iWorx Physiology Lab Experiment

Experiment HS-2

Breathing and Gravity

Note: The lab presented here is intended for evaluation purposes only. iWorx users should refer to the User Area on www.iworx.com for the most current versions of labs and LabScribe2 Software.

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Experiment HS-2: Breathing and Gravity

Background

Over a long time, the amount of oxygen (O_2) taken up and carbon dioxide (CO_2) given off at the tissues is matched with the amount of O_2 taken up and CO_2 given off at the lungs. Changes in the body's demand cause the respiratory control center in the medulla to change the depth and rate of breathing. This was seen in Experiment HS-1, when the effect of exercise was examined.

The exchange of O_2 and CO_2 at the lungs relies upon diffusion between the air and the blood. Any change in the rate of diffusion could produce a change in breathing parameters. One factor that influences the rate of diffusion is surface area. All other parameters being held constant, an increase in the surface area will increase the rate of diffusion and thus decrease the rate and depth of breathing. Gravity affects the amount of usable surface area in the lungs; this effect will be studied in this experiment.

Gaseous exchange between the alveolar air and the blood takes place at the pulmonary capillaries. These thin-walled vessels are distensible and easily collapse. The diameter of the pulmonary capillaries is determined by the transmural pressure—the pressure difference between the inside (blood pressure) and the outside (alveolar pressure) of the capillary. If the pressure in the alveoli is greater than the blood pressure, the pulmonary capillaries will collapse and blood will not flow through them. Under these conditions, while the diffusion gradients may be present for the exchange of O_2 and CO_2 between the air and the blood, the collapse of the vessels prevents gas exchange.

In this experiment, students will examine the effects of gravity on breathing by measuring the differences in lung volumes of a resting subject while he or she is sitting, standing, or lying down.

Experiment HS-2: Breathing and Gravity

Equipment Required

PC or Mac Computer

IXTA data acquisition unit

USB cable

IXTA power supply

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

IXTA Setup

1. Place the IXTA on the bench, close to the computer.

2. Check Figure T-1-1 in the Tutorial Chapter for the location of the USB port and the power socket on the IXTA.

3. Check Figure T-1-2 in the Tutorial Chapter for a picture of the IXTA power supply.

4. Use the USB cable to connect the computer to the USB port on the rear panel of the IXTA.

5. Plug the power supply for the IXTA into the electrical outlet. Insert the plug on the end of the power supply cable into the labeled socket on the rear of the IXTA. Use the power switch to turn on the unit. Confirm that the red power light is on.

Start the Software

1. Click on the LabScribe shortcut on the computer's desktop to open the program. If a shortcut is not available, click on the Windows Start menu, move the cursor to All Programs and then to the listing for iWorx. Select LabScribe from the iWorx submenu. The LabScribe Main window will appear as the program opens.

2. On the Main window, pull down the Settings menu and select Load Group.

3. Locate the folder that contains the settings group, IPLMv4Standard.iwxgrp. Select this group and click Open.

4. Pull down the Settings menu again. Select the Breathing-Gravity-LS2 settings file in the Human Spirometry folder.

5. After a short time, LabScribe will appear on the computer screen as configured by the Breathing-Gravity-LS2 settings file.

6. For your information, the settings used to configure the LabScribe software and the IXTA unit for this experiment are programmed on the Preferences Dialog window which can be viewed by selecting Preferences from the Edit menu on the LabScribe Main window.

7. Once the settings file has been loaded, click the **Experiment** button on the toolbar to open any of the following documents:

- Appendix
- Background
- Labs
- Setup (opens automatically)

Spirometer Setup

1. Locate the A-FH-300L flow head and the airflow tubing (Figure HS-2-S1) in the iWorx kit.

2. Firmly push the two air flow tubes onto the two outlets on the A-FH-300L flow head.

3. Carefully connect the other ends of the two air flow tubes into the Channel A1 input of the IXTA (Figure HS-2-S2). Connect the red port to the red connector on the tubing.

Figure HS-2-S1: The A-FH-300L flowhead and the airflow tubing.

Figure HS-2-S2: 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 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. Turbulence in the flow head will produce a noisy signal. To reduce turbulence, the subject should place his or her lips around the outside of the opening of the flowhead, or around the cardboard mouthpiece or bacterial filter attached to the flowhead.

5. Use a 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. The settings file, Breathing-Gravity-LS2, programs LabScribe to record the breathing of the subject on the Air Flow channel. A computed function is programmed on the Lung Volumes channel to convert the data recorded on the Air Flow channel to lung volume measurement.

7. 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 room temperature, barometric pressure and expired air temperature as needed.

   - Click OK.

8. Allow the IXTA to warm up for 10 minutes before recording for the first time.

9. When spirometry data is recorded in the conventional manner, inhalation is always displayed as an upward deflection. To determine if the subject is breathing through the correct end of the flow head.

   - Click on the Save to Disk button in the lower left corner of the Main window to switch the LabScribe software into Preview mode. When LabScribe is in Preview mode, there is a red X across the Save to Disk button. In Preview mode, the iWorx recording system works without recording data on the hard drive or any other storage media which allows a subject to become comfortable with breathing through a spirometer.

   - Click on the Preview button. Have the subject inhale through the spirometer flowhead. Click on the AutoScale button at the upper margin of the Air Flow and Lung Volumes channels. If the flowhead is oriented properly, the traces on the Air Flow and Lung

Volumes channels will go up during inhalation. If the traces on these channels go down during inhalation, have the subject breathe through the other end of the flowhead, or reverse the positions of the airflow tubes at the outlets of the flowhead.

Note: If the user clicks the Preview button and an error window appears the Main window indicating the iWorx hardware cannot be found, make sure the iWorx unit is turned on and connected to the USB port of the computer. Then, click on the OK button in the error window. Pull down the LabScribe Tools menu, select the Find Hardware function, and follow the directions on the Find Hardware dialogue window

10. Click on the Stop button.

11. Before proceeding to the actual exercises, make sure the LabScribe software in set to Record mode. Click on the Save to Disk button, in the lower left corner of the Main window, to change LabScribe from Preview mode to Record mode. When LabScribe is in Record mode, there is a green arrow on the Save to Disk button.

Experiment HS-2: Breathing and Gravity

Exercise 1: Breathing While Sitting

Aim: To measure breathing parameters in a sitting subject.

Procedure

1. Instruct the subject to:

   - Sit quietly and become accustomed to breathing through the spirometer flowhead.

   - Breathe 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.

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 <Subject's Name> Sitting in the Mark box that is to the right of the Mark button.

3. 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.

4. 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.

5. Type Forced in the Mark box. 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 exhale as quickly and as completely as possible.

6. After the forced exhalation is complete, the subject should continue to breathe normally through the spirometer for five breath cycles.

7. Click Stop to halt recording. Your data may look like Figure HS-2-L1.

8. 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.
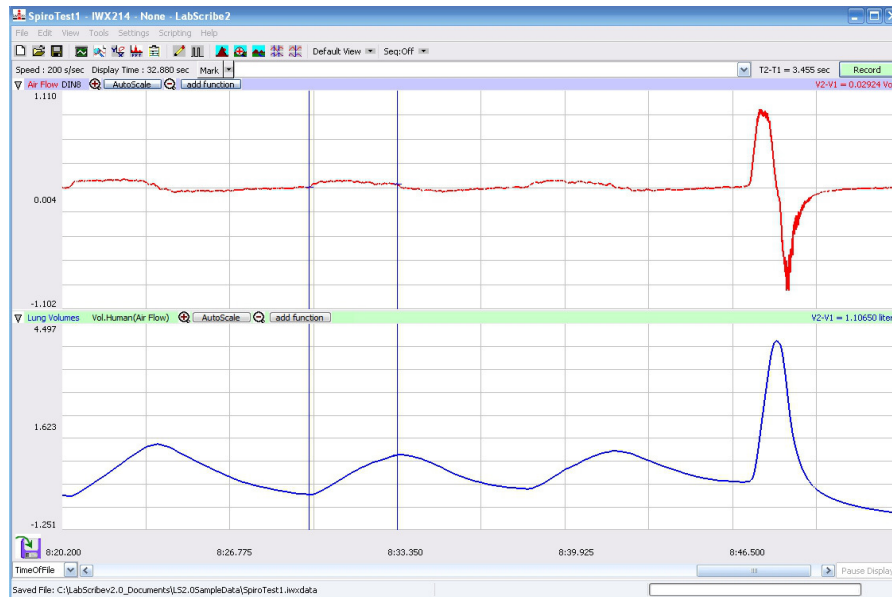
Figure HS-2-L1: Air flow and lung volumes of the normal and forced breathing of a subject at rest.

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 at least four complete breathing cycles on the Main window. 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 to expand the four selected breathing cycles to the width of the Main window.

3. Click on the Analysis window icon in the toolbar (Figure HS-2-L2) or select Analysis from the Windows menu to transfer the data displayed in the Main window to the Analysis window (Figure HS-2-L3).

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.
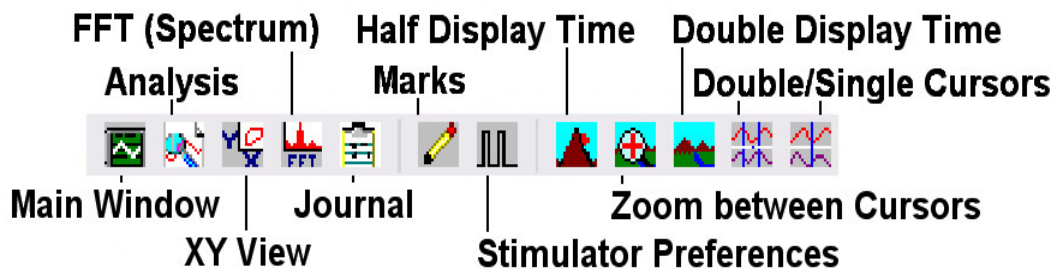
Figure HS-2-L2: The LabScribe toolbar.

5. Minimize the height of the Air Flow channel by clicking on the arrow to the left of the channel's title to open the channel menu. Select Minimize from this menu to reduce the height of the channel display.

6. Maximize the height of the trace on the Lung Volumes channel by clicking on the arrow to the left of the channel's title to open the channel menu. Select Scale from the menu and AutoScale from the Scale submenu to increase the height of the data on that channel.

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, or on a separate data table.

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. 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. To measure the tidal volume of the subject during breathing at rest, 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.(Figure HS-2-L3).

    • 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.

- Maximum Expiratory Flow Rate, which is the maximum rate of air movement during exhalation. To measure the maximum expiratory flow rate of the subject during breathing at rest, 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 (Figure HS-2-L4).This function is used since the exhalation portion of the breath cycle has a negative slope.

- Breath Period, which is the duration of each breathing cycle. To measure the breath period of the subject during breathing at rest, 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.
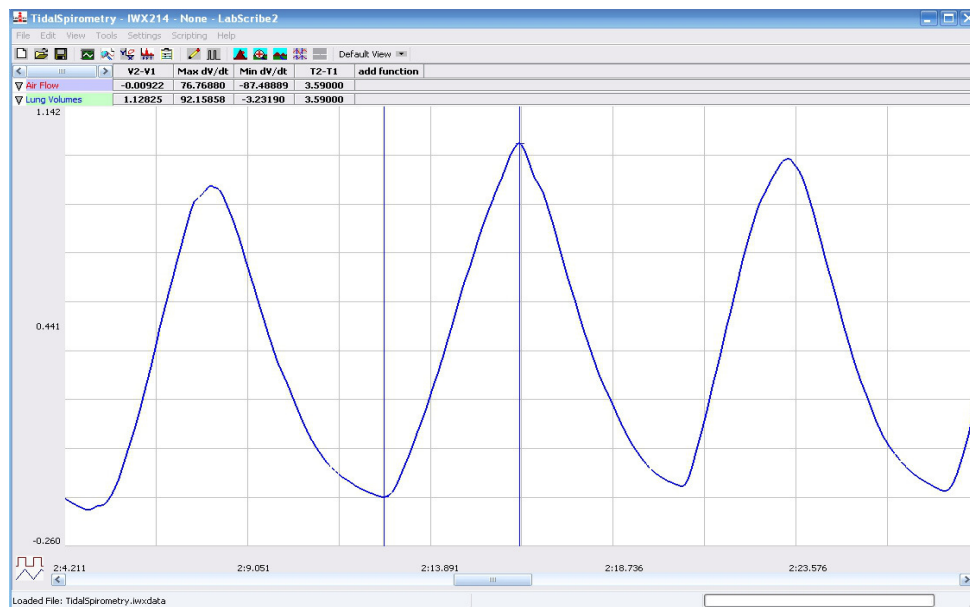

Figure HS-2-L3 Breathing pattern of a sitting subject, displayed on the Lung Volumes channel in the Analysis window. The cursors are positioned on the trough and the peak of the breath cycle to measure the tidal volume (TV) with V2-V1 function and the maximum inspiratory flow rate with the Max_dv/dt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

10. Record the values in the Journal using the one of the techniques described in Steps 7 or 8.

11. Repeat the measurements of tidal volume, maximum inspiratory flow rate, maximum expiratory flow rate, and breath period on two additional normal breath cycles.

12. 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 (Figure HS-2-L2).
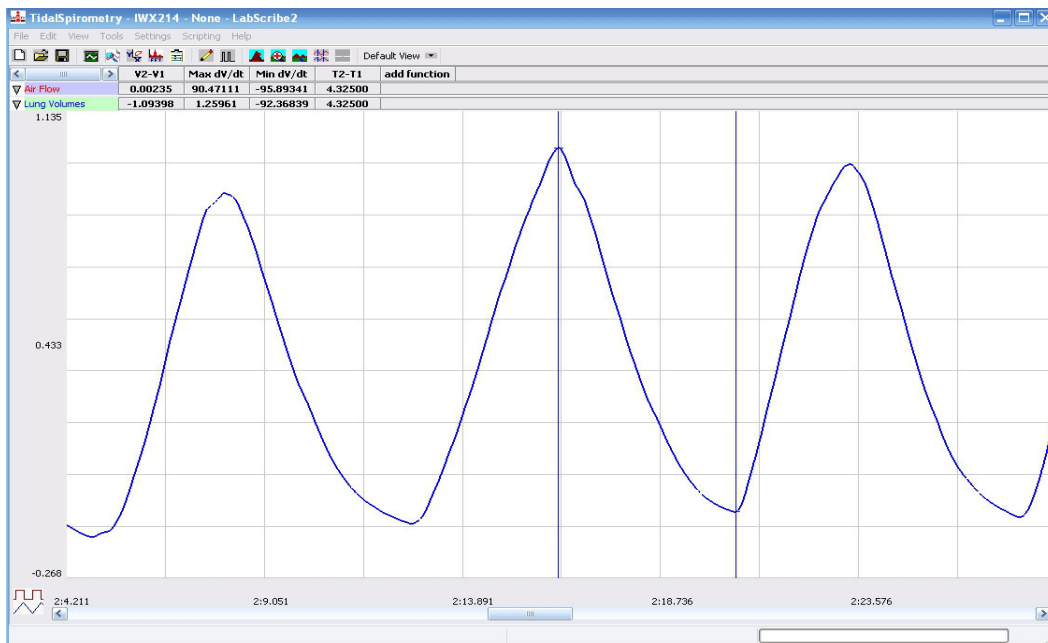
Figure HS-2-L4: Breathing pattern of a sitting subject, displayed on the Lung Volumes channel in the Analysis window. The cursors are positioned on the peak of the breath cycle and the trough of the succeeding cycle to measure the maximum expiratory flow rate with the Min_dv/dt function.
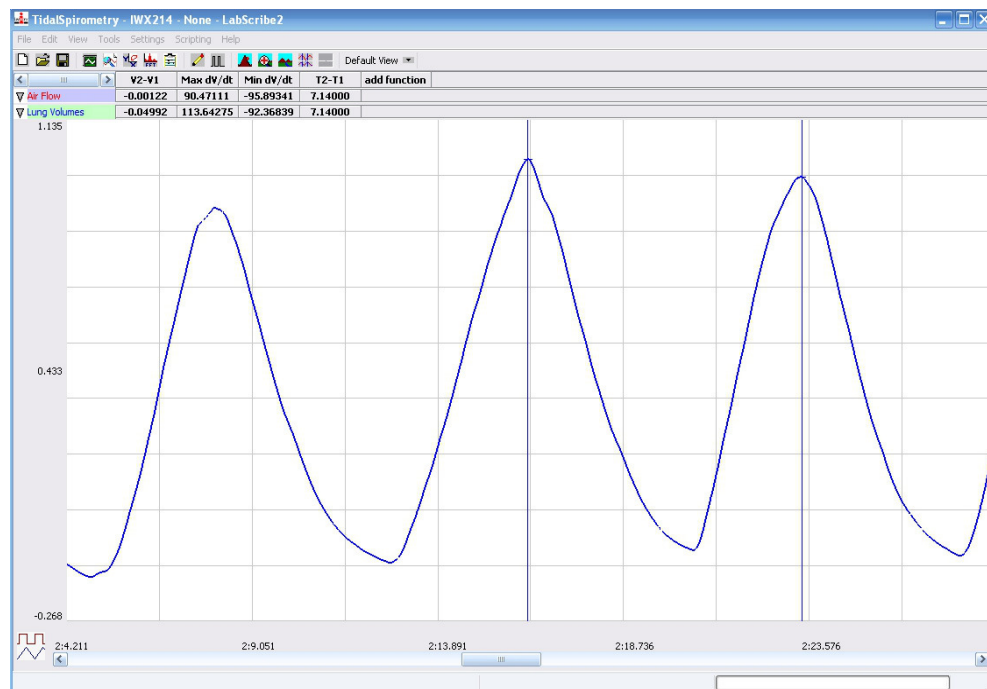

Figure HS-2-L5: Breathing pattern of a sitting subject, displayed on the Lung Volumes channel in the Analysis window. The cursors are positioned on the peaks of successive breath cycles to measure the breath period with the T2-T1 function.

13. Record the means for the tidal volume, rates, and breath period in Table HS-2-L1.

14. 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)

15. 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.

16. 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. These breathing cycles can also be selected by:

    • Placing the cursors on either side of the group of appropriate 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.The segment of the recording displayed in the window should be like the recording in Figure HS-2-L6.

3. Use the one of the techniques described earlier to record volumes and rates in the Journal.

4. Place the cursors 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 on Figure HS-2-L6 to identify the volumes and rates that you will measure:

    • Tidal Volume (TV), by placing one cursor in the trough before the inhalation segment of the resting breath and the second cursor on the peak of that resting breath cycle. The value for the V2-V1 function on the Lung Volumes channel is the tidal volume.

    • 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 his or her 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 his or her 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.

- 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.
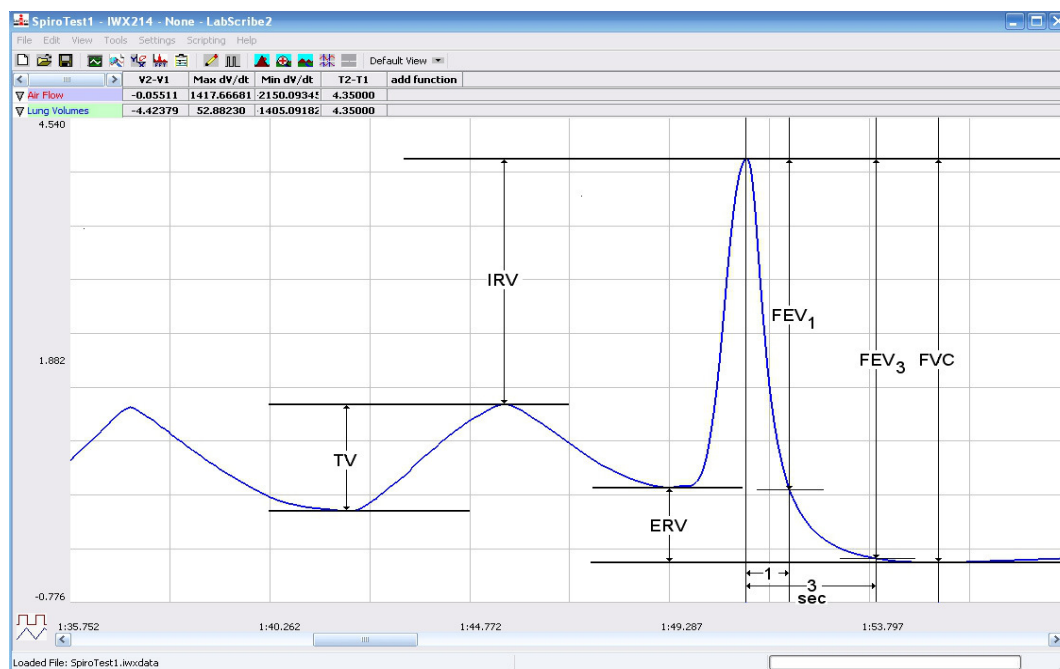

Figure HS-2-L6: Normal and forced lung volumes from a subject at rest, and displayed in the Analysis window. Lines and labels were added to figure to indicate to volumes that should be measured for each subject: Tidal Volume (TV), Inspiratory Reserve Volume (IRV), Expiratory Reserve Volume (ERV), Vital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

5. Record these volumes and rates in Table HS-2-L2.

6. Calculate the subject's FEV_1/FVC ratio by dividing the subject's FEV_1 value by his or her FVC value.

7. Calculate the subject's FEV_3/FVC ratio by dividing the subject's FEV_3 value by his or her 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.

Procedure

Repeat Exercise 1 while the subject is standing.

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).

Procedure

1. The subject should lie down on their back and relax.

2. Assist the subject when he or she is removing and replacing the flowhead in his or her mouth. Place the flowhead on the benchtop near the subject's head in a position that prevents any air to move through the flowhead.

3. Repeat Exercise 1 while the subject is supine.

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?

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			