Experiment HS-3: Factors that Affect Breathing Patterns

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

Needle and thread

18-24" of plastic tubing that fits over the end of flow head

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.

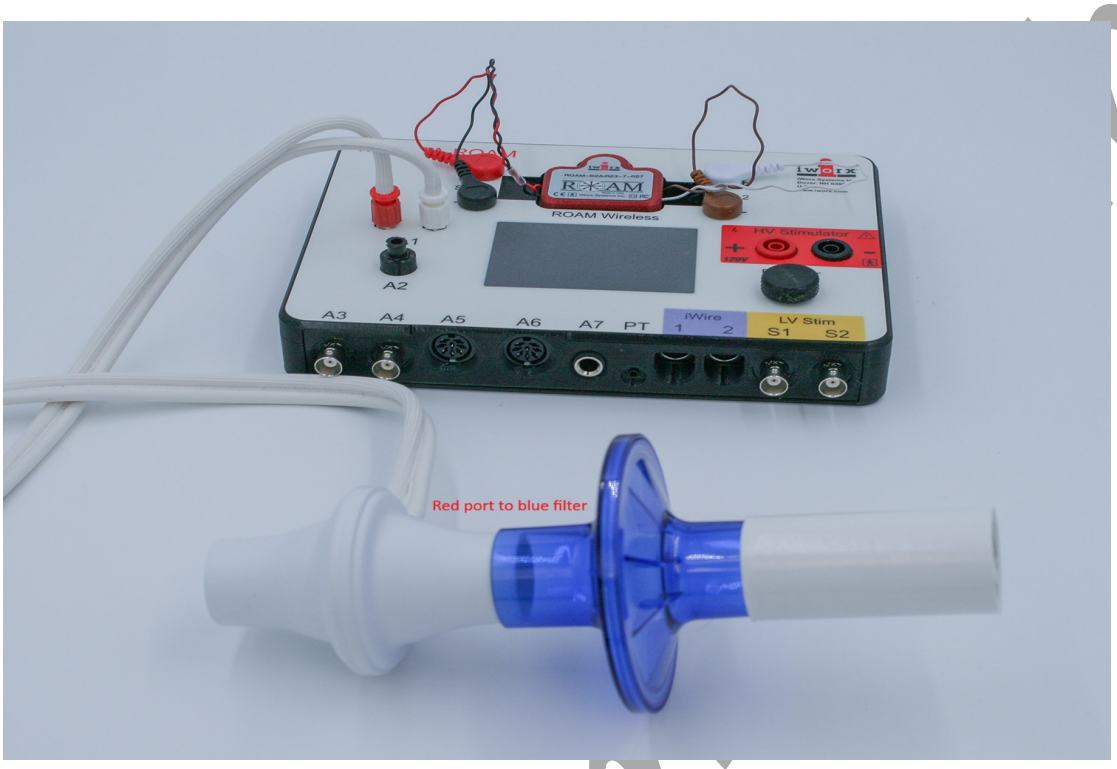

Figure HS-2-S2: The flow head connected to the internal spirometer of the IXTA unit.

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-3: Factors that Affect Breathing Patterns

Exercise 1: Coughing

Aim: To study changes in breathing due to coughing.

Approximate Time: 30 minutes

Procedure

1. Instruct the subject to:
    - Sit quietly and become accustomed to breathing through the spirometer flow head.
    - Make sure the subject is breathing 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 the mouth level in a position that prevents a breath from moving through the flow head.

Note: The LabScribe software will zero the Lung Volumes channel during the first ten seconds of recording. No air should be moving through the flow head during this time.

2. 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 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.
7. Type **Cough** in the Mark box. Once the subject's breathing has returned to a normal resting pattern, instruct the subject to cough through the flow head as the mark button is clicked.
8. Click Stop to halt recording. Your data may look like image below.
9. 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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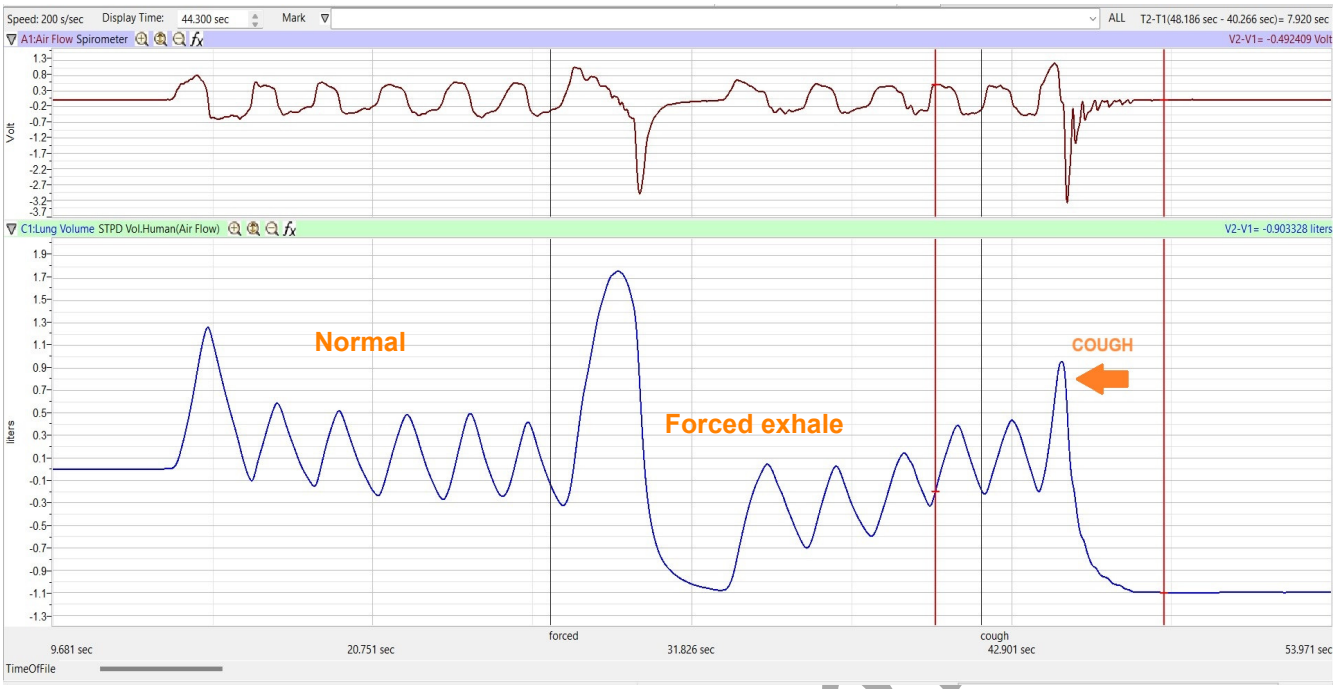

Figure HS-3-L1: Air flow and lung volumes for normal, forced breathing and a cough of a subject at rest.

Data Analysis-Normal Breathing

1. Scroll through the recording and find the section of data recorded when the subject was breathing normally.
2. Use the Display Time icons to adjust the Display Time of the Main window to a couple of normal breath cycles before it on the Main window.

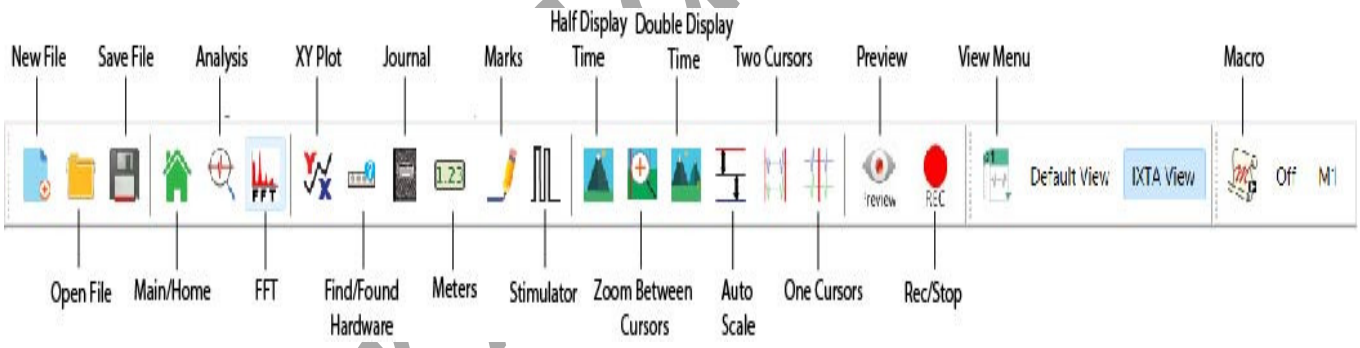

Figure HS-3-4: The LabScribe toolbar.

3. Click on the Analysis window icon in the toolbar or select Analysis from the Windows menu 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.

Work Sample

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 breathing cycle. Place one cursor in the trough prior to inhalation, and the second cursor on the peak of the cycle. The value for the V2-V1 function on the Lung Volumes channel is the tidal volume.
    - **Maximum Inspiratory Flow Rate,** which is the maximum rate of air movement during inhalation. Leave the cursors in the same positions used to measure the tidal volume. The value for the Max_dv/dt function on the Lung Volumes channel is the maximum inspiratory flow rate of that breath cycle.

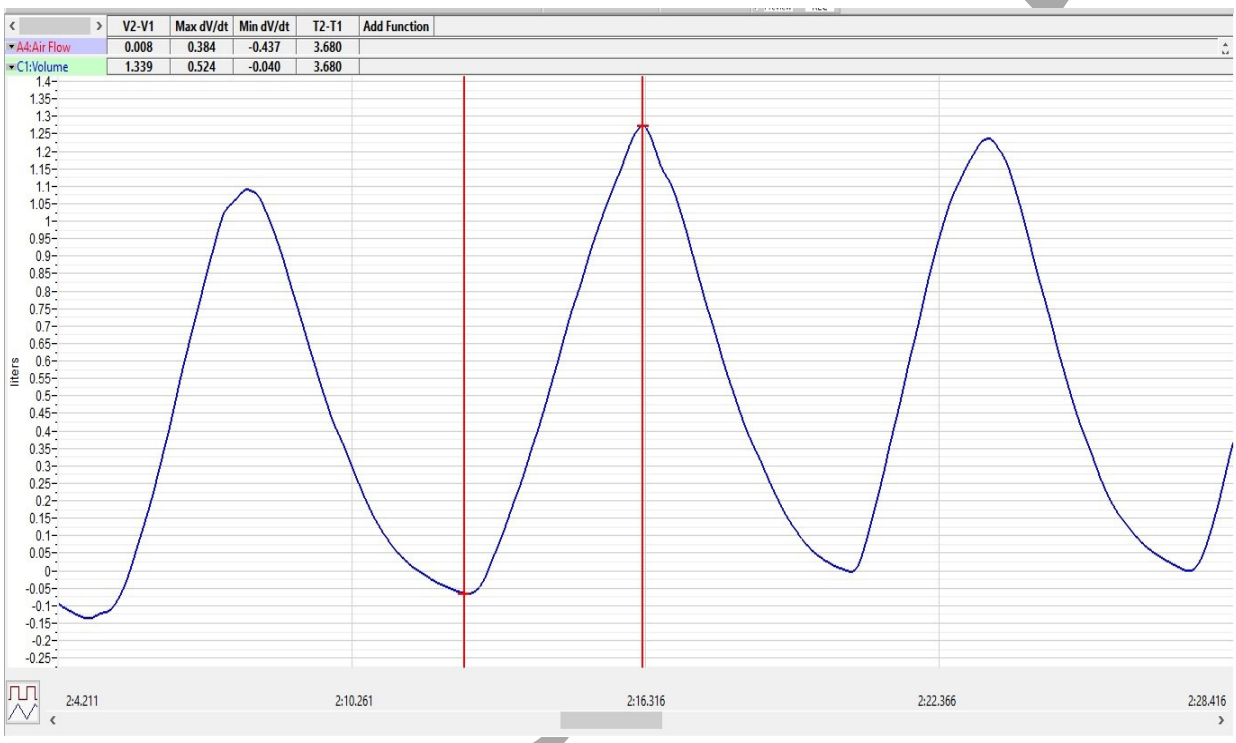

Figure HS-3-L3: Breathing of a sitting subject, displayed on Lung Volumes channel in the Analysis window. The cursors are positioned on the trough and the peak of the breath cycle to measure the tidal volume (TV) with V2-V1 function and the maximum inspiratory flow rate with the Max_dv/dt function.

- **Maximum 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.

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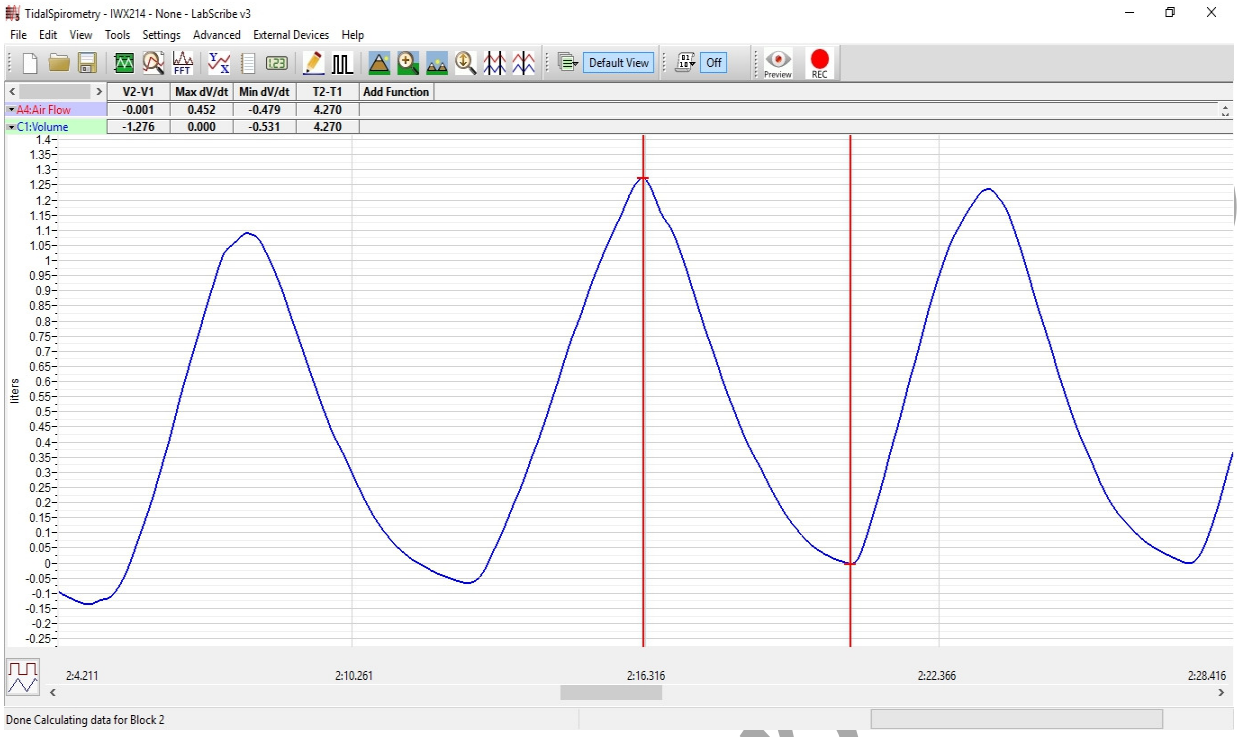

Figure HS-3-L4: Breathing pattern of a sitting subject, displayed on the Lung Volumes channel in the Analysis window. The cursors are positioned on the peak of the breath cycle and the trough of the succeeding cycle to measure the maximum expiratory flow rate with the Min_dv/dt function.

- **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.

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.
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 math 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.
8. Record the values in the Journal using the one of the techniques described in Step 7.
9. Calculate means and enter the values for the parameters measured in Table 1.

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Data Analysis-Forced Breathing

1. Use the slider or the arrows on the scroll bar, at the bottom of the Analysis window, to position the data from the subject's forced breathing in the window.
2. Use the Display Time icons, or the cursors and the Zoom between Cursors button, to adjust the Display Time of the Analysis window to show the complete forced expiration curve in the Main window as shown in Figure HS-3-L5.

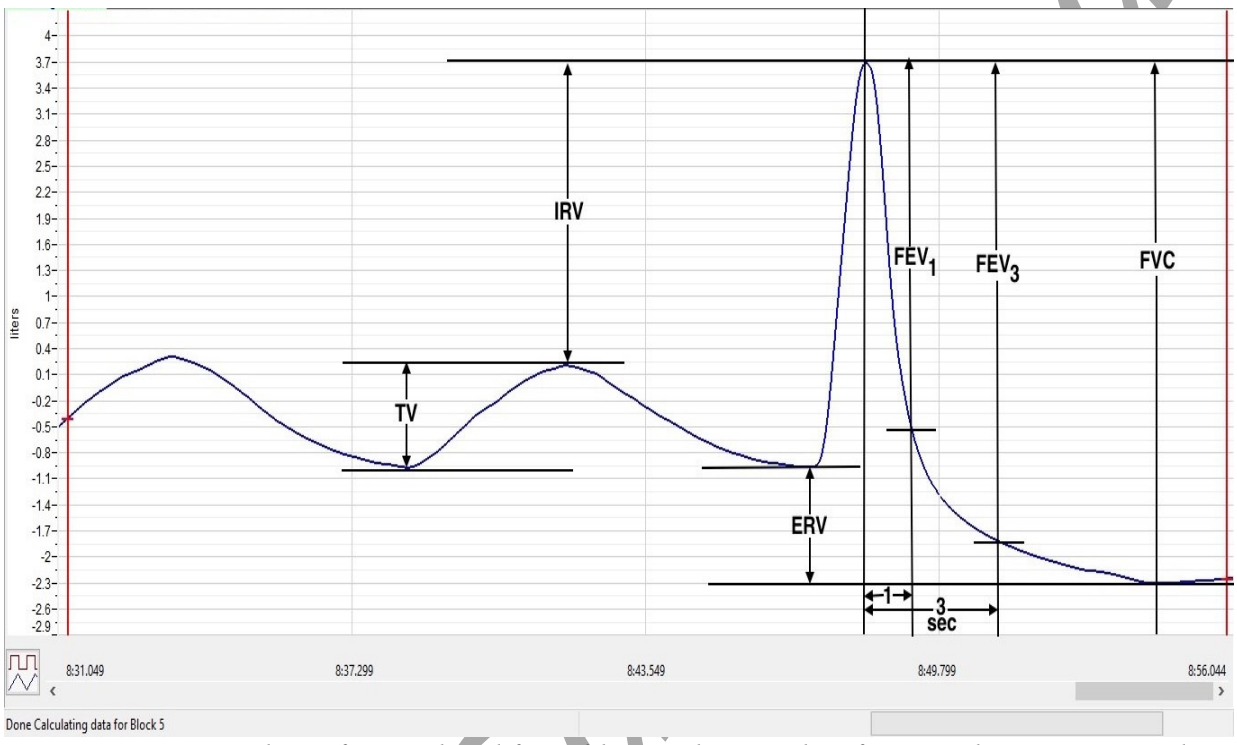

Figure HS-3-L5: Recording of normal and forced lung volumes taken from a subject at rest, and displayed on the Lung Volumes channel in the Analysis window. The normal breathing cycles are to the left of the forced inspiration and expiration. Lines and labels were added to figure to indicate to volumes that should be measured for each subject: Tidal Volume (TV), Inspiratory Reserve Volume (IRV), Expiratory Reserve Volume (ERV), and Vital Capacity.

3. 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 to identify the volumes and rates that you will measure:
    - **Forced Inspiratory Flow Rate,** 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 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.

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- **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.

5. Enter the values for the parameters measured in Table 1.

Data Analysis-Coughing

1. Use the slider or the arrows on the scroll bar, at the bottom of the Analysis window, to position the data recorded while the subject coughed in the window.
2. Place the cursors on the coughing data on the Lung Volumes channel to measure the following parameters using the V2-V1, T2-T1, Max_dv/dt, and Min_dv/dt functions. Measure the following:
    - Maximum Inspiratory Flow Rate before Cough. If the subject inhaled before coughing, determine the maximum flow rate by placing one cursor in the trough or on the baseline prior to the inhalation and the second cursor on the peak of that inhalation. The value for the Max_dv/dt function on the Lung Volumes channel is the maximum flow rate prior to the cough.
    - Maximum Expiratory Flow Rate during Cough. Since a cough is similar to an exhalation, place one cursor on the peak of the inhalation or the baseline before the cough and the second cursor on the trace at the end of the cough. The value for the Min_dv/dt function on the Lung Volumes channel is the maximum flow rate during the cough.
    - Air Expelled during Cough, by keeping the cursors in the same positions used for measuring the maximum exhalatory flow rate.The value for the V2-V1 function on the Lung Volumes channel is the volume of air expelled during the cough.
5. Enter the values for the parameters measured in the data table.

Table HS-3-L1: Breath Rates and Volumes during Normal and Forced Breathing and Coughing

	Normal	Forced	Cough
Tidal Volume			
Forced Vital Capacity			
Air Expelled			
Inspiratory Flow Rate (Maximum or Forced)			
Expiratory Flow Rate (Maximum or Forced)			

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Questions

1. What phase of the breathing cycle (exhalation or inhalation) immediately precedes the cough?
2. How does the maximum flow rate during the cough compare to the maximum expiratory flow rate during normal breathing?
3. How does the maximum flow rate during the cough compare to the forced expiratory flow rate during forced breathing?
4. How does the volume of air expelled during a cough compare to the subject's tidal volume and FVC?

Exercise 2: Concentration

Aim: To study any changes in breathing patterns while performing a task.

Approximate Time: 20 minutes

Procedure

1. Push the tip of a needle firmly into a piece of wax or an eraser. Place the needle close to the subject, on the bench top or the top of the computer monitor. Other tasks such as balancing on an exercise ball, doing a math exercise or other similar activities that take concentration.
2. Instruct the subject to:
    - Sit quietly and become accustomed to breathing through the spirometer flow head.
    - Make sure the subject is breathing 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 the mouth level in a position that prevents a breath from moving through the flow head.

REMINDER - ***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.***

3. Type **Before Task** in the Mark box.
4. 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.
5. Click the AutoScale All button. Notice the slowly moving wave on the Lung Volumes channel. While recording the subject's normal breathing for about one minute, type **ThreadingNeedle** in the Mark box.
6. Instruct the subject to thread the needle. Click the mark button as the subject starts this task. Type **Finished** in the Mark box.

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7. When the subject finishes the task of threading the needle, click the mark button. Continue to record as the subject's breathing returns to normal. The subject should continue to breathe normally through the spirometer for at least five breath cycles.
8. Click Stop to halt recording.
9. Select Save in the File menu.

Data Analysis-Before the Task

1. Scroll through the recording and find the data collected before the subject threaded the needle.
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.
3. Click on the Analysis window icon in the toolbar or select Analysis from the Windows menu to transfer the data displayed in the Main window to the Analysis window.
4. Use the same techniques for Exercise 1 and measure the same parameters before the concentration task.
9. Record the means for the tidal volume, rates, and breath period in Table 2.
10. 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)

11. 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.
12. Record the values for these calculations in Table 2.

Data Analysis-During Task

1. Scroll through the recording and find the data collected while the subject was threading the needle.
2. Perform the same types of measurements on the data recorded in this section of the exercise as were performed on the data recorded before the subject performed the task. Record the measurements in the Journal. Report the appropriate measurements in Table 2.
3. Determine the values for the calculated parameters taken from this section of data. Report these values

Data Analysis-After the Task

1. Scroll through the recording and find the data collected after the subject threaded the needle.
2. Perform the same types of measurements on the data recorded in this section of the exercise as were performed on the data recorded before the subject performed the task. Record the measurements in the Journal. Report the appropriate measurements in the data table.

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3. Determine the values for the calculated parameters taken from this section of data. Report these values in the table.

Questions

1. Which breathing parameters changed when fine motor control was required?
2. Explain the reasons why these parameters changed?
3. How long did it take the subject to return to normal breathing after performing the task?

Table HS-3-L2: Breath Volumes and Rates When Completing a Task Requiring Concentration.

	Threading Needle		
	Before	During	After
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			

Exercise 3: Sitting Up Quickly

Aim: To study any changes in breathing patterns when sitting up.

Approximate Time: 20 minutes

Procedure

1. Instruct the subject to:
    - Lie down on their back and relax.
    - Become accustomed to breathing through the flow head and breathe normally before any recordings are made.
    - Hold the flow head so that its outlets are pointed up.

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2. Assist the subject when they are removing and replacing the flow head in their mouth. Place the flow head on the table near the subject's head in a position that prevents any air to move through the flow head.
3. Type **LyingDown** in the Mark box.
4. Click Record. After waiting at least ten seconds, have the subject place the flow head in their mouth and begin breathing. Click the mark button to mark the recording.
5. Click the AutoScale All button. Notice the slowly moving wave on the Lung Volumes channel. While recording the subject's normal breathing for about one minute, type **SitUpInhaling** in the Mark box.
6. Click the mark button as the subject sits up for a few breaths. Type **Lying Down** in the Mark box.
7. Instruct the subject to lie down. When they are lying flat, click the mark button. Continue to record as the subject's breathing returns to normal. Type **SitUpExhaling** in the Mark box.
8. After about 60 seconds, instruct the subject to sit up while exhaling normally. Click the mark button as the subject sits up.
9. Click Stop to halt recording.

Data Analysis

1. Scroll through the recording and find the section of data recorded when the subject was lying down.
2. Use the same techniques used in Exercises 1 and 2 to display a couple of breath cycles on the Main window, and transfer the data to the Analysis window.
3. 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 while the subject is breathing normally.
        - To measure the tidal volume from inhalation data, place one cursor in the trough prior to inhalation, and the second cursor on the peak of the inhalation.
        - To measure the tidal volume from exhalation data, place one cursor on the peak of the inhalation, and the second cursor in the trough after the exhalation.
        - 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. place one cursor in the trough prior to inhalation, and the second cursor on the peak of the inhalation. The value for the Max_dv/dt function on the Lung Volumes channel is the maximum inspiratory flow rate of that breath cycle.

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- **Maximum Expiratory Flow Rate**, which is the maximum rate of air movement during exhalation. To measure the maximum expiratory flow rate of the subject, place one cursor on the peak of the inhalation, 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 exhalation has a negative slope.

4. Once the cursors are placed in the correct positions for determining the volume and rates of each breath cycle, transfer the names and values of the parameters measured in the Analysis window to the Journal using one of the two techniques described in Exercises 1.
5. Record these measurements in Table 3.
6. Scroll through the recording and find the section of data recorded when the subject sat up while inhaling. Repeat Steps 2 through 5 on this section of data.
7. Scroll through the recording and find the section of data recorded when the subject sat up while exhaling. Repeat Steps 2 through 5 on this section of data.

Table HS-3-L3: Breath Volumes and Rates When Breathing While Sitting Up.

	Lying Down	Sit Up Inhale	Sit Up Exhale
Tidal Volume (mls/breath)			
Max Air Flow Rate (mls/sec)			
during inhalation			
during exhalation			

Questions

1. Does the maximum inspiratory flow rate while lying down differ from the rate while sitting up while inhaling?
2. Does the maximum expiratory flow rate while lying down differ from the rate while sitting up while exhaling?
3. Does the volume inhaled or exhaled while sitting up differ from the subject's title volume while lying down?

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Exercise 4: Increasing the Length of the Airways

Aim: To study any changes in breathing patterns when the subject breathes through a longer airway.

Approximate Time: 20 minutes

Procedure

1. In this exercise, use a subject whose normal breathing while sitting has already been recorded.
2. 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.
    - Remove the flow head from their mouth. Place a 18-24" length of plastic tubing, about the same diameter as the opening of the flow head, on the end used as the mouthpiece.
    - Hold the flow head and the tubing at the same level as the subject's mouth, but in a position that prevents the subject's breath to move through the flow head.
3. Type **BreathingThroughTube** in the Mark box.
4. Click the Record button. After waiting at least ten seconds and then have the subject place the free end of the tubing in their mouth and begin breathing. Click the mark button to mark the recording.
5. ClickAutoScale All. Notice the slowly moving wave on the Lung Volumes channel. Record the subject's breathing for about one minute.
6. Click Stop to halt recording. Select Save in the File menu.

Data Analysis

1. Scroll through the recording and find the section of data recorded when the subject was breathing through a longer airway.
2. Use the same techniques used in Exercises 1 and 2 to display a couple of breath cycles on the Main window, and transfer the data to the Analysis window.
3. Once the cursors are placed in the correct positions for determining the volumes and rates of each breath cycle, transfer the names and values of the parameters measured in the Analysis window to the Journal using one of the two techniques described in Exercise 1.
4. Collect the same data as for the previous exercises.
5. Record the means for the tidal volume, rates, and breath period in Table 4.
6. Calculate the breathing rate of the subject, using an extended airway, with the following equation:

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

7. 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.

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8. Record the values for these calculations in the table.

Questions

1. Do you think the oxygen requirements of the subject changed dramatically when the tube was attached?
2. Where does gas exchange take place in the lungs? Does gaseous exchange occur across the walls of the airways (trachea, bronchi and bronchioles)?
3. If you increased the volume of the airways to match the resting tidal volume, would fresh air ever reach the alveoli?
4. Why does the tidal volume increase when the subject breathes through a tube?

Table HS-3-L4: The Effect of Airway Length on Breathing

	Airway Length	
	Normal	Long
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		

Exercise 5: Testing Another Factor on Breathing

Approximate Time: Depends on the factor chosen.

Choose another factor that might affect breathing and test its effect. Design your own experimental protocol based on one of the exercises presented in this experiment. Some suggestions include:

- Meditating before recording breathing.
- Listening to different types of music while breathing.
- Being blindfolded or wearing earplugs while breathing.
- Watching a suspenseful movie, watching someone else thread a needle.

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