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 selected pulmonary volumes and capacities.
2.) To compare the observed values of volume and capacity with average values.
3.) To compare the normal values of pulmonary volumes and capacities of subjects differing in sex, age, weight, and height.

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. 12.8 MP3X (top) and MP45 (bottom) equipment connections

5. **Start** the Biopac Student Lab program.
6. Choose "**L12 – Pulmonary Function I**" and click **OK**.
7. Type in a unique **filename** and click **OK**.

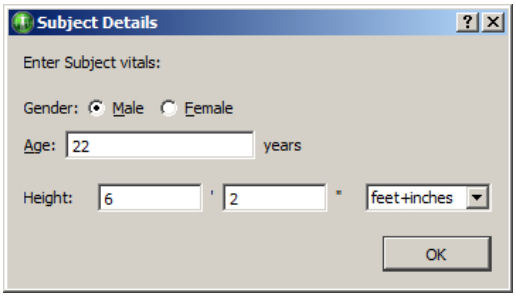
Start Biopac Student Lab by double-clicking the Desktop shortcut.

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. Enter the "**Subject Details**" and click **OK**. (BSL 4.01 and higher only.)

Subject Details records the gender, age and height of the **Subject** prior to beginning the lesson. Domestic or metric units may be selected. These details are displayed in the Journal following the lesson. (BSL 4.01 and higher only.)



9. ***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 normal spirometer or airflow transducer, so the BSL software sets a value between 0 and 5 liters (default is 1 L)

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. After 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. 12.9).
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. 12.11).

   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. 12.9

Calibration lasts from 4 to 8 seconds.

Fig. 12.10 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.

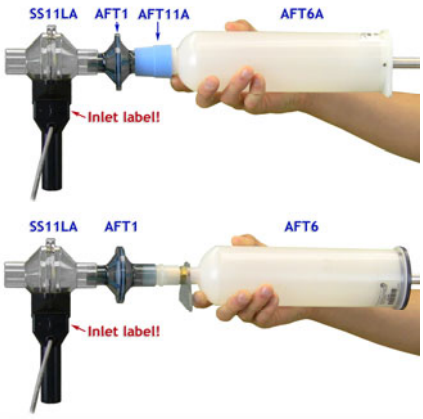


Fig. 12.11 Example AFT6A/6 connections.

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. 12.12 AFT6A calibration stage 2 starting position

Fig. 12.13 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** to proceed.
   - 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.

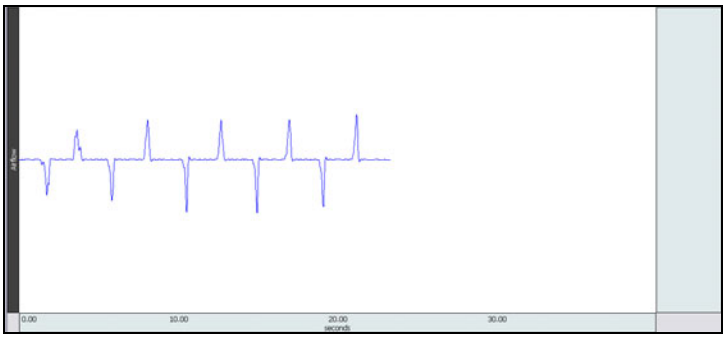


Fig. 12.14 Example Calibration (stage 2) Data

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. 12.15) 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.

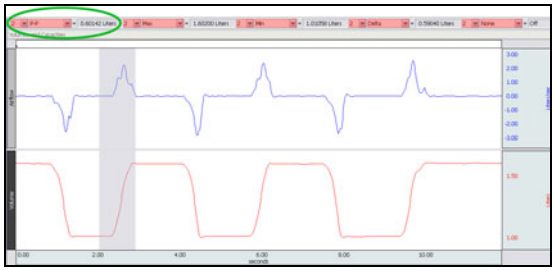


Fig. 12.15 Calibration Validation shows P-P result 0.6 liters

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).

IMPORTANT!
Subject must be relaxed to obtain accurate measures.

2. Insert the filter into the "Inlet" side of the transducer, and then attach the mouthpiece (Fig. 12.16).
   - If your lab does not use disposable filters, attach a sterilized mouthpiece (AFT8) directly to the "Inlet" side of the transducer (Fig. 12.17).

Recording continues…

Detailed Explanation of Recording Steps

The filter used during calibration should not be re-used by the **Subject** as it will not be sterile.

Hints for obtaining optimal data:

- **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. 12.18).
- If recording is started on an inhale, try to stop recording on an exhale, or vice versa. (A breath is considered a complete inhale-exhale cycle.)

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 13).

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

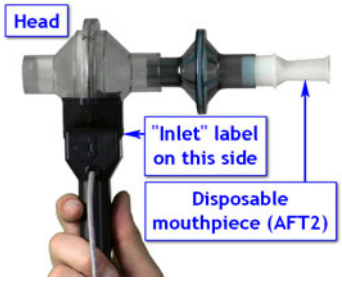


Fig. 12.16 SS11LA with unsterilized head

Fig. 12.17 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.

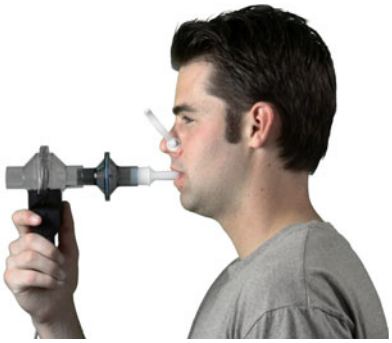


Fig. 12.18 Keep Airflow Transducer vertical at all times

4. Click **Record**.
   - Breathe normally for five cycles.
   - Inhale as deeply as possible then exhale completely.
   - Breathe normally for five more cycles.

1 cycle = inspiration + expiration

If a recording is started on an inhale, try to stop recording on an exhale, or vice versa. (A breath is considered a complete inhale/exhale cycle.)

5. Click **Stop**.

After clicking **Stop**, the Biopac Student Lab software will automatically calculate volume data based on the recorded airflow data. At the end of the calculation, both waveforms will be displayed on the screen (Fig. 12.19).

6. Verify that Volume channel reading resembles the example data.
   - If similar, proceed to Step 7.

The deep inhale/exhale should be clearly seen in the Volume data and there should be five normal breathing cycles both before and after deep breathing. It is common to have some "tilt" in the volume data as shown in Fig. 12.19. If the volume data exhibits excessive tilt (Fig. 12.20,) redo the recording.

Recording continues…

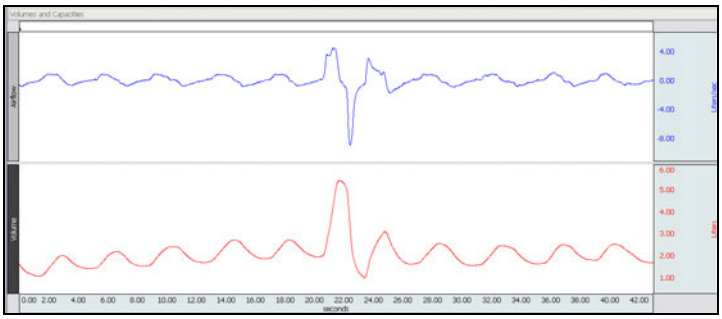


Fig. 12.19 Example Data

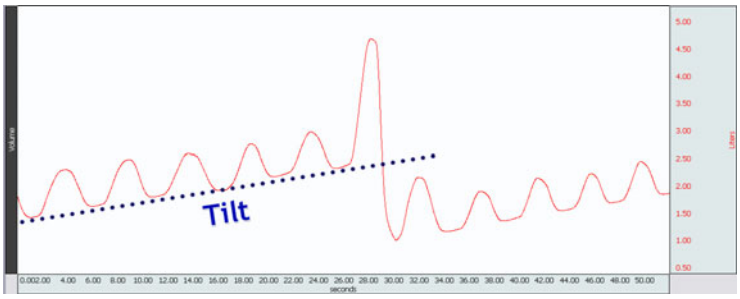


Fig. 12.20 Excessive tilt in the Volume data

- If necessary:

  Click **Redo** and repeat Steps 4 – 6

  OR

  Re-run the lesson and perform **Stage 1 Calibration.**

<u>If recording does not resemble Fig. 12.19:</u>

- If the data is noisy or flatline, check all connections to the MP unit.
- If there is excessive "tilt" in the data (Fig. 12.20):
- Make sure there are five normal breathing cycles on either side of the deep inhale/exhale.
- Verify there are no air leaks; mouthpiece and filter are firmly attached, the noseclip is snug and the **Subject's** mouth is sealed around mouthpiece.
- If a recording is started on an inhale, try to stop recording on an exhale, or vice versa.
- Verify the airflow transducer is kept vertical and still for the entire recording.

Click **Redo** and repeat Steps 4 – 6 if necessary.

If redoing the recording does reduce data "tilt," Stage 1 calibration (baseline adjust) must be repeated. To re-run lesson and redo stage 1 calibration:

- Click Redo.
- Choose "L12 – Pulmonary Function I" from the Lessons menu.
- Re-enter your name and proceed with calibration and recording.

Note that once **Redo** is clicked or the lesson is re-run, the most recent recording will be erased.

7. Click **Done**.
8. Choose an option and click **OK**.

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

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 1	**Airflow** (hidden)
CH 2	**Volume**

   - Note the measurement box settings:

Channel	*Measurement*
CH 2	**P-P**
CH 2	**Max**
CH 2	**Min**
CH 2	**Delta**

Data Analysis continues…

Detailed Explanation of Data Analysis Steps

If entering **Review Saved Data** mode from the Startup dialog or Lessons menu, make sure to choose the correct file.

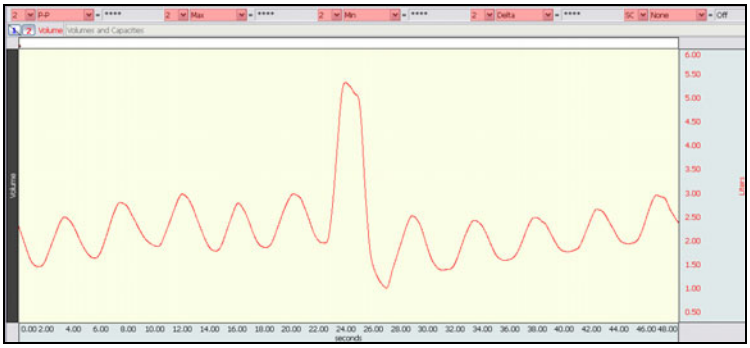


Fig. 12.21 Example data

All measurements will be performed on the Volume (CH 2) data. The Airflow (CH 1) data, used to calculate volume, is hidden to avoid confusion. It can be shown by "Alt + click" (Windows) or "Option + click" (Mac) the channel number box.

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.

Brief definition of measurements:

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

Max: Displays the maximum value in the selected area.

Min: Displays the minimum value in the selected area.

Delta: Computes the difference in amplitude between the last point and the first point of 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: Overlap, Split, Show Grid, Hide Grid, -, +

Hide/Show Channel: "Alt + click" (Windows) or "Option + click" (Mac) the channel number box to toggle channel display.

2. Review the measurements described in the Introduction to identify the appropriate selected area for each.

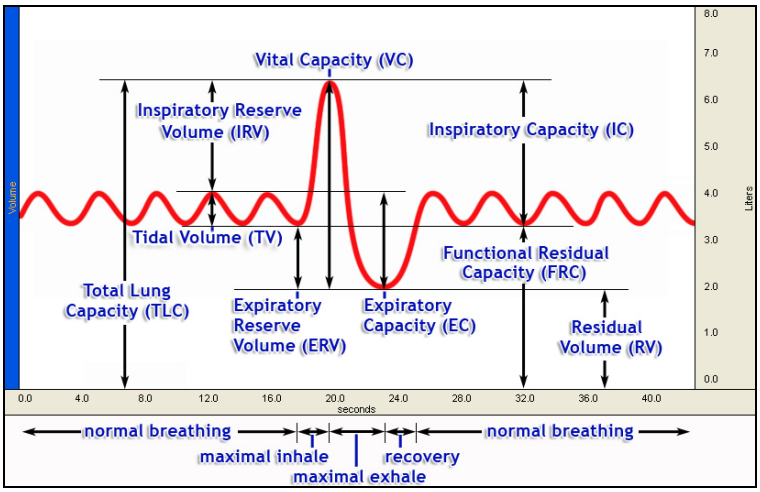


Fig. 12.22 Measurement areas for respiratory volumes and capacities

3. Calculate the Predicted Vital Capacity, then measure VC and then compare the two.

A

The selected area should start just prior to the maximum peak and end just after the minimum peak. The **P-P** (peak to peak) measurement displays the VC.

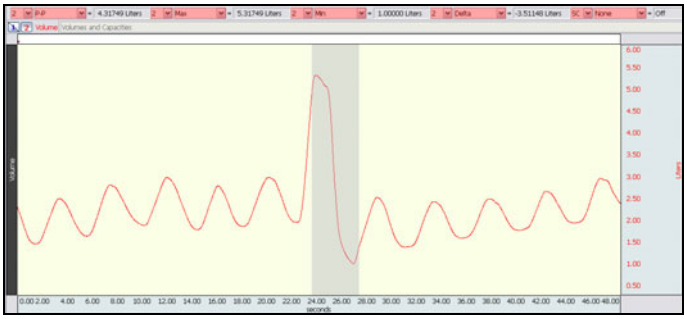


Fig. 12.23 Example selected area; P-P measures VC

4. Take two measures on the third TV cycle:
   a) Use the **I-beam** cursor to select the **inhalation** of cycle 3 and note the P-P result (Fig. 12.24). The selected area should be from the valley to the peak of the third cycle.

B

The **P-P** measurement in Fig. 12.24 represents the first value required for the averaged TV calculation.

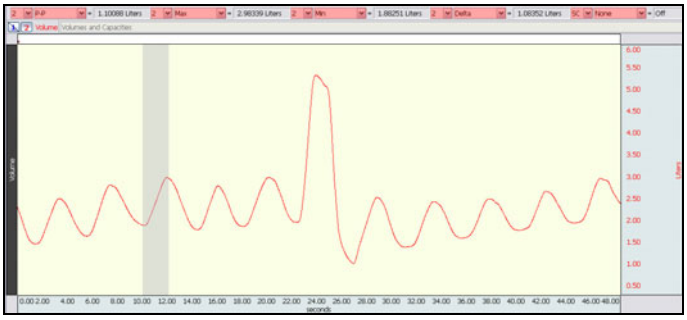


Fig. 12.24 Example of cycle 3 – Inhale selection to measure TV

   b) Use the **I-beam** cursor to select the **exhalation** of cycle 3 and note the P-P result (Fig. 12.25). The selected area should be from the peak to the valley of the third cycle.

B

The **P-P** measurement in Fig. 12.25 represents the second value required for the averaged TV calculation.

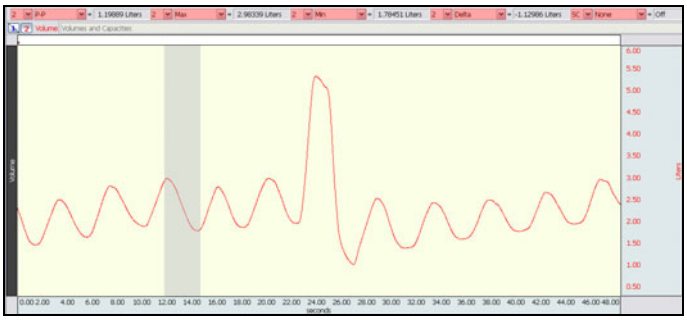


Fig. 12.25 Example of cycle 3 – Exhale selection to measure TV

Data Analysis continues…

5. Repeat TV measurements, as in Step 4, but on cycle 4 data. Calculate average value of all four TV measurements.

   B

6. Use the I-beam cursor and measurement tools to record the volumes and capacities required by the data report (defined in Fig. 12.22).

   B

7. Answer the questions at the end of the Data Report.
8. **Save** or **Print** the data file.
9. **Quit** the program.

END OF DATA ANALYSIS

Note that the Delta measurement requires precise placement of the selected area.

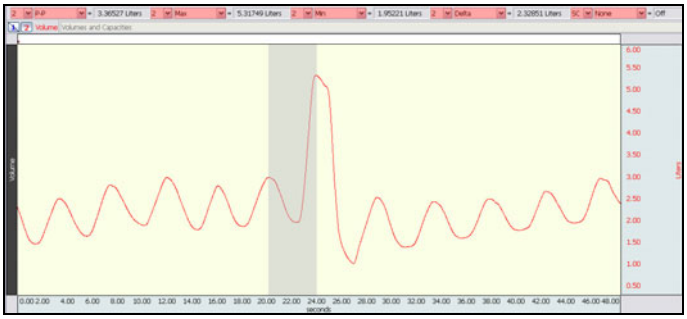


Fig. 12.26 Example selection for measurements of TLC (Max) and IRV (Delta)

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 LESSON 12

Complete the Lesson 12 Data Report that follows.

PULMONARY FUNCTION I

- *Volumes and Capacities*

DATA REPORT

Student's Name: _____

Lab Section: _____

Date: _____

Subject Profile

Name:_____ Height:_____ Gender: Male / Female

Age:_____ Weight:_____

I. Data and Calculations

A. Vital Capacity

i) Predicted: Use the equation below to calculate your **Predicted Vital Capacity**:_____

Equations for Predicted Vital Capacity (Kory, Hamilton, Callahan: 1960)	
Male	V.C. = 0.052H - 0.022A – 3.60
Female	V.C. = 0.041H - 0.018A – 2.69

Where

V.C.	Vital Capacity in liters
H	Height in centimeters
A	Age in years

ii) Observed: Use the P-P result to note **Observed Vital Capacity**: _____

= 2 P-P

iii) Observed *vs.* Predicted

What is Subject's observed Vital Capacity to predicted Vital Capacity as a percentage?

Observed/Predicted VC = _____ x 100= _____%

Note: Vital capacities are dependent on other factors besides age and height. Therefore, 80% of predicted values are still considered "normal."

B. Volume & Capacity Measurements

Complete Table 12.2 with the requested measurement results and calculate results per the formulas provided.

Table 12.2 Measurements

Title		Measurement Result		Calculation	
Tidal Volume	TV	a = 2 P-P Cycle 3 inhale: b = 2 P-P Cycle 3 exhale: c = 2 P-P Cycle 4 inhale: d = 2 P-P Cycle 4 exhale:		(a + b + c + d) / 4 =	
Inspiratory Reserve Volume	IRV	2 Delta			
Expiratory Reserve Volume	ERV	2 Delta			
Residual Volume	RV	2 Min		Default = 1 (*Preference setting*)	
Inspiratory Capacity	IC	2 Delta		TV + IRV =	
Expiratory Capacity	EC	2 Delta		TV + ERV =	
Functional Residual Capacity	FRC			ERV + RV =	
Total Lung Capacity	TLC	2 Max		IRV + TV + ERV + RV =	

C. Observed vs. Predicted Volumes

Using data obtained for Table 12.2, compare Subject's lung volumes with the average volumes presented in the Introduction.

Table 12.3 Average Volumes *vs.* Measured Volumes

Volume Title		Average Volume	Measured Volume
Tidal Volume	TV	Resting subject, normal breathing: TV is approximately 500 ml. During exercise: TV can be more than 3 liters	greater than equal to less than
Inspiratory Reserve Volume	IRV	Resting IRV for young adults is males = approximately 3,300 ml females = approximately 1,900 ml	greater than equal to less than
Expiratory Reserve Volume	ERV	Resting ERV for young adults is males = approximately 1,000 ml females = approximately 700 ml	greater than equal to less than

II. Questions

D. Why does predicted vital capacity vary with height?

E. Explain how factors other than height might affect lung capacity.

F. How would the volume measurements change if data were collected after vigorous exercise?

G. What is the difference between volume measurements and capacities?

H. Define **Tidal Volume**.

I. Define **Inspiratory Reserve Volume**.

J. Define **Expiratory Reserve Volume**.

K. Define **Residual Volume**.

L. Define **Pulmonary Capacity**.

M. Name the **Pulmonary Capacities**.

End of Lesson 12 Data Report