SPIROMETRY - MANUAL OF OPERATIONS

CARDIOVASCULAR HEALTH STUDY

CHS EXAM 9, 1996-1997

Pulmonary Function Reading Center

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FORWARD

This manual serves three purposes:

- a study guide for training of nurses and technicians to perform pulmonary function testing
- a practical "how-to" reference guide to be used during the study
- documentation of the pulmonary function testing procedures for analyses and manuscript preparation.

BACKGROUND

Spirometry is the simplest, most effective test for assessment of lung function (1). That is why it has been included in many cardiovascular epidemiology studies, including the Tecumseh, Framingham, CARDIA, ARIC, and Honolulu Heart studies (6-10). Spirometry and maximal respiratory pressures (MIP & MEP) were measured during the CHS baseline exam (2); and reference values for the 65-85 year-old age group were thereby established from the healthy CHS participants (3-4). The FEV1, FVC, and MIP were found to be associated with cardio-pulmonary symptoms, anthropometric measures, past exposures, and subclinical cardiovascular disease (CVD) and overt clinical CVD and lung disease (4).

Spirometry, and ambulatory monitoring of peak flows were measured during CHS exam 6 for both the original cohort and the new African American participants. Spirometry reference values were reported from the healthy subset of the elderly black participants. Spirometry (measuring the FEV1 but not the FVC) will again be repeated during CHS year 9 to determine change in FEV1, and as a disease outcome measure. In addition, a six minute walk with pulse oximetry will be performed.

Spirometry records the relationship between airflow (FEV1) and the exhaled volume of air during a breathing maneuver called the FVC maneuver (forced vital capacity maneuver). The most common lung diseases reduce forced expiratory flows. Such "obstructive" lung diseases include asthma, bronchitis, and emphysema. The ratio of FEV1/FVC is very sensitive for detecting mild airways obstruction, such as that due to mild airway inflammation secondary to exposure to cigarette smoke, asthma triggers, and mild pulmonary congestion due to CVD.

EXAM 9 SPIROMETRY CHANGES

1. Maneuvers need last only 3 seconds (not 10 sec)
2. A maximum of 5 maneuvers will be performed (not 8)
3. The PEF and FEV1 repeatability goals have been relaxed
4. Slow VC, MIP, and MEP tests will not be done

DEFINITIONS

A/D CONVERTER is a small electronic interface card mounted inside the spirometer which changes the analog voltages from the spirometer potentiometer and temperature sensor to digital numbers that the computer can understand. These are transferred to the personal computer via the RS-232 serial interface.

ARCHIVAL FLOPPY DISK is the floppy disk which stores a backup copy of participant test results, to be stored at the Field Center in case the PF Workstation's hard disk crashes.

ATPS is the condition of air inside the spirometer - Ambient Temperature and Pressure, and Saturated with water vapor. The ambient temperature of the spirometer is usually lower than body temperature; this has the effect of cooling and contracting the volume of air exhaled into the spirometer.

ATS is short for American Thoracic Society, the scientific branch of the American Lung Association (ALA). The ATS promotes accurate spirometers by recommending spirometry standards. The ALA raises money by selling Easter Seals, etc. The ATS and ALA may get divorced this year.

BACK EXTRAPOLATION is the standard method used to determine "time zero" when measuring the FEV1. The amount of slowly exhaled volume at the start of the maneuver excluded from the FEV1 by this technique is called the back extrapolated volume (BEV or EV). The BEV should be less than 5% of the vital capacity, otherwise the maneuver is considered to have started too slowly.

BTPS stands for Body Temperature (usually 37 degC) and Pressure, and Saturated with water vapor (100% humidity), which is the condition of air inside the lungs before it is exhaled into a spirometer. ATS standards require that volumes and flows be reported as if they were under these conditions.

CALIBRATION SYRINGE is a large metal cylinder with a rubber sealed piston used to check the volume accuracy of spirometers. The ATS recommends that it be 3.00 liters in size and we use a sturdy aluminum model made by Hans Rudolph.

COPD stands for Chronic Obstructive Pulmonary Disease, a general term for lung disease caused by cigarette smoking - a mixture of emphysema, bronchitis, and hyperreactive airways.

EV (see Back Extrapolation)

FET is short for Forced Exhalation Time. The FET is displayed on the incentive screen as the maneuver "Duration," and should be at least 3 seconds.

FEV1 is the most important spirometry variable, short for Forced Expiratory Volume in one second. It is convenient to think of it as the average flow rate during the first second of the FVC maneuver. It is reduced with airflow obstruction.

FEV1/FVC RATIO is the most sensitive and specific index of airways obstruction measured by a spirometer. It is normally above 70%.

FEV3 is the volume exhaled after 3 seconds. It is always larger than the FEV1 but smaller than the FVC.

FLOPPY DISKS are removable, rather slow, computer storage media. The personal computer's floppy disk (drive A:) uses high density (HD) 3 1/2 inch floppy disks which can each store up to 1.44 million characters (Mbytes).

FLOW-VOLUME CURVE is the graph obtained from a forced exhalation maneuver plotted with flow on the vertical axis and volume on the horizontal axis. When compared with the traditional spirogram, it has the advantage of allowing easy recognition of unacceptable or poorly reproducible maneuvers and disease patterns.

FVC is the Forced Vital Capacity, the volume of air exhaled during the maneuver named after it. The subject takes as deep a breath as possible and then quickly exhales as much air as possible. The FVC is reduced with restrictive disorders. The FVC will not be measured during CHS Exam 9, only the FEV1 and FEV3.

HARD DISK is the personal computer's fast, mass storage device (drive C:) which stores millions of characters.

OBSTRUCTION is a decrease in maximal airflow rates caused by airway narrowing. The FEV1/FVC ratio and the FEV1 are both decreased.

PEF stands for Peak Expiratory Flow Rate, the highest flow measured during the FVC maneuver. It is a good index of effort used at the onset of the maneuver.

PF is short for Pulmonary Function (lung tests).

PRED is short for the predicted value of a PF parameter. It is determined from the regression equation from a large population study of supposedly normal people.

RAM is very fast computer memory which "goes away" when the power is turned off. Results are copied from RAM to a disk for permanent storage. The personal computer has at least 640K of RAM memory.

RESTRICTION is a decrease in lung volumes. Scarring of lung tissue (fibrosis), severe heart failure (CHF), pneumonia, and simple obesity are some of many causes. The FVC is reduced while the FEV1/FVC ratio is normal or increased.

Equations

BTPS Correction Factor (ATPS to BTPS):

$$[(273 + 37)/(273 + T)] \times [(PB - PH_2O)/(PB - 47)]$$

T = spirometer temperature (20-30 deg C) at the end of each maneuver
PB = barometric pressure (625-760 mmHg)
PH_2O = water vapor pressure (17-30 mmHg)

Factor to convert inches to centimeters:
Inches x 2.54

To convert degrees F to Centigrade:

$$(5/9) \times (degF - 32)$$

Prediction equations for healthy elderly women and men

	Equation	LLN
MEN		
FVC	.0567 Ht -.0206 Age -4.37	-1.12
FEV1	.0378 Ht -.0271 Age -1.73	- .84
FEV1/FVC%	-.294 Age +93.8	-11.7
WOMEN		
FVC	.0365 Ht -.0330 Age -0.70	- .64
FEV1	.0281 Ht -.0325 Age -0.09	- .48
FEV1/FVC%	-.242 Age +92.3	- 9.3

volumes in liters, BTPS
Ratio = FEV1/FVC x 100%
Ht = height in cm
LLN = lower limit of the normal range (fifth percentile)
Equations are from the healthy CHS participants during their baseline exam (3) and are valid for ages 65-85

METHODS SUMMARY

Daily Procedures

Calibrate Instruments
- Power-up computer and spirometer
- Run leak and volume checks
- Wash your hands

Identify the participant
- Enter name, ID number, age, height, weight

Perform FVC maneuvers
- Demonstrate the FVC maneuver
- Obtain 3 acceptable FVC maneuvers
- Review maneuver quality
- Add comments
- Print and store the results

Clean Equipment at the end of the day
- Clean breathing hoses
- Rinse and dry hoses overnight

Weekly Procedures

Monday mornings
- Refill with distilled water
- Run leak and volume cal checks
- Perform a biologic control test

Friday afternoons
- Send data to Tucson (via modem)
- Remove spirometer shell
- Clean bell & internal hose
- Rinse and dry the bell overnight

DESCRIPTION OF THE PF WORKSTATION

A dry-sealed spirometer is connected to a personal computer using a 12 bit analog to digital (A/D) interface. The spirometer is equipped with a potentiometer (pot) which changes the mechanical motion of the spirometer bell into a voltage which is proportional to exhaled volume. An electronic sensor measures the spirometer temperature for automated BTPS corrections. The A/D converter, mounted on a board inside the spirometer takes the analog voltages, converts them into digital numbers and sends them to the computer via an RS-232 serial interface. The computer then calculates the exhalation time (FET) and airflow rates (FEV1) using a crystal controlled clock and stores all the results in RAM memory. The results are stored on the hard disk, printed, and transmitted to the PF Reading Center in Tucson Arizona.

MAIN MENU

The MAIN MENU is automatically displayed when the computer's power is turned ON. If you are faced with the DOS prompt C:> type **GO** The MAIN MENU is the control center or hub of the system. Moving from one function to another is performed by going back to the MAIN MENU first.

You usually move forward within a program by pressing either the Enter key or the spacebar. Directions are often given at the bottom of the screen. If you obtain a program or screen by mistake, you can usually get back to the MAIN MENU by pressing the Esc key.

Select the desired program from the MAIN MENU by highlighting your selection using the cursor (arrow) keys. Then press the Enter key. An alternate method for experienced users is to merely press the three letter code for the program (not followed by Enter).

The first column of selections, under the heading **PRE:Tests** lists the most frequently used programs in the order in which they are usually selected:

INF - Enter patient information
Used to enter the name, ID number, age, height, etc for a new participant.
The name of the "current participant" is given in parentheses on this line.

FVC - Forced Vital Capacity
Guides performance of FVC maneuvers. Flow-volume curves are displayed on the screen for quality control.

EOS - End the Test Session
Asks you for comments, then prints a report for the participant and his/her physician and a tabular report for the participant's on-site CHS chart. The data are then stored in a directory on the hard disk.

SVC - Slow Vital Capacity
If the participant can't perform good FVC maneuvers, the slow VC test should be done. It requires very little effort.

TXT - Enter Comments
You may go back and edit your comments about what happened during testing at any time.

PARTICIPANT INFORMATION

Select "INF - Identify the Participant for the MAIN MENU." If you did not complete a leak and volume cal check today, you will be instructed to do so at this time, before testing a participant (see the CALIBRATION section of this manual for details).

Enter or verify the information requested in each box. End each entry by pressing the ENTER key. Every item must be entered in order to calculate predicted values.

Name Enter the participant's last name, a comma, then his first name (up to a maximum of 22 letters) Use all capital letters. *Don't add a space after the comma.* Press F2 here to edit the currently selected participant's data (instead of entering data for a new participant).

ID # Enter the participant's 7 digit CHS ID number and verify that it is correct. If you enter it in error, use the backspace key to correct it.

Date Verify that the computer knows the correct date.

Location Your Field Center's name should be here.

Age Enter the participant's age.

Sex Press M for male or F for female.

Height Enter the participant's measured standing height (in stocking feet) in inches.

Weight Enter their weight in pounds. If computed BMI exceeds 27, you will be instructed to ask the participant to stand during spirometry maneuvers.

Race Enter the ethnic code: A for Asian, B for Black, C for Caucasian, H for Hispanic, I for American Indian, or O for other.

Note: When based on standing height, predicted values for Asians and Blacks are reduced by 12%, due to a shorter trunk to height ratio.

Baro The average barometric pressure at your location (usually between 720 and 760) should be displayed here. It should NOT be changed.

Temp The spirometer temperature is measured by an internal sensor and displayed here. Verify that it reads within 2 degC of the small MICRONTA thermometer mounted on the spirometer.

If the readings differ by more than 2 degC, call the PF Reading Center. If the spirometer temperature is below 17 degC (60 degF), the room is probably too cold for testing. Turn up the room's thermostat and blow into the spirometer yourself to warm it before testing participants.

Help. Each entry is verified to make sure it is within a reasonable range. If your entry is rejected, press the F1 key for a help message which explains the entry expected.

Editing. If a mistake was made when entering information, use the arrow keys to move the cursor to the error. Then begin typing the information. Press ENTER to complete the line.

The predicted PF values will be displayed in a box in the lower right hand corner of the screen. Ignore them and press the Enter key.

A comments screen is displayed next. Press the Enter key twice to skip over the two lines of general comments. (You will get a chance to enter these just before you print the report.)

Indicate if the participant will stand for the maneuvers due to a large body mass index (above 27). Press the Enter key at the bottom of the screen to return to the MAIN MENU.

FORCED VITAL CAPACITY TESTING

You, the technician, are **the** critical part of the pulmonary function testing system, since you must guide the participant through breathing maneuvers which are highly dependent on participant effort. You must coach the participant to inhale maximally and then to exhale maximally. You also must judge the quality of his effort. To obtain accurate results, the testing must be done in a standardized fashion.

Note: This manual refers to the participant as "he" or "him" for easy reading. Of course CHS participants are of either gender.

Wash your Hands Participants will appreciate your consideration if you make a point of washing your hands before testing them. Do this as you enter the testing room if it has a sink, otherwise, just before you enter the room. Another thing you can do to minimize the risk of cross-contamination is to store the fresh mouthpieces in a sanitary plastic box and ask the participant to use a Kleenex tissue to remove one for their use. Then allow them to attach it to the clean breathing tube.

Explain the Procedure Explain that the purpose of the next test is to determine how fast he can exhale air. Explain that, as before, he should take in as deep a breath as possible, and when his lungs are completely full, quickly position the mouthpiece, and then BLAST out as hard and fast as possible.

Position the Participant Testing should usually be conducted in the **sitting position**; however, obese participants (BMI > 27) should stand. A chair (without wheels) should be positioned behind obese participants who stand for the test. Use the chair if the participant becomes light-headed or faint during testing. Ask the participant to sit erect with chin slightly elevated.

Tight clothing, such as a tie, vest, or belt, which might restrict maximal breathing efforts, should be loosened. **Dentures**, if they are loose, should be removed and placed in a clean denture cup, since they will prevent a tight seal from being formed around the mouthpiece. If dentures are not loose, leave them in place.

Always Demonstrate the Maneuver Ask the participant to watch you perform the FVC maneuver. Again demonstrate correct placement of the mouthpiece. Stand up straight. Take a deep breath, throw back your shoulders, widen your eyes, and stand on your toes to **emphasize the maximal depth of inhalation**. Then place the mouthpiece and dramatically **BLAST** out as fast as you can.

Your vigorous demonstration will prevent time and effort from being wasted on unacceptable forced expiratory efforts which are caused by the participant's failure to understand a verbal explanation of the procedure.

FVC Test Steps

Step 1 From the MAIN MENU, select **FVL**. The FVC Incentive screen will then be displayed.

Step 2 Tell him to "take in as deep a breath as you possibly can, then put the mouthpiece in your mouth." Watch him as he does so and then coach him: "now inhale a little bit more," until you are sure that his lungs are full.

Step 3 Shout "**BLAST OUT !!!** Lower your voice a bit and say "keep going for 3 seconds"

Watch the body language of the participant as he attempts to follow your instructions. **Pay attention to him, not the instrument.**

Encourage him to blow out smoothly without re-breathing.

Don't press the Esc key during testing until you are certain that you have performed enough good maneuvers.

Press the spacebar to get the results screen. (You'll have to press it twice if you didn't wait for 15 seconds to elapse.) Then save the maneuver by pressing the spacebar again. If you press the N key at this point, the maneuver will be erased forever. Do this only if the maneuver was terrible and you are sure that the participant can do a better maneuver. Analyze the flow-volume curve produced by this maneuver. Note the maneuver quality message in the box.

If after the initial demonstration, the participant fails to perform the maneuver correctly, **again** demonstrate both the error and the correct performance yourself. You may have to repeat the demonstration after **every** maneuver for some participants!

Your goal is to obtain at least **3 good** maneuvers, 2 of which match each other closely. If the current maneuver did not match the best prior maneuver, a message like "Next time, take a deeper breath" will be displayed at the bottom of the screen. Quality grades from A-D will be displayed immediately after the FVC and FEV1 results. These indicate the reproducibility of the best and second best maneuvers.

To perform another maneuver, merely press the Spacebar.

Review the Results

After the participant has performed three apparently good FVC maneuvers, review the results. **Press the F9 key** to see the three best maneuvers superimposed, each in a different color.

The blue maneuver with numeric results listed at the top right of the screen in blue is the "best" maneuver obtained so far. The Trial number is the order in which it was performed.

The "best" maneuver is the one with the highest sum of FVC + FEV1. Ignore the predicted and %predicted values displayed in the right-hand columns.

If you still don't have 3 good maneuvers, press the Spacebar twice to perform another maneuver. If the quality and reproducibility of the 3 maneuvers displayed looks good, and you think that you might be done testing, press the F10 key.

Maneuver Quality Review Window (F10)

The best three maneuvers are again indicated at the top of the columns. First look at the bottom row marked QC. Any letters there are maneuver Error Codes which mean that the maneuver was not acceptable or reproducible, and that more maneuvers should be performed. Press the F1 key for an explanation of these codes. Press the Spacebar twice to resume testing.

Numbers listed under the Stored Values column are the highest obtained from all maneuvers performed and will be printed on the report. The number listed under the (%) column for each maneuver (Trial) is the percent of the highest value.

If all 3 maneuvers are "Good tests", you have obtained enough FVC maneuvers, and should press the Esc key to store the results. The hard disk light will illuminate as the results are stored, and you will be returned to the MAIN MENU.

FVC Maneuver Acceptability

According to the ATS standards, you should coach every participant to obtain at least three maneuvers that are "acceptable" and two that are "reproducible." The criteria for acceptability and reproducibility are described below. The accuracy of results depends much more on the quality of the maneuvers than on the instrument calibration.

Acceptability Messages Errors in FVC maneuver performance are identified by the computer and displayed in the F10 QC box:

QC	Message	Criterion
S	Start faster	BEV > 5% FVC
P	BLAST out harder	PEFT > 120 msec
C	Avoid coughing	> 50% drop
T	Blow out longer	FET < 3 sec
A	Blow out more air	Abrupt termination

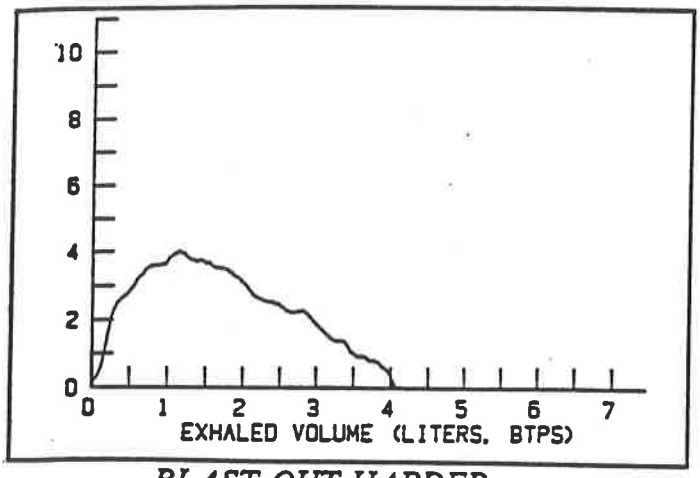
After the first maneuver, reproducibility messages are also displayed on a line at the bottom of the screen prior to the next maneuver if the current maneuver's result was lower than the previous highest value from an acceptable maneuver:

d	Deeper breath	dFVC > 0.20 L
f	Blow out faster	dFEV1 > 0.20 L
h	Blow out harder	dPEF > 2 L/s

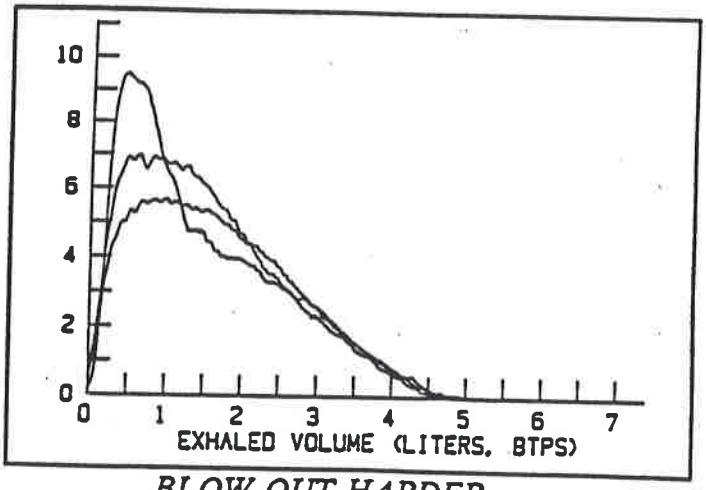
Notes: QC = error code displayed in the Review QC window - F10 key.
BEV = back extrapolated volume
dPEF, dFVC, dFEV1 = the difference between the current maneuver's value and the highest value from any other acceptable maneuver from the testing session

Maximum Number of Maneuvers. Don't exhaust the participant by asking them to perform more than **FIVE** FVC maneuvers. If you haven't obtained 3 acceptable maneuvers by the time you have done five maneuvers, it is unlikely that you will. Make a note of the reason why the participant couldn't perform the maneuvers well in the Comment Screen later.

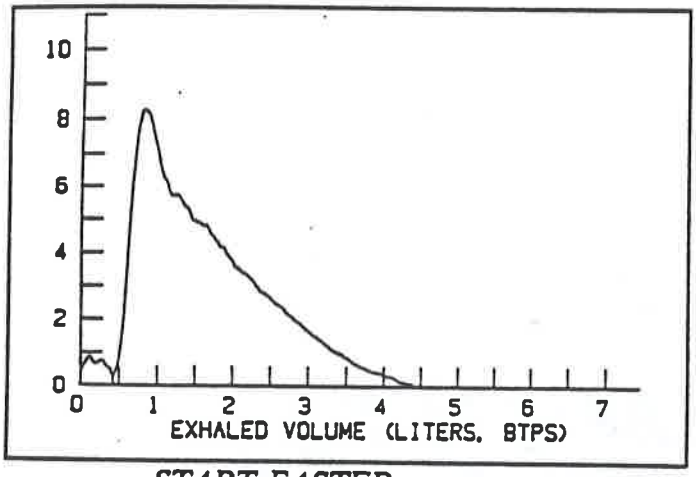
The following figures show examples of flow-volume curves from acceptable and unacceptable maneuvers.



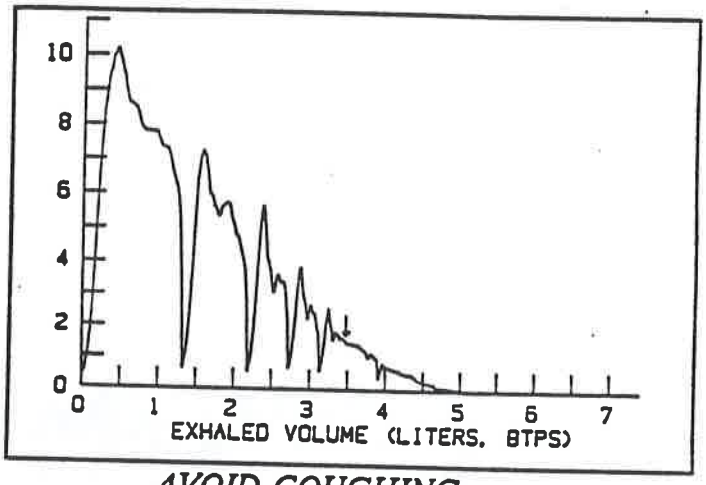
BLAST OUT HARDER



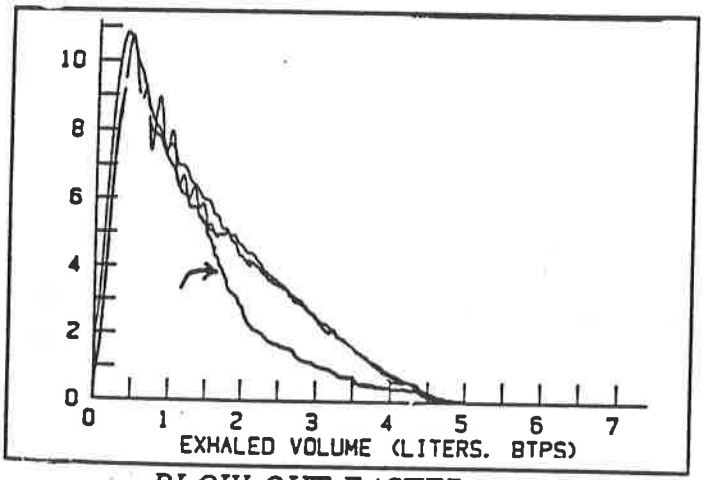
BLOW OUT HARDER



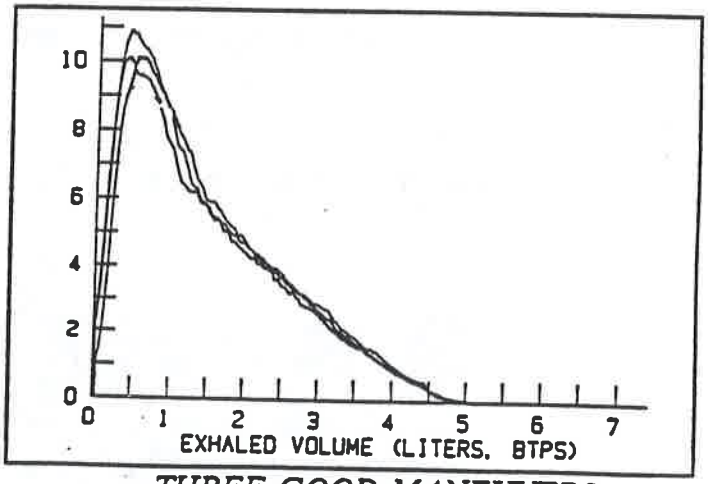
START FASTER



AVOID COUGHING



BLOW OUT FASTER



THREE GOOD MANEUVERS

END TEST SESSION

After you have performed all of the maneuvers, congratulate the participant for a job well done and tell him that the results will be explained to him at the end of the visit. Do not attempt to explain them to him yourself.

Get the printer ready to print the report.

Select "EOS - End test session" from the MAIN MENU. The results will be added to the patient directory and database on the hard disk.

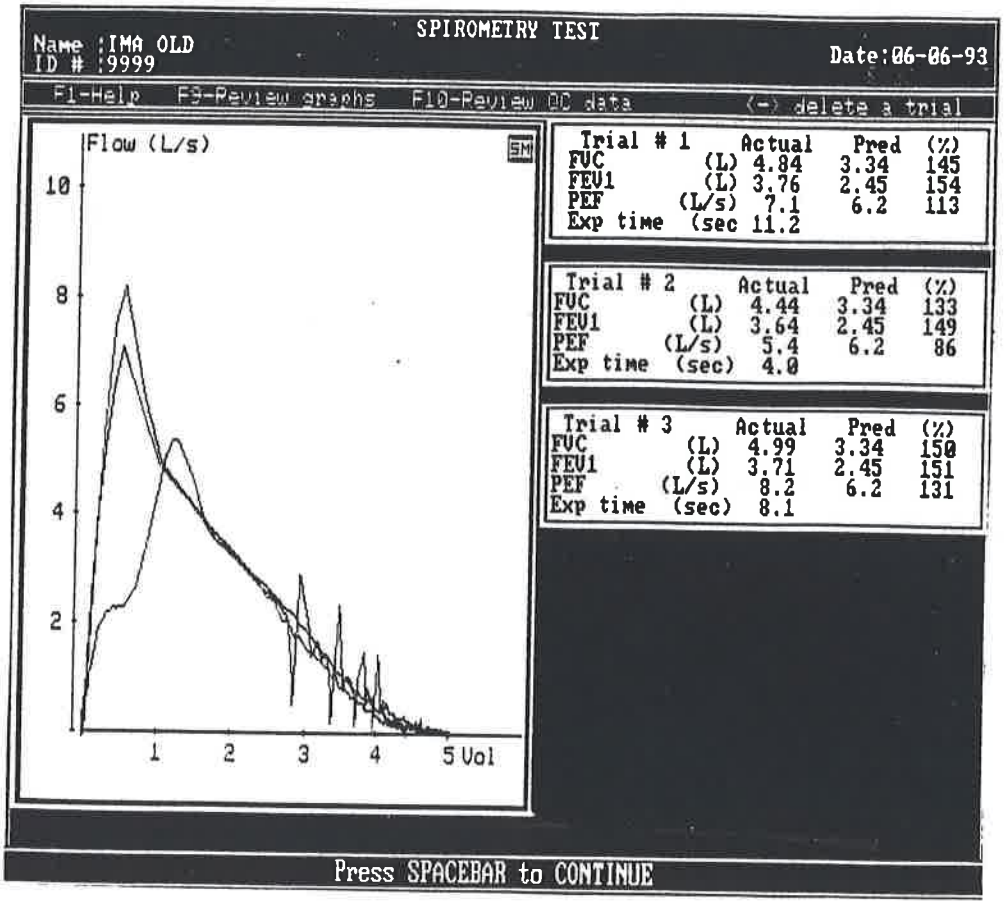
You will then be asked if you have any comments. If anything unusual happened during the testing, enter your comments on the two lines provided.

The report will then be printed to place in the participant's CHS file. We do not plan to give a full-page spirometry report to the participant this year.

PRINT-SCREEN

Anytime while you are testing a participant and you wish to make a copy of what is displayed on the screen, you may do so by pressing the <Print Screen> key located in the upper right-hand corner of the keyboard. A box will then be displayed near the bottom of the screen asking if you want a Small, Medium, or Large size print. Normally you should select a small print by pressing the S key. This will allow two such screens to be printed on a single sheet of paper.

To eject the page from the printer, following a Print-Screen, you may need to take it "off-line" then press the Form Feed button, wait for it to eject, then press the On-line button again.



LEAK AND CALIBRATION CHECKS

Leak Check Select "LEA - Leak Check" from the QC column of the MAIN MENU. The leak test must be performed BEFORE the Volume Cal Check, since a leak will affect the volume calibration.

1. First check the spirometer's **water level**. Water should always be visible through the round window.

Note: If the water level is not visible, add distilled water as follows: grasp the black knob at the top of the bell, raise the bell several inches, and pour water against the side of the bell to prevent spillage.

2. Attach a breathing hose. Raise the spirometer bell by the black knob to midposition (approximately 4 liters) and hold it as you cork the clear breathing tube with a black #8 rubber stopper.

Don't lift the bell by the clear plastic guides.

3. Place the black kymograph drum gently on top of the spirometer bell (to provide a constant pressure within the spirometer).

4. Enter a test time of 1 minute.

The Leakage Rate displayed after one minute should be less than 40 cc/min.

If a Leak is Detected Determine whether the leak is in the breathing tube, the blue internal tube, or in the spirometer bell as follows:

1. Disconnect the breathing tube from the spirometer. Raise the bell halfway and insert a green #7 rubber stopper into the metal breathing tube connector at the front of the spirometer. Place the weight on top of the spirometer bell.

2. Select LEA again and enter a time of 1 minute. Start the leak test.

If the Leakage Rate is now less than 40 cc/min, then the breathing tube is the source of the leak. Discard it and check the new one for leaks. If, however, the Leakage Rate is still larger than 40 cc/min, then the internal tube or the bell is leaking.

3. Reach underneath and inside the spirometer, and disconnect the internal tube from the topmost internal port. Raise the bell halfway and insert a green #7 rubber stopper into this topmost internal metal tube connector. Place the weight on top of the spirometer bell. Repeat Step 3.

If the Leakage Rate is now below 40 cc/min, then the internal tube is leaking - throw it away and replace it with a new one. If, however, the Leakage Rate is still above 40 cc/min, then the leak is in the spirometer bell. Replace it and check the new bell for leaks and recalibrate the system.

To locate a leak in the spirometer bell, remove the bell, turn it upside down, and fill it with about an inch of water (above the seam). Tip the bell at an angle and turn it, observing to see where water escapes. Repair it with silicone sealant.

Volume Cal Check

Select "CAL - Volume Cal Check" from the QC section of the MAIN MENU. You should have first done a leak check. You'll need the 3.00 liter calibration syringe.

Carefully follow the directions at the bottom of the screen.

1. Make sure that you have stored the calibration syringe very close to the spirometer so that they remain at the same temperature. Flush the syringe and the spirometer at least 3 times with room air. Detach the white mouthpiece adaptor.

2. Pull back on the syringe plunger until it clicks (thereby filling it completely with room air).

3. Firmly attach the calibration syringe to the breathing hose. Place the syringe flat on the table and don't move the tubing during the next step. Then press the Spacebar.

4. Empty the syringe into the spirometer; then press the Spacebar again.

5. Disconnect the cal syringe. (The Flow reading should be between -0.05 and +0.05 with the bell empty.)

If the volume calibration error is too high press the Y key to re-run the volume cal check.

Press Enter to return to the MAIN MENU.

If the Volume Check Fails

Possible reasons for the volume check to fail (in order of decreasing likelihood) include:

- Failure to completely fill and/or discharge the syringe into the spirometer. Make sure the syringe clicks against the stops with each stroke.

- Differences in the air temperature between the spirometer and the syringe. Reflush and repeat the check.

- An air leak in the calibration syringe. Fill the syringe, plug the end with the rubber stopper and try to empty the syringe. If the plunger moves inward, this indicates a leak in the syringe seal. Call the PF Reading Center to replace the syringe.

- A large flow number (beyond -20 or +20 liters/sec) may indicate a problem with the A/D interface. Call the PF Reading Center to discuss this.

ADJ If the volume error was greater than 5% during the calibration check, you will be instructed to try the above 5 steps again. If the error remains too high, you will be instructed to adjust (ADJ) the A/D converter calibration constants by carefully following the directions at the bottom of the screen.

Note: Stroke the syringe in and out completely at least three times. Take about one second for each stroke. End up with the syringe completely full (shaft extended). Make sure you hear it click at the end of each stroke, but don't "bang" it too forcefully.

CLEANING THE SPIROMETER

Clean the Breathing Tubes at the end of each day of testing. First wash them in warm soapy water, rinse, roughly dry, then soak them in the disinfectant solution for at least 30 minutes. Be sure to wear protective rubber gloves and eye protection when using the disinfectant since it causes a rash in some persons. Rinse thoroughly and hang them to dry completely overnight before reusing.

Clean the Spirometer every Friday afternoon. You will need a small screwdriver and one liter of distilled water.

1. Disconnect the cable leading from the base of the spirometer to the rear of the computer. Detach the breathing tube.

2. There are two vertical guide rods located on either side of the spirometer. At the top of the guide rod holding the square red potentiometer (pot) is a **bell stop** which prevents the spirometer bell from being raised to a position which could damage the grey plastic shaft. Unscrew and remove the bell stop. **The grey plastic shaft is very fragile.** Do not twist it. Do not bend it except when it is fully extended.

3. Loosen, by 1/2 turn, the **white screw** at the top of the pot clamp.

4. At the top of the spirometer bell, across from the potentiometer clamping piece, is the **pen holder screw**. Remove this screw. Raise the spirometer bell up about six inches by the black knob, then gently slide the silver clamp away from the white screw and remove the bell.

5. Wash the inside and outside of the spirometer bell with **vinegar** and rinse it with water. Vinegar will remove the film that tends to build up on the bell. CAUTION: The plastic bell is very fragile. Don't squeeze it. Don't lay it on its side.

6. **Drain** the spirometer by tipping it sideways over a sink. Avoid getting any water near the grey pot shaft.

7. Remove the **blue internal hose**: reach up under the spirometer and twist the ends off the metal tubes. Clean it just like the white breathing tubes. Swab the inside of the two stainless steel breathing tubes (at the top and front of the bell housing) with alcohol to disinfect them.

8. **Replace the bell**: Insert the clear plastic guides over the rods, then slide the silver clamp under the white screw before lowering the bell. Insert and retighten the pen holder screw, making sure the clear pen holder doesn't rub against the tan wall of the spirometer. Tighten the white screw. CAUTION: Be sure to not secure the white screw too tightly, as this may cause the potentiometer rod to break (a $250 repair). Lift the bell and make sure that it moves freely from 0 to 8 liters.

Replace the bell stop. Position the bell stop so that the pen stops at the top line on the paper chart (8.0 liter mark) when the spirometer is filled with air.

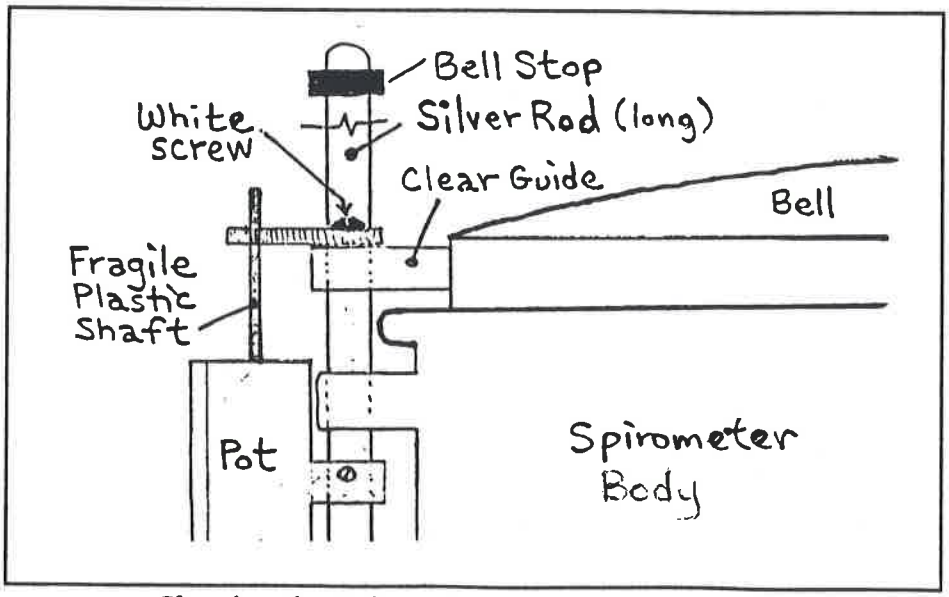
9. Attach a clean blue internal hose securely. Reattach the cable to the computer. Wait until ready to operate the spirometer again, then refill it with one liter of **distilled** water and attach a clean breathing tube.

Calibration Syringe Care

The 3.00 liter calibration syringe should be stored next to the spirometer so that it remains at the same temperature as the spirometer. Store the syringe with the plunger pushed all the way in. Take care not to drop the syringes.

DO NOT attempt to make any adjustments to the syringe. Do not loosen the metal rings on the shafts, since this will spoil the factory calibration. The accuracy of each syringe will be verified by returning it to the manufacturer for measurement of its water displacement at the beginning of the last year of testing or whenever any evidence of physical damage to the syringe is noticed.

You should periodically check each syringe for leaks. Fill it with air, hold your palm against the outlet snout, and try to empty it. If you can expel any air with the outlet plugged, the syringe has a leak and must be repaired.



Cleaning the Spirometer

TECH CERTIFICATION

The certification examination includes 50 multiple choice questions based on this Manual of Procedures, and a practical demonstration of skills including leak and calibration checks, cleaning, and testing of a naive subject (50 points). A passing score of at least 75 points is necessary for certification. Only certified technicians will perform pulmonary function testing in this study.

Certification of new technicians after the initial central training session may be performed by a centrally trained, certified PF technician. The written exam will be administered locally, and the first 20 PF tests performed will be observed by a certified PF technician and then examined by the PF Reading Center and found to be satisfactory before the new technician is certified. The results of the first 50 spirometry test sessions performed by each technician will be closely examined at the PF Reading Center. Copies of suboptimal quality test sessions with comments for improvements will be mailed to the technician the same day as they are evaluated.

A site visit to the clinical center may be made early during the exam year. Complete calibration, leak, and complete PF testing of at least three participants by each PF certified technician will be observed. Copies of suboptimal quality test sessions will be reviewed. More efficient methods as well as protocol violations will be discussed during the site visits and later in a written report.

QUALITY CONTROL

Need for Spirometry QC. Examination of spirograms from the Framingham study revealed that more than 18% were of clearly unacceptable quality (11). Two more recent studies, with over 12,000 adults each, found that 40 - 50% of the spirometry maneuvers were of unacceptable quality (12-14). Manual measurements from spirograms are tedious and prone to error (15), and deviations in test performance and lack of regular leak checking and calibration can result in loss of study data (16-18).

The Epidemiology Standardization Project (19), the new American Thoracic Society spirometry standards (20), and recent evaluations of commercially available spirometers emphasize the importance of spirometry quality control procedures. Factors which affect spirometry quality (22) include:

1. Participant
2. Maneuvers
3. Technician
4. Equipment
5. Analysis

Feasibility of QC Procedures. Personal computer systems, such as the S&M Instruments system used by the CHS, have been developed and validated by an unbiased University testing program (21). The software assists the pulmonary technician with quality control of maneuvers, calculates the PF variables, suggests interpretations, formats and prints reports, and compresses graphics data for transmission and archival storage (23). The Lung Health Study (24), Cardiovascular Health Study, Framingham Study, and ARIC studies have used similar systems and procedures since 1987. The computerization of spirometry QC procedures dramatically decreases the overhead time associated with spirometry testing.

Implementation of QC Procedures. There are five separate levels of quality control implemented for spirometry testing which address the five factors known to influence the results:

1. Daily spirometer leak and calibration checks using a 3.00 liter syringe as the "gold standard" check the **equipment** accuracy.

2. Eight computerized checks of FVC maneuver acceptability and reproducibility check **every maneuver** immediately after it is performed.

3. The PF technician is trained to recognize the patterns of unacceptable maneuvers, **watching the participant** during the performance, and reviewing the colorfully displayed flow-volume curves on the computer monitor.

4. The results of the leak and calibration checks and the FVC maneuvers are stored and sent to the PF Reading Center for review by the PF QC Supervisor. Monthly reports are compiled for each **technician's performance.**

5. Results from all of the above are taken into account during the **analysis** of the data by the PF Reading Center (3,24). The calibration factors, PF tech's impression of participant and maneuver quality, and the QC supervisor's impression of test session quality are all integrated to obtain the final FEV1 and FVC results reported to the Data Coordinating Center.

6. **Replicate testing** will be performed on a total of 30 participants scattered throughout the recruitment period. Choice of the participants will be by the Field Center staff, usually a participant who did not complete an exam and must return on another day to finish it. Spirometry should then be performed again by a different PF technician. The PF reading center will then examine the two sets of results for reproducibility.

7. After instrument QC checks, a **biologic control** subject (nonsmoker without asthma) will be tested each Monday morning (the Field Center Supervisor is preferred). The results will be compared with their prior mean values for FVC and FEV1.

Weekly Biologic Control

Type GET from the MAIN MENU. Use the same technician and the same ID number for all tests. It should be 999xxxc where xxx is the tech's 3 digit ID code and c is the appropriate check digit. Press Enter to skipp all the comments. Perform FVC maneuvers as if testing a participant. Store the results and then review the trends by selecting TRD from the MAIN MENU. Ensure that your current FEV1 is within %5 of the mean of your previous values.

QC ANALYSIS AND REPORTING

Each week the PF Reading Center will establish a modem connection with each Field Center and download all PF data for participants tested during the previous week and the calibration result files.

At the PF Reading Center, the result files are read by the PF QC workstation. The PF QC workstation displays the FVC maneuvers from a test session as differently colored flow-volume curves superimposed at the onset of each maneuver. The best maneuver is marked "B". The color of the maneuver sequence number (#1-8) corresponds with the color of that maneuver's flow-volume curve. The peak expiratory flow (PEF), FEV1, forced expiratory time (FET), and forced vital capacity (FVC) follow.

The field center and the PF technician who performed the testing are hidden from the QC Supervisor to avoid bias. The spirometer temperature is displayed and is highlighted if it falls outside the 17-33 degree C range, since BTPS corrections for volume spirometers become less accurate outside of this "normal" range (27).

After evaluating the flow-volume curves and the array of results, the QC supervisor indicates her choice of the single best maneuver, and enters a test session QC grade from A to F for both flow and volume. The flow grade is an index of reliability of the FEV1 from that test session. A flow grade of **A** is entered if at least 3 maneuvers demonstrate sharp peak flows and if the best two have very reproducible PEFs and reproducible FEV1s (28).

After overreading a batch of test sessions, the QC grades are added to a QC database. All sessions with either a volume or flow grade of **C** or less or with a spirometer temperature outside the normal range are printed, comments are added by the QC Supervisor, and a cover letter is added and mailed to the technician who performed the test. The final, overread PF results are generated and sent by mail to the Coordinating Center at least monthly.

At the end of each month, a report is generated from the QC database, summarizing the performance of each PF technician. For each PF technician, the report includes the number of sessions reviewed and their average QC grades. The report is mailed each month to the Principal Investigators and to all PF technicians.

ANNUAL INSTRUMENT CHECKS

Prior to the onset of each exam year, the following items will be checked by the PF Reading Center to ensure spirometer accuracy:

1. **Spirometer temperature sensor accuracy** - A thermometer accurate to within 0.1 deg C is placed inside the spirometer bell and allowed to equilibrate for an hour. The temperature displayed by the spirometer on the INF screen is then compared with it. If there is more than a 0.3 deg C discrepancy, the correct temperature is entered by using the up arrow to move the cursor to the temp box and entering the correct temperature. The new temp cal factor is then noted using the EQU command.

2. **Volume linearity** - The linearity of the spirometer throughout its volume range is checked using a 1.00 liter calibrated syringe with internal one-way valves (Vitalograph). The LIN command invokes a program which directs the operation of this check. A worst-case linearity of 0.2% is the threshold of acceptability.

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EQUIPMENT AND SUPPLIES

Attach the spirometer cable to the computer with the two screws on the connector, otherwise it will fall off easily. Attach the printer cable to the rear of the PC. Attach all power plugs to the switched outlet strip.

PF Workstation Major Components

1. WE Collins "Survey" spirometer
   potentiometer, temperature sensors, data cable
2. 3.00 L calibration syringe
3. IBM type '386 personal computer
   Pneumoscreen software
   30 Mbyte hard disk
   12 bit A to D converter (SMI)
   Modem, 14.4bps internal, with phone cord
4. Inkjet printer
   parallel cable, power strip
5. VGA color monitor with cables

Spirometry Supplies

Mouthpieces, 1 & 3/8 inch cardboard (regular size), qty 500
Small mouthpieces, 1 inch (optional size), qty 100
Sanitary clear plastic storage box for mouthpieces
Noseclips (qty 10)
Breathing hoses, 36" long (qty 10)
Blue internal spirometer tubes (qty 2)
Denture cups (qty 30)

The tool kit includes:

Blue rubber adaptors for small mouthpieces, qty 2
Rubber stoppers, size #7 (green, spiro) and #8 (black, hose)
Adhesive to repair leaks
Allen wrench, Small screwdriver
Spare inkjet cartridges

Other supplies to be purchased locally:

Standard size copier paper for the printer
Detergent and cleaning bucket
Disinfectant solution (Cidex, Metracide, etc)
White vinegar, Distilled water
Alcohol wipes, Cleaning cloths, Q-tips
Water pitcher, 1 quart size

COMPUTER INTERPRETATION

The Printer Workstation will compare the observed values to those predicted by the CHS baseline data from the healthy participants (27), and then interpret them based on the American Thoracic Society recommendations for disability testing (28):

Interpretation:	Criteria
Normal spirometry:	FEV1/FVC ratio $\geq$70% and FEV1$\geq$80% pred and FVC $\geq$80% pred
Borderline obstruction:	FEV1/FVC ratio < 70% but FEV1$\geq$80% pred.
Mild obstruction:	FEV1/FVC ratio < 70% and FEV1 60% to 79% pred.
Moderate obstruction:	FEV1/FVC ratio < 70% and FEV1 of 41% to 59% pred.
Severe obstruction:	FEV1/FVC ratio < 70% and FEV1 < 40% pred.
Reduced vital capacity:	FVC < 80% pred, in addition to obstruction.
Mild restriction:	FVC 60% to 79% pred, with FEV1/FVC ratio $\geq$ 70%
Moderate restriction:	FVC 51% to 59% pred, with FEV1/FVC ratio $\geq$ 70%
Severe restriction:	FVC 50% or less than pred with FEV1/FVC ratio $\geq$ 70%

MAINTENANCE

Serial cable. The RS-232 serial interface cable uses standard 9 pin IBM PC AT connectors. Only pins 2,3,5,8,9 are connected.

A/D Converter Check. A program to check the A/D converter channels is easily obtained by pressing **ADT** from the MAIN MENU. Nine different options are then displayed on the A/D Check menu. The most useful is "6 Check S&M Channels" which gives a continuous display of the Volume, Flow, and Temperature readings in converted units. You may then move the spirometer bell up and down and watch the Volume and Flow change.

The "7 Check all Channels (Raw)" option on the ADT menu displays the instantaneous Actual inputs in raw A/D counts from 0 to 4000:
Press the R key to reset the "Difference" column to all zeroes and the drift or noise may then be measured by observing the maximum change for each channel.

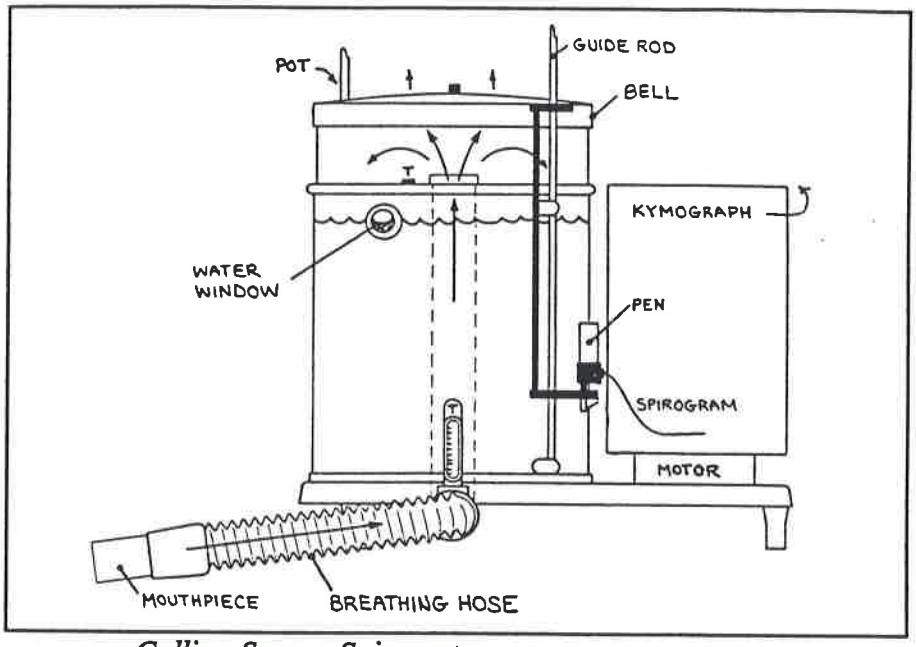
Channel 1 is spirometer Volume. It should be near zero (0-50) when the pen is on the baseline, and increase to close to 4000 when the bell is raised to 8.0 liters. If not, the potentiometer or its connections may be bad.

Channel 2 is Flow (obtained by differentiating the volume signal using an analog circuit on the A/D interface card). It should be about 2000 with no spirometer motion. It should flicker to higher or lower values when the spirometer bell is moved.

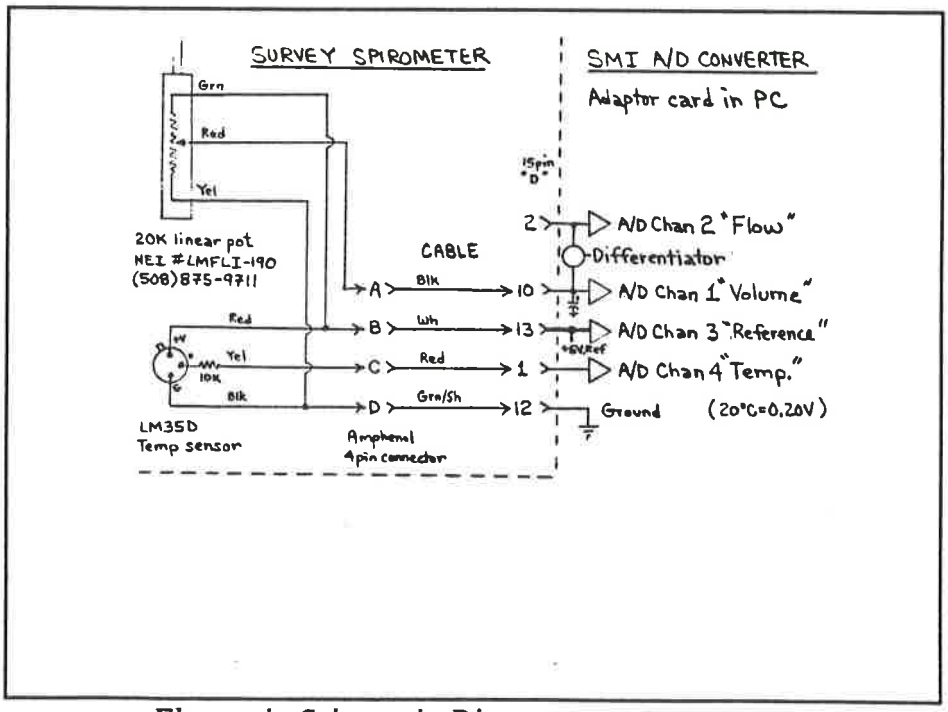
Channel 3 is the Reference voltage (+5 volts DC). It should remain constant at about 4000 counts.

Channel 4 is the spirometer temperature. It should be between 150 and 250 at room temperature (higher at higher temperatures).

Channels 5-8 are not used and should all read 0.



Collins Survey Spirometer.



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SIX MINUTE WALK PROCEDURE

CHS EXAM 9

May 27, 1996 File: 6mwalk.chs

BACKGROUND & RATIONALE

The ability to walk for a distance is an important component of quality of life and is reduced by several types of diseases, including obstructive lung disease, heart failure, arthritis, and neuromuscular disease. The distance walked during six minutes is a quick and safe test, and is an independent predictor of morbidity and mortality. The addition of pulse oximetry during the six minute walk may allow the cause of exercise limitation to be identified.

Pulse Oximetry is a noninvasive method of monitoring arterial blood oxygen saturation (SpO2). The amount of arterial hemoglobin that is saturated with oxygen is determined by beams of light passing through the tissue. The sensor with the light source is placed on the finger or other site. The SpO2 and pulse rate is stored by the portable oximeter with every heart beat and after the exercise, the data is transferred to a personal computer for analysis. Patients with moderate to severe COPD, interstitial lung disease, or heart failure will often show a decrease in their SpO2 during the first minute of exercise which persists during the exercise and recovers to their baseline value during the first minute at the end of the exercise. Healthy persons will show an increase in pulse rate and a slight increase (or no change) in SpO2 during exercise. Changes in SpO2 of less than 4% are within the instrument's measurement noise. Motion artifact can cause false decreases in the measured SpO2.

More than 90% of elderly patients can perform a six minute walk at their own pace, stopping whenever desired. The total time for the test is less than 10 minutes, including 1-2 minutes before and after the walk. The test was introduced in 1976 as the "12 minute corridor walking test" (McGavin 1976), and has been validated by high correlations with workloads, heart rate, oxygen saturation, and dyspnea responses when compared to standard bike and treadmill exercise tests (Langenfeld 1990, Spense 1993). There is a learning effect when performed on two successive days, with a mean 15% improvement in distance walked, but thereafter the repeatability is very good, with a 95th percentile change of -15% to +18% (Leach 1992). The learning effect should not be a problem for us since we are not using it to measure change following an intervention.

In patients with COPD, the six minute walking distance is modestly correlated ($r = .4$ to $.6$) with the FEV1 and peak flow, diffusing capacity (a measure of emphysema), maximal inspiratory pressure (MIP, measured during the CHS baseline exam), MRC dyspnea grade (Mak 1993, Wijkstra 1994), self-reported mobility and energy level (Alonso 1992). The degree of oxygen desaturation during the six minute walk was correlated with pulmonary hypertension in one group of COPD patients (Taguchi 1994).

The six minute walk distance was an excellent independent predictor of morbidity and mortality after only one year in 898 patients with heart failure (CHF or ejection fraction <.45) in the SOLVD study (Bittner 1993). The six minute walk test has also been used safely and successfully in a wide variety of very sick patients to evaluate pacemaker performance (Langenfeld 1990), the outcome of total hip replacement surgery (Laupacis 1993), the need for and efficacy of oxygen therapy during exercise in patients with COPD, interstitial lung disease, and severe kyphoscoliosis (Leach 1992, Jones 1995), and to predict the success of lung transplantation (Holden 1992).

Participants are encouraged to walk from end to end of a hallway at their own pace while attempting to cover as much ground as possible in the allotted period of six minutes. Testing is conducted in a 100 foot section of hallway, with the distance marked every five feet by colored tape along the baseboard.

QUALITY ASSURANCE AND SAFETY All technicians administering the test will read the pulse oximeter operator's manual and this protocol, and will be supervised for their first 8 tests. Exclusions from testing include:

1. Resting oxygen saturation less than 90%
2. Can't walk due to musculo-skeletal problems
3. Heart attack, angioplasty, or heart surgery within 3 months
4. Acute ischemic findings, or frequent PVCs on ECG
5. The participant refuses

EQUIPMENT NEEDED

Countdown timer
Lap Counter
Borg Dyspnea Scale
Nellcor Pulse Oximeter N-3000
Semi-disposible oximeter sensors Nellcor D-25
Paper tape, 2 chairs on rollers
Fingernail polish remover

6 MIN WALK PROCEDURE

1. Set the timer to seven minutes. Set the lap counter to zero.

   Explain the procedure to the participant. If they are wearing dark fingernail polish, ask if you may remove it from the nail of the non-dominant index finger. (If they refuse, place the sensor in a lateral position on the finger.)

2. Position the sensor on the top and bottom of the end of the index finger. Place the light emitter portion on the finger nail side and the detector on the side opposite of the nail. Align the windows (detector and emitter portions of the sensor) over the tissue. Tape the sensor in place securely, but not so tight as to reduce blood flow to the fingertip.

3. Secure the cable independently from the sensor, by taping it to the back of the hand and forearm. Provide stress loops to allow free wrist and finger movement.

4. Complete the preliminary check list provided on the datasheet. Walk participant to the end of hall by the clinic.

5. Obtain the baseline SpO2 and pulse rate as follows:

   a. Plug cable into the oximeter.
   b. Turn on the oximeter. Ensure that finger perfusion (blood flow) is adequate. Obtain the preliminary SpO2 and leave the oximeter on. If necessary reposition and/or retape the sensor.

6. Instruct the participant:

   a. "Please walk from end to end of the hallway."
   b. **"Attempt to complete as many laps as possible in the six minutes without jogging or running."**
   c. "Please refrain from talking, singing, or whistling."
   d. "Please stop walking and stay where you are when I call out STOP."

NOTE: THE DISTANCE COVERED IS THE MOST IMPORTANT DATA COLLECTED. EMPHASIZE TO THE PARTICIPANT THAT THEY SHOULD COVER AS MUCH GROUND AS POSSIBLE DURING THE SIX MINUTES.

7. Place a chair to the side of the 0 and 100 foot marks. You can take the zero mark chair with you should your participant need to rest and can not make it to either chair. If the participant needs to rest, the clock continues to keep time. The participant may sit, and then resume the walk as soon as they are able until the six minutes have elapsed. If they pause to rest, indicate this on the worksheet.

8. Hold up the Borg Dyspnea Scale and ask the Participant to point to the number indicating their current degree of shortness of breath on the worksheet.

9. Record the baseline SpO2 and pulse on the datasheet.

10. Instruct the Participant to start the walk while starting the timer.

11. When the Participant comes by you, state the time elapsed and encourage them by saying:

    "You're doing well" or **"Keep up the good work"**.

    DO NOT USE OTHER PHRASES

12. MOST IMPORTANT: Keep count each time the Participant changes direction (makes the turn at end of hall) by pressing the counter.

13. When the timer reaches "0100" call out "STOP" and identify time from a clock.

14. Taking the chair on rollers, walk over to the participant and identify the current SpO2 and pulse. Allow him/her to be seated until the timer sounds. Turn off the oximeter when timer reaches the "0000" and beeps (Press the "0" key).

15. Using the Borg Dyspnea Scale, ask them to identify the number indicating the current degree of shortness of breath.

16. Ask if they are experiencing any dyspnea, chest pain, lightheadedness, leg pain, and/or other symptoms as a result of the walk.

17. Identify the distance walked to nearest foot.

18. Identify the number of laps completed from the lap counter.

19. Walk the Participant to an exam room. Allow them to sit if desired. Offer them a glass of water.

20. Disconnect the oximeter sensor, and thank the participant.

21. Download the data into the personal computer used for spirometry. Complete the Final Check List, and jot your initials on the worksheet.

DATA DOWNLOAD FROM PULSE OXIMETER

To download data from the pulse oximeter to the personal computer used for spirometry, perform the following steps.

1. Remove the sensor cable from the oximeter.

2. Plug the power supply cable into the oximeter base.

3. Plug the serial interface cable into the oximeter.

4. Turn ON the oximeter.

5. From the spirometry MAIN MENU, select "F1-Tests,"
   and then select "OXY - receive data from oximeter."

6. The oximeter transfer software will run, flashing several irrelevant messages on the screen. When you see the message "N-3000 Trend STOP Reply received" at the bottom of the screen, press the spacebar.

7. The participant data entry screen will then be displayed.
   Enter the requested information from the six minute walk worksheets.

The program will then store the oximetry data and return to the MAIN MENU.

6 MIN WALK REFERENCES

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Structure of RESULTS.DAT for CHS

Field	Type	Width	Decimal Places
0. STUDY ID	N	4	fixed "1084"
1. ID	N	7	
2. NAME	C	6	
3. DATE	D	8	e.g. 10/21/93
5. SEX	C	1	M=male, F=female
6. HEIGHT	N	5	1
8. AGE	N	3	0
12. VPRED	N	5	2
13. FPRED	N	5	2
14. SVC	N	5	2
18. NECK_CM	N	4	1
19. TECHID	N	3	0
45. FQC	N	1	A=4...F=0
46. VQC	N	1	A=4...F=0
47. FVC	N	5	2
48. FEV1	N	5	2

Note: Neck size and Techid are taken from comment fields in the S&M patient data screens.

Structure of RESULTS.DAT for CHS

Field		Type	Width	Decimal Places
0.	STUDY ID	N	4	fixed "1084"
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12.	VPRED	N	5	2
13.	FPRED	N	5	2
14.	SVC	N	5	2
18.	NECK_CM	N	4	1
19.	TECHID	N	3	0
45.	FQC	N	1	A=4...F=0
46.	VQC	N	1	A=4...F=0
47.	FVC	N	5	2
48.	FEV1	N	5	2

Note: Neck size and Techid are taken from comment fields in the S&M patient data screens.

BOWMAN	TOTAL	NEVER SMOKED	QUIT MORE THAN 1 YR AGO	QUIT LESS THAN 1 YR AGO	CURRE-NT SMOKER
TOTAL	546	250	232	7	57
F = FAST	5% 28	8% 19	6	0	5% 3
D	10% 55	12% 30	18	2	9% 5
C	21% 113	19% 47	51	1	25% 14
B	30% 162	32% 79	66	1	28% 16
A = HIGHEST	34% 188	30% 75	91	3	33% 19

0 1 2 3 4

DAVIS	TOTAL	NEVER SMOKED	QUIT MORE THAN 1 YR AGO	QUIT LESS THAN 1 YR AGO	CURRE-NT SMOKER
TOTAL	647	317	275	10	45
F	2% 10	9	0	0	1
D	6% 37	23	12	0	2
C	10% 65	36	24	0	5
B	31% 202	101	83	4	14
A	51% 333	148	156	6	23

HOPKINS	TOTAL	NEVER SMOKED	QUIT MORE THAN 1 YR AGO	QUIT LESS THAN 1 YR AGO	CURRE-NT SMOKER
TOTAL	500	246	207	8	39
F	3% 14	9	5	0	0
D	7% 36	19	12	1	4
C	10% 50	29	17	0	4
B	35% 173	72	80	4	17
A	45% 227	117	93	3	14

PITTSBURGH	TOTAL	NEVER SMOKED	QUIT MORE THAN 1 YR AGO	QUIT LESS THAN 1 YR AGO	CURRE-NT SMOKER
TOTAL	555	211	281	14	49
F	3% 17	7	7	1	2
D	8% 44	21	20	1	2
C	14% 79	33	37	2	7
B	28% 158	57	82	6	13
A	46% 257	93	135	4	25

BOWMAN	TOTAL	NEVER SMOKED	QUIT MORE THAN 1 YR AGO	QUIT LESS THAN 1 YR AGO	CURRE-NT SMOKER
TOTAL	546	250	232	7	57
F	9% 47	12% 29	5% 12	0	11% 6
D	8% 46	9% 23	7% 17	28% 2	7% 4
C	20% 109	22% 55	16% 38	29% 2	25% 14
B	22% 118	20% 51	23% 54	0	23% 13
A	41% 226	37% 92	48% 111	43% 3	35% 20

DAVIS	TOTAL	NEVER SMOKED	QUIT MORE THAN 1 YR AGO	QUIT LESS THAN 1 YR AGO	CURRE-NT SMOKER
TOTAL	647	317	275	10	45
F	6% 41	9% 30	3% 7	0	9% 4
D	4% 28	6% 19	3% 8	0	2% 1
C	10% 63	9% 29	10% 28	0	13% 6
B	22% 140	22% 71	19% 53	50% 5	24% 11
A	58% 375	53% 168	65% 179	50% 5	51% 23

HOPKINS	TOTAL	NEVER SMOKED	QUIT MORE THAN 1 YR AGO	QUIT LESS THAN 1 YR AGO	CURRE-NT SMOKER
TOTAL	500	246	207	8	39
F	7% 35	8% 20	7% 14	0	3% 1
D	6% 28	6% 14	5% 10	0	10% 4
C	11% 57	12% 30	9% 19	13% 1	18% 7
B	21% 107	22% 55	19% 39	37% 3	26% 10
A	55% 273	52% 127	60% 125	50 4	44% 17

PITTSBURGH	TOTAL	NEVER SMOKED	QUIT MORE THAN 1 YR AGO	QUIT LESS THAN 1 YR AGO	CURRE-NT SMOKER
TOTAL	555	211	281	14	49
F	5% 30	6% 12	5% 13	14% 2	6% 3
D	7% 37	9% 18	5% 15	14% 2	4% 2
C	14% 77	16% 33	13% 36	7% 1	14% 7
B	23% 128	22% 46	22% 62	43% 6	29% 14
A	51% 283	46% 102	55% 155	21% 3	47% 23