Experiment RP-2: The Effect of Gravity on Breathing

Background

Over 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 RP-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, you 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.

Equipment Required

PC or Mac Computer

IX-ELVIS

USB cable

Power supply

SPN-304 Spirometer and airflow tubing

SP1 flowhead

IX-ELVIS Setup

1. Place the IX-ELVIS unit on the bench, close to the computer.

2. Connect the IX-ELVIS to the computer with the supplied USB cable.

3. Insert the power plug into the rear of the IX-ELVIS and plug the transformer into the electrical outlet. Turn on the power switches on the rear and on the upper right side of the top of the unit and confirm that the LEDs are illuminated.

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, ELVISNI.iwxgrp. Select this group and click Open.

4. Pull down the Settings menu again. Select the Gravity-Breathing-LS2 settings file.

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

6. The settings used to configure the LabScribe software and the IX-ELVIS 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.

Spirometer Setup

1. Locate the SPN-304 spirometer, the plastic SP1 flowhead, and the airflow tubing (Figure RP-1-S1).

2. Firmly push the two air flow tubes onto the two outlets on the flowhead, ribbed tubing to red outlet.. Push the other ends of the two air flow tubes onto the two outlets on the SPN-304 spirometer unit, ribbed tubing to red outlet.

3. The Heart Sounds-Spirometer switch on the SPN-304 should be set to the Spirometer position, to the left, when the labeled surface of the SPN-304 is facing you.

Figure RP-1-S1: The SPN-304 spirometer, the SP1 flowhead, and airflow tubing.

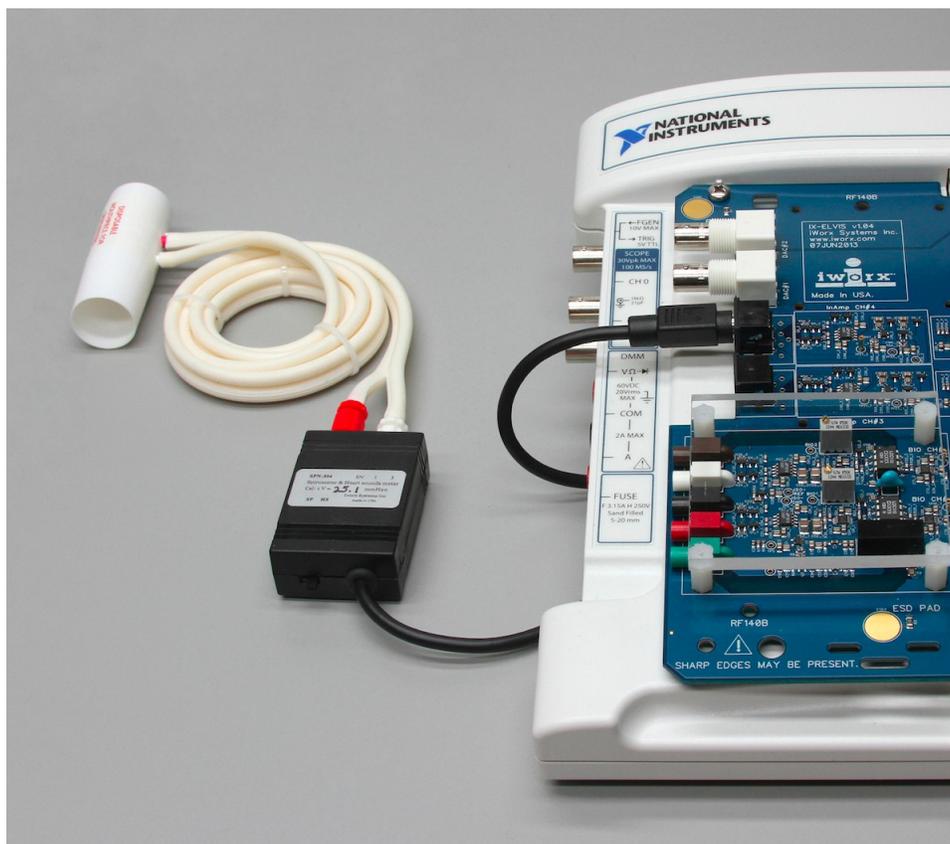4. Plug the mini-DIN connector to the SPN-304 spirometer into the Channel 4 input of the IX-ELVIS (Figure RP-1-S2).

Figure RP-1-S2: SPN-304 spirometer and SP1 flowhead connected to the IX-ELVIS.

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. On the flowhead, the outlets connected to the airflow tubing should always be pointed up to avoid problems with condensation developing within the tubing.

4. 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.

5. The settings file, Gravity-Breathing, programs LabScribe to record the breathing of the subject on the Air Flow channel. The computed function used on the Lung Volume channel converts the data recorded on the Air Flow channel to lung volume measurements.

6. To be sure that the spirometer calibration parameters are properly configured to accurately measure Lung Volume:

- Click on the words STPD Vol Human (Air Flow), that are next to the title of the Lung Volume channel, to open the computed function pull-down menu.

- Select Setup from this pull-down menu to open the Spirometer Calibration Dialog window.

- The SPN-304 spirometer and the SP1 flowhead should be chosen.

- Make sure the reset time is set to 'No Reset' and the first ten seconds of the recording are used to zero the baseline of the Volume channel.

- The calibrated volume difference between cursors should be set to one liter. Click OK.

8. Allow the SPN-304 to warm up for 10 minutes before recording for the first time.

Note: Do not hold the spirometer amplifier in your hand; the heat of your hand will alter the volumes recorded.

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 flowhead.

- 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 IX-ELVIS 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 flowhead. Click on the AutoScale button at the upper margin of the Air Flow and Volume channels. If the tube is oriented properly, the traces on the Air Flow and Volume channels will go up during inhalation. If the traces on these channels go down during inhalation, 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 IX-ELVIS cannot be found, make sure the IX-ELVIS 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.

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 tube from his or her mouth and hold it at the mouth level in a position that prevents a breath from moving through the tube.

    Note: The LabScribe software will zero the Volume channel during the first ten seconds of recording. No air should be moving through the flowhead 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 Volume 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 Volume channels. Notice the slowly moving wave on the Volume channel. Record ten breaths, which normally takes about 90 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 RP-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. Designate the file type as *.iwxdata. Click on the Save button to save the data file.
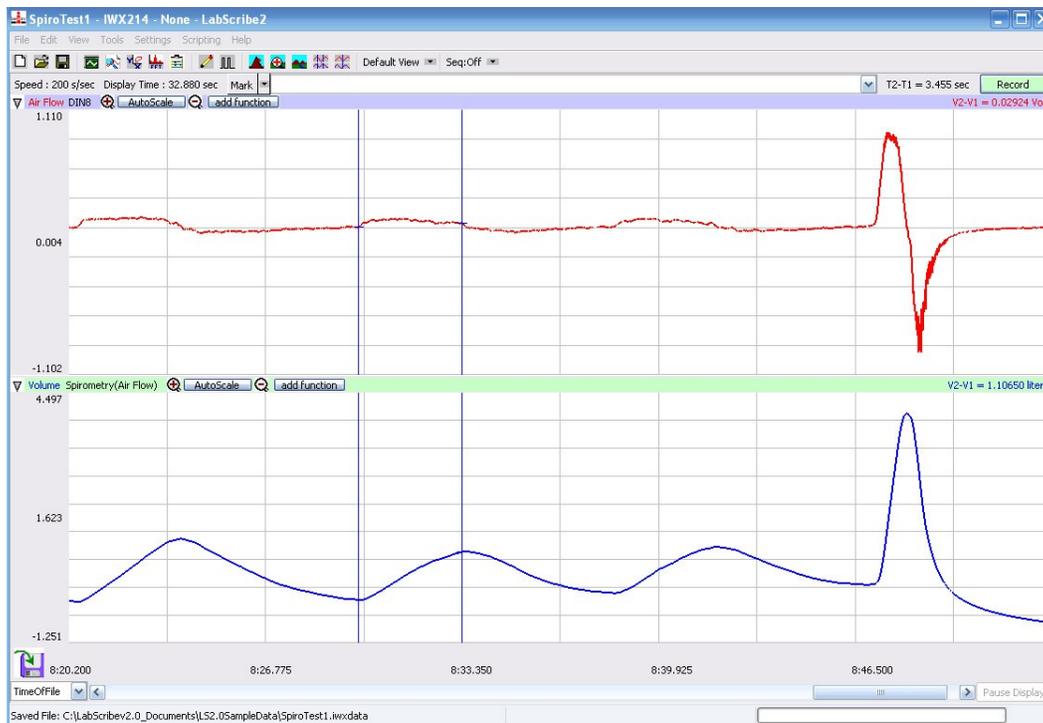
Figure RP-2-L1: Air flow and lung volumes of the normal and forced breathing of a subject while sitting.

Data Analysis-Normal Breathing at Rest

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 five 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 five 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.
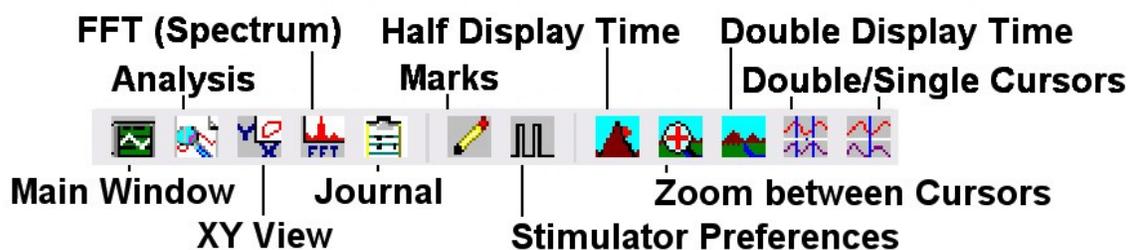

Figure RP-2-L2: The LabScribe toolbar.

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

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

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 Volume 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 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 of the breath cycle.

    • Transfer the names of the mathematical functions used to determine the volumes to the Journal using the Add Title to Journal function in the Volume Channel pull-down menu.

    • Transfer the values for the volumes to the Journal using the Add Ch. Data to Journal function in the Volume Channel pull-down menu.

9. On the Volume 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 Volume channel is the tidal volume ([Figure RP-2-l3](#)).

    • 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 Volume channel is the period of that breath cycle ([Figure RP-2-L4](#)).

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 and breath period on two additional normal breath cycles
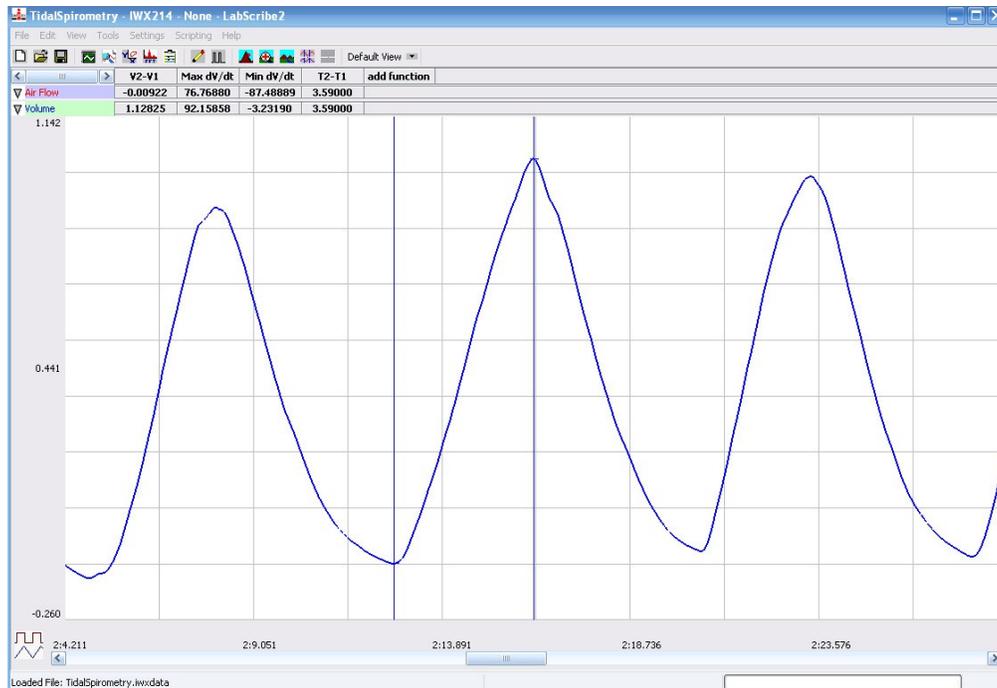
Figure RP-2-l3: Breathing pattern of a subject at rest, displayed on the Volume channel in the Analysis window. The cursors are positioned on the trough and the peak of the breath cycle to measure the tidal volume (TV) with V2-V1 function.
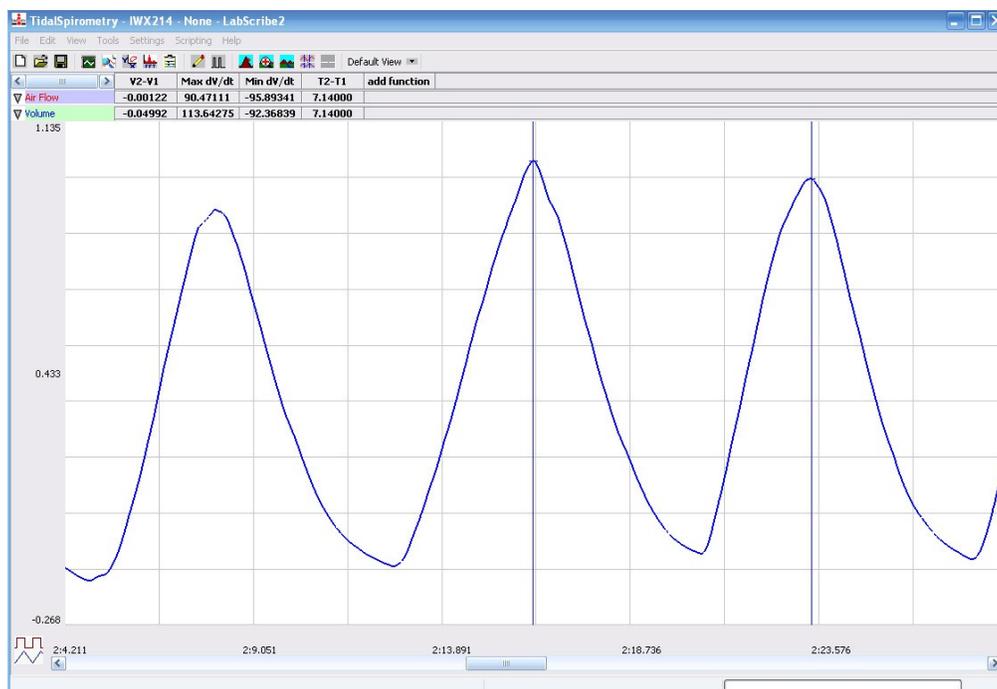

Figure RP-2-L4: Normal breathing pattern of a subject at rest, displayed on the Volume channel in the Analysis window. The cursors are positioned on the peaks of successive breath cycles to measure the breath period with the T2-T1 function.

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 RP-2-L2).

13. Record the means for the tidal volume and breath period in Table RP-2-L2.

14. 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)

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 Table RP-2-L2.

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. 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 force 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 RP-2-L5.

3. Use the same techniques used earlier to record volumes 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 Volume Channel menu.

4. Place the cursors on the forced expiration data displayed on the Volume channel to measure the following volumes using the V2-V1 and T2-T1 functions. Check the labels on Figure RP-2-L5 to identify the volumes 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 Volume 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 Volume channel is the inspiratory reserve volume.

   • 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 Volume channel is the forced vital capacity.

   • 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 Volume 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 Volume 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 Volume channel is the forced expiratory volume at three seconds.
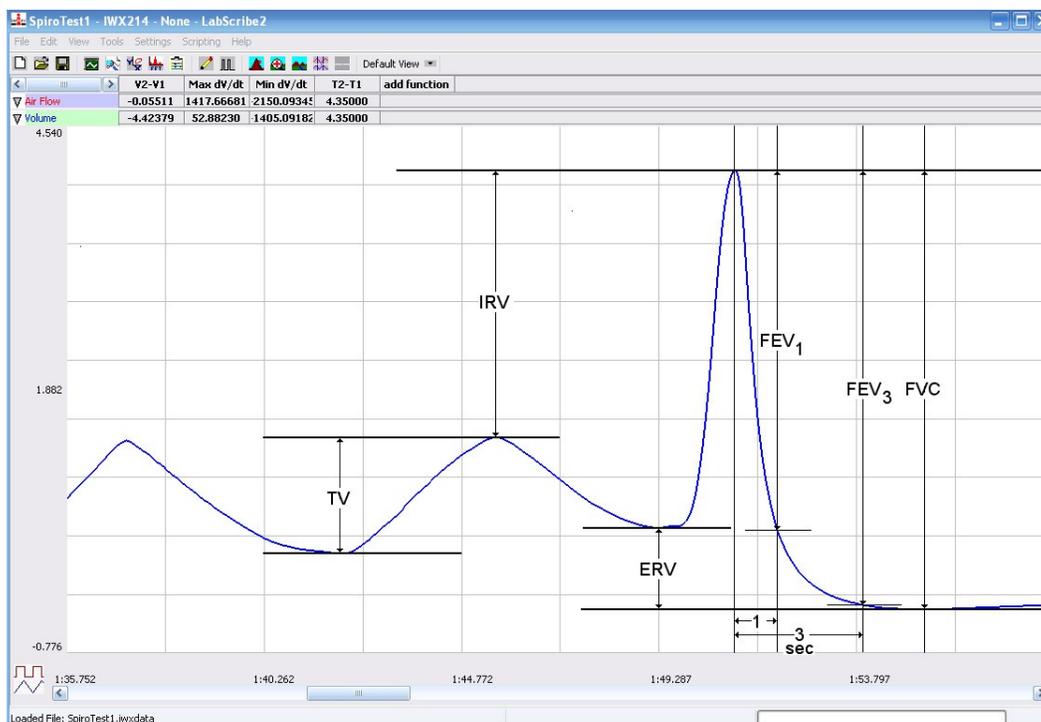

Figure RP-2-L5: Recording of normal and forced lung volumes taken from a subject at rest and displayed on the Volume channel in the Analysis window. The normal breathing cycles are to the left of the forced inspiration and expiration. Lines and labels were added to figure to indicate the volumes.

5. Record these volumes in Table RP-2-L3.

Table RP-2-L2: 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 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 Table RP-2-L2 and Table RP-2-L3.

2. Determine the values for the calculated parameters taken from the recordings of normal and forced breathing while standing. Report these values on Table RP-2-L2 and Table RP-2-L3.

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. 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 Table RP-2-L2 and Table RP-2-L3.

2. Determine the values for the calculated parameters taken from the recordings of normal and forced breathing while standing. Report these values on Table RP-2-L2 and Table RP-2-L3.

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 RP-2-L2: 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)			

Table RP-2-L4: Lung Volumes While Sitting, Standing and Reclining

Lung Volumes (liters)	Sit	Stand	Supine
Tidal Volume (TV)			
Inspiratory Reserve Volume (IRV)			
Expiratory Reserve Volume(ERV)			
Forced Vital Capacity (FVC)			
Forced Expiratory Volume at 1 sec (FEV1)			
FEV1/FVC Ratio			
Forced Expiratory Volume at 3 sec (FEV3)			
FEV3/FVC Ratio			