Richard Pflanzer, Ph.D.
Associate Professor Emeritus
Indiana University School of Medicine
Purdue University School of Science

William McMullen
Vice President, BIOPAC Systems, Inc.

II. EXPERIMENTAL OBJECTIVES

1.) To observe experimentally, record, and/or calculate forced expiratory volume (FEV) and maximal voluntary ventilation (MVV).
2.) To compare observed values of FEV with predicted normals.
3.) Compare MVV values with others in your class.

III. MATERIALS

- BIOPAC Airflow Transducer (SS11LA)
- BIOPAC Bacteriological Filter (AFT1): one per subject. If using calibration syringe, one dedicated to syringe.
- BIOPAC Disposable Mouthpiece (AFT2)
- BIOPAC Noseclip (AFT3)
- BIOPAC Calibration Syringe: 0.6-Liter (AFT6 or AFT6A+AFT11A) *or* 2-Liter (AFT26)
- *Optional*—BIOPAC Autoclavable Mouthpiece (AFT8)
- Biopac Student Lab System: BSL 4 software, MP36, MP35 or MP45 hardware
- Computer System (Windows 8, 7, Vista, XP, Mac OS X 10.5 – 10.8)

IV. EXPERIMENTAL METHODS

A. SETUP

FAST TRACK Setup

1. Turn your computer **ON**.
2. Turn **OFF** MP36/35 unit.
   - If using an MP45, make sure USB cable is connected and "Ready" light is **ON**.
3. **Plug the Airflow Transducer** (SS11LA) into Channel 1.
4. Turn **ON** the MP36/35 unit.

Setup continues…

Detailed Explanation of Setup Steps

Fig. 13.4 MP3X (top) and MP45 (bottom) equipment connections

5. **Start** the Biopac Student Lab program.
6. Choose "**L13 – Pulmonary Function II**" and click **OK**.
7. Type in a unique filename and click **OK**.

Start Biopac Student Lab by double-clicking the Desktop shortcut.

No two people can have the same filename, so use a unique identifier, such as **Subject's** nickname or student ID#.

A folder will be created using the filename. This same filename can be used in other lessons to place the **Subject's** data in a common folder.

8. ***Optional:*** Set Preferences.
   - Choose File > **Lesson Preferences**.
   - Select an option.
   - Select the desired setting and click **OK**.

This lesson has optional Preferences for data and display while recording. Per your Lab Instructor's guidelines, you may set:

Residual Volume: RV cannot be determined using a spirometer or airflow transducer, so the BSL software sets a default value of 1 liter. This can be changed to any value between 0 and 5 liters.

Grids: Show or hide gridlines

Calibration Syringe Values:

"*Set each time lesson is launched*": Syringe (Stage 2) calibration is required the first time the lesson is run. If the lesson is re-run without closing the application, Syringe calibration is not required.

"*Set once and use stored values*": After Syringe calibration is performed once, it will not be performed again. This is only recommended when specific SS11LA Airflow transducers are matched to specific MP units.

Calibration Syringe Size:

0.61 L (AFT6A/6,) 1 L, 2 L (AFT26,) 3 L, 4 L, or 5 L

END OF SETUP

B. CALIBRATION

Calibration establishes the hardware's internal parameters (such as gain, offset, and scaling) and is critical for optimal performance. Calibration will vary based on the Preference set by your lab instructor.

FAST TRACK Calibration

Stage 1 – Always required

1. Hold the Airflow Transducer upright and still, making sure no air is flowing through it (Fig. 13.5).
2. Click **Calibrate**.
   - Wait for Calibration to stop
3. Check Calibration data:
   - Verify data is flat and centered. If necessary, click Redo Calibration.
   - To proceed, click Continue.

Stage 2 – If required

4. *IF CALIBRATION STAGE 2 IS REQUIRED*—Attach Calibration Syringe and filter to Airflow Transducer (Fig. 13.7).

   IMPORTANT! Always insert on the side labeled "Inlet."

   - Pull Calibration Syringe plunger all the way out.
   - Hold syringe horizontally. Airflow Transducer must be vertical and unsupported.
   - **Review** Calibration procedure.

Calibration continues…

Detailed Explanation of Calibration Steps

Calibration Stage 1 precisely zeroes the baseline. Any baseline shift during this calibration can cause errors in the subsequent recordings. Baseline shift can occur from:

a) Airflow through the transducer from movement, an HVAC duct or even from breathing close to the unit.

b) Changes in transducer orientation. The transducer should be held still and in the same orientation that will be used during the recording.

Fig. 13.5

Calibration lasts from 4 to 8 seconds.

Fig. 13.6 Example Calibration Stage 1 data

Based on Lesson Preference settings, the Calibration Syringe may not be required. If not required, proceed to Step 9.

Notes:

- A bacteriological filter must be used between the transducer and syringe in order for calibration to be accurate.
- Different syringe sizes are supported via File > Lesson Preferences > Calibration Syringe Size. Check the pictures in the SET UP > Calibration tab to make sure they match your setup. If incorrect, the lesson must be re-run and the preference changed prior to calibration Stage 1. If you are using a non-BIOPAC syringe, always check the Preference setting prior to beginning calibration Stage 1.

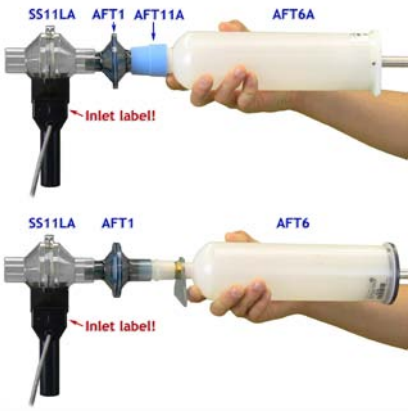


Fig. 13.7 Example AFT6A/6 connections.

Never hold onto the Airflow Transducer handle when using the Calibration Syringe or the syringe tip may break.

Always insert syringe assembly on the transducer side labeled "**Inlet**" so that the transducer cable exits on the left.

Stage 2 - Continued

5. Click **Calibrate**.

Fig. 13.8 AFT6A Calibration Stage 2 starting position

Fig. 13.9 AFT26 Calibration Stage 2 starting position

6. Cycle plunger in and out five times (10 strokes total).
   - Wait two seconds between each stroke.

Important:

- Complete exactly five cycles. Less or more cycles will result in inaccurate volume data.
- Syringe must be pushed in and pulled out all the way.
- Hold the assembly as still as possible.
- Use a rhythm of about one second per stroke with two seconds rest between strokes.

7. Click **End Calibration**.

8. Verify recording resembles the example data.
   - If similar, click **Continue** and proceed to Data Recording.
   - If necessary, click **Redo Calibration**.

There must be five downward deflections and five upward deflections. The first deflection must be downward. If the first stroke (push) resulted in an upward data deflection, the syringe/filter assembly must be reversed by inserting the assembly into the other port of the airflow transducer and rerunning the Calibration.

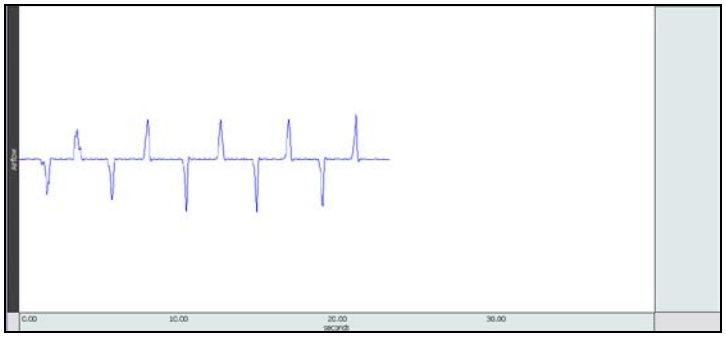


Fig. 13.10 Example Calibration Data

Calibration continues…

OPTIONAL

9. *Optional* Validate Calibration.
   a) Click **Record**.
   b) Cycle the syringe plunger in and out completely 3 times (6 strokes,) waiting about two seconds between strokes.
   c) Click **Stop**.
   d) Measure P-P on CH2 Volume (Fig. 12.16) to confirm the result matches the syringe volume:
   - AFT6 = 0.61 L acceptable range: 0.57 to 0.64 liters
   - AFT26 = 2 L acceptable range: 1.9 to 2.1 liters

   e) If measurements are correct, click **Redo** and proceed with **Subject** recording.
   f) If measurements are not correct:
   - Click **Redo** then choose File > **Quit**.

10. Re-launch the application and re-run the lesson.

END OF CALIBRATION

It is advisable to validate calibration once per lab session. Syringe must be pushed in and pulled out all the way.

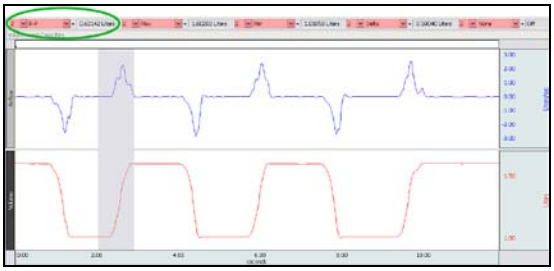


Fig. 13.11 Calibration Validation shows P-P result 0.6 liters

If recording does not resemble the Example Data

- If the data is noisy or flatline, check all connections to the MP unit.

Clicking **Redo** will erase the validation data and allow the **Subject** recording to continue.

It is necessary to re-launch the application in order to allow a new Stage 2 (Syringe) calibration. Prior to the next recalibration, make sure the lesson preference setting "Calibration Syringe Values" is assigned "Set each time lesson is launched" (see Setup Step 8).

C. DATA RECORDING

FAST TRACK Recording

1. Prepare for the recording.
   - Remove Calibration Syringe/filter assembly (if used).

2. Insert the filter into the “Inlet” side of the transducer, and then attach the mouthpiece (Fig. 13.12).
   - If your lab does not use disposable filters, attach a sterilized mouthpiece (AFT8) directly to the “Inlet” side of the transducer (Fig. 13.13).

Setup continues...

Detailed Explanation of Recording Steps

In this recording, two conditions will be performed to measure pulmonary flow rates:

Forced Expiratory Volume (FEV)

Maximal Voluntary Ventilation (MVV)

Each test will be saved as a separate data file.

Hints for obtaining optimal data:

- Review onscreen “Tasks” to prepare for the recording steps in advance.
- **Subject** should wear loose clothing so clothing does not inhibit chest expansion.
- **Subject** must try to expand the thoracic cavity to its largest volume during maximal inspiratory efforts.
- Air leaks will result in inaccurate data. Make sure all connections are tight, noseclip is attached and that **Subject’s** mouth is sealed around the mouthpiece.
- Keep the Airflow Transducer vertical and in a constant position. (Fig. 13.14).

IMPORTANT: Each Subject must use a personal filter, mouthpiece and noseclip. The first time they are used, the **Subject** should personally remove them from the plastic packaging. It is advisable to write **Subject’s** name on the mouthpiece and filter with a permanent marker so they can be reused later (i.e. Lesson 12).

If your lab sterilizes the airflow heads after each use, make sure a clean head is installed prior to Subject use.

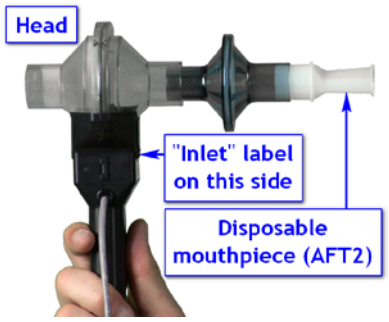


Fig. 13.12 SS11LA with unsterilized head

Fig. 13.13 SS11LA with sterilized head

3. Prepare the **Subject:**
   - **Subject** must be seated, relaxed and still, facing away from the monitor.
   - Place noseclip on **Subject's** nose.
   - **Subject** holds Airflow Transducer vertically, breathing through mouthpiece.
   - Before recording, **Subject** acclimates by breathing normally for 20 seconds.
   - **Review** recording steps.

Verify there are no air leaks; mouthpiece and filter are firmly attached, the noseclip is snug and the Subject's mouth is tightly sealed around mouthpiece.

Fig. 13.14 Keep Airflow Transducer upright at all times

Part 1 — FEV

4. Click **Record FEV.**
5. **Subject** performs the following procedure:
   - Breathe normally for three cycles.
   - Inhale as deeply as possible (maximum inspiration).
   - Hold breath for just an instant.
   - Forcefully and maximally exhale (maximum expiration).
   - Resume normal breathing for three more cycles.

1 cycle = inspiration + expiration

After maximum inspiration, hold breath for an instant so that when analyzing the data the beginning of the exhale can be clearly seen.

For the maximum expiration, it is important to expel all air, which should take more than 3 seconds.

6. Click **Stop**.

If a recording is started on an inhale, try to stop recording on an exhale, or vice versa.

Upon **Stop**, the Biopac Student Lab software will automatically convert the air flow data to volume data as shown in Fig. 13.15.

7. Verify recording resembles the example data.
   - If similar, click **Continue** and proceed to the next recording.

The maximal inhale and maximal exhale should be clearly visible in the data and there should be three normal breathing cycles both before and after.

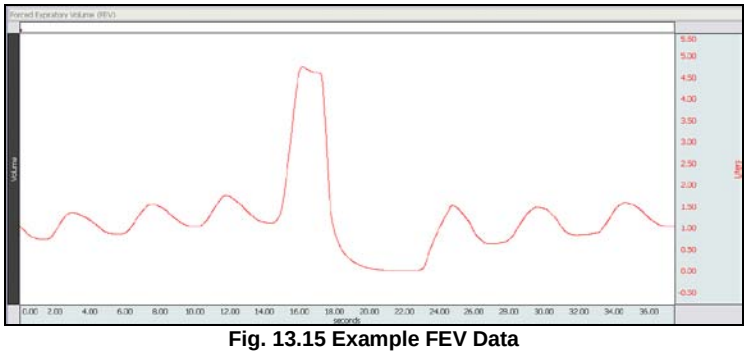


Fig. 13.15 Example FEV Data

Recording continues…

- If necessary, click **Redo**.

If recording does not resemble the Example Data

- If the data is noisy or flatline, check all connections to the MP unit.
- If there are not three normal breathing cycles on either side of the maximal inhale/exhale, Redo the recording.
- If it is difficult to determine the beginning of maximal expiration, the Subject may not have held breath for an instant after maximal inhalation; consider redoing the recording.
- If the maximal inhale/exhale data is not much greater in amplitude than that during normal breathing; verify there are no air leaks; mouthpiece and filter are firmly attached, the noseclip is snug and the Subject's mouth is firmly sealed around the mouthpiece.

Click **Redo** and repeat Steps 4 – 6 if necessary. Note that once **Redo** is clicked the data will be erased.

8. Zoom in using the zoom tool, on the area of maximal exhale.

The selected area should include some data both before and after maximal exhale.

9. Use the I-beam cursor to select the area of from beginning of maximal expiration to the end of maximal expiration. At least three seconds must be selected (Fig. 13.16).

The left mouse button is held down while selecting with the I-beam cursor.

The first measurement box will display **Delta T** so you can make sure the selected area is longer than 3 seconds.

If Delta T is less than 3 seconds, the Subject may not have expelled all air during maximum expiration. Click **Redo** and repeat Steps 4 – 6 if necessary.

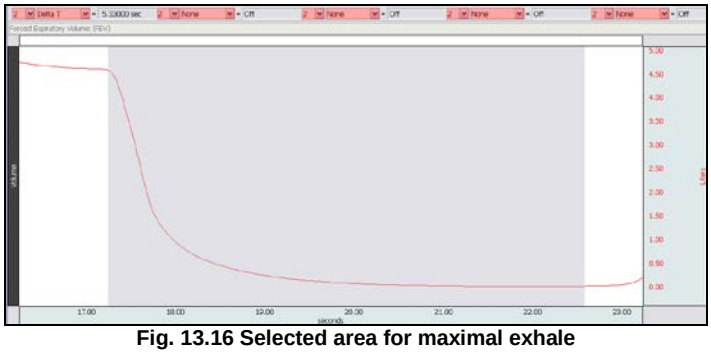


Fig. 13.16 Selected area for maximal exhale

10. Click **Calculate FEV**.

The program will cut out the selected area, invert it, zero the offset, and paste it into a new channel (Fig. 13.17). The original volume data will be deleted.

11. Verify the FEV plot resembles the example data.
    - If similar, click **Continue** and proceed to the MVV recording.
    - If necessary, click **Redo** to reselect area of maximal exhale and recalculate FEV.
    - If you will not be recording MVV, click **Done** and proceed to the Data Analysis section.

If the data was selected properly in Step 8, the first data sample should be the minimum (0 Liters) and the data should continue to increase for at least 3 seconds.

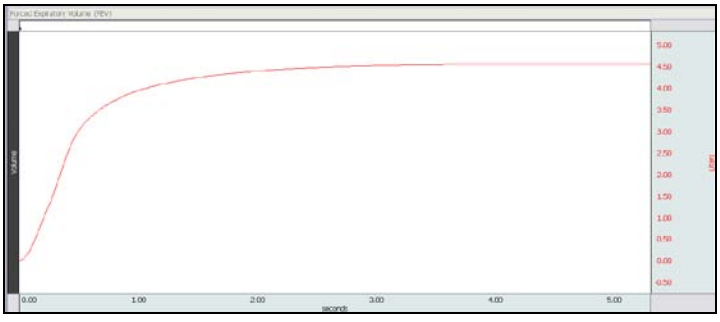


Fig. 13.17 Example FEV Plot

Upon **Continue**, the FEV data will be automatically saved for later analysis.

Recording continues…

Part 2 — MVV

12. Prepare the **Subject**.
    - **Subject** must be seated, relaxed and still, facing away from monitor.
    - Place noseclip on **Subject's** nose.
    - **Subject** holds airflow transducer vertically, breathing through mouthpiece.
    - **Subject** breathes normally for 20 seconds prior to starting recording.
    - **Review** recording steps.
13. Click **Record MVV**
14. **Subject** performs the following procedure:
    - Breathe normally for five cycles.
    - Breathe quickly and deeply for 12 – 15 seconds.
    - Breathe normally for five additional cycles.
15. Click **Stop**.
16. Verify that recording resembles the example data.
    - If similar, proceed to Step 15.

Recording continues…

1 cycle = inspiration + expiration

WARNING: This procedure can make Subject dizzy and light headed. Subject should be sitting down and Director should watch Subject. Stop the procedure if Subject feels sick or excessively dizzy.

Upon **Stop**, the Biopac Student Lab software will automatically convert the airflow data to volume data as shown in Fig. 13.18.

The rapid, deep breathing data should be clearly visible in the data.

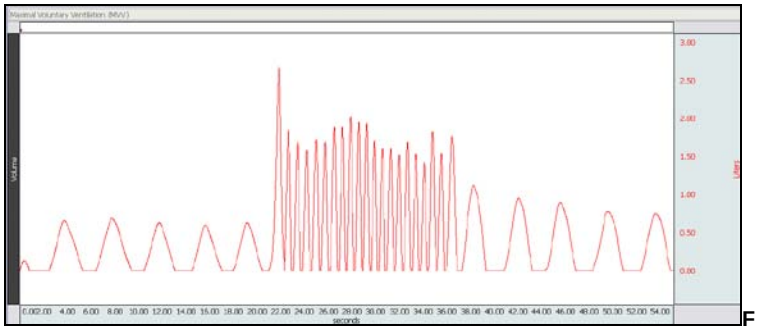


Fig. 13.18 Example MVV data

Note:

The software zeros the baseline after each cycle, which can result in data resembling the example to the right. It is not necessary to redo the recording, as data analysis will not be affected.

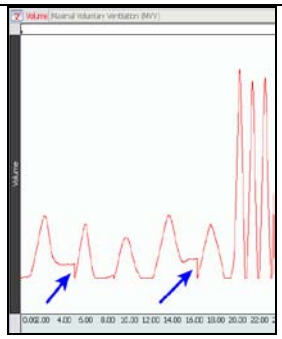


Fig. 13.19 Example of baseline reset

- If necessary, click **Redo**.

If recording does not resemble the Example Data

- If the data is noisy or flatline, check all connections to the MP unit.
- If the rapid, deep breathing data is not much greater in amplitude than that during normal breathing; verify there are no air leaks; mouthpiece and filter are firmly attached, the noseclip is snug and the Subject's mouth is firmly sealed around the mouthpiece.

Click **Redo** and repeat Steps 13 – 15 if necessary. Note that once **Redo** is clicked the data will be erased.

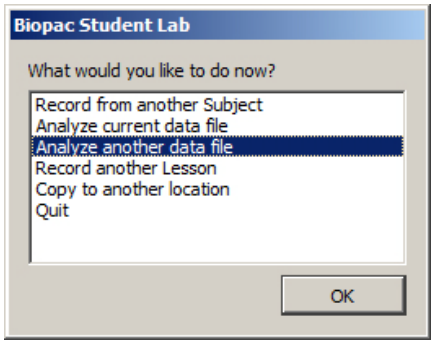
17. Click **Done**.
18. Choose an option and click **OK**.

This lesson creates two data files; one for FEV data and one for MVV data, as indicated by the file name extension.

When **Done** is clicked, a dialog with options will be generated. Make a selection and click OK.

If FEV and MVV recordings were both performed, choosing the "Analyze current data file" option will open the MVV file, but the FEV data file should be opened first, as this file is referenced in Part 1 of the Data Analysis section that follows.

To open the FEV file first, choose "Analyze another data file" from the list of options and navigate to the correct "FEV – L13" file in the **Subject's** folder.



If choosing the "**Record from another Subject**" option:

- Repeat Calibration Steps 1 – 3, and then proceed to Recording.

END OF RECORDING

V. DATA ANALYSIS

FAST TRACK Data Analysis

1. Enter the **Review Saved Data** mode.

   - Note channel number (CH) designations:

Channel	*Displays*
CH 2	**Volume**

   - Note measurement box settings:

Channel	*Measurement*
CH 2	**Delta T**
CH 2	**P-P**

2. Use the **I-beam** cursor to select the area from time zero to the end of the recording. Record the Vital Capacity (VC).

   A

Data Analysis continues…

Detailed Explanation of Data Analysis Steps

If entering **Review Saved Data** mode from the Startup dialog or Lessons menu, be sure to choose the file with "**FEV – L13"** file name extension.

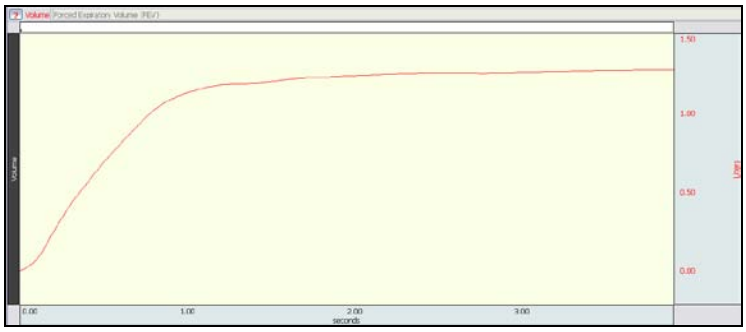


Fig. 13.20 Example FEV data

The measurement boxes are above the marker region in the data window. Each measurement has three sections: channel number, measurement type, and result. The first two sections are pull-down menus that are activated when you click them. The following is a brief description of these specific measurements.

Brief definition of measurements:

Delta T: Displays the amount of time in the selected area (the difference in time between the endpoints of the selected area).

P -P (Peak-to-Peak): Subtracts the minimum value from the maximum value found in the selected area.

The "selected area" is the area selected by the I-Beam tool (including endpoints).

Useful tools for changing view:

Display menu: Autoscale Horizontal, Autoscale Waveforms, Zoom Back, Zoom Forward

Scroll Bars: Time (Horizontal); Amplitude (Vertical)

Cursor Tools: Zoom Tool

Buttons: Show Grid, Hide Grid, -, +

The **P-P** measurement for the selected area represents the Vital Capacity (VC).

Note: In the example, the Grids have been enabled to assist in data selection.

Fig. 13.21 All data selected

3. Use the **I-beam** cursor to select the first one-second interval (Fig. 13.22). Record the volume expired and calculate $FEV_{1.0}$.

   B

The selected area should be from Time 0 to the one-second reading, as displayed in the Delta T measurement. The grid can be used as a reference. The volume expired is indicated by the **P-P** measurement.

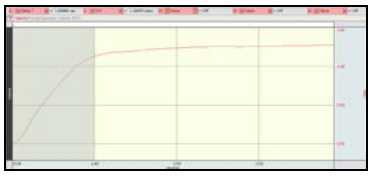


Fig. 13.22 $FEV_{1.0}$

4. Use the **I-beam** cursor to select the first two-second interval (Fig. 13.23). Record the volume expired and calculate $FEV_{2.0}$.

   B

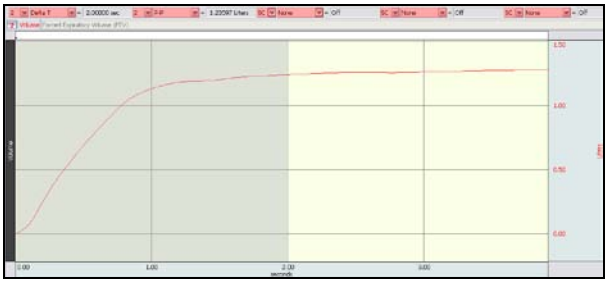


Fig. 13.23 $FEV_{2.0}$

5. Use the **I-beam** cursor to select the first three-second interval (Fig. 13.24). Record the volume expired and calculate $FEV_{3.0}$.

   B

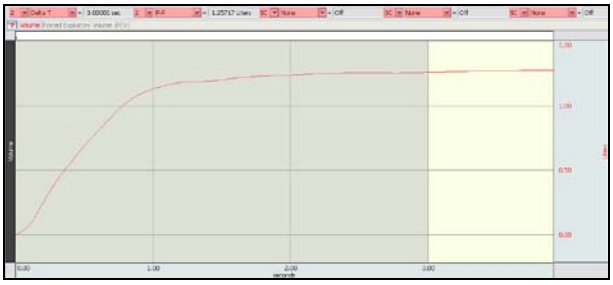


Fig. 13.24 $FEV_{3.0}$

6. Answer the **FEV**-related questions in the Data Report before continuing to the **MVV** section.
7. Select File > **Save Changes**.
8. Pull down the **Lessons** menu, select **Review Saved Data**, and choose the correct **MVV – L13** file.

Choose the data file that was saved with "**MVV – L13"** extension.

9. Use the **zoom** tool to set up your display window for optimal viewing of the deep, fast breathing portion of the recording (Fig. 13.25).

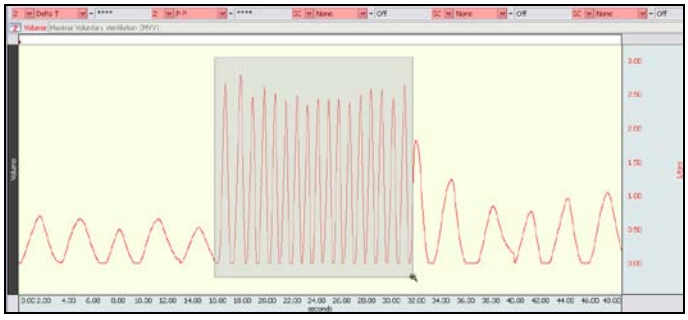


Fig. 13.25 Zoom in on rapid/deep breathing data

10. Use the **I-beam** cursor to select a twelve-second area that is convenient to count the number of cycles in the interval (Fig. 13.26).

    C

Use the Delta T measurement to determine the time interval. In the example below, 13 cycles are in the 12 second interval.

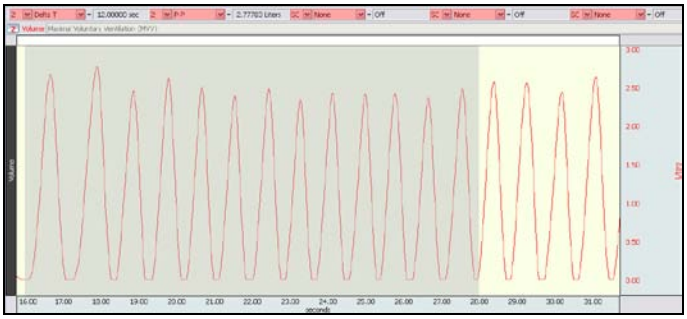


Fig. 13.26 Example of 12 second data selection

Data Analysis continues…

11. Place an event marker at the end of the 12 second selected area (Fig. 13.27).

It's helpful to clearly mark the end of the individual cycle measurement area by placing an **event marker** at the end of the selected 12 second interval. To place an event marker, right-click in the marker region just above the data display and select "Insert New Event." If the event marker is not placed correctly, it can be moved by holding down the Alt key and dragging with the mouse.

You may also enter event text in the field above the marker.

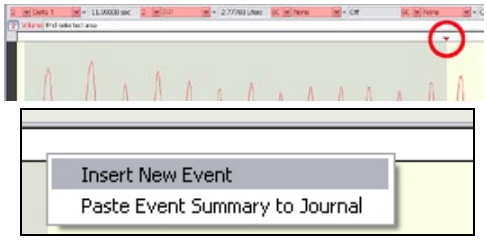


Fig. 13.27 Event Marker insertion

12. Use the **I-beam** cursor to select <u>each complete individual cycle</u> in the 12-second interval defined in Step 9. Record the volume of each cycle.

C

13. Calculate the average volume per cycle (AVPC) and then the Maximal Voluntary Ventilation (MVV).

C

The Volume is measured by the P -P (Peak-to-Peak) measurement.

Fig.13.28 shows the first cycle of the 12-second interval defined in Fig. 13.26 selected:

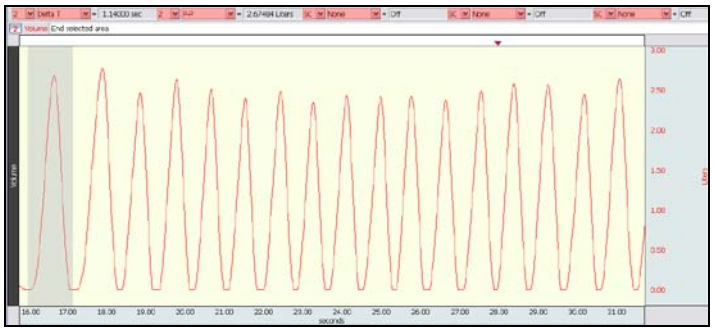


Fig. 13.28 Example of first cycle selection

14. Answer the MVV-related questions at in the Data Report.
15. **Save** or **Print** the data file.
16. **Quit** the program.

An electronically editable **Data Report** is located in the journal (following the lesson summary,) or immediately following this Data Analysis section. Your instructor will recommend the preferred format for your lab.

END OF DATA ANALYSIS

END OF LESSON 13

Complete the Lesson 13 Data Report that follows.

PULMONARY FUNCTION II

- *Pulmonary Flow Rates*
- *Forced Expiratory Volume (FEV)*
- *Maximal Voluntary Ventilation (MVV)*

DATA REPORT

Student's Name: _____

Lab Section: _____

Date: _____

Subject Profile

Name:_____ Height:_____

Age:_____ Gender: Male /Female Weight:_____

I. Data and Calculations

A. Vital Capacity (VC)

2 P-P = _____

B. Forced Expiratory Volumes: $FEV_{1.0}$, $FEV_{2.0}$, $FEV_{3.0}$

Table 13.2

Time Interval (sec)	Forced Expiratory Volume 2 P-P	Vital Capacity (VC) *from A*	FEV/VC *calculate*	(FEV/VC) x 100 = % *calculate*	= FEV_x	*Normal Adult Range*
0-1				%	$FEV_{1.0}$	66% - 83%
0-2				%	$FEV_{2.0}$	75% - 94%
0-3				%	$FEV_{3.0}$	78% - 97%

C. MVV Measurements (Note, all volume measurements are in liters)

1) Number of cycles in 12-second interval: _____

2) Calculate the number of respiratory cycles per minute (RR):

RR = Cycles/min = Number of cycles in 12-second interval x *5*

Number of cycles in 12-second interval (from above): _____ x 5 = _____cycles/min

3) Measure each cycle

Complete Table 13.3 with a measurement for each individual cycle. If Subject had only 5 complete cycles/12-sec period, then only fill in the volumes for 5 cycles. If there is an incomplete cycle, do not record it. (The Table may have more cycles than you need.)

Table 13.3

Cycle Number	Volume Measurement 2 P-P	Cycle Number	Volume Measurement 2 P-P
Cycle 1		Cycle 9	
Cycle 2		Cycle 10	
Cycle 3		Cycle 11	
Cycle 4		Cycle 12	
Cycle 5		Cycle 13	
Cycle 6		Cycle 14	
Cycle 7		Cycle 15	
Cycle 8		Cycle 16	

4) Calculate the average volume per cycle (AVPC):

Add the volumes of all counted cycles from Table 13.3.

Sum = _____ liters

Divide the above sum by the number of counted cycles. The answer is the average volume per cycle (AVPC)

AVPC = _____ / _____ = _____liters
Sum # of counted cycles

5) Calculate the MVV_{est}

Multiply the AVPC by the number of respiratory cycles per minute (RR) as calculated earlier.

MVV = AVPC x RR = _____ x _____ = _____liters/min
AVPC RR

II. Questions

D. Define **Forced Expiratory Volume** (FEV).

E. How do Subject's FEV values compare to the average per Table 13.2?

$FEV_{1.0}$	*less than*	*same as*	*greater than*
$FEV_{2.0}$	*less than*	*same as*	*greater than*
$FEV_{3.0}$	*less than*	*same as*	*greater than*

F. Is it possible for a Subject to have a vital capacity (single stage) within normal range but a value for $FEV_{1.0}$ below normal range? Explain your answer.

G. Define **Maximal Voluntary Ventilation** (MVV.)

H. How does Subject's MVV compare to others in the class? *less than* *same as* *greater than*

I. Maximal voluntary ventilation decreases with age. Why?

J. Asthmatics tend to have smaller airways narrowed by smooth muscle constriction, thickening of the walls, and mucous secretion. How would this affect vital capacity, $FEV_{1.0}$, and MVV?

K. Bronchodilator drugs open up airways and clear mucous. How would this affect the FEV and MVV measurements?

L. Would a smaller person tend to have less or more vital capacity than a larger person? ☐ Less ☐ More

M. How would an asthmatic person's measurement of $FEV_{1.0}$ and MVV compare to an athlete?

Explain your answer.

End of Lesson 13 Data Report