The Advancement of Rwandan Rehabilitation Services Project

Presents

Respiratory Rehabilitation

January 29-30, 2015

Taught by
Lori M. Kohls, PT, DPT, PCS

Presented in Partnership with
Acknowledgements

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Health Volunteers Overseas gratefully acknowledges the work of HVO volunteer Lori M. Kohls, PT, DPT, PCS in developing and teaching the course, “Respiratory Rehabilitation.”
Pulmonary Physical Therapy
Lori Kohls, PT, DPT, PCS
ARRSP, HVO Rwanda
January 2015

Objectives
At the end of the course, all participants will be able to:
• Auscultate lungs and describe findings with standardized terms
• Perform manual CPT with postural drainage to all lobes
• Understand benefits and contraindications for manual CPT
• Teach incentive spirometry to various ages and describe benefits
• Demonstrate correlation between posture and breathing and describe atypical postures found in chronic lung conditions.
• Develop an individualized pulmonary rehab protocol.

Normal Lung Physiology

Lobes

Alveoli: Tiny air sacs within the lungs where the exchange of oxygen and carbon dioxide takes place
Diaphragm

Inhalation: Diaphragm lowers, chest cavity expands and draws air IN

Exhalation: Diaphragm raises, chest cavity contracts to push air OUT
**Tidal Volume (VT):** Amount of air inspired and expired during normal resting ventilation (~ 500 mL)

**Inspiratory Reserve Volume (IRV):** The volume of air that can be inspired when needed. The “room to breathe” (~3000 mL)

**Inspiratory Capacity (IC):** VT + IRV

**Expiratory Reserve Volume (ERV):** Amount of air that can be exhaled beyond the end of a tidal exhalation (~1000 mL)

**Reserve Volume (RV):** Air remaining in lungs after ERV has been exhaled (~1500 mL)

**Functional Reserve Capacity (FRC):** Sum of RV and ERV

**Vital Capacity (VC):** Sum of the three volumes that are under voluntary control.

\[
\text{IRV} + \text{TV} + \text{ERV} = \text{VC} \\
3000 + 500 + 1000 = 4500 \text{ mL}
\]

**Total Lung Capacity (TLC):** The sum of the 4 lung volumes

\[
\text{VT} + \text{IRV} + \text{ERV} + \text{RV} = \text{TLC} \\
500 + 3000 + 1000 + 1500 = 6000 \text{ mL}
\]

**Forced Vital Capacity (FVC):** Maximal volume of air one can forcefully exhale after a maximal inspiration.

This is measured during pulmonary function testing (PFT).
**Pulmonary Function Testing**
Performed using spirometer (instrument designed to measure lung volumes and air flow)
In Rwanda this is performed by the pulmonologist.
Used to assess the status of the lungs including:
   - How much air volume can be moved in and out of the lungs
   - How fast the air in the lungs can be moved in and out
   - How stiff are the lungs and chest wall

**Forced Expiratory Volume in one second (FEV1)**
The volume of air that can be forcefully exhaled in the first one second of the forced vital capacity maneuver.
FEV1 = >75% FVC
   - Healthy young man: 4500 x 0.75 = 3375 mL

**FEV1/FVC Ratio**
Used to determine whether airflow obstruction is present.
   - FEV1 estimates severity of obstruction
Healthy Male: 3375/4500 = 0.75
COPD = <0.70 (Post bronchodilator, according to GOLD)
Asthma = post bronchodilator, should normalize

PFT predicted values depend on 4 characteristics:
   - Age, Height, Gender, and Ethnicity
Predicted value: Value patient should achieve based on above characteristics
Percent predicted value: value comparing measured value to predicted value.
Age: Lung function plateaus between 20-30 yrs old.
   - Decline in FEV1 of 25-30 mL/yr in healthy non-smokers
   - RV increases, maintaining TLC volume
Height: Differences in trunk length relative to standing height. Larger thoracic cavity will have larger TLC.
Gender: women have smaller lungs than men.
Ethnicity:
   - Trunk length relative to standing height
   - Fat-free mass
   - Chest dimensions
   - Respiratory muscle strength
Abnormal Lung Physiology

Pneumonia (PNA): lung infection caused by virus or bacteria.
Asthma: spasms in the bronchi of the lungs causing difficulty breathing
COPD: Chronic obstructive pulmonary disease
Atelectasis: collapse of the alveoli
Pleural effusion: excess fluid builds around the lung in plural space
Pneumothorax: air pockets in plural space
CF: Cystic fibrosis - disease of sodium transport ions causing thick mucus to build in lungs.

Obstructive diseases: cause increased airflow obstruction causing air trapping in lungs.

Examples: COPD, asthma, bronchiectasis, CF

GOLD Classification of severity of COPD

<table>
<thead>
<tr>
<th>Stage</th>
<th>FEV₁/FVC</th>
<th>FEV₁</th>
</tr>
</thead>
<tbody>
<tr>
<td>I - Mild COPD</td>
<td>&lt; 70</td>
<td>FEV₁ ≥80% predicted</td>
</tr>
<tr>
<td>II - Moderate COPD</td>
<td>&lt; 70</td>
<td>FEV₁ &gt;50% &amp; &lt;80% predicted</td>
</tr>
<tr>
<td>III - Severe COPD</td>
<td>&lt; 70</td>
<td>FEV₁ ≥30% &amp; &lt;50%</td>
</tr>
<tr>
<td>IV - Very Severe COPD</td>
<td>&lt; 70</td>
<td>FEV₁ &lt;30% OR &lt;50% with signs of chronic respiratory failure</td>
</tr>
</tbody>
</table>

GOLD: Global Initiative for Chronic Obstructive Lung Disease
Obstructive Lung Disease PFTs

<table>
<thead>
<tr>
<th>Spirometry</th>
<th>Measured</th>
<th>Predicted</th>
<th>% Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC (L)</td>
<td>3.00</td>
<td>5.27</td>
<td>57%</td>
</tr>
<tr>
<td>FEV1 (L)</td>
<td>1.23</td>
<td>4.09</td>
<td>30%</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>41</td>
<td>78</td>
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Lung Volumes

<table>
<thead>
<tr>
<th></th>
<th>Measured</th>
<th>Predicted</th>
<th>% Predicted</th>
</tr>
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<tbody>
<tr>
<td>TLC (L)</td>
<td>8.85</td>
<td>7.05</td>
<td>126%</td>
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<tr>
<td>RV (L)</td>
<td>5.85</td>
<td>1.93</td>
<td>303%</td>
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</table>

Restrictive diseases: decreased compliance of thorax and lung tissues causing poor gas exchange.

- Intrinsic Restrictive Lung Disorders: Sarcoidosis, Tuberculosis, Pneumonectomy (loss of lung), Pneumonia
- Extrinsic Restrictive Lung Disorders: Scoliosis, Kyphosis, Ankylosing Spondylitis, Pleural Effusion, Pregnancy, Gross Obesity, Tumors, Pain on inspiration (rib fracture, pleurisy)
- Neuromuscular Restrictive Lung Disorders: Generalized Weakness – malnutrition, Paralysis of the diaphragm, Muscular Dystrophy, Poliomyelitis, Amyotrophic Lateral Sclerosis

Restrictive Lung Disease PFTs

<table>
<thead>
<tr>
<th>Spirometry</th>
<th>Measured</th>
<th>Predicted</th>
<th>% Predicted</th>
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<tbody>
<tr>
<td>FVC (L)</td>
<td>1.74</td>
<td>4.25</td>
<td>41%</td>
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<tr>
<td>FEV1 (L)</td>
<td>1.66</td>
<td>3.37</td>
<td>49%</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>95</td>
<td>79</td>
<td></td>
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<tr>
<td>Lung Volumes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TLC (L)</td>
<td>3.47</td>
<td>5.94</td>
<td>58%</td>
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<tr>
<td>RV (L)</td>
<td>1.73</td>
<td>1.90</td>
<td>91%</td>
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## Case #1:

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<td>FVC (L)</td>
<td>1.85</td>
<td>4.30</td>
<td>43%</td>
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<td>FEV1 (L)</td>
<td>0.53</td>
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<td>FEV1/FVC</td>
<td>29</td>
<td>73</td>
<td></td>
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<tr>
<td>Lung Volumes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TLC (L)</td>
<td>9.37</td>
<td>6.21</td>
<td>151%</td>
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<tr>
<td>RV (L)</td>
<td>7.52</td>
<td>2.26</td>
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Obstructive or Restrictive disease?
Severity?
Notes:

## Case #2:

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<td>FEV1 (L)</td>
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<td>18%</td>
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<tr>
<td>Lung Volumes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TLC (L)</td>
<td>7.71</td>
<td>5.11</td>
<td>151%</td>
</tr>
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<td>RV (L)</td>
<td>5.74</td>
<td>1.65</td>
<td>347%</td>
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Obstructive or Restrictive disease?
Severity?
Notes:
### Case #3:

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<td>FEV1 (L)</td>
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<td>FEV1/FVC</td>
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<td>82</td>
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**Lung Volumes**

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<th>Predicted</th>
<th>% Predicted</th>
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<tr>
<td>TLC (L)</td>
<td>6.23</td>
<td>6.45</td>
<td>96%</td>
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<td>RV (L)</td>
<td>1.82</td>
<td>1.89</td>
<td>96%</td>
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Obstructive or Restrictive disease?  
Severity?  
Notes:

### Case #4:

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<th>Measured</th>
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<td>FVC (L)</td>
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<td>5.68</td>
<td>78%</td>
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<td>FEV1 (L)</td>
<td>3.52</td>
<td>4.90</td>
<td>72%</td>
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<td>FEV1/FVC</td>
<td>79</td>
<td>84</td>
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**Lung Volumes**

<table>
<thead>
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<th>Predicted</th>
<th>% Predicted</th>
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<tr>
<td>TLC (L)</td>
<td>4.91</td>
<td>6.42</td>
<td>76%</td>
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<td>RV (L)</td>
<td>1.89</td>
<td>2.26</td>
<td>83%</td>
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Obstructive or Restrictive disease?  
Severity?  
Notes:
Case #5:

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<td>FVC (L)</td>
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<td>3.21</td>
<td>94%</td>
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<td>FEV1 (L)</td>
<td>0.74</td>
<td>2.47</td>
<td>30%</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>25</td>
<td>77</td>
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### Lung Volumes

<table>
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<th>Measured</th>
<th>Predicted</th>
<th>% Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLC (L)</td>
<td>6.96</td>
<td>4.64</td>
<td>150%</td>
</tr>
<tr>
<td>RV (L)</td>
<td>3.69</td>
<td>1.70</td>
<td>217%</td>
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Obstructive or Restrictive disease?
Severity?
Notes:
Lung Sounds

Technique for auscultation:
- Quiet room
- Insert into ears in correct direction
- Preferably on skin (can do over thin shirt if needed)
- Use diaphragm side for higher pitch, bell for lower pitch.
- Ask patient to refrain from speaking

Note differences in sounds in different parts of lungs
Recognize normal versus abnormal sounds.

Normal Lung Sounds

Vesicular- caused by the normal movement of air through the bronchioles during inspiration and expiration

Bronchial- present over the large airways near the second and third intercostal spaces. These sounds are more tubular and hollow sounding than vesicular sounds

Abnormal Lung Sounds

Crackles/rales- caused by interstitial fluid or plasma that has leaked in the airways. They are characterized as discontinuous high pitched bubbling sounds

Wheeze- characterized by a high pitched continuous sound that occurs either at the end of inspiration or during the expiratory phase. They are caused by the narrowing of airways around an obstruction.

Rhonchi- caused by the same expansion and narrowing of the airways as sibilant wheezes. The difference between the two is that rhonchi are typically associated with secretions that are obstructing the larger airways. This causes a lower pitched vibrating sound on auscultation that is similar to snoring.

Plural rub- caused by an inflammation of either the visceral and/or parietal pleura. It is characterized by a low-pitched grating sound.
**Airway Clearance**
Assists in removal of thick secretions in the lungs.
Most effective portion of airway clearance is HUFF and COUGH for mobility of secretions

Airway clearance includes:
- Manual chest PT (percussion, vibration, postural drainage)
- Autogenic drainage
- PEP (positive expiratory pressure) devices
- Exercise (at intensity to increase ventilatory response)

Common diagnosis:
- Pnuemonia
- Cystic Fibrosis
- Asthma
- bronchiectasis
- lung abscess

Common symptoms:
- secretion retention
- persistent rhonchi
- decreased breath sounds
- subjective signs of difficulty expectorating sputum
- progression of disease that might be due to secretion retention
- recurrent exacerbations
- infections
- fast decline in pulmonary function

The techniques may also be effective for a patient who cannot cough up sputum effectively, as may happen with older people or with people who have muscle weakness or who are recovering from surgery, injury, or severe illness.

**Effectiveness of Airway Clearance**
Sputum production
- Increased following treatment?
Lung sounds
- Listen to patient before and after treatment- do breath sounds improve?

Patient Report
- Does the patient feel better following treatment?
Use this information to determine most effective strategy for YOUR patient.
Signs of Mucus Retention
Chronic suppurative airway disease
Frequent exacerbations or infections
Rapid decline of pulmonary function
Subjective difficulty in clearing mucus
Persistent rhonchi

Yes

Cough or huff effective?

Yes

No indication for CPT

No

Try to improve the patient's adherence to treatment

Effective

Try huffing or coughing with less force and starting at higher lung volume

Ineffective

No

Signs of airway collapse

Yes

No

Consider Other Airway Clearance Techniques
Autogenic drainage, exercise, PEP, vibratory PEP, high-frequency chest wall compression
**Manual Chest PT**

**Contraindications:**
- unable to tolerate the position required
- anticoagulation drugs
- recently vomited up blood
- Recent hemoptysis (within 24 hrs)
- recent rib or vertebral fracture
- severe osteoporosis
- Pneumothorax or pleural effusion (Air or fluid in pleural space)
- Postural drainage also should not be used for people who are unable to produce any secretions.

**Postural Drainage**
Postural drainage pertains to placing the body in a position that allows the mucus to drain from the smaller airways into the main airway with gravity. To obtain the head-down positions, the use of a pillow, a bean bag chair or couch cushions works well.

**Percussion**
Percussion and vibration help loosen and mobilize secretions. Percussion is a repetitive tapping on the designated position. The palm of your hand should be cupped to provide a pocket of air that cushions the percussion. 2-3 beats per second rate of percussion

**Vibration**
Vibration is done at the end of the 3-5 minutes of percussion in each position. After a big breath in, vibrate when the air is slowly blown out, for three big breaths. Using palms on area just percussed
Cue patient to take a deep breath in
As they slowly exhale, use your palms to vibrate their chest
Perform 3-5 cycles
Cue patient for a strong cough at end
6 Positions for manual CPT

CPT Recommendations

Each position requires proper placement for percussion and should be done for three to five minutes followed by 3-5 cycles of vibration.
A strong cough is encouraged after each position to remove the mucus.
Nothing should be placed in the mouth (pacifiers, food, etc.) while doing manual chest physiotherapy.
It is recommended that manual chest physiotherapy be done before meals and bedtime.
Frequency of 3-4x/day during period of illness, can be used daily for chronic lung patients (CF) to prevent recurrent infections.
Chest Physiotherapy in the NICU

- Previously standard of care for all babies post-extubation.
- Recent studies questioning efficacy and safety of procedure in neonates.
- Very stressful event - increased heart rate, blood pressure and intracranial pressure.
- May aggravate gastro-esophageal reflux
- Limited value when applied prophylactically to all babies after extubation.
- No significant differences in apneic episodes, need for re-intubation, oxygen requirements or duration of oxygen therapy between CPT and control group (position changes and suctioning every 4 hrs.)
- No evidence of increased risk of inter-cranial hemorrhage when performed on infants >1000g and are medically stable.
  - Intolerance of CPT described as SpO2 < 85% OR heart rate <100 bpm for 4 seconds or longer.
  - Neurological signs and known IVH
- Benefits babies with chest x-ray changes indicating increased secretions or mucus plugging
- Perform CPT in the NICU judiciously
- Know WHY you are doing the procedure and what results you expect
- Don’t be afraid to try something else if you feel that it will work better, or work the same with less stressful conditions for the neonate.
**Autogenic Drainage Breathing Techniques**

AD uses air that you breathe out to move mucus from the smaller airways to the central airways.

Once it is in the central airways it can be cleared out. There are three phases of the breathing exercise:

"Unsticking" the mucus in the smaller airways by breathing in the base of your lungs,
"Collecting" the mucus from the middle airways by breathing at low to mid lung levels,
"Evacuating" the mucus from the central airways by breathing at mid to high lung levels.

First: breathe all the way in, then all the way out.
Breathe in a small amount into the bases of your lungs and pause, then sigh the air out through an open mouth.
Repeat the cycle. Inhale slowly to avoid sending the mucus back down. Keep breathing at the low level until the mucus collects and moves upward.

**Signs of this are:**
Crackling of the mucus can be heard as you exhale.
You feel the mucus moving up.
You feel a strong urge to cough.

The level of breathing is raised when mucus collects. Moving the breathing from lower to higher lung area takes the mucus with it.
Finally the collected mucus reaches the large airways where it can be cleared by a high lung volume huff. Don't cough until the mucus is in the larger airways.
The Three Lung Levels of Autogenic Drainage:

**Level One:** "Unsticking" of mucus by low lung level breathing. First, exhale completely; inhale a small to normal breath. Hold the breath for 1-3 seconds, then exhale completely again. This step is repeated for 1-3 minutes. Repeat until crackles are heard when breathing out.

**Level Two:** "Collecting" the mucus in larger or mid-sized airways. Take in a slightly larger breath. Hold for 1-3 seconds, and then exhale, but not as low as in level one. Repeat this step for 1-3 minutes. Listen for crackles at the end of exhaling. Continue for 2-3 more breaths. Then proceed to level III.

**Level Three:** "Evacuating" the mucus in the central airways is achieved by breathing at normal to high volumes. Take in a slow deep breath. Hold the breath for 1-3 seconds. Exhale forcefully with open glottis. This moves the mucus into your mouth. Then spit it out into a container or tissue.

Each level requires about 2-3 minutes. The full cycle takes 6-9 minutes. When mucus is felt in the larger, central airways, do 2-3 effective "Huff" type coughs. The Huff cough uses the mid to high lung volumes of level III.

Coughing should be avoided if possible in levels I and II. Do 2-3 Huff coughs if you must cough.
**Incentive Spirometry**

Indications for use
- Improve lung capacity
- Open areas of atelectasis (collapsed alveoli)
- Can assist in airway clearance

General guidelines
- Perform deep breath to maximum capacity 10 times.
- Complete every hour when awake until lung function improves

Techniques for adapting to pediatrics
- Bubbles
- Blowing paper
- Pinwheels
- Focus on inhalation
- Blowing up balloon
**Posture**

Typical postures for diagnosis

**Barrel chest:** due to bucket handle motion and tight intercostals

**Kyphosis:** due to increased use of accessory muscles

**Digital clubbing**
Result of chronic hypoxia
Posture and Breath correlation
Forces that affect respiration also affect posture
Soda Can Model (ref) illustrates this concept
Aluminum can is flimsy and thin, but when unopened is functionally strong.
When opened, loses its strength and is easily crushed.
The trunk of the body is similar, and requires muscular strength to prevent
external forces from crushing it.

Figure 1: Clinical application of the concept of the ‘crushed soda-pop’ can.
Melissa, age 3.5 years, had a C5 complete spinal cord injury secondary to a
traumatic birth experience. Notice that her skeletal frame (her ‘aluminum shell’)
has collapsed upon itself. Melissa’s paralysis prevents her from generating
adequate internal pressures in her thoracic and abdominal cavities that could
counteract the force of gravity upon her ‘aluminum shell’, thus her skeletal shell
gives way to the external pressure.
Figure 2 Soda-pop can model of postural control and respiration. (a) Shows the dual relationship of the trunk muscles for postural support and ventilation. Note that the control of the internal trunk pressures begins at the vocal folds and ends at the pelvic floor. Any breech in the system will result in an unintended release of pressure through the ‘weak’ spot. Clinically, this undesired release of internal pressure may be expressed by urinary stress incontinence, a poor balance reaction, poor breath support, weak cough, etc. (b) Illustration of the primary internal organ systems that either generate or use the internal pressures in the thoracic and abdominal cavities to improve their functional performance. For example, if the abdominal muscles are weak and cannot generate adequate abdominal pressure, the clinical result may be slow gastric emptying and/or low blood pressure. (GI, gastrointestinal)

Figure 3 Pressure dysfunction related to cystic fibrosis (CF). Children with CF have the opposite problem than that of children with neurologic dysfunction. Due to their lung pathology, they exert excessive, repetitive, positive pressure on their skeleton secondary to coughing. This causes abnormal, prolonged outward pressures, like a soda-pop can that was frozen. (a) Note outward displacement of the top of the frozen can of soda-pop. (b) Clinically, this excessive pressure may be reflected as a thoracic kyphosis*, urinary stress incontinence, protracted scapulae, etc. [Ref.]
As musculoskeletal specialists, there is more that we can do than just airway clearance for these patients!

Strengthen core musculature:

Pelvic floor: “Kegel Exercises” Refer to following pages for more information.

Lower abdominals:

Scapular musculature:

Stretch-
Pectoral muscles
**Stretch:**
Upper abdominals:

Lateral trunk flexors:

**Posture and breath correlation**
Extension of spine with inhalation, flexion with exhalation

**Breath with movements**
Cat and camel:
Pelvic Floor strengthening

Men

How can I find my pelvic floor muscles?
The first step in performing pelvic floor muscle exercises is to identify the correct muscles. There are several ways to identify them.

Method 1 - Stopping the flow
When you go to the toilet, try to stop or slow the flow of urine midway through emptying your bladder. If you are able to do this you are squeezing the correct muscles. Do not do this repetitively. This is not an exercise, but a way to identify the correct muscles.

Method 2 - Visualization
Stand in front of the mirror (with no clothes on) and tighten your pelvic floor muscles. If you are tightening the right muscles, you should see the base of the penis draw in and scrotum lift up. The back passage will tighten too but it is not the focus of the exercise. When you relax your muscles you should feel a sensation of ‘letting go’.

Women

How can I find my pelvic floor muscles?

Method 1 - Stopping the flow
The first step in performing pelvic floor muscle exercises is to identify the correct muscles. There are several ways which may help you to correctly identify the different parts of your pelvic floor muscles. One way is to try to stop or slow the flow of urine midway through emptying the bladder. Stopping the flow of urine repeatedly on the toilet is not an exercise, but a way of identifying your pelvic floor muscles. This should only be done to identify which muscles are needed for bladder control.

If you can, stop the flow of urine over the toilet for a second or two, then relax and finish emptying without straining. This ‘stop-test’ may help you identify the muscles around the front passage which control the flow of urine. It is not recommended as a regular exercise.

Method 2 - Visualization
Another method to identify your pelvic floor muscles is to imagine stopping the flow of urine and holding in flatus (wind) at the same time. This can be done lying down, sitting or standing with legs about shoulder width apart.

- Relax the muscles of your thighs, bottom and tummy.
- Squeeze in the muscles around the front passage as if trying to stop the flow of urine.
- Squeeze in the muscles around the vagina and suck upwards inside the pelvic.
- Squeeze in the muscles around the back passage as if trying to stop passing wind.
- The muscles around the front and back passages should squeeze up and inside the pelvis.
- Women who are familiar with using tampons can imagine squeezing in the vagina as if squeezing a tampon up higher in the vagina.
- Identify the muscles that contract when you do all these things together. Then relax and loosen them.
Getting the technique right

This is the most important part of the pelvic floor muscle exercises as there is no point doing them if you are not doing them correctly. Imagine letting go like you would to pass urine or to pass wind. Let your tummy muscles hang loose too. See if you can squeeze in and hold the muscles inside the pelvis while you breathe. Nothing above the belly button should tighten or tense. Some tensing and flattening of the lower part of the abdominal wall will happen. This is not a problem, as this part of the tummy works together with the pelvic floor muscles.

Try tightening your muscles really gently to feel just the pelvic floor muscles lifting and squeezing in. If you cannot feel your muscles contracting, change your position and try again. For example, if you cannot feel your muscles contracting in a seated position, try lying down or standing up instead.

After a contraction it is important to relax the muscles. This will allow your muscles to recover from the previous contraction and prepare for the next contraction.

Exercising your pelvic floor muscles

If you have mastered the art of contracting your pelvic floor muscles correctly, you can try holding the inward squeeze for longer (up to 10 seconds) before relaxing. Make sure you can breathe easily while you squeeze. If you can do this exercise, repeat it up to 10 times, but only as long as you can do it with perfect technique while breathing quietly and keeping everything above the belly button relaxed. This can be done more often during the day to improve control.

**Respiratory Acidosis**

Respiratory acidosis is a condition that occurs when the lungs cannot remove all of the carbon dioxide the body produces. This causes body fluids, especially the blood, to become too acidic. Excess carbon dioxide in the blood will cause the blood to become more acidic.

Aqueous carbon dioxide, CO₂, reacts with water forming carbonic acid, H₂CO₃. Carbonic acid may loose protons to form bicarbonate, HCO₃⁻, and carbonate, CO₃²⁻. In this case the proton is liberated to the water, decreasing pH.

Normal blood pH = 7.35-7.45

**Causes of respiratory acidosis include:**

- Diseases of the airways (such as asthma and chronic obstructive lung disease)
- Diseases of the chest (such as scoliosis)
- Diseases affecting the nerves and muscles that "signal" the lungs to inflate or deflate
- Drugs that suppress breathing (including powerful pain medicines, such as narcotics, and "downers," such as benzodiazepines), especially when combined with alcohol
- Severe obesity, which restricts how much the lungs can expand

**Chronic respiratory acidosis** occurs over a long period of time. This leads to a stable situation, because the kidneys increase body chemicals, such as bicarbonate, that help restore the body's acid-base balance.

**Acute respiratory acidosis** is a condition in which carbon dioxide builds up very quickly and before the kidneys can return the body to a state of balance.

**Symptoms may include:**

- Confusion
- Easy fatigue
- Lethargy
- Shortness of breath
- Sleepiness

**Treatment:**

Aimed at the underlying disease, and may include:

- Bronchodilator drugs to reverse some types of airway obstruction
- Noninvasive positive-pressure ventilation (sometimes called CPAP or BiPAP) or a breathing machine, if needed
- Oxygen if the blood oxygen level is low
• Treatment to stop smoking

**Respiratory Alkalosis**
Respiratory alkalosis is a condition marked by low levels of carbon dioxide in the blood due to breathing excessively.

**Common causes include:**
- Anxiety
- Fever
- **Hyperventilation**
- Any lung disease that leads to shortness of breath can also cause respiratory alkalosis.

**The symptoms may include:**
- Dizziness
- Lightheadedness
- Numbness of the hands and feet

**Treatment:**
Aimed at the condition that causes respiratory alkalosis.
Breathing into a paper bag -- or using a mask that causes you to re-breathe carbon dioxide -- sometimes helps reduce symptoms.
**Ventilators:**
Mechanical ventilation is used when the patient cannot maintain an airway or adequate oxygenation or ventilation.
Mechanical ventilators are set to deliver a constant volume, a constant pressure or a combination of both with each breath.

**Assist-control ventilation (A/C)** maintains a minimum respiratory rate regardless of whether or not the patient initiates a spontaneous breath.

**Peak airway pressure**
The total pressure needed to push gas into the lung
Composed of pressures resulting from:
- inspiratory flow resistance
- elastic recoil of the lung and chest wall
- alveolar pressure present at the beginning of the breath (positive end-expiratory pressure)

**Volume-cycled ventilation**
The ventilator delivers a set tidal volume.
The airway pressure is not fixed but varies with the resistance of the respiratory system and with the flow rate selected.
Includes volume-control (V/C) and synchronized intermittent mandatory ventilation (SIMV)

**Volume Controlled Ventilation**
The simplest and most effective means of providing full mechanical ventilation
Each inspiratory effort beyond the set sensitivity threshold triggers delivery of the fixed tidal volume.
If the patient does not trigger the ventilator frequently enough, the ventilator initiates a breath, ensuring the desired minimum respiratory rate.

**Synchronized Intermittent Mandatory Ventilation (SIMV)**
Delivers breaths at a set rate and volume that is synchronized to the patient's efforts
Patient efforts above the set respiratory rate are unassisted, and the intake valve opens to allow the breath.
Does not provide full ventilator support
Does not help to wean from ventilator support
**Pressure-cycled ventilation**
Includes pressure control ventilation (PCV), pressure support ventilation (PSV)
The ventilator delivers a set inspiratory pressure for the set length of time.
Tidal volume varies depending on the resistance of the respiratory system.

**Pressure control ventilation**
Assist control ventilation
Each inspiratory effort triggers full pressure support maintained for a fixed inspiratory time.
A minimum respiratory rate is maintained.

**Pressure support ventilation**
A minimum rate is not set
All breaths are triggered by the patient
The ventilator assists the patient by delivering a pressure that continues during the length of inspiration.
A longer or deeper inspiratory effort by the patient results in a larger tidal volume.
This mode is commonly used to wean patients from mechanical ventilation by letting them assume more of the work of breathing.

**Ventilator Settings:**

**Tidal Volume**
- Too high a volume risks over-inflation of the lungs
- Too low a volume allows for atelectasis.

**Respiratory Rate**
- Too high a rate risks hyperventilation and respiratory alkalosis along with inadequate expiratory time
- Too low a rate risks inadequate minute ventilation and respiratory acidosis.

**Trigger Sensitivity**
Level of negative pressure required to trigger the ventilator.
A typical setting is ~2 cm H$_2$O.
- Too high a setting causes weak patients to be unable to trigger a breath.
- Too low a setting may lead to over-ventilation by causing the machine to auto-cycle.

**Inspiratory: Expiratory (I:E) ratio**
The ratio of time spent in inhalation versus that spent in exhalation
Patients with normal mechanics ratio are usually 1:3.
Patients with asthma or COPD exacerbations should have ratios of 1:4.
This decreases risk of air trapping and over inflation

**Inspiratory flow rate**
The speed at which the air is delivered to the lungs.
Usually set at about 60 L/min but can be increased up to 120 L/min
Positive End-Expiratory Pressure

Increases end-expired lung volume and reduces airspace closure at the end of expiration.

Usually set at 5 cm H₂O

Limits the atelectasis caused by endotracheal intubation, sedation, paralysis, and/or supine positioning.

Improves oxygenation and decreased FiO₂ level required

Increases intra-thoracic pressure which can impede venous return and cause hypotension

May over-distend portions of the lung causing ventilator-associated lung injury (VALI).

BUT if PEEP is too low- may result in cyclic airspace opening and closing, which in turn may also cause VALI from the resultant repetitive shear forces.

Complications of mechanical ventilation

Ventilator-associated pneumonia

- Elevating the head of the bed to > 30° decreases risk
- Chest physiotherapy can decrease risk

Skin breakdown due to immobility

- Routine turning of the patient every 2 hrs decreases risk

Deep venous thrombosis

- Prophylaxis includes either heparin or sequential compression devices
- Active mobility will decrease risk.

The most effective way to reduce complications of mechanical ventilation is to limit its duration.

Intensive Care Unit

Best practice in ICU includes early mobilization

Progressive rehabilitation includes:

- Passive range of motion
- Active range of motion
- Sitting at edge of bed
- Transfers
- Ambulation

Performed even while the patient requires life support therapies

Benefits of Early Mobilization in ICU

- Reduce muscle atrophy
- Improve strength and physical functioning
- Decrease length of stay in hospital and ICU
- Decrease complications including
  - Venous thromboembolisms
  - Pressure ulcers
Pneumonia
Decrease readmission rate
Decrease cost of care

Guidelines for Early Mobility in ICU
Heart rate: 40-130 bpm
Systolic blood pressure: <180 mmHg
Mean arterial pressure: >65 mmHg
Mechanical ventilation: < 100 mmHg
FiO2 <0.60, PEEP <10
Alertness
Ability to follow commands
Lack of agitation

Patients who are not stable enough to participate should be re-assessed daily to determine eligibility for participation in physiotherapy.

The earlier we can start our intervention, the better!

Coordination with team members is vital for success
Work together to determine appropriateness for mobility
  Oxygen or medication changes required
    Decreased sedation
    Timing of pain medication
    Increased oxygenation support

Barriers to Early Mobility in ICU
  Severity of patient illness
  Safety concerns
  Time constraints
  Staff shortages
  Fear of pulling out lines and tubes

Education can help to break down these barriers and improve patient outcomes.
**Pulmonary Rehabilitation**

Exercise intolerance is a primary symptom in chronic respiratory disease. Typically during exercise, the increased tidal volume rate will increase volume of air to alveoli to provide adequate oxygen needs for increased workload. In healthy individuals, SpO2 remains at 99-100% during exercise. Pulmonary disease makes it difficult to increase alveolar volume, decreasing the gas exchange capabilities and causing hypoxia during exercise.

**Causes of Exercise Intolerance**

- Gas Exchange abnormalities
- Associated cardiac abnormalities
- Lower limb muscle dysfunction
  - Can lose 12% of quadriceps strength per week during bed rest
- Respiratory muscle dysfunction
- Dynamic Hyperinflation of the lungs
- Dyspnea
- Fatigue

**Exercise and Dynamic Hyperinflation**

![Diagram showing normal and affected alveoli with labels for TLC, IC, IRV, VT, FRC, ERV, RV, and progression of OLD, Static Hyperinflation, and Dynamic Hyperinflation over years, decades, rest, and seconds to minutes of exercise.](image-url)
How does exercise intolerance affect a patient's daily life? (ICF Model)

Body structure/function: fatigue, dyspnea, pain
Activity: walking, squatting, reaching, cooking, cleaning
Participation: shopping, visiting friends, playing sports, going out to eat

Patients with pulmonary disease need individualized exercise programs to increase their activity and improve exercise tolerance.

This program must include:
- Cardiovascular endurance
- Strengthening
- Flexibility

*Goal of the program is to increase physical activity with decreased breathlessness and fatigue.

**VO2 Max**

Measure of the maximum volume of oxygen that a person can use while exercising. It is measured in millilitres per kilogramme of body weight per minute (ml/kg/min)

Best indicator of cardiovascular fitness and aerobic endurance

**VO2 Max Measurement**

![Image of VO2 Max measurement equipment]

Exact measurement performed using specialized equipment and precise protocol in sports performance laboratory

**VO2 Max Estimation Equations**

1.5 Mile Run-Walk Test

\[ \text{VO2max} = \frac{483}{T} + 3.5 \]

\[ T = \text{Test completion time (in minutes)} \]

Resting Heart Rate Based

\[ \text{VO2max} = 15.3 \times (\text{MHR/RHR}) \]

\[ \text{MHR} = \text{Maximum heart rate (beats/minute)} = 208 - (0.7 \times \text{Age}) \]

\[ \text{RHR} = \text{Resting heart rate (beats/minute)} = 20 \text{ second heart rate} \times 3 \]
## VO2 Max Norms for Men - Measured in ml/kg/min

<table>
<thead>
<tr>
<th>Age</th>
<th>Very Poor</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
<th>Excellent</th>
<th>Superior</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-19</td>
<td>&lt;35.0</td>
<td>35.0-38.3</td>
<td>38.4-45.1</td>
<td>45.2-50.9</td>
<td>51.0-55.9</td>
<td>&gt;55.9</td>
</tr>
<tr>
<td>20-29</td>
<td>&lt;33.0</td>
<td>33.0-36.4</td>
<td>36.5-42.4</td>
<td>42.5-46.4</td>
<td>46.5-52.4</td>
<td>&gt;52.4</td>
</tr>
<tr>
<td>30-39</td>
<td>&lt;31.5</td>
<td>31.5-35.4</td>
<td>35.5-40.9</td>
<td>41.0-44.9</td>
<td>45.0-49.4</td>
<td>&gt;49.4</td>
</tr>
<tr>
<td>40-49</td>
<td>&lt;30.2</td>
<td>30.2-33.5</td>
<td>33.6-38.9</td>
<td>39.0-43.7</td>
<td>43.8-48.0</td>
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<td>50-59</td>
<td>&lt;26.1</td>
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<td>41.0-45.3</td>
<td>&gt;45.3</td>
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<tr>
<td>60+</td>
<td>&lt;20.5</td>
<td>20.5-26.0</td>
<td>26.1-32.2</td>
<td>32.3-36.4</td>
<td>36.5-44.2</td>
<td>&gt;44.2</td>
</tr>
</tbody>
</table>

## VO2 Max values for Women as measured in ml/kg/min

<table>
<thead>
<tr>
<th>Age</th>
<th>Very Poor</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
<th>Excellent</th>
<th>Superior</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-19</td>
<td>&lt;25.0</td>
<td>25.0-30.9</td>
<td>31.0-34.9</td>
<td>35.0-38.9</td>
<td>39.0-41.9</td>
<td>&gt;41.9</td>
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<td>20-29</td>
<td>&lt;23.6</td>
<td>23.6-28.9</td>
<td>29.0-32.9</td>
<td>33.0-36.9</td>
<td>37.0-41.0</td>
<td>&gt;41.0</td>
</tr>
<tr>
<td>30-39</td>
<td>&lt;22.8</td>
<td>22.8-26.9</td>
<td>27.0-31.4</td>
<td>31.5-35.6</td>
<td>35.7-40.0</td>
<td>&gt;40.0</td>
</tr>
<tr>
<td>40-49</td>
<td>&lt;21.0</td>
<td>21.0-24.4</td>
<td>24.5-28.9</td>
<td>29.0-32.8</td>
<td>32.9-36.9</td>
<td>&gt;36.9</td>
</tr>
<tr>
<td>50-59</td>
<td>&lt;20.2</td>
<td>20.2-22.7</td>
<td>22.8-26.9</td>
<td>27.0-31.4</td>
<td>31.5-35.7</td>
<td>&gt;35.7</td>
</tr>
<tr>
<td>60+</td>
<td>&lt;17.5</td>
<td>17.5-20.1</td>
<td>20.2-24.4</td>
<td>24.5-30.2</td>
<td>30.3-31.4</td>
<td>&gt;31.4</td>
</tr>
</tbody>
</table>
6 Minute Walk Test

VO2 max can also be estimated using 6 min walk test. Useful for patients with respiratory disease as VO2 Max scores are in “very poor” range

**Standardized outcome measure**

Assesses distance walked over 6 minutes as a sub-maximal test of aerobic capacity and endurance

Can be used to measure changes in fitness

  Minimally clinically important difference: 54 meters in COPD patients

6 Minute Walk Test guidelines:

Walk as far a distance as possible over 6 minutes

Measure and record distance walked

  • Use premeasured course of no shorter than 20 meters to decrease effect of turns

  • Count laps walked and measure last partial lap completed to determine total distance

Record vital signs pre and post test

Assistive devices can be used but should be kept consistent from test to test

  • Document if an assistive device was used

Individual should be able to ambulate without physical assistance

6 min walk test normative values

COPD: Average distance walked: 380 m (range 160-600 m)

Distance < 200 m is predictive of hospitalization or mortality

Significant decline in 6MWD demonstrated in healthy adults as age increases

Average Distance walked by community dwelling elderly

<table>
<thead>
<tr>
<th>Age</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>60-69 yrs</td>
<td>572 m</td>
<td>538 m</td>
</tr>
<tr>
<td>70-79 yrs</td>
<td>527 m</td>
<td>471 m</td>
</tr>
<tr>
<td>80-89 yrs</td>
<td>417 m</td>
<td>392 m</td>
</tr>
</tbody>
</table>
Perceived exertion is an individual's rating of exercise intensity, formed by assessing their body's physical signs such as heart rate, breathing rate and perspiration/sweating.

Can help physiotherapist to determine "just right" challenge during exercise.
**Dyspnea Scale**
How much difficulty is your breathing causing you right now?

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Nothing at all</td>
</tr>
<tr>
<td>0.5</td>
<td>Very, very slight (just noticeable)</td>
</tr>
<tr>
<td>1</td>
<td>Very slight</td>
</tr>
<tr>
<td>2</td>
<td>Slight</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>Somewhat severe</td>
</tr>
<tr>
<td>5</td>
<td>Severe</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Very severe</td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Very, very severe (almost maximal)</td>
</tr>
<tr>
<td>10</td>
<td>Maximal</td>
</tr>
</tbody>
</table>
**Benefits of Endurance Exercise**

Increase exercise capacity  
Improve activity and participation areas of ICF  
Increase oxidative capacity of skeletal muscle  
Decrease symptoms of dyspnea and fatigue  
Increase cardiovascular function  

**Cardiovascular Endurance**  
Frequency: 3-5 days/week  
Intensity: Rate of perceived exertion: 12-14  
Time: 20-60 min (use intervals of work: rest if needed)  
Type: Walking, cycling, UE exercise  
Progression: Titrate to symptoms, increase as ability allows  
Supplemental Oxygen? Titrate to keep SpO2 >= 88-90%  

**Strengthening Exercises**  
Frequency: 2-3 days/week, non-consecutive  
Intensity: Able to complete only 10-15 reps at that weight  
Time: 1-2 sets, 8-12 repetitions, 8-10 exercises  
Type: Target major muscle groups of upper and lower body  
Devise exercises that the patient can complete in their home for improved compliance with program  

**Flexibility exercises**  
Frequency: 3-5 days/week  
Intensity: Stop before point of pain, but should feel stretch  
Time: 2-3x 30 sec hold for each muscle group  
Type: Target major muscle groups of upper and lower body  

**Breathing strategies**  
Slower respiration rate helps to decrease air trapping and hyperinflation  
Pursed lip breathing can slow exhalation and decrease dyspnea  
Upper extremity support surface:  
- Decreased work of breathing due to increased ability of accessory muscles of breathing to assist in respiration.
Obstructive
62 yo caucasian male with GOLD stage IV- very severe COPD, height 5’8”

<table>
<thead>
<tr>
<th>Spirometry</th>
<th>Measured</th>
<th>Predicted</th>
<th>% Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC (L)</td>
<td>1.85</td>
<td>4.30</td>
<td>43%</td>
</tr>
<tr>
<td>FEV1 (L)</td>
<td>0.53</td>
<td>3.12</td>
<td>17%</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>29</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>Lung Volumes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TLC (L)</td>
<td>9.37</td>
<td>6.21</td>
<td>151%</td>
</tr>
<tr>
<td>RV (L)</td>
<td>7.52</td>
<td>2.26</td>
<td>333%</td>
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</table>
Restrictive
38 yo caucasian female with CF, 5’3 in

<table>
<thead>
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<th>Spirometry</th>
<th>Measured</th>
<th>Predicted</th>
<th>% Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC (L)</td>
<td>1.37</td>
<td>3.70</td>
<td>37%</td>
</tr>
<tr>
<td>FEV1 (L)</td>
<td>0.53</td>
<td>2.94</td>
<td>18%</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>39</td>
<td>79</td>
<td></td>
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</table>

Lung Volumes

<table>
<thead>
<tr>
<th></th>
<th>Measured</th>
<th>Predicted</th>
<th>% Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLC (L)</td>
<td>7.71</td>
<td>5.11</td>
<td>151%</td>
</tr>
<tr>
<td>RV (L)</td>
<td>5.74</td>
<td>1.65</td>
<td>347%</td>
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</table>
## PFT Results Practice

<table>
<thead>
<tr>
<th>Spirometry</th>
<th>Measured</th>
<th>Predicted</th>
<th>% Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC (L)</td>
<td>5.98</td>
<td>5.04</td>
<td>119%</td>
</tr>
<tr>
<td>FEV1 (L)</td>
<td>4.58</td>
<td>4.11</td>
<td>111%</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>77</td>
<td>82</td>
<td>100%</td>
</tr>
<tr>
<td>TLC (L)</td>
<td>6.23</td>
<td>6.45</td>
<td>96%</td>
</tr>
<tr>
<td>RV (L)</td>
<td>1.82</td>
<td>1.89</td>
<td>96%</td>
</tr>
</tbody>
</table>

This person is Normal! 😊
Mild restrictive disease- scoliosis?

### PFT Results Practice

<table>
<thead>
<tr>
<th>Spirometry</th>
<th>Measured</th>
<th>Predicted</th>
<th>% Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC (L)</td>
<td>4.43</td>
<td>5.68</td>
<td>78%</td>
</tr>
<tr>
<td>FEV1 (L)</td>
<td>3.52</td>
<td>4.90</td>
<td>72%</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>79</td>
<td>84</td>
<td></td>
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<tr>
<td>Lung Volumes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TLC (L)</td>
<td>4.91</td>
<td>6.42</td>
<td>76%</td>
</tr>
<tr>
<td>RV (L)</td>
<td>1.89</td>
<td>2.26</td>
<td>83%</td>
</tr>
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</table>
Obstructive
63 yo caucasain female, 5 ft 1 in, severe COPD

<table>
<thead>
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<th>Spirometry</th>
<th>Measured</th>
<th>Predicted</th>
<th>% Predicted</th>
</tr>
</thead>
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<tr>
<td>FVC (L)</td>
<td>3.02</td>
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<td>94%</td>
</tr>
<tr>
<td>FEV1 (L)</td>
<td>0.74</td>
<td>2.47</td>
<td>30%</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>25</td>
<td>77</td>
<td></td>
</tr>
</tbody>
</table>

Lung Volumes

<table>
<thead>
<tr>
<th>Lung Volumes</th>
<th>Measured</th>
<th>Predicted</th>
<th>% Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLC (L)</td>
<td>6.96</td>
<td>4.64</td>
<td>150%</td>
</tr>
<tr>
<td>RV (L)</td>
<td>3.69</td>
<td>1.70</td>
<td>217%</td>
</tr>
</tbody>
</table>
References

3. van der Schans, CP. Conventional Chest Physical Therapy for Obstructive Lung Disease. Respiratory Care September 1, 2007 vol. 52 no. 9 1198-1209.

