Experiment HS-1: Breathing Parameters at Rest and After Exercise

Background

The amount of air that moves in or out of the lungs during any one breathing cycle is called the tidal volume. After normal inspiration, it is possible to breathe in additional air—this is called the inspiratory reserve volume. Similarly, after a normal expiration, it is possible to exhale additional air from the lungs—this is the expiratory reserve volume. Even if the expiratory reserve volume is fully expelled from the lungs, there is still a volume of air in the lungs, called the residual volume, that cannot be exhaled. The residual volume has low oxygen and high carbon dioxide concentrations. Upon inhalation, fresh air mixes with stale air from the residual volume to create air in the alveoli that still has oxygen and carbon dioxide concentrations that facilitate the diffusion of O_2 into and CO_2 out of the capillaries.

The respiration center in the medulla insures that gaseous exchange at the lung matches the requirements of the body. During times of increased demand, the tidal volume can be increased, using some of the reserve lung volumes to bring more fresh air into the body. In addition, the rate of breathing and the rate of air movement in and out of the lungs can be changed. In this lab you will measure these parameters in a subject at rest and immediately after exercise, when the body's demands for oxygen have been elevated.

Equipment Required

PC Computer

IWX/214 data acquisition unit

USB cable

IWX/214 power supply

SP-304 Spirometer

FH-300 Spirometer flow head and plastic tubes

IWX/214 Setup

1. Place the IWX/214 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 IWX/214.
3. Check Figure T-1-2 in the Tutorial Chapter for a picture of the IWX/214 power supply.
4. Use the USB cable to connect the computer to the USB port on the rear panel of the IWX/214.
5. Plug the power supply for the IWX/214 into the electrical outlet. Insert the plug on the end of the power supply cable into the labeled socket on the rear of the IWX/214. 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.
1. On the **Main window**, pull down the **Settings menu** and select **Load Group.**
2. Locate the folder that contains the settings group, **IPLMv4Standard.iwxgrp**. Select this group and click **Open**.
3. Pull down the **Settings menu** again. Select the **Breathing-Rest-Exercise-LS2** settings file.
4. After a short time, LabScribe will appear on the computer screen as configured by the **Breathing-Rest-Exercise-LS2** settings.
5. For your information, the settings used to configure the LabScribe software and the IWX/214 unit for this experiment are listed in Table HS-1-1 on page HS-1-1. These settings are programmed on the **Preferences Dialog window** which can be viewed by selecting **Preferences** from the **Edit menu** on the LabScribe **Main window**.

Table HS-1-1: Settings on the Channel Window of the Preferences Dialog Used to Configure the iWorx Recording System for Experiment HS-1.

Parameter	Units/Title	Setting	Mode/ Function
Acquisition Mode		Chart	
Start		User	
Stop		User	
Display Time	Sec	10	
Speed	Samples/Sec	200	
Channel A4	Air Flow	S	DIN8
Channel C1	Lung Volumes	S	Vol.Human

Spirometer Setup

1. Locate the SP-304 spirometer, the FH-300, and the airflow tubing in the iWorx kit (Figure HS-1-1 on page HS-1-2).
2. Firmly push the two air flow tubes onto the two outlets on the FH-300 flow head.
3. Firmly push the other ends of the two air flow tubes onto the two outlets on the SP-304 spirometer unit.
4. Plug the DIN8 connector to the SP-304 spirometer into the Channel 4 input of the IWX/214 (Figure HS-1-2 on page HS-1-2).

Figure HS-1-1: The SP-304 spirometer, the FH-300 flowhead, and the airflow tubing.

Figure HS-1-2: A SP-304 spirometer connected to an IWX/214 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 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 flowhead, place a disposable cardboard mouthpiece, that contains a screen, over the opening of 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-Rest-Exercise-LS2**, programs LabScribe to record the breathing of the subject on the **Air Flow channel**. The computed function used on the **Lung Volumes** channel converts the data recorded on the **Air Flow** channel to lung volume measurements.

7 Enter the calibration voltage of your SP-304 spirometer into the **Spirometry** computed function used 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**.

• Enter the **calibration voltage**, that is listed on the label of your SP-304 spirometer unit, into the equation that sets the calibration voltage equal to one liter of lung volume.

• Make sure the **reset time** is set to **60 sec**, and the first **5 seconds** of the recording are used to zero the baseline of the **Lung Volumes** channel. Click **OK**.

8 Allow the SP-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 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 channel**s 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.

Exercise 1: Breathing While Resting

Aim: To measure breathing parameters in a healthy, resting 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 the 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 five seconds of recording. No air should be moving through the flow head during this time.*

2 Type **<Subject's Name> Resting** in the **Mark box** that is to the right of the **Mark** button.

3 Click on the **Record** button. After waiting five 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. Every sixty seconds into the recording, the baseline of the **Lung Volumes** channel automatically resets itself to zero, which has no impact on the data being recorded.

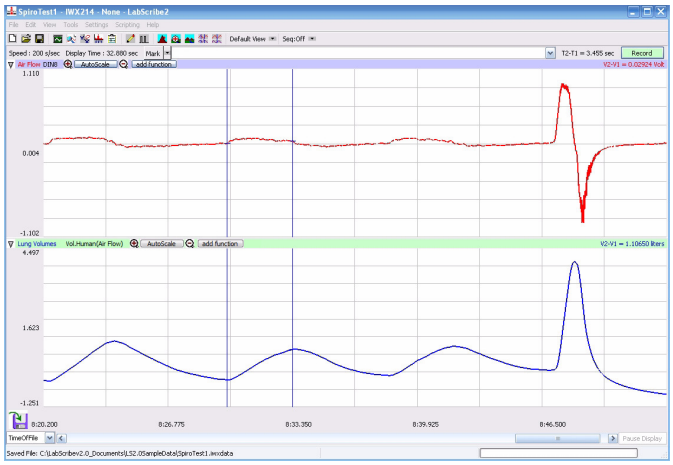

Figure HS-1-3: Air flow and lung volumes of the normal and forced breathing of a subject at rest.

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-1-3 on page HS-1-3.

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.

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 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**.

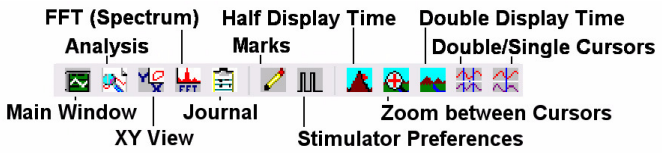

Figure HS-1-4: The LabScribe toolbar.

3 Click on the **Analysis window** icon in the toolbar (Figure HS-1-4 on page HS-1-3) or select **Analysis** from the **Windows menu** to transfer the data displayed in the **Main window** to the **Analysis window** (Figure HS-1-5 on page HS-1-4).

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 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**.

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-1-5 on page HS-1-4).

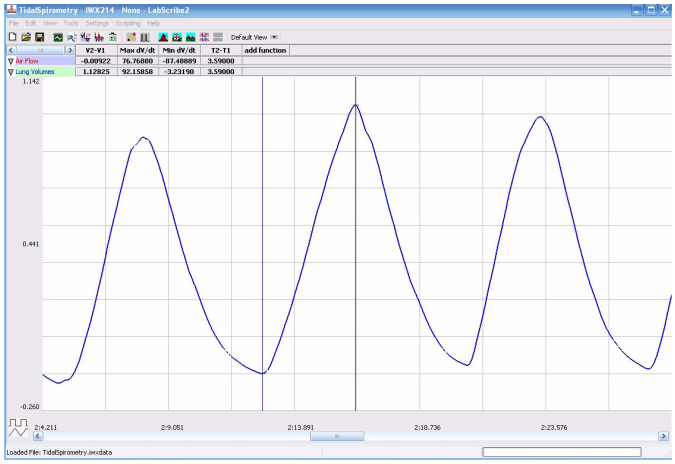

*Figure HS-1-5: Breathing pattern of a subject at rest, displayed on the **Lung Volumes** channel in the **Analysis** window. The cursors are positioned on the trough and the peak of the breath cycle to measure the tidal volume (**TV**) with **V2-V1** function and the maximum inspiratory flow rate with the **Max_dv/dt** function.*

• **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-1-5 on page HS-1-4).

• **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-1-6 on page HS-1-4).This function is used since the exhalation portion of the breath cycle has a negative slope.

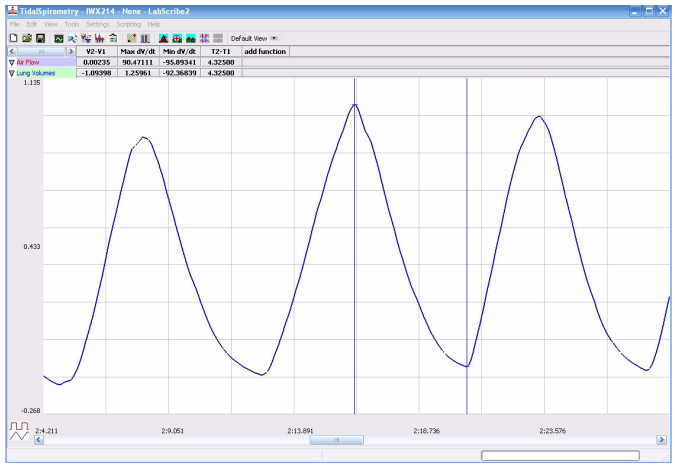

*Figure HS-1-6: Breathing pattern of a subject at rest, displayed on the **Lung Volumes** channel in the **Analysis** window. The cursors are positioned on the peak of the breath cycle and the trough of the succeeding cycle to measure the maximum expiratory flow rate with the **Min_dv/dt** function.*

• **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-1-7 on page HS-1-4).

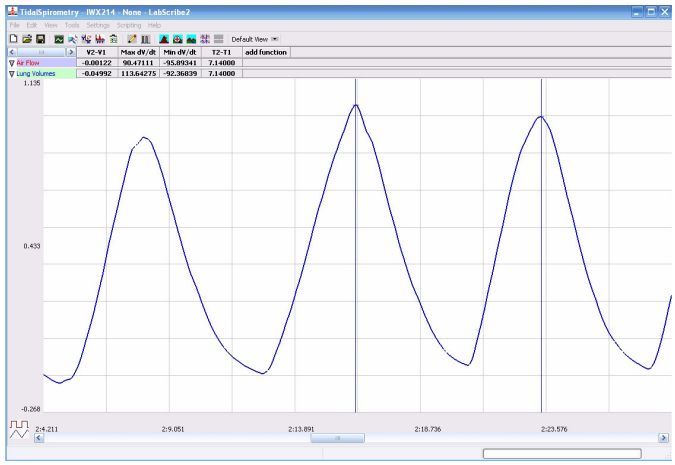

*Figure HS-1-7: Normal breathing pattern of a subject at rest, displayed on the **Lung Volumes** channel in the **Analysis** window. The cursors are positioned on the peaks of successive breath cycles to measure the breath period with the T2-T1 function.*

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-1-4 on page HS-1-3).

13 Record the means for the tidal volume, rates, and breath period in Table HS-1-3 on page HS-1-7.

14 Calculate the normal breathing rate of the subject at rest using the following equation:

$$\text{Breath Rate (breaths/minute)} = \frac{60 \text{ seconds/minute}}{\text{mean breath period (sec/breath)}}$$

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 HS-1-3 on page HS-1-7.

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 HS-1-8 on page HS-1-5.

3 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**.

4 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 Figure HS-1-8 on page HS-1-5 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 **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 **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 **VC**.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.

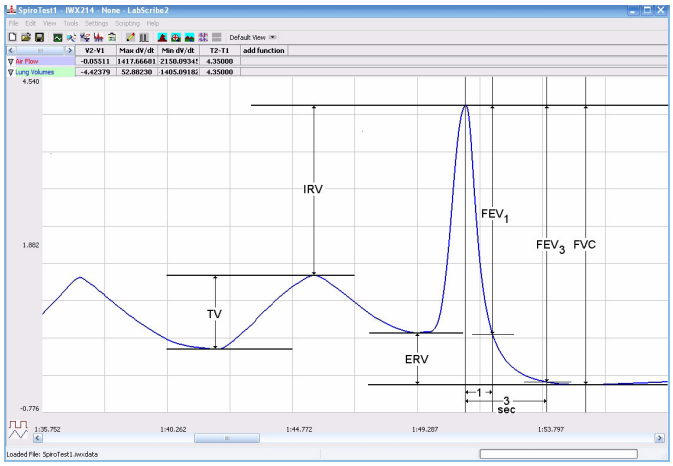

*Figure HS-1-8: Recording of normal and forced lung volumes taken from a subject at rest, and displayed on the **Lung Volumes** channel in the **Analysis** window. The normal breathing cycles are to the left of the forced inspiration and expiration. Lines and labels were added to figure to indicate to 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-1-4 on page HS-1-7.

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 Table HS-1-4 on page HS-1-7.

10 Record the volumes, rates, and ratios from your subject in the table being compiled for all the subjects in the class.

Table HS-1-2: 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 Immediately After Exercise

Aim: To measure the breathing parameters of the same healthy subject after exercise.

Procedure

1 In this exercise, use the same healthy subject whose breathing parameters at rest were measured in Exercise 1.

2 Type **After Exercise** in the **Mark box** to the right of the **Mark** button.

3 The subject should exercise to sufficiently elevate breathing rate, but with minimal class disruption. Running up and down flights of stairs is a good method. The subject should sit down after the exercise period.

4 Click on the **Record** button. After waiting five 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.

5 Click the **AutoScale** buttons of the **Air Flow** and **Lung Volumes** channels. Record at least five breaths as the subject is recovering from exercise. Remember the baseline of the **Lung Volumes** channel automatically resets every sixty seconds.

6 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.

7 The subject should return to breathing as normally as possible through the spirometer.

8 Click **Stop** to halt recording.

9 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.

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 HS-1-3 on page HS-1-7 and Table HS-1-4 on page HS-1-7

2 Determine the values for the calculated parameters taken from the recordings of normal and forced breathing after exercise. Report these values on Table HS-1-3 on page HS-1-7 and Table HS-1-4 on page HS-1-7.

Exercise 3: Breathing Parameters from Other Students

Aim: To measure breathing parameters in other students in your lab group. Obtain data from subjects in other lab groups

Procedure

1 Attach a clean flowhead and clean air flow tubing to the spirometer for each new subject in your group doing this exercise.

2 Open a new data file for the new subject by selecting **New** on the **File menu** of the LabScribe program. The **Save File dialogue window** will appear on the screen if the current data file displayed on the LabScribe window if that file has not been saved recently. Click **Yes** to save the current file. The **Choose a file dialogue window** will appear on the screen. Select the folder where you would like the data file to be saved. Enter a name for the file and select the ***.iwxdata** as the type of file being saved. Click the **Save** button in the lower right corner of the dialogue window.

3 Repeat Exercise 1 with the new subject.

Data Analysis

1 Perform the same types of measurements on the data recorded in Exercise 2.

2 Record the measurements in the **Journal**. Report the appropriate measurements in Table HS-1-3 on page HS-1-7 and Table HS-1-4 on page HS-1-7

3 Determine the values for the calculated parameters taken from the recordings of normal and forced breathing. Report the values for each subject on copies of Table HS-1-3 on page HS-1-7, Table HS-1-4 on page HS-1-7, and on the table being compiled for all subjects in the class.

Questions

1 Are the lung volumes the same in all students?

2 Combine class data to see whether there is any correlation between tidal volume or vital capacity and gender, smoking, or apparent fitness.

Table HS-1-3: Mean Breathing Volumes and Rates from a Healthy Subject at Rest and after Exercise

	Resting	After Exercise
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-1-4: Forced Expiration Volumes and Rates from a Healthy Subject at Rest and after Exercise

	Resting	After Exercise
Lung Volumes (liters)		
Tidal Volume (TV)		
Inspiratory Reserve Volume (IRV)		
Expiratory Reserve Volume (ERV)		
Vital Capacity (VC)		
Forced Expiratory Volume-1sec (FEV_1)		
Forced Air Flow Rate (mls/sec)		
during inhalation		
during exhalation		
FEV_1/VC Ratio		
FEV_3/VC Ratio		

Questions

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

1 Did tidal volume change after exercise? Did inspiratory and expiratory reserves change after exercise?

2 Did exercise influence the time taken for each breathing cycle?

3 Did the rate of air flow during the inhalation phase increase or decrease with exercise? How can you account for the change?

4 Did the rate of air flow during the exhalation phase increase or decrease with exercise—how can you account for the change?

5 Did the volume of air passing in and out of the resting subject's lungs each minute increase or decrease due to exercise? If so, was the change due to an increase in the rate of breathing, the depth of breathing (tidal volume), or a combination of both factors?

6 Did exercise influence the vital capacity of the individual?

7 If the tidal volume changed due to exercise, can this be accounted for by changes in the IRV, the ERV, or a combination of both?

8 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?