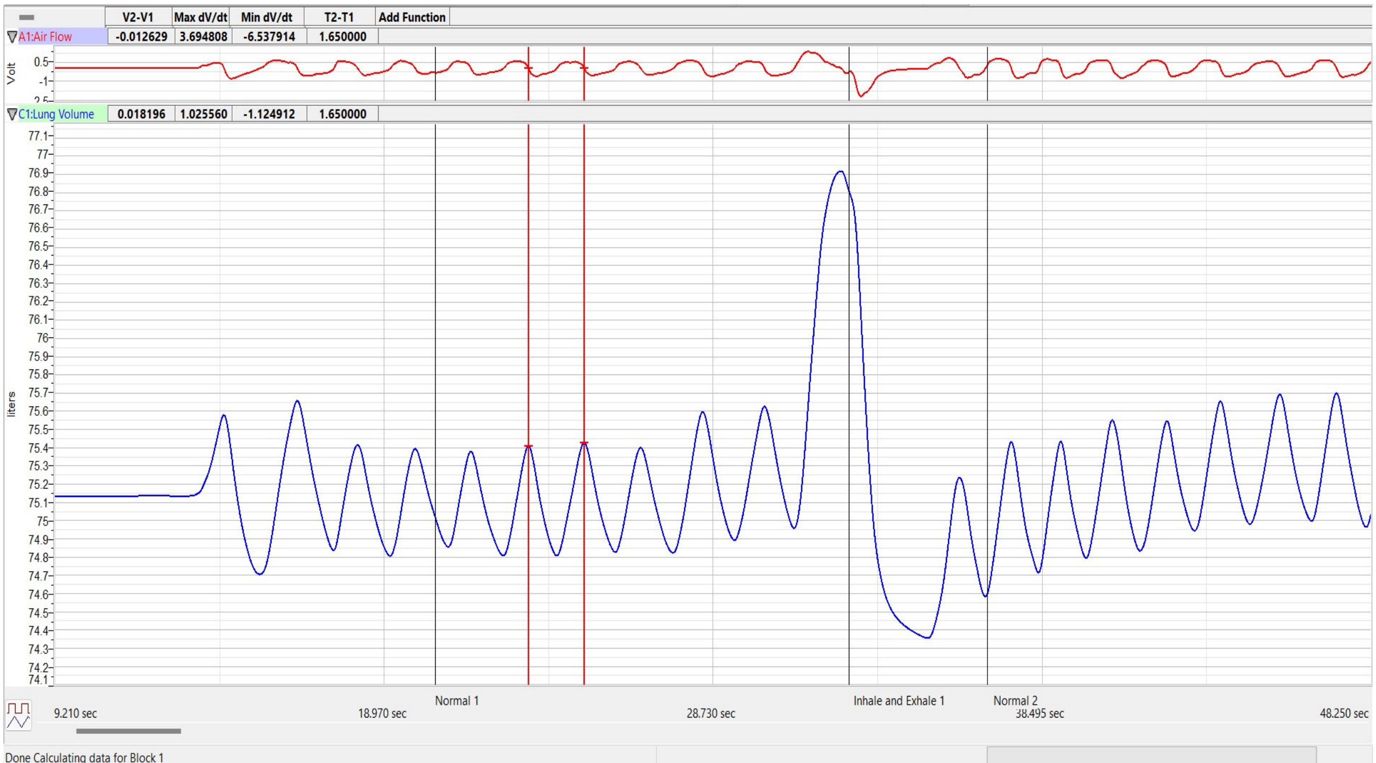


Figure HS-8-L5 Normal breathing pattern of a subject at rest, displayed on the Lung Volumes channel in the Analysis window. The cursors are positioned on the peaks of successive breath cycles to measure the breath period with T2-T1.

7. Once the cursors are placed in the correct positions for determining the volumes and rates of each breath cycle, 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:
    - Place the cursors at the locations used to measure the volumes and rates of 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 Ch. Data to Journal function in the Lung Volumes Channel pull-down menu.
9. Record the values in the Journal using the one of the techniques described in Step 8.
10. Repeat the measurements of tidal volume, maximum inspiratory flow rate, maximum expiratory flow rate, and breath period on two additional normal breaths.

11. Average the three values obtained for each parameter and 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, rates, and breath period in Table 2. Calculate the normal breathing rate of the subject at rest using the following equation:

Breath Rate (breaths/minute) = 60 (seconds/minute) / mean breath period (sec/breath)

13. Multiply the mean tidal volume by the breathing rate to calculate the volume of air passing in and out of the resting subject's lungs each minute.
14. Record the values for these calculations in the table.

Data Analysis-Forced Expiration at Rest

1. Use the slider or the arrows on the scroll bar, at the bottom of the Analysis window, to position data recorded when the subject exhaled with maximum force in the window.
2. Place the cursors on the forced expiration data displayed on the Lung Volumes channel to measure the following volumes and rates using the V2-V1, T2-T1, Max_dv/dt, and Min_dv/dt functions. Check the labels on the graph below to identify the volumes and rates that you will measure:
    - **Inspiratory Reserve Volume (IRV)**, by placing one cursor on the peak of the normal breath prior to the maximum inhalation and the second cursor on the peak of the forced breath cycle. The value for the V2-V1 function on the Lung Volumes channel is the inspiratory reserve volume.
    - **Forced Inspiratory Flow Rate**, by keeping the cursors in the same positions used for measuring IRV. The value for the Max_dv/dt function on the Lung Volumes channel is the forced inspiratory flow rate.
    - **Forced Vital Capacity (FVC)**, by placing one cursor on the peak of the forced breath cycle and the second cursor on the flat line after the subject has expelled all the air from their lungs. The value for the V2-V1 function on the Lung Volumes channel is the forced vital capacity.
    - **Forced Expiratory Flow Rate,** by keeping the cursors in the same positions used for measuring FVC.The value for the Min_dv/dt function on the Lung Volumes channel is the forced expiratory flow rate.
    - **Expiratory Reserve Volume (ERV)**, by placing one cursor in the trough before maximal inhalation and the second cursor on the flat line after subject has expelled all the air from their lungs. The value for the V2-V1 function on the Lung Volumes channel is the expiratory reserve volume.
    - **Forced Expiratory Volume at 1 Second (FEV_1)**, by placing one cursor on the peak of the maximum breath cycle and the second cursor on the data point that is one second after the peak. Use the T2-T1 function to determine the data point that is one second

after the peak. The value for the V2-V1 function on the Lung Volumes channel is the forced expiratory volume at one second.

- If the subject was able to breathe out for 3 seconds - measure the **Forced Expiratory Volume at 3 Seconds (FEV_3)**, by placing one cursor on the peak of the maximum breath cycle and the second cursor on the data point that is three seconds after the peak. Use the T2-T1 function to determine the data point that is three seconds after the peak. The value for the V2-V1 function on the Lung Volumes channel is the forced expiratory volume at three seconds.

3. Record these volumes and rates in Table 3.
4. Use the same techniques used earlier to record volumes and rates in the Journal by:
    - Typing the names and values of the parameters directly into the Journal, or;
    - Transferring the names and values of the parameters into the Journal by using the Add Title to Journal and the Add Ch. Data to Journal functions in the Lung Volumes Channel menu.
5. Calculate the subject's FEV_1/FVC ratio by dividing the subject's FEV_1 value by their FVC value.
6. Calculate the subject's FEV_3/FVC ratio by dividing the subject's FEV_3 value by their FVC value.

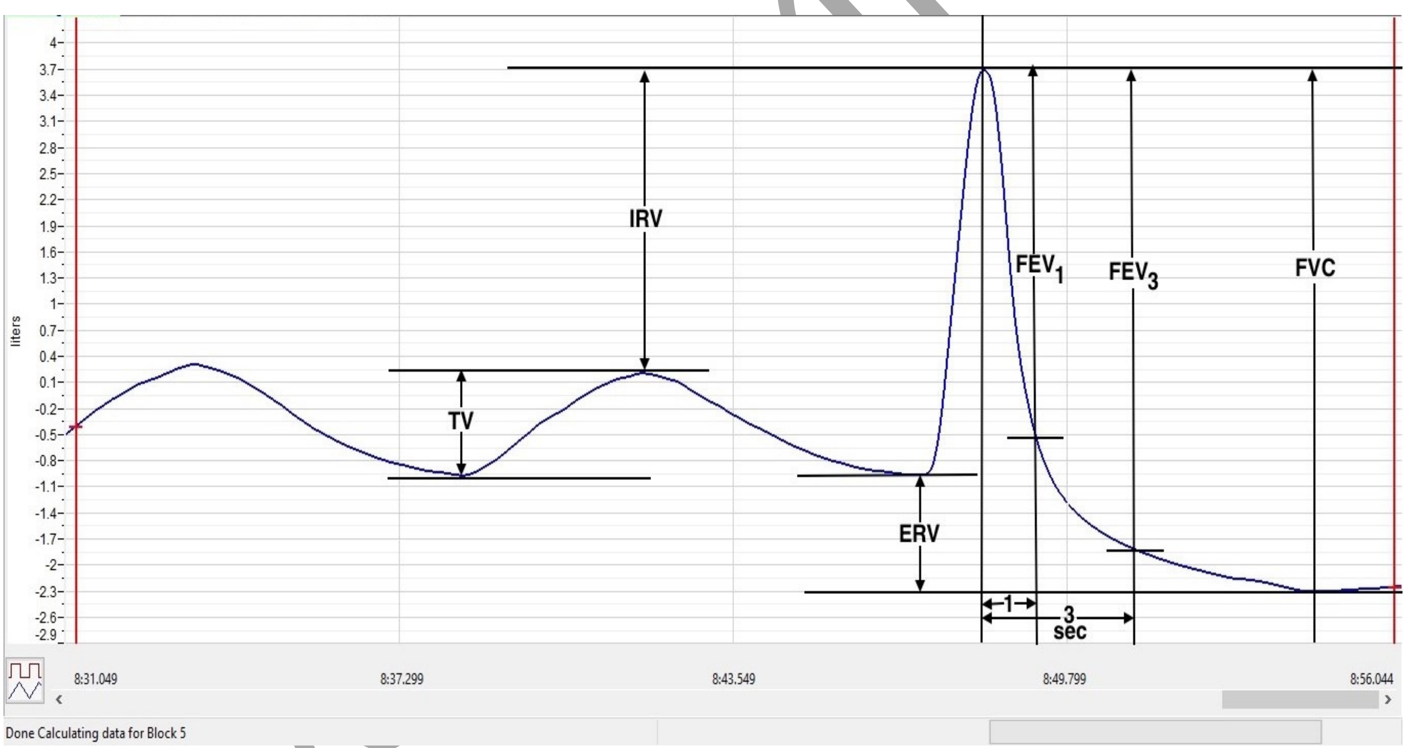


Figure HS-8-8: Normal breathing cycles are to the left of the forced inspiration and expiration. Lines and labels were added to the figure to indicate volumes that should be measured for each subject: Tidal Volume (TV), Inspiratory Reserve Volume (IRV), Expiratory Reserve Volume (ERV), Vital Capacity (VC), and Forced Expiratory Volumes at 1 Second (FEV_1) 3 seconds (FEV_3).

7. Compare the FEV_1/FVC and FEV_3/FVC ratios of the subject to the normal values of 0.80 and 0.95, respectively, for young healthy adults. Both of these ratios decrease with age.
    - In obstructive airway diseases, like asthma, bronchitis, or emphysema, both FVC and FEV_1 are reduced, and FEV_1/FVC ratios are usually less than 0.70.
    - In restrictive lung diseases, like fibrosis, FVC is reduced. But, because of the low compliance and high recoil of the lungs, the FEV_1/FVC ratio may be normal (~0.80) or greater than normal (>0.85).
8. Record the FEV_1/FVC and FEV_3/FVC ratios in Table 3.
9. Record the volumes, rates, and ratios from your subject in the table being compiled for all the subjects in the class.

Table HS-8-L1: Lung Volumes for an Average- Sized Human Male (70kg).

Volumes	Volume (mls)
Tidal Volume (TV)	500
Inspiratory Reserve Volume (IRV)	3100
Expiratory Reserve Volume (ERV)	1200
Forced Vital Capacity (FVC)	4800
Residual Volume (RV)	1200

Exercise 2: Breathing Parameters in a Subject with Restrictive Airway Disease

Aim: To measure the breathing parameters of the same healthy subject using the small black restrictive rings attached to the flow head.

Approximate Time: 30 minutes

Procedure

1. In this exercise, use the same healthy subject whose breathing parameters at rest were measured in Exercise 1.
2. Type **Restrictive –** ***size of cap (14)*** in the Mark box.
3. Attach the size 14 to the as shown in the *Setup* document. Make sure to make a note of the size of the cap in the Mark.
4. Click on the Record button. After waiting 10 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.

5. Click the AutoScale All button.
6. Follow the directions from Exercise 1 and record a series of three complete breathing cycles including the large in and out breaths.
7. Click Stop to halt recording.
8. Allow the subject to take a break and rest, breathing normally, for a few minutes before using the next sized cap.
9. Repeat this experiment using 2 smaller cap sizes. Make sure to Mark the cap sizes used.
10. Select Save in the File menu, and click on the Save button to save the data file.

Data Analysis

1. Perform the same types of measurements on the data recorded in Exercise 1. Record the measurements in the Journal. Report the appropriate measurements in Table 2 and Table 3.

2. Determine the values for the calculated parameters taken from the recordings of normal and forced breathing after exercise. Report these values on the tables.

Questions

Use your Anatomy and Physiology textbook to help determine the correct answers to the following questions.

1. Did tidal volume change while the subject was using the restrictive cap? Did inspiratory and expiratory reserves change while the subject was wearing the corset?
2. Explain your answers to Question #1.
3. Did restriction influence the time taken for each breathing cycle?
4. Did the rate of air flow during the inhalation phase increase or decrease with restriction? How can you account for the change?
5. Did the rate of air flow during the exhalation phase increase or decrease with restriction - how can you account for the change?
6. Did the volume of air passing in and out of the resting subject's lungs each minute increase or decrease while the subject's breathing was restricted?
7. Did restriction influence the forced vital capacity of the individual?
8. If the forced vital capacity changed due to restriction, can this be accounted for by changes in the IRV, the ERV, or a combination of both?

Exercise 3: Breathing Parameters in a Subject with Obstructive Airway Disease

Aim: To measure the breathing parameters of the same healthy subject using different tube lengths and diameters to imitate Obstructive Airway Disease.

Approximate Time: 30 minutes

Note: If the subject feels light headed at any time during this experiment, discontinue recording and have the subject breathe normally.

Procedure

1. In this exercise, use the same healthy subject whose breathing parameters at rest were measured in Exercises 1 and 2.
2. Obtain a drinking straw and a clean cardboard mouthpiece.
3. Carefully tape the straw to the cardboard mouthpiece, so that the subject can easily breathe through it. Tape the rest of the opening on the mouthpiece so no air moves through any other location except through the straw.
4. Place the cardboard mouthpiece on the flow head.
5. Type **Obstructive Narrow** in the Mark box.
6. Repeat Exercise 1 while breathing through the narrowed opening.

Data Analysis

1. Perform the same types of measurements on the data recorded in Exercise 3.
2. Record the measurements in the Journal. Report the appropriate measurements in the tables.
3. Determine the values for the ratios taken from the recordings of normal and forced breathing. Report these values in the tables.

Exercise 4: Breathing Parameters in a Subject with Obstructive Airway Disease - part 2

Aim: To measure the breathing parameters of the same healthy subject using different tube lengths and diameters to imitate Obstructive Airway Disease.

Approximate Time: 30 minutes

Note: If the subject feels light headed at any time during this experiment, discontinue recording and have the subject breathe normally.

Procedure

1. In this exercise, use the same healthy subject whose breathing parameters at rest were measured in Exercises 1, 2 and 3.
2. Obtain a 6” length of smooth interior tubing or tape cardboard mouthpieces together.

3. Place one end of the tubing on the cardboard mouthpiece, and place the cardboard mouthpiece on the flow head.
    - Have the subject breathe through the 6” length of tubing.
    - If the breathing doesn't feel labored, have the subject try the 8” length of tubing.
    - Keep increasing the length of tubing (up to 12”) until the subject feels that it is difficult to breathe normally.
4. The other end of the tubing should be open and the subject should be able to breathe through the tubing.
5. Type **Obstructive Long** in the Mark box.
6. Repeat the previous exercise while breathing through the lengthened tubing.

Data Analysis

1. Perform the same types of measurements as in the previous exercises on the data recorded in Exercise 4.
2. Record the measurements in the Journal. Report the appropriate measurements in the tables.
3. Determine the values for the ratios taken from the recordings of normal and forced breathing. Report these values in the tables.

Questions

Note: *Both Restrictive and Obstructive Airway Diseases influence breathing parameters in different ways. It is important to understand how an individual’s breathing patterns are affected when afflicted with one of these diseases.*

Use your Anatomy and Physiology textbook to help determine the correct answers to the following questions.

1. Did tidal volume change while the subject was breathing through the narrowed opening? The long tubing?
2. Did inspiratory and expiratory reserves change while the subject was breathing through the narrowed opening? The long tubing?
3. Explain your answers to Questions #1 and #2.
4. Did the length or diameter of the tubing influence the time taken for each breathing cycle?
5. Did the rate of air flow during the inhalation phase increase or decrease with obstruction of the chest? How can you account for the change?
    - Did the narrowed opening have different values than the long tubing?

6. Did the rate of air flow during the exhalation phase increase or decrease with obstruction of the chest —how can you account for the change?
    - Did the narrowed opening have different values than the long tubing?
7. Did the volume of air passing in and out of the resting subject's lungs each minute increase or decrease while the subject's chest was breathing through the narrowed opening? The long tubing?
8. Did the size of the tubing (narrow and long) influence the forced vital capacity of the individual?
9. If the forced vital capacity changed due to the tubing length and diameter, can this be accounted for by changes in the IRV, the ERV, or a combination of both?
10. Compare your data to what is supposed to happen physiologically. How do expected results compare to the observed results? Did you see what is expected?

Table HS-8-L2: Mean Breathing Volumes and Rates from a Healthy Subject at Rest and after Restriction and Obstruction.

	Rest	Large Cap	Medium Cap	Small Cap	Narrow Opening	Long Opening
Mean Breath Period (sec/breath)						
Breathing Rate (breaths/min)						
Mean Tidal Volume (mls/breath)						
Minute Air Flow Rate (liters/min)						
Max. Normal Air Flow Rate (mls/sec)						
during inhalation						
during exhalation						

Table HS-8-L3: Forced Expiration Volumes and Rates from a Healthy Subject at Rest and after Restriction and Obstruction.

	Rest	Large Cap	Medium Cap	Small Cap	Narrow Opening	Long Opening
Lung Volumes (liters)						
Tidal Volume (TV)						
Inspiratory Reserve Volume (IRV)						
Expiratory Reserve Volume (ERV)						
Vital Capacity (FVC)						
Forced Expiratory Volume - 1sec (FEV_1)						
Forced Expiratory Volume - 3sec (FEV_3)						
Forced Air Flow Rate (mls/sec)						
during inhalation						
during exhalation						
FEV_1/FVC Ratio						
FEV_3/FVC Ratio						