Experiment HS-2: Breathing and Gravity

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

The nose clip is optional. You can just hold your nose if that is easier. ONLY breathe through your mouth.

Spirometer Setup

1. Locate the A-FH-300L 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-300L 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.

Figure HS-2-S1: The student respiratory kit and A-FH-300L flow head and the airflow tubing. The blue filter attaches to the flow head.

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.

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4. To reduce turbulence, the subject should place their lips around the outside of the opening of the flow head, or around the cardboard mouthpiece or bacterial filter attached to the flow head.

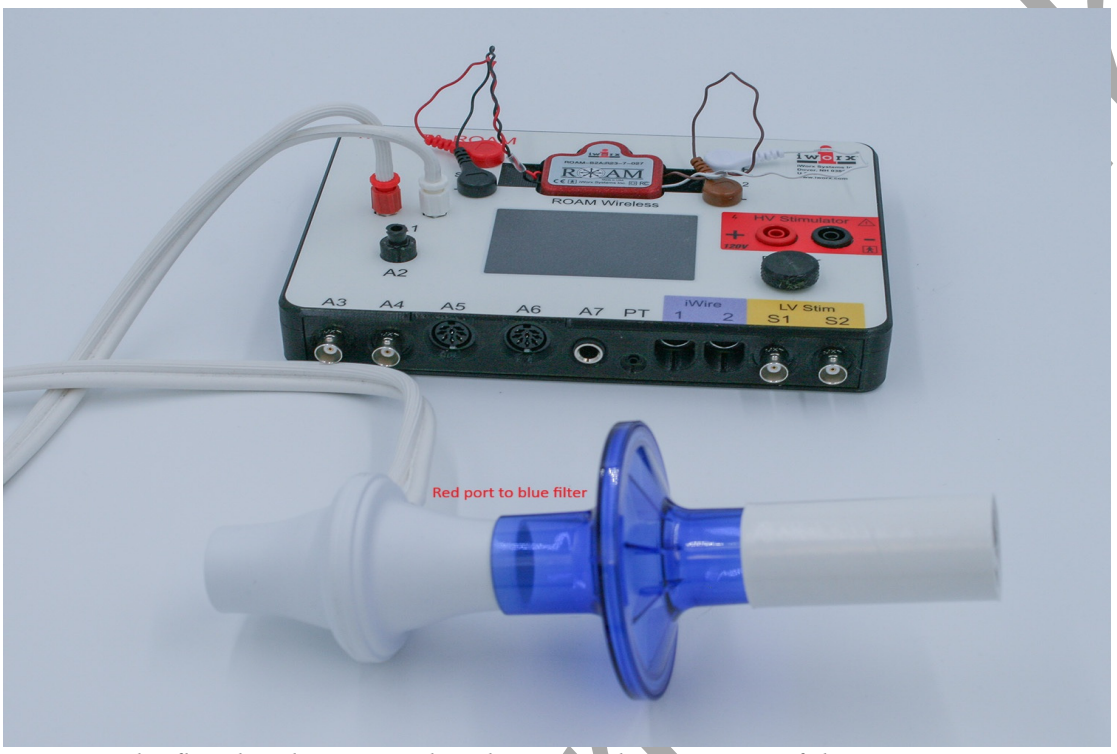

Figure HS-2-S2: The flow head connected to the internal spirometer of the IXTA unit.

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 **black** 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 and the flow head is the 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.**
8. Make sure the subject is breathing through the **red port side** of the flow head.

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Experiment HS-2: Breathing and Gravity

Exercise 1: Breathing While Sitting

Aim: To measure breathing parameters in a sitting subject.

Approximate Time: 20 minutes

Procedure

1. 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 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.

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. Type **Sitting** in the Mark box.
3. Click Record. 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 or six breaths, which normally takes about forty-five seconds to record.
5. Type **Forced** in the Mark box. Click the mark button as the subject inhales as deeply as possible to reach their maximum inhalation volume. Do not hold it in. Then, as quickly as possible the subject should exhale as much as possible and do another inhale before returning breathing to normally. Make sure to blow out all the air from the big breath.
6. After the forced exhalation is complete, the subject should continue to breathe normally through the spirometer for five to six breath cycles.
7. Click Stop to halt recording. Your data may look like the image below.
8. Select Save As in the File menu, type a name for the file. Click on the Save button to save the data file.

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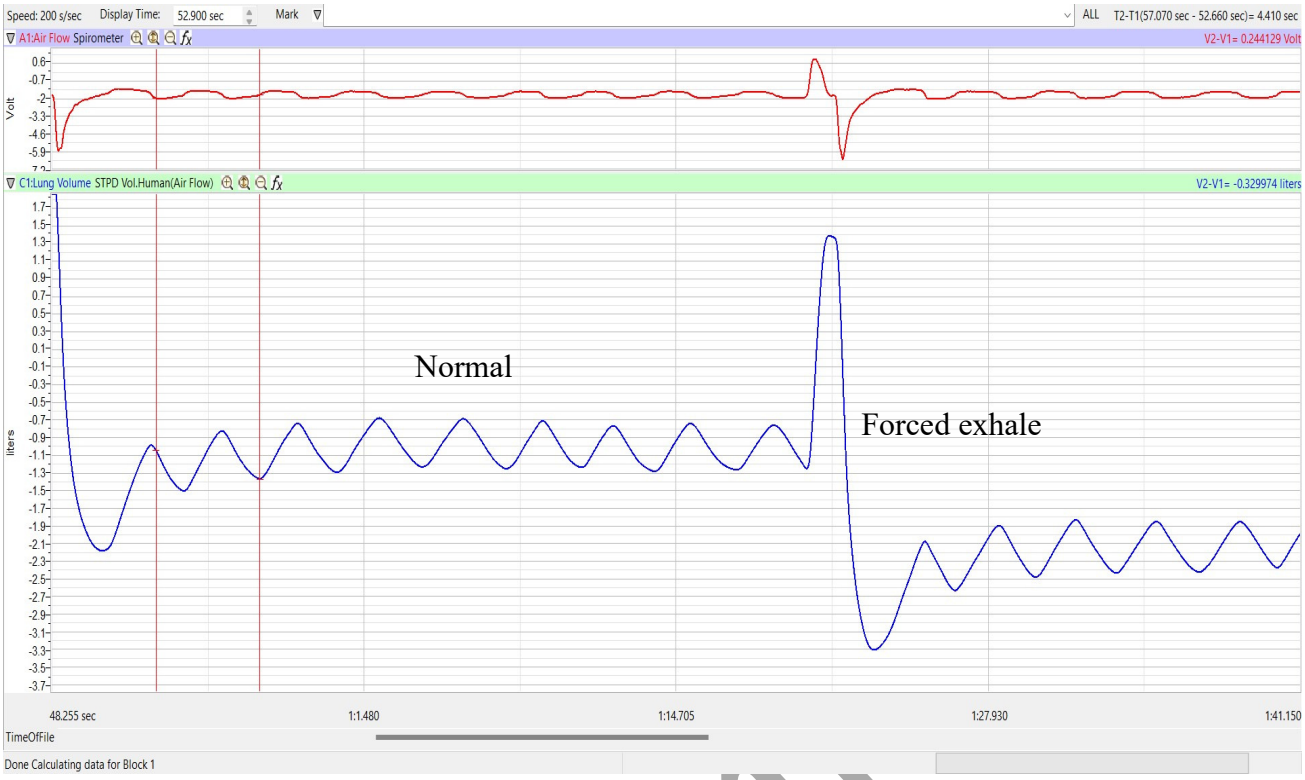

Figure HS-2-L1: Air flow and lung volumes of the normal and forced breathing of a subject at rest.

Data Analysis-Normal Breathing While Sitting

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 the complete breathing cycles on the Main window. The breathing cycles can also be selected by:
    - Placing the cursors on either side of a group of complete breathing cycles; and
    - Clicking the Zoom between Cursors button on the LabScribe toolbar to expand the selected breathing cycles to the width of the Main window.
    -

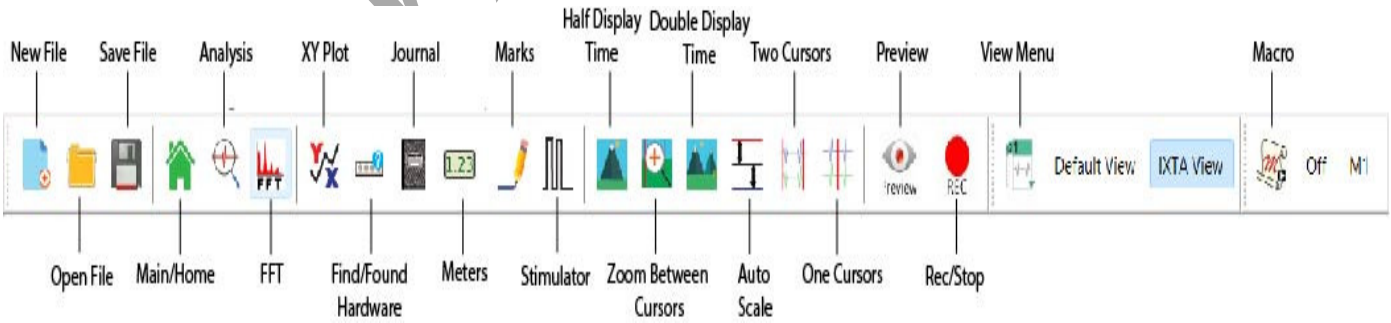

Figure HS-2-L2: The LabScribe toolbar.

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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.
5. 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. To measure the maximum inspiratory flow rate of the subject during breathing at rest, 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.

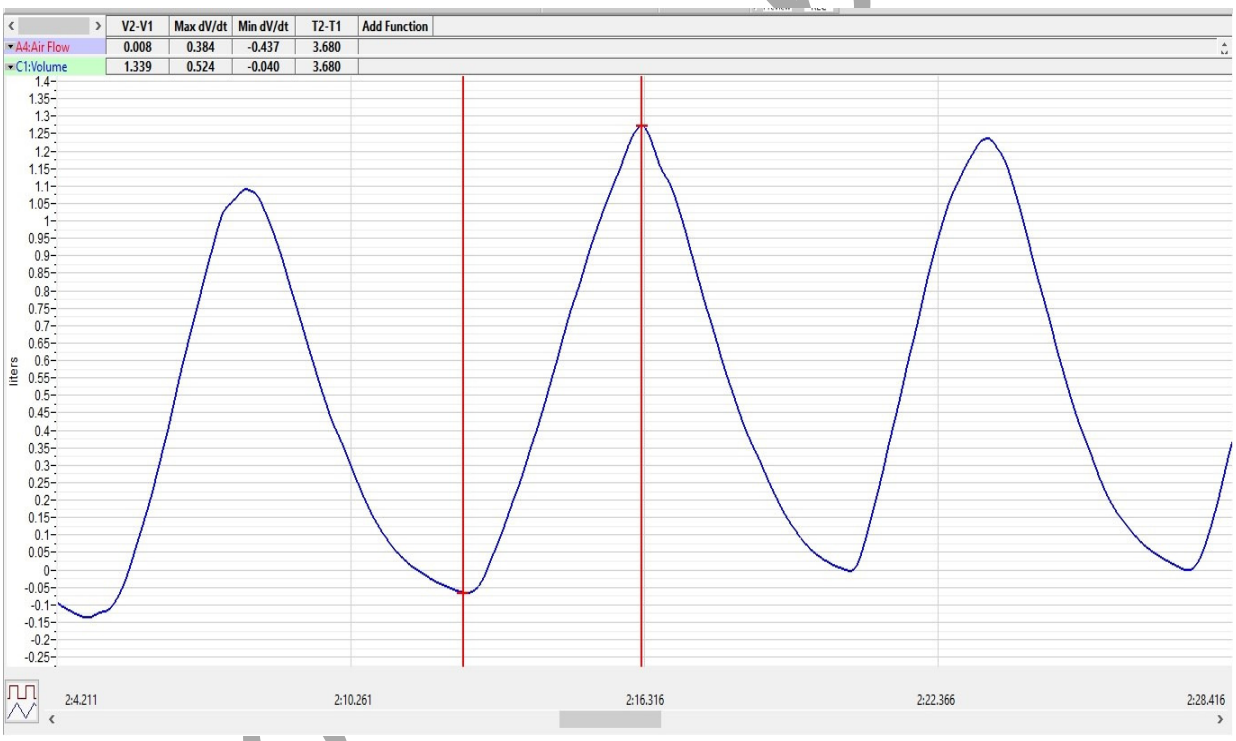

Figure HS-2-L3 Breathing pattern of a sitting subject, displayed on the Lung Volumes channel in the Analysis window. The cursors are positioned on the trough and the peak of the breath cycle to measure the tidal volume (TV) with V2-V1 function and the maximum inspiratory flow rate with the Max_dv/dt function.

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- **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.

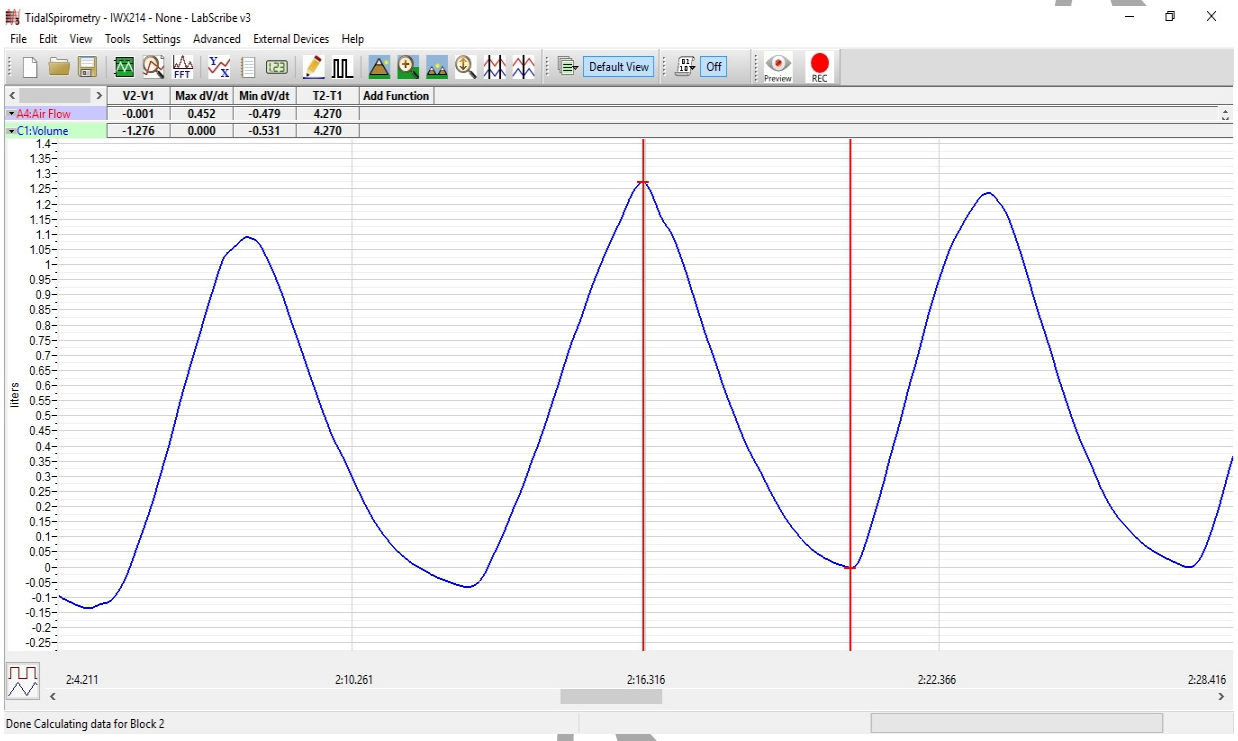

Figure HS-2-L4: Breathing pattern of a sitting subject, displayed on the Lung Volumes channel in the Analysis window. The cursors are positioned on the peak of the breath cycle and the trough of the succeeding cycle to measure the maximum expiratory flow rate with the Min_dv/dt function.

- **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.

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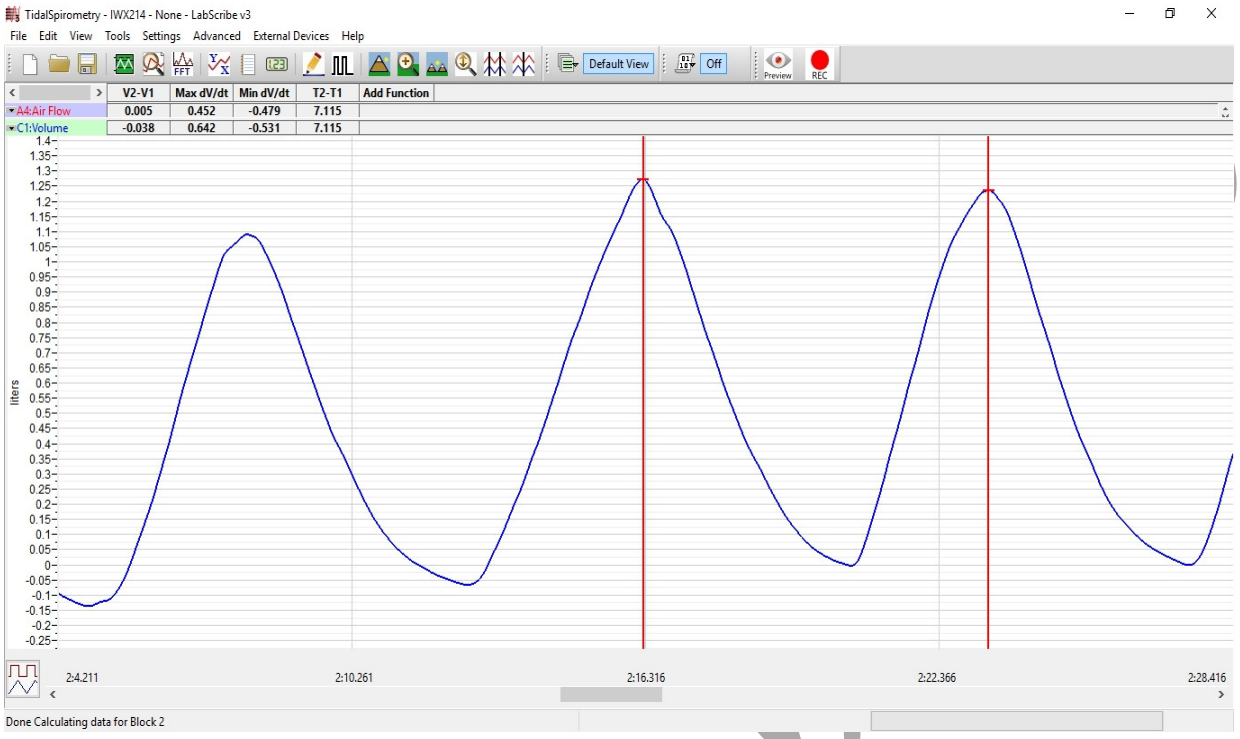

Figure HS-2-L5: Breathing pattern of a sitting subject, displayed on the Lung Volumes channel in the Analysis window. The cursors are positioned on the peaks of successive breath cycles to measure the breath period with the T2-T1 function.

6. 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, or on a separate data table.
7. 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.

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8. Record the values in the Journal using the one of the techniques described in Step 7.
9. Repeat the measurements of tidal volume, maximum inspiratory flow rate, maximum expiratory flow rate, and breath period on two additional normal breath cycles.
10. 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.
11. Record the means for the tidal volume, rates, and breath period in Table 1.
12. Calculate the normal breathing rate of the sitting subject 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 data table.

Data Analysis-Forced Expiration While Sitting

1. Use the slider or the arrows on the scroll bar, at the bottom of the Analysis window, to position the Forced expiration in the window.
2. Use the Display Time icons to adjust the Display Time of the Analysis window to show the forced expiration curve and the two normal breaths, that occur before the forced expiration curve, on the same window.
3. Place the cursors on the forced expiration data 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 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.

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- **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 inhalation 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.
- **Forced Expiratory Volume at 3 Seconds (FEV_3)**, by placing one cursor on the peak of the maximum inhalation 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.

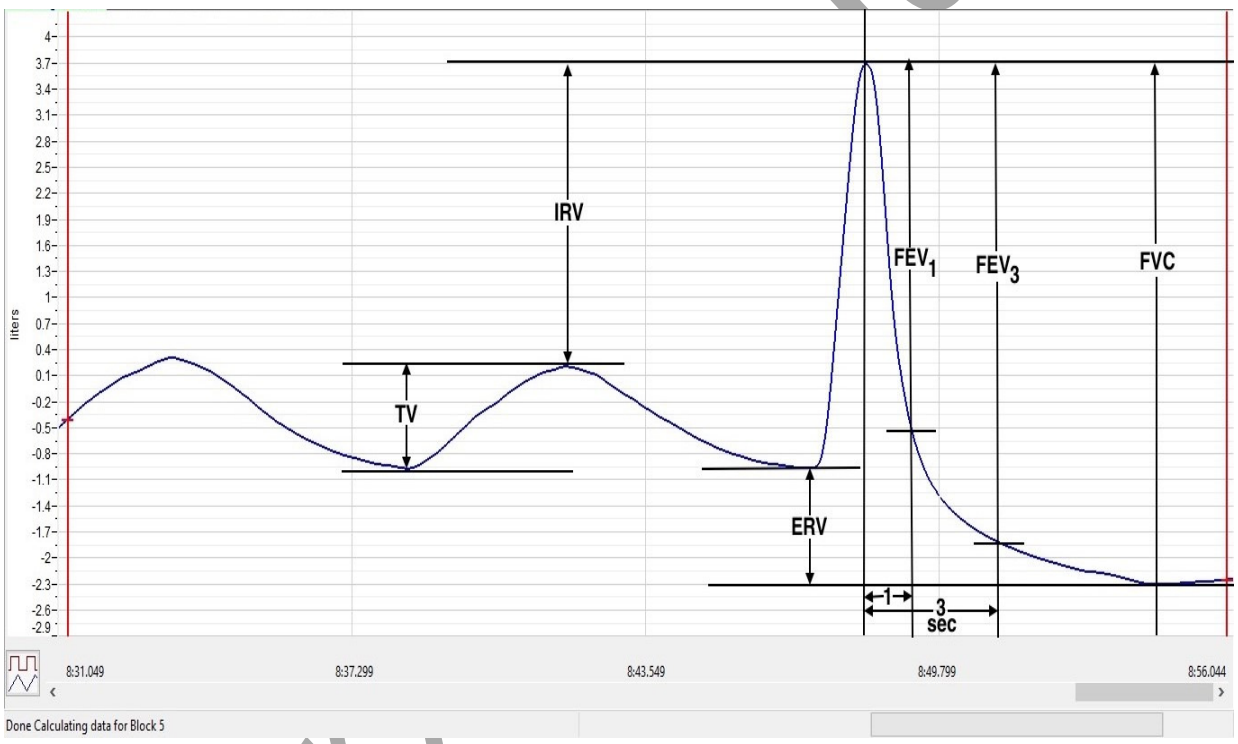

Figure HS-2-L6: Normal and forced lung volumes from a subject at rest, and displayed in the Analysis window. Lines and labels were added to figure to indicate to volumes that should be measured for each subject: Tidal Volume (TV), Inspiratory Reserve Volume (IRV), Expiratory Reserve Volume (ERV), Vital Capacity (VC), and Forced Expiratory Volume at 1 Second (FEV_1).

5. Record these volumes and rates in Table 2.
6. Calculate the subject's FEV_1/FVC ratio by dividing the subject's FEV_1 value by their FVC value.

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7. Calculate the subject's FEV_3/FVC ratio by dividing the subject's FEV_3 value by their FVC value.
8. 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).
9. Record the FEV_1/FVC and FEV_3/FVC ratios in the table.

Exercise 2: Breathing While Standing

Aim: To measure various breathing parameters in a standing subject.

Approximate Time: 15 minutes

Procedure

Repeat Exercise 1 while the subject is standing.

REMINDER: ***No air should be moving through the flow head during the first 10 sec.***

Data Analysis

1. Use the same techniques used in Exercise 1 to measure the data recorded in Exercise 2. Record the measurements in the Journal. Report the appropriate measurements in the tables.
2. Determine the values for the calculated parameters taken from the recordings of normal and forced breathing while standing. Report these values on the tables.

Exercise 3: Breathing While Supine (face up)

Aim: To measure various breathing parameters in a subject who is lying face up (supine).

Approximate Time: 15 minutes

Procedure

1. The subject should lie down on their back and relax.
2. Assist the subject when they are removing and replacing the flow head in their mouth. Place the flow head on the benchtop near the subject's head in a position that prevents any air to move through the flow head.
3. Repeat Exercise 1 while the subject is supine.

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Data Analysis

1. Perform the same types of measurements on the data recorded in Exercise 3 as were performed on the data recorded in Exercise 1. Record the measurements in the Journal. Report the appropriate measurements in the tables.
2. Determine the values for the calculated parameters taken from the recordings of normal and forced breathing while supine. Report these values on the tables.

Questions

1. What effect does lying down have on the minute volume (the total amount of air breathed into the lungs in a minute)?
2. What effect does lying down have on the various lung volumes, including tidal volume?
3. Would the blood pressure in the pulmonary capillaries at the bottom of a lung be the same as the blood pressure in the capillaries at the top of a lung in the standing individual? Which area would have the lower blood pressure?
4. With the answer to Question 4 in mind, if lower blood pressure allows more pulmonary capillaries to be open, where in the lung would you expect to find more collapsed capillaries, at the base or at the apex?
5. If some capillaries are collapsed, what is the functional effect on the diffusion of O_2 and CO_2?
6. Would you expect any difference in capillary blood pressures in the apex or in the base of the lungs in a subject who is lying down?
7. If the blood pressure in all pulmonary capillaries is the same, would you expect the capillaries to be open or collapsed?
8. If all pulmonary capillaries are open when lying down, what is the functional effect on the diffusion of O_2 and CO_2?
9. If the demands for O_2 and CO_2 are the same in either body position, should tidal volume and breathing rate be affected by body position? Do you see this?
10. Would you expect any difference in the levels of O_2 and CO_2 in the exhaled air of a subject who is standing or lying down?

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Table HS-2-L1: Normal Breathing Volumes and Rates While Sitting, Standing, and Reclining

	Sit	Stand	Supine
Mean Breath Period (sec/breath)			
Breathing Rate (breaths/min)			
Mean Tidal Volume (mls/breath)			
Minute Air Flow Rate (liters/min)			
Max Air Flow Rate (mls/sec)			
during inhalation			
during exhalation			

Table HS-2-L2: Forced Expiration Volumes and Rates at Rest and after Exercise

	Sit	Stand	Supine
Lung Volumes (liters)			
Tidal Volume (TV)			
Inspiratory Reserve Volume (IRV)			
Expiratory Reserve Volume (ERV)			
Vital Capacity (VC)			
Forced Expiratory V-1sec (FEV_1)			
Forced Expiratory V-3sec (FEV_3)			
Forced Air Flow Rate (mls/sec)			
during inhalation			
during exhalation			
FEV_1/VC Ratio			
FEV_3/VC Ratio			

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