BREATHING AND POSTURE: A MULTI-SYSTEM EVENT!

Massery. Impaired breathing mechanics and/or postural control. Cardiovascular & Pulmonary PT Evidence & Practice, ed. 4, 2006:695-717.

I. Which body systems impact postural control of the trunk?

A. Which systems are identified in Guide to PT Practice as being primary systems of motor impairment?

1. Musculoskeletal (MS)
2. Neuromuscular (NM)
3. Cardiovascular / Pulmonary (CP)
4. Integumentary (skin and other connective tissue) (INT)
5. Internal Organs (IO)- especially gastrointestinal system (GI)

B. Which systems impact postural control and movement?

1. Obvious systems
   a) Musculoskeletal
   b) Neuromuscular

2. Less obvious systems
   a) Cardiovascular/ Pulmonary
   b) Integumentary
   c) Gastrointestinal

II. Skeletal Support for posture and respiration

A. Skeleton of the thorax - Anterior support

1. Ribs - 12 individual components
   a) Designed for mobility at the expense of stability
   b) Each rib: single articulation with costal cartilage, which in turn articulate with the sternum body with a single articulation
c) Ribs 1-7: true ribs
   (1) inserts to sternum via their own cartilage
   (2) more stability than false ribs
   (3) in some pediatric cases, the true ribs may not adequately elongate downward thereby preventing the intercostal spacing from widening. May result in a visual appearance of a small upper chest and in some cases, it may appear as a separation between the true and false ribs.

d) Ribs 8-12: false ribs
   (1) more mobility than true ribs due to increased length of the level arms and longer cartilaginous segments
   (2) ribs 8-10 insert to sternum through rib 7’s cartilage. In addition to their obvious role in respiration, expansion of false ribs laterally is used for balance in a coronal plane.
   (3) ribs 11-12 are struts and do not insert to the sternum

e) Boney landmarks of anterior rib cage
   (1) ribs 1 – 3: between clavicle and axilla
   (2) ribs 4 – 7: under the “sports bra” area
   (3) ribs 8 – 10: inferior to the “lower bra strap” or “bathing suit top” line

2. Sternum - mobility driven

   a) 3 component parts
   (1) manubrium (top)
   (2) body (middle)
   (3) xiphoid process (bottom)

   b) Suprasternal notch (jugular notch)

   c) Sternal angle (approximately the width of 3-4 fingers down from jugular notch)
   (1) Sternal angle is at the level of the second rib
   (2) It is also the level of the carina (bifurcation of trachea into mainstem bronchi)
   (3) It is a reliable boney landmark for palpating individual rib segments
   (4) Clinical method for palpating sternal angle:
       (a) place one index finger at the suprasternal notch, say your right hand.
       (b) place your left hand sideways across the manubrium (parallel to the ground) snugly meeting your left index finger to your right index finger.
       (c) move right index finger down to just under your left baby finger.
       (d) Your right index finger should be on or very near the sternal angle.
       (e) the width of your 3-4 fingers is approximately the same length as the manubrium. Use the patient’s own hand to be accurate.

   d) xiphoid process: inferior point of sternum. very mobile
3. **Functional movements** - 3 potential planes of movement
   a) Potential mobility of the chest
      (1) potential mobility increases as you move inferior on rib cage
      (2) potential mobility increases as you move anterior on rib cage
      (3) therefore, the most potential mobility lies along the xiphoid process and the inferior borders of the anterior and lateral ribs; area of commonly noted rib cage
deformities
   b) Primary planes of movement
      (1) upper ribs - move primarily anterior and superior
      (2) middle ribs - transition between the upper and lower ribs, all 3 planes of movement fairly equal
      (3) lower ribs - move primarily lateral and superior
   c) Movements for ‘normal’ inspiration
      (1) **THERE IS NO NORMAL!**
      (2) Rib cage movements during inspiration depend on the alignment of the rib cage with the rest of the trunk (pelvis and spine), superimposed on the inspiratory motor strategies of the individual

B. **Skeleton of thorax - posterior support**

1. **Thoracic spine / posterior thoracic cage**
   a) Vertebral column is “stacked” providing mechanical support for upright postures

2. **Posterior rib landmarks**
   a) Bony landmarks of the posterior rib cage
      (1) Rib 2: ~ superior border of scapula
      (2) Rib 4: ~ spine of the scapula
      (3) Rib 8: ~ inferior border of scapula
      (4) Rib 12: lowest most palpable rib (floating rib)
   b) Head: 2 articulating surfaces for superior and posterior costotransverse ligament attachments to vertebral body
   c) Neck: no articulations with ribs
   d) Tubercle: articulation with transverse costotransverse ligament to transverse process
   e) Angle: posterior rib angle (under scapulae)
   f) Thoracic kyphosis: forces scapulae into protraction because it can not easily glide over the more prominent posterior rib angles
   g) Body: main shaft of rib
3. **Rib/vertebral articulations: very stable**

   a) Posterior junctions

   (1) lateral costotransverse ligament (axial rotation of thoracic spine)

   (2) superior costotransverse ligament (extension/flexion)

   (3) inferior (or posterior) costotransverse ligament (extension/flexion)

   (4) intertransverse ligament (small, vertical ligament connecting transverse processes of adjacent vertebrae, lateral side bending)

   b) Anterior junctions

   (1) radiate ligament of the head of the rib (attaching rib to same number thoracic vertebrae and one vertebrae higher)

   (2) anterior longitudinal ligament along entire spine

III. "**Soda-pop Can**" Model of Postural Support

A. What makes a thin aluminum soda-pop can “strong”?

1. **Internal pressure** makes the closed can “strong”.

2. The exterior aluminum can is weak: easily crushed if the top is open.

3. Positive pressure from the carbonated gases inside the can is greater than the atmospheric pressure exerted upon the can, creating functional strength for the weak external can much like our own skeletal structure.
B. Components of our own "aluminum can"

1. **diaphragm**: completely divides the upper and lower trunk chambers.
   a) It is not just a “respiratory muscle” but rather the body’s major pressure regulator.
   b) Respiration needs regulated pressure in both cavities (thoracic and abdominal) in order for the lungs to function.
   c) However, the diaphragm also plays a significant role in pressure regulation for postural control, venous return via the inferior vena cava, enhancing gastrointestinal motility, depressing reflux forces, and enhancing lymphatic drainage.

2. two internal pressure cavities
   a) thoracic cavity
   b) abdominal cavity

3. **top of cylinder**: vocal folds and vocal apparatus

4. **bottom of cylinder**: pelvic floor

5. three horizontal valves contain the thoracic and abdominal pressures
   a) two external valves: vocal folds (top) and pelvic floor (bottom)
   b) one internal valve: diaphragm

C. Pressure support for our trunk (our soda-pop can)

1. Internal trunk pressures determined by interaction of trunk muscles and horizontal valves
   a) Normal adult intra-abdominal pressure (IAP): pressure is always positive
      (1) High pressure system compared to thoracic cavity and atmosphere.
      (2) IAP fluctuates with breathing: IAP increases during inhalation and drops during the exhalation.
      (3) IAP 5-7cm H\textsubscript{2}O in supine and slightly higher in sitting (De Keulenaer 2009)
      (4) IAP triples in standing: 16-20 cm H\textsubscript{2}O IAP.
      (5) Highest IAP noted with cough (107 cm H\textsubscript{2}O) and jumping (171 cm H\textsubscript{2}O). Lifting 10 lb weight or bending knees (squat) increased IAP to 25 cm H\textsubscript{2}O. Patients with higher BMI had higher IAP than healthy weight adults (Cobb 2005).

   b) Intra-thoracic pressure (ITP): Low pressure system compared to atmosphere and abdominal cavity.
      (1) Lower pressure relative to atmosphere (negative pressure) pulls air inward causing inhalation.
      (2) Higher pressure relative to atmosphere (positive pressure) pushes the air outward causing exhalation.
      (3) ITP can be dramatically increased if the exit (glottis) is restricted or closed.
      (4) Small ITP changes drive airflow direction:
          (a) Inhalation moment created when ITP decreases at least 3 cm H\textsubscript{2}O
          (b) Exhalation moment created when ITP increases at least 3 cm H\textsubscript{2}O
2. Primary muscles involved in generating, maintaining and regulating pressure in the abdominal and thoracic chambers
   a) intrinsic laryngeal muscles
   b) intercostals
   c) diaphragm
   d) abdominals
   e) paraspinals
   f) pelvic floor muscles

3. A breach in the pressure support will result in the loss of the trunk muscles’ ability to generate, maintain and regulate pressure in both chambers, causing collapsing forces. Examples:
   a) tracheostomies: bypasses vocal folds, thus inability to create sustained positive ITP
   b) intercostal weakness/paralysis: collapse of the anterior chest potentially causing a consequential pectus excavatum
   c) abdominal weakness/paralysis: allows excessive anterior excursion of abdominal visera potentially resulting in inadequate positive IAP needed for control of the lumbar spine, optimal breathing mechanics, normal GI motility, etc.
   d) paraspinal weakness/paralysis: total kyphotic posture (long “C” shaped curve) limits anterior movement limits development of normal IAP and ITP
   e) pelvic floor dysfunction: inadequate ability of muscles to support the positive pressure exerted on the pelvic floor may result in incontinence
   f) other structural changes or motor control changes: may compromise the ability of the whole ‘soda-pop can’ to generate appropriate pressure support for the limb force production through the extremities, and may result in:
      (1) elbows bending while weight bearing in spite of ‘normal’ tricep muscle strength
      (2) hips and knees bending while weight bearing in spite of ‘normal’ gluteal and quadricep muscle strength

D. Integument
   1. Prolonged weight bearing will change the integrity of the skin over the weight bearing surfaces.
   2. Watch for trophic ‘clues’ such as brown discoloration or calluses.

E. Research support: Dual nature of postural control and breathing
   1. Trunk muscles are both respiratory and postural muscles
      a) Hodges & Gandevia ’00
      b) Respiration and posture are linked!
      c) Diaphragm and abdominal muscles increase postural response with increased postural demand, while continuing to synchronize movement for respiration as well
2. Cardiopulmonary system’s unique role in movement: physiologic as well as physical responses to the demand for postural control
   a) Hodges et al ’01
   b) CNS coordinates dual role of postural control and breathing for all muscles of the trunk
   c) When push comes to shove, the respiratory muscles will decrease postural support in order to focus on the immediate needs of respiration
   d) **Breathing Always Wins!**

3. Research has since confirmed these initial studies and has gone on to show many more connections between breathing and postural control
   a) **Janssens**
      (1) 2013 - Patients with LBP demonstrated greater diaphragm fatigability than controls
      (2) 2014 – 8 week inspiratory muscle training (IMT) training resulted in increased inspiratory muscle strength, improved back proprioceptive strategies and decreased LBP. IMT appears to facilitate proprioceptive involvement of the back muscles for postural control in patients with LBP and may be appropriate intervention for LBP rehabilitation.

4. Emerging Research: “Top of the Can” - vocal folds as postural stabilizers (to be discussed later in this lecture)
   a) **Hagins 2004 & 2006, Orlikoff 2008, Massery 2013**

5. Research: **Take home message . . . .**
   a) *All the trunk muscles work together to support postural stability as well as to provide simultaneous support for their primary functions such as respiration, limb force production, and continence.*

**F. Internal organs that generate and/or use positive pressure**

1. pulmonary
2. heart / circulation
3. gastointestinal tract
4. lymphatic system
G. Physiology can drive motor behaviors and may be incorrectly attributed to neurological dysfunction

1. **EXAMPLE:** a common infant issue: GI dysfunction with severe reflux & constipation, as well as torticollis and motor delays

2. Constipation can cause reflux (backed up pressures) much like a sewer pipe that is blocked at the exit. Noxious stimulus from the acid reflux stimulates a survival response to avoid the pain: trunk extension which lowers abdominal pressures. Persistent pain from the left side of the abdominal cavity may refine the aversion response to include extension with right trunk rotation, resulting in torticollis. This physiologic torticollis response often includes neck extension rather than neck flexion.

3. Severe physiologic driven motor responses like this in response to painful, repeated reflux may include full opisthotonus with torticollis. Diagnosis: **Sandifer’s Syndrome.**
   a) Possible additional consequences: trunk asymmetry and scoliosis

4. Postural control patterns may be extension dominant because of repeated pain when moving into flexion. Example, toe walkers may have a significant history of reflux. Repeated noxious stimulus during flexion patterns reinforced reliance on extension strategies (survival response).

5. Eye gaze may tend to be upward (reflecting extension pattern)
   a) may impair bilateral UE manipulation skills
   b) and later, may impair reading skills

H. Research - clinical application of this model to divergent patient populations

1. Recommended readings for GERD’s far reaching motor and health symptoms such as **Sandifer’s Syndrome** and others:

2. GERD, asthma, and/or nocturnal symptoms:
   a) **Sontag 2003:** 62 veterans with severe, chronic asthma followed for 2-20 years. 16 had Nissen fundoplication: immediate resolution or near resolution of nocturnal symptoms. 12/16 showed dramatic improvement of asthma overall. Medication group (n=22) improved but not as dramatically. 50% of control group (n=24) symptoms stayed the same, 50% worsened.

   b) **Kobernick 2009:** 2 year prospective study, 62 school kids, moderate non-atopic (non-allergic) asthma. 2/3 had GERD. 32/44 were treated for GERD (meds &/or sx) as well as asthma: 75% decrease in asthma exacerbations (0.7 incidents/yr) compared to non-GERD group (2.9 incidents/yr). Doctors may be under-estimating the benefit of identifying and treating GERD in kids with non-atopic asthma.
3. **Button et al 2006**: Prevent, Control & Treat Urinary Incontinence in Cystic Fibrosis & COPD (Presented at the European Cystic Fibrosis Society Annual Meeting 2006 Copenhagen, Denmark)
   a) 37 CF women (19-61 y/o) 67% incontinent
   b) 22 COPD women (48-77 y/o) 59% incontinence
   c) 66 normal controls (19-81 y/o) 27% incontinent
   d) EMG showed normal strength & timing in both groups for a single PFM contraction, but pulmonary groups had decreased endurance probably due to prolonged bouts of coughing and poor postural strategies prior to cough.
   e) PT intervention to increase endurance and postural strategies for 4 CF & 6 COPD patients: 5 sessions over 3 months. Results: significant reduction in UI episodes (p=.008).

4. **Smith - ongoing research**
   a) **Smith et al 2006**: Associations with Low Back Pain (LBP) for 38,000 adult Australian women. This study should revolutionize low back pain assessment and treatment.
      1. 3 cohorts: 18-23 y/o young, 45-50 y/o middle-age, 70-75 y/o older
      2. Frequency of LBP increases with age
      3. BMI (obesity) and inactivity were not consistently associated with LBP
      4. However, urinary incontinence, breathing difficulty and allergies were associated with LBP
      5. The authors suspect the findings reflect that UI women are often overweight, and breathing difficulties usually reduces activity levels, therefore perhaps prior studies showing increase LBP with obesity and inactivity were really reflective of the underlying UI and pulmonary dysfunction and that impact on the development of LBP
   b) **Smith et al 2009**: Added GI dysfunction to the above mix --- increased LBP risk
   c) **Smith et al 2010**: Patients with COPD have balance impairments. Balance impairments increased when respiratory workload increases following UE exercise. (My interpretation – conflict between breathing and postural control causes these patients to choose breathing.)
   d) **Smith et al 2013**: tied all of the above together from continence to breathing to GI symptoms to LBP. Every system influences other body systems (no surprise 😊).

5. **Hodges et al 2007**: multiple relationships exist between the trunk, pelvic floor, diaphragm and shoulder muscles in their roles as postural stabilizers during varying upright tasks including standing still and breathing, a fast single prompted UE movement, repetitive fast unilateral arm swing and other tasks.

6. **Adult obesity**:
   a) Morbid obesity causes adverse increase in IAP (intra-abdominal pressure) which has been identified as the likely cause of systemic hypertension (**Varela 2009**).
   b) Pressure related co-morbidities such as gastroesophageal reflux disease, hernias, stress incontinence, diabetes, hypertension, and venous insufficiency showed increased prevalence, especially for obese patients with IAPs of 12 cm H$_2$O compared to obese patients with IAPs 9 cm H$_2$O (**Lambert 2005**).
IV. Core Muscles

A. New definition of “core” stability

1. Core stabilization extends from the vocal folds on the top to the pelvic floor on the bottom and includes EVERY muscle in between.

B. Muscles of Ventilation / Posture: A “Triad”

1. Diaphragm, intercostals and abdominals together provide more biomechanical support for breathing than any of these muscles alone

C. Diaphragm

1. Innervation – phrenic nerve C3-5
2. major muscle of passive ventilation, provides ~2/3 to 3/4 of tidal volume (quiet breathing) effort and volume
3. primary movement - all 3 planes
4. completely separates thoracic and abdominal cavities to regulate pressures
6. additional support: vocal folds and pelvic floor
7. dependency on intercostal and abdominal muscles to help the diaphragm generate adequate pressure changes between the thoracic (negative pressure) and abdominal (positive pressure) cavities during inhalation
8. uses the positive pressure of the abdominal cavity to help "stabilize" the central tendon of the diaphragm (primarily inferior expansion).
9. Peripheral fibers of the diaphragm can then use this "stability" to enhance their effectiveness (primarily lateral and superior expansion)
10. concentric contractions - quiet and forceful inhalation patterns
11. eccentric contractions - controlled exhalation & speech
D. Intercostals

1. **innervation** - T1-T12
2. **primary function** - stabilizes rib cage during inhalation to prevent chestwall from being sucked inward (paradoxical breathing) due to the negative pressure generated in the thoracic cavity
3. **primary movement** - concentric contractions
   a) lateral & superior expansion in lower chest (both quiet and forceful inhalation), anterior expansion usually least significant component
   b) anterior & superior expansion in upper chest, lateral expansion usually least component
   c) primary rotator of thoracic cage / spine
   d) forceful exhalation - primarily medial and inferior compression in lower chest; posterior and inferior compression in upper chest
4. **eccentric contractions**
   a) slow release of inspiratory muscles needed for controlled exhalation & speech
   b) vocal folds are the “gatekeepers” for thoracic chamber positive pressure regulation; controlling exhalation volume and speed.
   c) Patients with tracheostomies but no speaking valves, can not perform eccentric thoracic maneuvers because the trach tube bypasses the vocal folds, thus allowing the air to escape at will.

E. Abdominals

1. **innervation** T6 - L1
2. **external obliques and rectus**; stabilizes inferior border of rib cage, covering the false ribs (mid-trunk interfacing). Insertion is on exterior rib cage.
3. **internal obliques** pulls the inferior border of the rib cage downward for trunk stabilization and forceful exhalation maneuvers. Insertion on inferior border of ribs.
4. **transverse abdominus** (TA): significant role in synchronizing pressure changes with the diaphragm for optimal respiratory movements while simultaneously meeting the abdominal pressure needs for postural support. TA is the only abdominal muscle to insert on interior rib cage. It inter-digitates with the diaphragm’s insertions on ribs 8-10 forming the superior muscular dome of the abdominal cavity.
5. provides visceral support along anterior, lateral and posterior trunk
6. provides positive pressure support for the diaphragm
7. provides necessary intrathoracic pressure for an effective cough, bowel movements, venous return, etc.
F. Sequence of a normal quiet breath (tidal volume)
   1. first: easy onset, subtle rise of the upper abdomen
   2. second: lateral costal expansion of the lower chest
   3. third: gentle rise of the upper chest primarily in the superior and anterior planes

V. Internal Organs

A. Pressure support used functionally for body activities such as:
   1. expanding the lungs via negative thoracic pressure
   2. mobilizing fluid based systems such as the GI tract, lymphatic drainage and arterial and venous circulation

B. Thoracic Cavity
   1. Trachea & esophagus
      a) tightly aligned to spine, thus spinal abnormalities can clinically affect breathing, airway protection and swallowing mechanics
      b) trachea and esophagus are anatomically tied together.
      c) a trach tube will impair normal tracheal elevation during swallow, thus the presence of a trach tube indicates dysphagia
   2. Aorta
   3. Lymphatic system
   4. Heart
   5. Lungs
   6. Diaphragm and esophageal sphincter

C. Diaphragm’s 3 openings: for the great vessels: aorta, esophagus, inferior vena cava
   1. Aorta
      a) high pressure system
      b) aorta passes through the diaphragm at its most stable point between the crural legs (posterior attachments to lumbar spine) and is the least affected of the 3 great vessels by the diaphragm’s inspiratory excursion
   2. Esophagus
      a) passes through diaphragm’s crural muscle region, not through the central tendon
      b) the diaphragm couples with the lower esophageal sphincter (LES) to effectively control reflux forces more efficiently than either one alone.
3. **Inferior vena cava**
   a) passes through the diaphragm’s central tendon at the peak of the diaphragm’s dome.
   b) During inhalation, the coupling between the diaphragm and inferior vena cava aids in venous return from the lower body: pressure drops in the vena cava above the diaphragm (negative thoracic pressure) while pressure increases below the diaphragm (positive abdominal pressure). Action is similar to sucking fluid up through a straw.

D. **Abdominal Cavity**

1. Stomach and intestines
   a) inhalation pressure creates a peristaltic like action for the intestines; massaging lower intestines to enhance lower GI motility

2. Other internal organs

3. Arteries & veins

4. Lymphatic system

E. **Research on the diaphragm and its relationship to other internal systems**

1. **Shafik 2004**
   a) Illustrated the relationship between crural diaphragm and LES
   b) 17 subjects: tested diaphragm / LES junction under sudden strain (simulated cough) and sustained strain (simulated defecation or urination) conditions while under surgical repair for abdominal hernias unrelated to the esophagus
   c) Crural diaphragm accounted for 44% of the expressed lower esophageal pressure.
      LES 54%.

2. **Pandolfino 2007 & 2009**
   a) Demonstrated the link between the role of the diaphragm and the LES
   b) High resolution manometry allows for isolation of the crural diaphragm contraction from the LES contraction
   c) 75 controls. 156 GERD patients
      (1) Strongest association, and the only independent predictor of GERD as an outcome, was impaired crural diaphragm function (less ability to increase lower esophageal pressure (normals 17 mmHg, GERD 10-11 mmHg): ~40% less pressure generated by GERD group.

3. **Congenital diaphragmatic hernia (CDH) survivors: incidence of GERD**
   a) **Koivusalo 2008**: prospective study, 26 left & right CDH patients, 6 mo – 10 y/o
   b) And **Arena 2008**: 31 Left CDH from infant to young adults
      (1) GER significant: some groups >50%. Foregut dysmotility also found.
      (2) Long term GI follow up is needed for CDH.
   c) **Shah 2009**: Minimally invasive surgical repairs are becoming more successful and may reduce the necessity of an open surgical approach to repair CDHs.
4. **Pinsky 2005**
   
   a) Discusses complex interactions of the hemodynamics of breathing, cardiac function and circulation for sick patients in the ICU and the applicability to vent weaning strategies.
   
   b) Spontaneous breathing off of mechanical ventilation increases venous return due to improve pressure differentials:
      
      (1) Combining a drop in ITP (intra thoracic pressure) during inhalation with an increase in IAP (intra abdominal pressure) increases venous return (i.e. straw effect).

F. **The Diaphragm: Is it just a respiratory muscle?**

1. NO!
2. Multiple simultaneous roles
   
   a) Respiratory muscle
   
   b) Postural control muscle
   
   c) GI muscle:
      
      (1) anti-reflux muscle
      
      (2) lower GI motility muscle
   
   d) Venous return muscle

VI. **Accessory Support for Breathing and Posture**

A. **Paraspinals**

1. innervated at T1 - S3
2. provides dynamic posterior thoracic stabilization which optimizes normal anterior chest wall movements in three planes.
B. Pectoralis muscles

1. innervated C5 - T1
2. when used in reverse direction - provides upper chest anterior and lateral expansion
3. can also assist in expiratory maneuvers if the trunk moves into flexion
4. can be a substitute rib cage stabilizer following paralysis of the intercostal muscles to prevent paradoxical breathing

C. Serratus Anterior

1. innervated C5 - C7
2. provides posterior expansion of rib cage when upper extremities are fixated
   a) can be helpful - i.e. Cystic Fibrosis for specific aeration techniques
   b) can be problematic - i.e. patient with a brain injury may use posterior breathing pattern with no other perceived options. Patient may pull into flexed postures and have difficulty "sitting up straight."
3. this is the only inspiratory muscles that is paired with trunk flexion movements rather than trunk extension movements

D. Scalenes

1. innervated C3 - C8
2. provides superior and anterior expansion of the upper chest
3. stabilizes upper chest during inhalation even with normal quiet breathing

E. Sternocleidomastoid

1. innervated C2 - C3 and Accessory Cranial Nerve
2. similar function as scalenes

F. Trapezius

1. innervated C2 - C4 and Accessory Cranial Nerve
2. provides superior expansion of the upper chest
3. least energy efficient accessory muscle. Must lift the weight of entire upper extremity to assist in inhalation
VII. Vocal Folds and surrounding laryngeal support structures at the "top of the cylinder"

A. "Gate Keeper"
   1. "Gate Keeper" between upper and lower airway
   2. "Gate Keeper" of pressure support in thoracic cavity which in turn contributes to IAP support.

B. Larynx
   1. 9 cartilages
      a) 3 single cartilages: thyroid, cricoid, epiglottis
      b) 3 pairs of cartilage: arytenoids, corniculate, cuneiform
   2. 1 bone: hyoid
   3. 2 muscle groups
      a) extrinsic
      b) intrinsic

C. Protects opening of lower airway to prevent aspiration
   1. Epiglottis: primary protection (penetration)
   2. Vocal folds: backup protection (aspiration)

D. Maintains proper airway opening during inhalation
   1. Entire larynx descends: transverse airway enlarges, dropping airway pressure by at least 3 cm H2O which creates an inspiratory moment.
   2. Quiet breathing: vocal folds abduct only slightly
   3. Deep breathing: vocal folds abduct significantly to enlarge opening
   4. Phonation:
      a) Regulates tension / position of vocal folds & laryngeal cartilages for optimal voicing
      b) Regulates balance between vocal tension & exhaled airway pressure
      c) Creates sub-glottal pressure with vibration: one of the body’s natural airway clearance mechanisms

E. Stabilizes: “Glottal effort closure reflex”
   1. Increases upper extremity (UE) and trunk power and stability through adduction of entire larynx which results in increased thoracic pressure
   2. Examples
      a) coughing
      b) yelling
      c) pushing
      d) twisting tight “jar top”
      e) powerful tennis serve
      f) bowel evacuation

F. Sequence of a normal swallow: coordination between vocal structures and esophagus
G. Research

1. **Hayama 2002**
   a) 4 subjects: Olympic and elite gymnasts. EMG data and fiberoptic endoscope
   b) Air trapping via glottal closure used during heaving loading, i.e. when postural
demand on the shoulder musculature exceeded force production by the UE alone.

2. **Eliasz 2004**
   a) During acceleration, airforce pilots experience an increased gravitational force
acting upon their bodies.
   b) Pilots achieve an increase in their tolerance to these forces (G-tolerance) by
isometrically contractiong their trunk flexors and lower extremities against a closed or
partially closed glottis.
   c) The author assessed success of glottal/ trunk isometric training by measuring an
increase in LE force output on a force plate.
   d) By extrapolation, this concept could be used in PT
      1) gait: to measure and account for LE force production at heel strike and stance
phase of gait with and without glottal maneuvers.
      2) chestwall collapse: to explain the musculoskeletal deformities of the chest and
spine commonly noted in children (and adults) who can not counteract normal
gravitational forces due to impaired activation of intrinsic laryngeal muscles, trunk
muscles, and/or leg muscles.

3. **Hagins 2004**
   a) compared 4 different breathing patterns to force and timing measurements over 75
trials while 11 subjects pulled against an isometric load
   b) significance: greatest isometric load pulled when using a “maximal inspiratory
hold” breathing pattern
   c) no difference: amongst the other 3 patterns
   d) conclusion: glottal closure against a full volume of air produced necessary postural
stability of diaphragm and trunk to maximize lift potential

4. **Orlikoff 2008**
   a) 20 healthy subjects lifted 4 progressively heavier hand-held weights from 0 – 15 lbs
on outstretched hands while phonating
   b) Vocal fold adduction and subglottal pressures increased as postural demand
increased, but voicing continued
   c) **my comment**: at what weight if any, would postural demand exceed postural control
causing breath holding to occur and phonation to cease?
5. **Massery et al. 2013**


b) 12 healthy subjects subjected to gentle forward and backward postural perturbations in upright during 7 voicing/glottal conditions

c) Conclusion: glottal modulation plays an active role in postural stability in response to perturbations in stance

(1) **Thoracic stability:**

   a) **Least stable:** forced open-glottal conditions like a sigh had the greatest thoracic displacement compared to partial (talking or natural breathing) or closed (breath holding) glottal conditions regardless of the direction (backward or forward) of the perturbation

   b) **Most stable:** static breath-holding maneuvers showed the least thoracic displacement

(2) **Center of Pressure (CoP) stability:**

   a) **Least stable:** greater CoP displacement occurred with backward perturbations and at either end of glottal modulation (open glottis or closed glottis).

   b) **Most stable:** the least displacement occurred during partially opened glottal conditions of talking (mid-range control), especially ‘counting’

(3) **Clinical implications:**

   a) Our findings may help to explain common clinical breath-holding strategies used by patients with balance impairments. The thorax was indeed more stable, but breath-holding may not afford the dynamic control necessary to efficiently control CoP.

   b) Without the ability to recruit glottal structures as part of dynamic postural control, balance strategies appear inherently disadvantaged. An open glottal condition was not stable for either the thorax or CoP.

   c) Based on our findings, we would anticipate that patients with tracheostomies (forced open-glottal conditions) would show balance impairments. Further study is warranted.

   d) Encouraging patients to talk during balance activities may improve their dynamic postural stability.

(4) **EXAMPLE**

   a) Kevin, TBI secondary to brain tumor. Vent dependent.

   ![Example Image]
VIII. Pelvic Floor at the "bottom of the cylinder"

A. **Strong muscle support** provides functional integrity at the base of the abdominal cavity in spite of constantly fluctuating abdominal pressures.

B. **Pelvic floor muscles** play an important role in:
   1. Completing the internal muscle shell that supports IAP. Diaphragm and transverse abdominus (TA) form the superior dome; the TA forms the lateral walls of the cylinder; the pelvic floor and TA together form the inferior dome.
   2. Preventing incontinence.
   3. Supporting dynamic postural stabilization of the lumbar spine during increased postural demand.
   4. Supporting breathing mechanics for both inspiratory and expiratory maneuvers.
   5. Supporting other fluid-based pressure-related tasks related to circulation, lymphatic drainage, etc.

C. **Breach in pelvic floor** will result in misdirected pressure during forceful expiratory maneuvers or positive pressure maneuvers such as:
   1. Coughing or sneezing
   2. Yelling or laughing
   3. Pushing
   4. Twisting the lid of a tight jar
   5. Powerful tennis serve

D. **EXAMPLE: Arriana**
   1. Benign hypotonia, balance impairments, poor breath support for speech, poor endurance
   2. Chronic constipation (bowel movement every 7 days): major contributor to poor breath support
   3. Backed up lower GI system impaired diaphragm’s descent.
   4. Inspiration became more shallow, forcing greater recruitment of accessory muscle breathing which in turn likely was the major reason for her cervical over-stabilization.
   5. All of which contributed to decreased vocal utterances and clarity when constipated.

E. **Nocturnal enuresis (bed wetting) and sleep disordered breathing (SDB)**
   1. **Bascom 2011**: Sleep disordered breathing, specifically obstructive sleep apnea, was prevalent in children with nocturnal enuresis especially for those with daytime incontinence (non-monosymptomatic enuresis).
   2. **Waleed 2011**: 33 of 47 children with nocturnal enuresis were also diagnosed with SDB. SDB decreased with age (5－10 y/o), all underwent surgery for airway obstruction. Afterward, 88% (29) improved: 15 were cured of enuresis completely and 12 made significant improvements within 90 days. 2 did not improve nocturnally, but all 29 significantly improved their daytime enuresis.
IX. **Integumentary**

A. Adequate mobility of the skin and other connective tissue is necessary for the freedom of the underlying structures to maximize the potential of both chest wall expansion for ventilation as well as postural responses.

B. Fascial restrictions can result in multiple consequential impairments

C. Clinical Case: Danny 9½ y/o boy with congenital tracheo-esophageal fistula (TEF) and resultant scars on trachea, right lateral rib cage, stomach, abdomen (vertical), anterior chest (horizontal), and multiple other small scars from the likes of chest tubes, etc., causing multiple system impairments as his body matured. *(Massery, Linda Crane Lecture 2009)*

X. **Summary**

A. The body functions as a whole unit with all the individual systems interacting and supporting one another for both physiologic and physical functions.

B. In particular, postural control and the mechanical support for breathing are inter-dependent, yet breathing needs always takes precedence over postural needs.

C. Trunk control, breathing, and internal functions such as the GI tract, are dependent on the ability of the body to generate, maintain and regulate pressure in the thoracic and abdominal chambers; the control of which extends from the vocal folds down to the pelvic floor.

D. Therefore, all body systems that generate or use pressure support for function must be screened for their role in the function or dysfunction of breathing and/or postural control maneuvers.

1. Musculoskeletal
2. Neuromuscular
3. Cardiovascular / Pulmonary
4. Integumentary
5. Internal Organs
XI. **Case Report:**

Ryan, 16 y/o: congenital pectus excavatum. Is it just a “cosmetic deformity?” No PT or other therapy had been attempted to correct chest deformity and secondary musculoskeletal postural deformities.


2. 6 months later after intensive PT (22 outpatient visits): dramatic improvement in postural alignment and postural control greatly reducing his risk of LBP and/or shoulder impairment.

3. Pectus corrective surgery: pectus impaired cardiac function. Surgery was medically necessary. Postural changes continue to show marked improvement. No PT was needed post-surgery.
BREATHING AND POSTURE: A MULTI-SYSTEM EVENT

References


Mary Massery e-mail: mmassery@aol.com
website: www.MasseryPT.com
(847) 803-0803


Mary Massery  
(847) 803-0803  
e-mail: mmassery@aol.com  
website: www.MasseryPT.com


Mary Massery  
(847) 803-0803  
e-m: mmassery@aol.com  
website: www.MasseryPT.com


Mary Massery
(847) 803-0803
website: www.MasseryPT.com

m: mmassery@aol.com


Mary Massery
e-m: mmassery@aol.com
(847) 803-8083
website: www.MasseryPT.com


WHAT YOU CAN DO IN 90 SECONDS OR LESS THAT HAS A PROFOUND AND LASTING EFFECT?

POSITIONING STRATEGIES

Massery. Impaired breathing mechanics and/or postural control. Cardiovascular & Pulmonary PT Evidence & Practice, ed. 4. 2006:695-717.

I. UPRIGHT POSTURES

A. What type of breathing pattern do you want to encourage?

1. More diaphragm activation
2. More accessory muscle activation
3. More symmetrical activation

B. How can you get it?

1. Pelvis and mid trunk
   a) Anterior tilt - tends to facilitate more upper chest breathing
   b) Posterior tilt - tends to facilitate more diaphragm breathing

2. Shoulders/upper extremities
   a) Full facilitation of upper accessory muscles: shoulder flexion/abduction/external rotation
   b) Full facilitation of diaphragmatic and lower chest muscles: shoulder extension/adduction/internal rotation
   c) Subtle changes
      (1) scapular retraction/protraction
      (2) shoulder flexion/extension
      (3) shoulder abduction/adduction
      (4) shoulder external/internal rotation
      (5) forearm supination/pronation
   d) Head & neck alignment
      (1) forward head
      (2) neutral chin tuck
         (a) swallowing
         (b) speech
C. How to achieve these alignments with simple adaptations

1. Increased lumbar lordosis increased lung volumes for patients seated in wheelchairs. (Landers 2003, Lin 2006)

2. Towel rolls for increase anterior tilt and opened anterior chest wall
   a) thoracic vertical roll
   b) ischial roll in sitting
   c) thoracic horizontal roll
   d) lumbar roll

3. Wedges

4. Household furniture

D. Wheelchair considerations

1. Abdominal/trunk support
   a) Soft support - abdominal binders
      (1) placement - around xiphoid process to iliac crest
      (2) how tight? tight enough to support not inhibit diaphragmatic excursion
      (3) Larson 2009 – post abdominal surgery. Binder helped to reduce pain and had a tendency to improve vital capacity, but did not effect length of stay
      (4) Wadsworth 2009 – patients with quadriplegic spinal cord injuries wearing an abdominal binder had longer phonation, louder voices and increased pulmonary function
   b) Rigid support - body jackets (total contact TLSO)
      (1) Full contact TLSO with an abdominal cutout increased FVC and FEV1. (Frownfelter 2006)
      (2) abdominal cutouts - from xiphoid process to umbilicus
      (3) abdominal binder used over opening

2. Lateral trunk supports

3. Head supports

4. Spine supports - lumbar and thoracic

5. Foot placement - effect on pelvis
II. RECLINING POSTURES

A. What kind of breathing pattern do you want to encourage here? Is it different than in upright?

B. Problem-solve the following question in supine. What do you need to do in terms of positioning to encourage these breathing patterns?

<table>
<thead>
<tr>
<th>Breathing Pattern Desired</th>
<th>Position of the head/neck</th>
<th>Position of the arms</th>
<th>Position of the spine</th>
<th>Position of the legs/pelvis</th>
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<tbody>
<tr>
<td>Diaphragmatic pattern</td>
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<tr>
<td>Upper accessory muscle pattern</td>
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<tr>
<td>Symmetrical pattern (hemiplegia)</td>
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<tr>
<td>Your patient</td>
<td></td>
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</tbody>
</table>
C. Sleep considerations

1. What was the patient's pre morbid sleeping posture?
2. What is the most effective breathing pattern for the patient now?
3. How is gravity affecting breathing?
4. Is the patient's preferred posture an option now?
5. Does he/she show signs of sleep disordered breathing such as snoring or stridor?
6. Central sleep disorders such as prolonged periods of apnea or irregular rhythms?
7. Equipment: How do beds or car seats affect breathing? (Cerar 2009, Shiraishi 2009)
8. Sleep disordered breathing in pediatrics:
   b) may be a major contribution to nocturnal enuresis (bed wetting) (Bascom 2011, Waleed 2011).
9. Sleep disordered breathing in adults:
   a) SDB present with some adults with ADHD complaining of sleep problems, and should be screened as a co-morbidity(Surman 2006).
   b) Nocturnal GER is prevalent for adults with asthma and OSA (obstructive sleep apnea) and appears likely due to the change in intra-thoracic pressures related to the increased work of breathing (Gislason 2002, Teodorescu 2009).
   c) Obesity is a high risk factor for SDB and is associated with cardiac dysfunction, onset of diabetes type 2, and other metabolic impairments (Cintra 2011, Dixon 2011, Lurie 2011).

D. What adjustments could you make in positioning to potentially improve your patient's breathing mechanics and/or ventilation-perfusion?

5. Design your intervention strategy for the following positions:
   a) Sleep positioning
   b) Recumbent positioning
   c) Upright positioning
      (1) Sitting with back support
      (2) Sitting without back support
POSITIONING AND MOVEMENT STRATEGIES

References


Bishop, T. (2005). The Effects of Lumbar Spine Position on Shoulder Range of Motion in Asymptomatic Subjects, Rocky Mountain University of Health Sciences, Provo, UT.


Mary Massery
(847) 803-0803
e-m: mmassery@aol.com
website: www.MasseryPT.com


Mary Massery
(847) 803-0803
website: www.MasseryPT.com


PUBLICATIONS BY MARY MASSERY, PT, DPT, DSc


38. Massery MP, Frownfelter DL. Assisted cough techniques - there's more than one way to cough. PT Forum1990:1-3.


Respiratory Equipment Resources

Information subject to change; a Google-search may be useful
Mary Massery has no financial association with any of the following companies

1. **Custom ordered abdominal binders**: Kerem Group, an American Sewing Co.:  
   www.americansewingcompany.com

2. **Ventilatory Muscle Trainers and other respiratory equipment**: Philips Respironics, Inc.,  
   a. IMT - Inspiratory muscles trainers ("P-Flex" and "Threshold"):
   b. EMT - Expiratory muscle trainers (TheraPEP and other positive expiratory pressure devices):

3. "The Breather" (inspiratory & expiratory muscle trainer in one unit): PN Medical,  
   http://www.pnmedical.com


   http://coughassist70.respironics.com

6. **Airway Clearance Vests**  

7. "Acapella", "Thera-PEP", and other respiratory equipment: Smiths Medical,  
   www.smiths-medical.com

8. "Respiratory Blowing Toys":  


RE: Joining Mary Massery’s Listserv at: Mary-Massery-Clinical-Discussions@yahoogroups.com

Dear Colleagues,

Therapists involved in my courses and clinics have expressed an interest in continuing their “Breathing” discussions long after the course has ended. In that spirit, I have created a Listserv to encourage these conversations. Therapists who have taken my courses, attended my patient clinics, or share a common cardiopulmonary interest, are welcomed to sign up. There is no membership fee.

I hope the Listserv will stimulate vigorous scientific discussions as well as spirited clinical-case discussions. This is not intended as a one-way discussion or as a forum for dispensing medical advice. It is intended for group discussions; I want all members to freely post questions and to answer questions so we all learn from each other. I will join in the discussions when I have time.

Several therapy disciplines and numerous countries will be represented on this Listserv, so please respect each posting. Please indicate your therapy discipline and your city/state or province/country in your responses.

Welcome. Joining is easy.
1. To join, send a blank e-mail to: Mary-Massery-Clinical-Discussions-subscribe@yahoogroups.com
2. You will receive a confirmation message to the email address you used to subscribe.
3. Simply hit “reply” to the confirmation e-mail and your subscription will be complete.
4. You do not need to sign up for a Yahoo e-mail account to be a member of this Listserv.

Once enrolled, you can post messages by sending an e-mail to:
Mary-Massery-Clinical-Discussions@yahoogroups.com

To Unsubscribe to the Listserv, send a blank e-mail to:
Mary-Massery-Clinical-Discussions-unsubscribe@yahoogroups.com

I look forward to our discussions!

Sincerely,

Mary Massery
NORMAL AND ABNORMAL CHEST WALL DEVELOPMENT AND FUNCTION

Massery. Impaired breathing mechanics and/or postural control. Cardiovascular & Pulmonary PT Evidence & Practice, ed. 4, 2006:695-717.

I. NORMAL INFLUENCES ON CHESTWALL DEVELOPMENT

A. Planes of ventilation - 3 dimensional activity
   1. Superior - inferior
   2. Anterior - posterior
   3. Lateral or transverse

B. Three major influences on normal chest wall development (outside of genetic predisposition)
   1. Gravity - friend or foe?
   2. Muscle strength
   3. Muscle tone

II. NORMAL CHEST & TRUNK DEVELOPMENT

A. Covered in 5 major developmental periods
   1. Newborn – 3 months
   2. 3-6 months old
   3. 6-12 months old
   4. Over 12 months old
   5. 4-5 years old

B. Newborn – 3 months of age
   1. Shape and size of chest and trunk
      a) Triangular shape
      b) Round circumferential shape
      c) No “neck”: head sits directly on thorax
      d) Trunk
         (1) 2 separate components: rib cage and abdomen, not yet one single functioning trunk
         (2) Trunk proportion: chest: abdomen ~1:3
      e) Narrow intercostal spacing
      f) Horizontal rib alignment

   2. Developmental advantage?
      a) Need for stability outweighs the need for mobility of the thorax in neonate
      b) Assists in transition from uterine to extra-uterine survival
3. Breathing patterns
   a) Diaphragmatic breathers
      (1) Rehan 2003, Omai 2000, Lamont 1995, Keens 1978 (old, but important study)
   b) No functioning accessory muscles, thus no functional pulmonary reserves
   c) Respiratory Rate (RR) 40-60 br/min
   d) Stress response
      (1) Breathe faster, can't realistically breathe deeper
      (2) Attempt to recruit accessory muscles, in particular the trapezius

4. Parallel gross motor development 0 – 3 months
   a) Minimal gross motor development
   b) Can't readily supply oxygen for gross motor tasks as well as inadequate motor control for the task
   c) Midline orientation
   d) Can be propped on prone on elbows
   e) Can't sit or roll independently

C. 3 - 6 months of age

1. Shape and size of chest and trunk
   a) Beginning to be more rectangular in shape
   b) Significant increase in upper chest movement and shape
   c) Anterior chestwall muscles can now move against gravity to upper chest is no longer flat
   d) Trunk
      (1) Rib cage still not elongating, trunk proportion still 1:3
      (2) May see small pectus excavatum (cave or funnel chest deformity) at base of sternum
      (3) May see rib flares

2. Breathing patterns
   a) Upper chest anterior expansion possible
   b) Still primarily diaphragmatic breather
   c) RR slowly decreasing as respiratory reserves increase
   d) Stability of chest wall is still primarily achieved through horizontal alignment of rib cage rather than intercostal muscle contractions
      (1) With increase inspiratory stress such as crying, laughing, hiccupsing, the chest may be transiently "sucked" in (pectus excavatum)
      (2) Due to marked increase in negative inspiratory force (NIF) which can not yet be supported by chest wall muscles support
3. **Parallel gross motor development 3 - 6 months**
   
a) Log rolling
   (1) Why “log” rather than rotary rolling?
   
b) Not quite ready for independent
   (1) Sitting
   (2) Antigravity movement and control of all trunk/respiratory muscles

4. **Chest wall deformities, head deformities, and motor delays**
   a) Pectus Excavatum
      (1) Cavus or funnel chest deformity of the lower sternum
      (2) Can be acquired or congenital
   
   b) Pectus Carinatum
      (1) Protrusion of lower sternum. Also called pigeon breast.
      (2) Can be acquired or congenital
   
   c) Head deformities and motor delays have increased since “back to sleep” program
      while deaths from SIDS has decreased.

D. **6 - 12 months of age** - Most significant stage of normal chest development

1. **Shape and size of chest and trunk**
   a) Anti-gravity movement of all trunk planes of motion is now possible
   b) Cervical elongation
      (1) Ability to use accessory muscles
      (2) Both for respiration and head turning
   c) Rib cage
      (1) Elongating
      (2) Downward rotation of ribs
         (a) Abdominals
         (b) Gravity
      (3) Separation between ribs
         (a) Wider intercostal spacing
         (b) Increased length-tension relationship of intercostals
         making them more functional
      (4) More rectangular shape
      (5) More elliptical rather than circular shape circumferentially
   d) Trunk
      (1) Proportion now 1:1
      (2) Midtrunk interfacing: functional joining of rib cage and abdomen into one functional trunk for breathing and postural control
2. Breathing patterns

   a) Diaphragm's mechanical advantage has improved with increased muscle length, allowing 3 dimensional movement


   b) All accessory muscles now available

   c) Respiratory reserves have increased for both inspiration and expiration

   d) Lung size increases 4x since birth

   e) RR continually decreasing to ~ 30 br/min by the end of the first year

3. Parallel gross motor development 6 - 12 months

   a) Respiration

   (1) Can support the oxygen demands of the large muscles involved in gross motor skills

   (2) Breathing patterns have been simultaneously developed with postural responses

   (3) Can breathe and move, not breathe or move

   b) Most rapid period of gross motor development

   (1) Multiple gross motor milestones including independent: sitting, creeping, crawling, standing, walking, climbing

   c) Trunk

   (1) Rib movement allow for individual separation allowing

      (a) Thoracic spine to move in lateral and axial planes as well as the previous anterior-posterior plane

   (2) Transitional movements from recumbency to upright is now functional
E. Surviving vs. Thriving

1. Medical issues: Related to health, which relates to surviving needs
2. Physical issues: Related to participation, which relates to thriving needs
3. Which mode is your patient in?
4. Where do you need to direct your intervention?

F. Over 12 months of age - trends continue at a less dramatic pace

1. **Shape and size of chest and trunk**
   a) More cervical elongation
   b) Shoulders down and more relative external rotation
   c) Scapula functional stabilization from surrounding muscles
   d) Trunk
      1. Proportion: rib cage now at least one half of the trunk space
      2. Midtrunk interfacing well defined and functional

2. **Breathing patterns**
   a) Refinement of breath support and postural control
   b) Can still readily meet the oxygen demands of task while continuing to breathe throughout activity.
   c) Rarely "breath holds" as a postural control strategy
   d) Speech breathing is different than rest breathing (Moore 2001)

3. **Parallel gross motor development over 12 months**
   a) Learning advanced gross motor skills

G. 4 - 5 years of age

1. **Shape and size of chest and trunk**
   a) Rib cage similar to adult except for anterior-posterior depth which increases significantly during puberty
   b) Trunk:
      1. Rib cage more than half of trunk space
      2. Highly developed mid-trunk interfacing between abdominals and intercostals

2. **Breathing patterns**
   a) All respiratory muscles functional
   b) Can take a fast deep breath without chestwall collapse from increased negative inspiratory force (NIF)
3. **Parallel gross motor development 4-5 years old**
   a) Has the refined breath support and postural strategies to continue to pursue more challenging gross motor tasks such as skipping, single limb hopping, etc.

H. **Trends in Aging**
   1. Increased lung compliance (decreased elastic recoil of lung tissue)
   2. Decreased chest wall compliance (stiff chest)
   3. Decreased lung volumes and expiratory flow rates, hence decreased cough effectiveness rendering older persons more susceptible to respiratory complications
   4. Many premature and intrauterine growth restricted infants achieve normal or near-normal lung function by adulthood ([Lima-Rda 2005](#)).

I. **Summary: Comparison of infant and adult chest/trunk function and alignment**

<table>
<thead>
<tr>
<th>CHEST</th>
<th>INFANT</th>
<th>ADULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>Occupies 1/3 trunk cavity</td>
<td>Occupies &gt;1/2 trunk capacity</td>
</tr>
<tr>
<td>Shape</td>
<td>Triangular frontal plane Circular A-P plane</td>
<td>Rectangular frontal plane Elliptical A-P plane</td>
</tr>
<tr>
<td>Upper chest</td>
<td>Narrow Flat apex</td>
<td>Wide Convex apex</td>
</tr>
<tr>
<td>Lower chest</td>
<td>Circular Flared lower ribs</td>
<td>Elliptical Integrated with abdominals</td>
</tr>
<tr>
<td>Ribs</td>
<td>Evenly horizontal</td>
<td>Rotated downward Especially inferiorly</td>
</tr>
<tr>
<td>Intercostal spacing</td>
<td>Narrow Limits movement</td>
<td>Wide Allows for individual movement</td>
</tr>
<tr>
<td>Diaphragm</td>
<td>Adequate Minimal dome shape</td>
<td>Adequate Large dome shape</td>
</tr>
<tr>
<td>Accessory muscles</td>
<td>Non-functional</td>
<td>Functional</td>
</tr>
</tbody>
</table>
III. SUMMARY OF NORMAL DEVELOPMENT OF BREATHING PATTERNS

A. Newborn: Diaphragmatic nose breathing

B. By 12 months old: Additional use of intercostals, abdominals and all other accessory muscles

C. Over 12 months of age: Refined skill level of breath support for movement and speech
   1. Voicing is the delicate balance between airway resistance and breath support
   2. Larynx and lungs synchronize their movements to use the Bernoulli Effect for the production of sound
   3. Primary pattern of breath support is eccentric contractions of the inspiratory muscles during phonation

D. Atypical breath support patterns for phonation
   1. Concentric exhalation (forced phonation)
   2. Passive exhalation (breathy and quiet)

IV. COMPENSATORY BREATHING PATTERNS

A. Brain stem lesions to respiratory centers
   1. Cheyne-Stokes breathing
   2. central neurogenic hyperventilation
   3. apneusis*
   4. cluster breathing*
   5. ataxic (or Biot's) breathing*
   6. Central Alveolar Hypoventilation (Ondine's curse)*

(*usually require mechanical ventilation)

B. Paradoxical breathing ("see-saw breathing")
   1. Paradox of the “triad muscles”: Two types
      a) Strong diaphragm, weak intercostals & abdominals
         (1) upper chest collapses during inspiration
         (2) belly rises excessively (diaphragm is stronger than the other respiratory muscles, overpowering them)
         (3) Also known as
            (a) belly breathing
            (b) see-saw breathing
            (c) inward breathing
      b) Or the opposite: weak diaphragm and strong abdominals &/or intercostals
         (a) lower chest and abdomen collapse during inspiration
         (2) upper chest rises excessively
C. Isolated diaphragm (no support from the rest of the "triad" - intercostals and abdominals). Lower chestwall often "sucked inward" with inhalation resulting in a pectus excavatum.

D. Diaphragm and upper accessory muscles only (paralyzed intercostals, primary lung disease such as asthma, etc.). Movement primarily superior-inferior plane, but may be adequate compensation for a neurologic condition yet inefficient for a pulmonary disease.

E. Upper accessory muscles only (none of the "triad" functioning) - it may be all that is available to the patient as for a patient with a high level spinal cord injury, or it may be over-recruitment of upper accessories tied to an increased respiratory work load.

F. Lateral breathers (weakness, not paralysis of trunk muscles) – these patients tend to breathe wherever gravity has its least influence which allows them to get the most out of their weak muscles. For example, in sidelying, these patients (often neurologic or very sick) breathe anteriorly; in supine, they breathe lateral; in sitting, they breathe inferior.

G. Asymmetrical breathers (hemiplegia, scoliosis, surgical situations, etc.) – one side of the chestwall needs to compensate for the lack of movement on the other and thus the difference between the two sides of the chestwall is even more exaggerated than the scoliosis, hemiparesis, atelectasis, etc., would predict.

H. Shallow breathers (typically high tone patients, painful conditions, anxiety, etc.) - very weak, very sick, very painful, very spastic conditions may result in very shallow breathing that may need external support for tidal volume. The breathing pattern may be normal, but the lung volumes are very minimal.

I. Altered speech support patterns (poor breath support in general or poor eccentric control for phonation) – lung volumes may be normal, but the patient has difficulty coordinating the simultaneous demands for breathing and postural control. Vocal utterances may become shorter and quieter. Or the patient has weak, paralyzed or damaged vocal folds which prevent effective eccentric exhalation control necessary for normal quiet speech. Voice may be breathy and short or it may be forced and short.
V. SUMMARY

A. Chestwall alignment:
   1. major changes occur from infant to adulthood
   2. significantly influenced by outside factors such as gravity, muscle strength and muscle tone in addition to genetic predisposition

B. Postural control and breathing strategies are developed simultaneously to support movement

C. Impairments to respiration and/or breathing mechanics may result in musculoskeletal impairments or vice versa

D. Therefore, chestwall development must be assessed within the context of motor and health development in order to assess its overall impact on the child’s function.

MELISSA’S CASE: C5 SCI AT BIRTH - AGE 3 & 12 YEARS OLD
NORMAL AND ABNORMAL CHEST WALL DEVELOPMENT AND FUNCTION

References


### CHEST ASSESSMENT LAB

**FOCUS ON MUSCULOSKELETAL ALIGNMENT AND BREATHING PATTERN ASSESSMENT**


*Massery. Impaired breathing mechanics and/or postural control. Cardiovascular & Pulmonary PT Evidence & Practice, ed. 4, 2006:695-717.*


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#### I. STATIC OBSERVATIONS (DEVELOPMENTALLY APPROPRIATE)

<table>
<thead>
<tr>
<th></th>
<th>ANTERIOR VIEW</th>
<th>LATERAL VIEW</th>
<th>POSTERIOR VIEW</th>
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<td>SCAPULAE</td>
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Mary Massery  
(847) 803-0803  
e-m: mmassery@aol.com  
website: www.MasseryPT.com
II. DYNAMIC OBSERVATIONS: IN PAIRS, OBSERVE BREATHING IN TWO DIFFERENT POSTURES. ASSUME A COMFORTABLE RESTING POSITION IN EACH POSTURE.

<table>
<thead>
<tr>
<th></th>
<th>STANDING</th>
<th>SUPINE</th>
<th>SIDE- LYING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NORMAL QUIET BREATHING: TIDAL VOLUME</strong></td>
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<tr>
<td>DESCRIBE:</td>
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</tr>
<tr>
<td>SEQUENCE OF BREATHING PATTERN</td>
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<td></td>
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<tr>
<td>PRIMARY BREATHING PATTERN</td>
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<tr>
<td>RESPIRATORY RATE</td>
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<td></td>
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<tr>
<td>QUALITY OF PATTERN</td>
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</table>

**MAXIMAL INSPIRATORY EFFORT: VITAL CAPACITY**

<table>
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<tr>
<th>DESCRIBE:</th>
<th>STANDING</th>
<th>SUPINE</th>
<th>SIDE-LYING</th>
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<tbody>
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<td>SEQUENCE OF BREATHING PATTERN</td>
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<tr>
<td>PRIMARY BREATHING PATTERN</td>
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</tr>
<tr>
<td>QUALITY OF PATTERN</td>
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</tbody>
</table>
III. INTERPRET RESULTS

A. Did the breathing patterns change in the different postures?
B. Was the tidal volume and vital capacity pattern the same, except for volume?

IV. MANUAL OBSERVATIONS

A. Confirm breathing pattern with manual palpation. (Remember that touch by itself can change patterns by facilitating or inhibiting movement.)

1. frontal view: palpate upper, mid, and lower chest expansion
2. posterior view: palpate upper, mid, and lower chest expansion

B. Assess trunk muscles alignment and function

1. neck and shoulder muscles
   a) perpendicular strum
   b) watch for tight (twanging) muscles

2. intercostals
   a) use sidelying with towel or pillow roll under the lower ribs (not waist)
   b) place fingers in intercostal spaces
      (1) watch for opening during inspiration
      (2) ask for side-bending, watch for closure

3. pectoralis
   a) use vertical towel roll along thoracic spine while supine to maximize stretch on pectoralis muscle
   b) perpendicular strum

4. abdominal interfacing with thorax
   a) supine in a hook-lying position (knees bent)
   b) place the side of your hand under lower border of ribs to lengthen abdominals. Your hand should “pop out” when you ask the patient to lift his head. Differentiate between
      (1) rectus: use a medial placement and raise head straight plane
      (2) external obliques: use a lateral placement and raise head diagonal plane
   c) test for transverse abdominus: “smash my hand” with exhalation
   d) test functional sequence by having patient “get out of bed” without knowing he is being tested

5. quadratus
   a) same position as intercostals
   b) arm at their side. Ask patient to lift their ear up to the ceiling. Quadratus should "pop out"

6. posterior musculature
   a) in prone
   b) perpendicular strum, watch for tight (twanging) muscles
C. Superficial fascia

D. Rib spacing and function

1. static positioning: side-bending in upright and in sidelying
2. dynamic movement: rib separation and folding (see intercostals above)
3. symmetry of static positioning and dynamic activity

E. Bony landmarks

1. sternum
2. rib attachment to sternum
3. clavicles
4. scapulae
5. spine

V. OBJECTIVE MEASUREMENTS

A. PFTs - graph your results

B. Chest wall excursion (CWE): circumferential expansion using a tape measure

<table>
<thead>
<tr>
<th>Tidal Volume</th>
<th>3rd rib (axilla)</th>
<th>Xiphoid</th>
<th>1/2 distance from xiphoid to naval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Supine</td>
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<td></td>
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<tr>
<td>Side-lying</td>
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</table>

<table>
<thead>
<tr>
<th>Vital Capacity</th>
<th>3rd rib (axilla)</th>
<th>Xiphoid</th>
<th>1/2 distance from xiphoid to naval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supine</td>
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<tr>
<td>Side-lying</td>
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</tbody>
</table>
C. Typical measurements for tidal volume excursion (unpublished data):

1. 3rd rib site - total excursion approximately 2/8th" (~.6 cm)
2. xiphoid site - total excursion approximately 3/8th" (~.95 cm)
3. 1/2 distance site - excursion approximately 4/8th" (~1.3 cm)
4. measurements fairly consistent from age 3 through adulthood regardless of patient's size or age
5. pediatric (< 3 y/o): same measurement sites: ~1/8th", 2/8th", 3/8th"

D. Typical measurements for vital capacity (published and unpublished data):

1. from 1½ - 3½ inches (~4 – 9 cm)
2. should get larger as you move down the chest wall sites
3. variable according to size, body type, posture, movement patterns, etc.
4. measurement will tell you the patient's recruitment pattern for a deep breath (i.e. recruitment of the upper accessory muscles vs. intercostals vs. more diaphragm, etc)
5. LaPier 2000 & 2002:
   a) Excellent inter & intra-tester reliability for CWE at xiphoid and axillary sites in both supine and standing. ICC > .92 for all four measurements.
   b) 120 Healthy adults 20 – 70+ years old. Divided into 6 groups by decade of life.
   c) Results: large variability in CWE during VC maneuvers. Comparison to norms may not be possible, but may be appropriate for individual patients.
   d) CWE decreased with age from 20-70+ years, but large variability.

VI. LISTEN

A. Auscultation of breath sounds

1. listen from one side to the other at the same horizontal position on the thorax
2. listen in a symmetrical posture

B. Quality of phonation

1. number of syllables/breath or length of vowel sound
2. voice variations/pitches/volumes

C. Cough effectiveness

1. assess all 4 phases
2. assess productivity
I. Decision Tree for Multisystem Analysis of Motor Dysfunction:

A. Identify the primary pathology: list it in an impairment category.

B. Identify the progression of impairments starting with the primary system of impairment.

C. Identify which impairment categories are currently adversely affected by the patient's condition.
   1. Impairments
   2. Functional Limitations

D. Prioritize the impairment categories from the most-pressing problem to a less-pressing problem or perhaps something that may occur later if the current problem is not addressed now.
   1. Remember that medical needs always take precedence over physical or motor needs

E. Identify appropriate tests and measures that you would use on this patient given the environment, the patient's condition, and the reality of the work setting (including budgetary concerns).
   1. Consider the variety of tests & measurements can you perform in a clinical setting?
      a) How often? Frequency counts
      b) How long? Measure of time or distance
      c) How much? An amount

F. State the diagnosis(es).

G. State your prognosis(es).

H. Write at least one goal for this patient stated as a desired change in impairment as it relates to functional limitations and then more globally to disability (health and participation).
   1. Example: "Improve chest wall mobility to decrease the work of breathing (Impairment) in order to improve endurance for walking (Activity/Functional Limitation) which is necessary for independence in his home environment (Participation).

   2. Breathing is synchronized with movement for optimal performance of the 6 following daily tasks.
      Consider the specific tests and measures pertaining to each of these functional skills.
      a) BREATHING
      b) COUGHING
      c) SLEEPING
      d) EATING
      e) TALKING
      f) MOVING (developmental skills, playing, walking, etc.)

I. List some suggested interventions prioritized as indicated above.
## MULTI-SYSTEM ANALYSIS

<table>
<thead>
<tr>
<th>IMPAIRMENT CATEGORIES*</th>
<th>MS</th>
<th>NM</th>
<th>CP</th>
<th>INT</th>
<th>IO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify primary pathology</td>
<td></td>
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<tr>
<td>Identify the progression of impairments</td>
<td>→</td>
<td>→</td>
<td>→</td>
<td>→</td>
<td>→</td>
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<tr>
<td>List current problems by category (Impairments and functional limitations)</td>
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<tr>
<td>Prioritize the affected categories</td>
<td>→</td>
<td>→</td>
<td>→</td>
<td>→</td>
<td>→</td>
</tr>
</tbody>
</table>

| Tests & Measures |    |    |    |     |    |
| Diagnosis |    |    |    |     |    |
| Prognosis |    |    |    |     |    |
| Primary goal(s) |    |    |    |     |    |
| Suggest interventions |    |    |    |     |    |

* MS = Musculoskeletal System  CP = Cardiovascular/Pulmonary System  IO = Internal Organ System (GI typically)
NM = Neuromuscular System  INT = Integumentary System

Mary Massery  
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e-m: mmassery@aol.com  
website: www.MasseryPT.com
Case Example

**MELISSA**: 3 y/o girl with C5 SCI at birth: 7 pneumonias, multiple hospitalizations, tracheostomy, failure to thrive, passive personality, rarely talks. Lives at home with good family support. Mom wants her to be healthy, to be able to talk and communicate, and to be mobile somehow in the house in order to feel like a more active part of the family.
# Case Example

**MELISSA**: 3 y/o girl with C5 SCI at birth: 7 pneumonias, multiple hospitalizations, tracheostomy, failure to thrive, passive personality, rarely talks. Lives at home with good family support. Mom wants her to be healthy, to be able to talk and communicate, and to be mobile somehow in the house in order to feel like a more active part of the family.

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<th>NM</th>
<th>CP</th>
<th>INT</th>
<th>IO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify primary pathology</td>
<td>SCI</td>
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<tr>
<td>Identify the progression of impairments</td>
<td>NM</td>
<td>CP</td>
<td>IO</td>
<td>MS</td>
<td>INT</td>
</tr>
<tr>
<td>List current problems by category (Impairments and functional limitations)</td>
<td>- adverse development of all joints</td>
<td>- paralysis below C5 distribution</td>
<td>- recurring pneumonias</td>
<td>- no problems (yet)</td>
<td></td>
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<tr>
<td></td>
<td>- weak above C5</td>
<td>- cor pulmonale</td>
<td>- constipation</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>- poor motor planning</td>
<td>- paradoxical breathing</td>
<td>- reflux</td>
<td></td>
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<tr>
<td></td>
<td>- poor vestibular development</td>
<td>- inadequate breath support for talking, eating, coughing, sleeping, moving</td>
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<tr>
<td></td>
<td>- weak cough</td>
<td>- 60 br/min RR</td>
<td>- failure to thrive</td>
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<td></td>
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<tr>
<td></td>
<td>- weak cough</td>
<td>- poor vestibular development</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- weak cough</td>
<td>- no desire to eat</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>- dehydration</td>
<td></td>
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<tr>
<td>Prioritize the affected categories</td>
<td>IO</td>
<td>CP</td>
<td>MS</td>
<td>NM</td>
<td>INT</td>
</tr>
<tr>
<td>Tests &amp; Measures</td>
<td>- ROM</td>
<td>- mmt</td>
<td>- RR, HR, O2 sats, CO2</td>
<td>- myofascial screening for connective tissue tightening</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- postural assessment</td>
<td>- outcome assessments</td>
<td>- breathing pattern in multiple postures</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>- phonation</td>
<td>- # syllables/hr &amp; sustained phonation</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>- auscultation, etc.</td>
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<tr>
<td>Diagnosis</td>
<td>3 y/o girl with C5 complete SCI with resultant serious secondary complications in her skeletal development, respiratory and nutritional health, as well as a complete dependence in all ADL skills.</td>
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<tr>
<td>Prognosis</td>
<td>Marked compromises of respiratory function and nutritional status appear to pose the greatest deterrents to successful rehabilitation. Without external support for her weakened musculoskeletal frame, and coordinated action of the entire rehabilitation team to meet her physical and medical needs, these conditions will likely continue to deteriorate, causing increased morbidity and possibly death.</td>
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<tr>
<td>Primary goal(s)</td>
<td>Improve chest wall and spine alignment, improve breathing and postural mechanics, and devise effective airway clearance strategies in order to improve respiratory health, improve ability to support phonation, and improve energy expenditure such that Melissa will have adequate oxygen and nutritional fuel to focus on eating, growing, communicating, and moving rather than just staying alive.</td>
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<tr>
<td>Suggest interventions</td>
<td>- TLSO &amp; abdominal binder</td>
<td>- power w/c</td>
<td>- nocturnal support for ventilation</td>
<td></td>
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<tr>
<td></td>
<td>- passive ROM</td>
<td>- neuromuscular retraining from breathing patterns to movement strategies</td>
<td>- comprehensive airway clearance program</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>- breathing retraining with all activities including phonation and eating</td>
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<td></td>
<td></td>
<td></td>
<td>- none at this time</td>
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</table>

* MS = Musculoskeletal System  
CP = Cardiovascular/Pulmonary System  
IO = Internal Organ System  
NM = Neuromuscular System  
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Case Example

CHARLES: 50 year old male with new diagnosis of hypertension just prior to his stroke. Patient stated that his doctor was trying to find the right combination of medications to stabilize his blood pressure when he had a right cerebral vascular accident (CVA) with resultant left hemiplegia 6 weeks ago. His blood pressure is now stabilized but at the high end of normal, generally 130/90. No remarkable pulmonary history. No diabetes. No congestive heart failure. He had been healthy prior to this incident. Patient was seen for initial 45 minute evaluation.

Charles was employed as a factory worker and stood all day long. Even if he recovered enough balance and endurance to return to work, he does not want to return. He would rather find a less physically demanding job. He has recently been discharged from rehabilitation. He uses a wide based quad cane with close stand by assistance by this wife for gait. His balance is fair and he is afraid of falling. He holds his breath in all upright activities more demanding than just quiet sitting. He has not tried walking outside his home other than to get into a car for an appointment. His speed is slow and measured. His left upper extremity has movement at all joints but the prevalent volitional movement is in flexion.

Hi personal goal is to return to the normal household activities that he enjoyed doing prior to the stroke, in particular, he wants to be able to do the dishes and laundry with his wife. He has never engaged in sporting activities as an adult. He is a quiet man. He isn’t ready to think about what kind of work he might want to do later.
Case Example

CHARLES: 50 year old male with sub acute stroke and resultant left hemiparesis. His blood pressure is stable but needs monitoring. His motor skills are returning in both extremities, but his household functional skills are severely curtailed. He wants to return to household chores.

<table>
<thead>
<tr>
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<th>CP</th>
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<td>Identify primary pathology</td>
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<td>CVA</td>
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<td>Identify the progression of impairments</td>
<td>CP</td>
<td>NM</td>
<td>MS</td>
<td>INT</td>
<td>IO</td>
</tr>
<tr>
<td>List current problems by category (Impairments and functional limitations)</td>
<td>- loss of ROM: left shoulder, hand and ankle</td>
<td>- poor core stabilization in upright / decreased postural control overall</td>
<td>- hypertension with medications</td>
<td>- no restrictions in movement</td>
<td>- well nourished</td>
</tr>
<tr>
<td></td>
<td>- shoulder impingement with pain</td>
<td>- weakness throughout left side</td>
<td>- BP 130/90</td>
<td>- no abnormal vascular changes</td>
<td>- well hydrated</td>
</tr>
<tr>
<td></td>
<td>- loss of trunk rotation, especially to left</td>
<td>- poor coordination of breathing and moving</td>
<td>- no CHF, diabetes or pulmonary disease</td>
<td>- connective tissue screening especially around left joints with decreased ROM</td>
<td>- no known GI dysfunction</td>
</tr>
<tr>
<td></td>
<td>- distal pulses intact</td>
<td>- breath holding with all exertion</td>
<td>- distal pulses</td>
<td>- interview about eating, nutrition, hydration, stomach and lower GI function</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- poor coordination of breathing and moving</td>
<td>- no restrictions in movement</td>
<td>- check for signs of vascular compromise</td>
<td></td>
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</tr>
<tr>
<td>Prioritize the affected categories</td>
<td>CP</td>
<td>MS</td>
<td>NM</td>
<td>IO</td>
<td>INT</td>
</tr>
<tr>
<td>Tests &amp; Measures</td>
<td>- ROM</td>
<td>- gross assessment of extremities and trunk movements in isolated and functional tasks (inadequate time for formal testing)</td>
<td>- Vital signs at rest and with activity</td>
<td>- monitor condition</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Postural assessment</td>
<td>- phonation with activities</td>
<td>- monitor hydration levels</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>- distal pulses</td>
<td></td>
<td></td>
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<tr>
<td>Diagnosis</td>
<td>50 y/o healthy male until new diagnosis of hypertension and right CVA 6 weeks ago which has resulted in moderate left hemiparesis and severe limitations in all ADL skills.</td>
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<tr>
<td>Prognosis</td>
<td>Loss of ROM and control of his left side, and poor coordination of breathing and moving has resulted in significant postural control impairments which has made him more dependent on his wife for assistance for all ADL skills than his weakness alone should cause. His quick neurologic recovery of motor skills both proximally and distally in his left extremities and trunk indicates the potential of a good motor prognosis. Because his health prior to the CVA had been good, and as his hypertension is coming under control, his medical prognosis should be good as well.</td>
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<tr>
<td>Primary goal(s)</td>
<td>Monitor BP and hydration levels with and without activities to help establish safe activity guidelines, increase ROM and strength, improve the balance and coordination of ventilatory and trunk control needs in order to improve his postural control such that he could use the strength of his trunk and extremities more efficiently and safely to move towards independence in the household motor tasks that are important to his sense of well being and recovery.</td>
<td></td>
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<tr>
<td>Suggest interventions</td>
<td>- Passive and active ROM</td>
<td>- use of ventilatory strategies with all motor tasks, especially in upright activities more demanding than quiet sitting</td>
<td>- monitor vital signs at rest and with activities</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>- consider more aggressive interventions if needed</td>
<td>- consider partial body weight supported treadmill training</td>
<td>- monitor condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- monitor hydration levels</td>
<td>- monitor condition</td>
<td></td>
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</tbody>
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NM = Neuromuscular System  INT = Integumentary System
FIND THE PROBLEM!

References


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website: www.MasseryPT.com

e-m: mmassery@aol.com

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Find the Problem!

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m: mmassery@aol.com
VENTILATORY OR MOVEMENT STRATEGIES: INTEGRATING NEUROMUSCULAR, MUSCULOSKELETAL, RESPIRATORY & SENSORY SYSTEMS

Frownfelter & Massery, Facilitating ventilation patterns. Cardiovascular & Pulmonary PT Evidence & Practice, ed. 4, 2006;Chap. 23.

I. WHAT IS A VENTILATORY OR MOVEMENT STRATEGY?

A. Definition: A ventilatory strategy is the intentional pairing of inhalation & exhalation patterns with movement in order to enhance the overall motor task.

B. Motor task: the movement you desire to accomplish, i.e. rolling over in bed, putting on your shoes, combing your hair, playing wheelchair sports, serving a tennis ball, etc.

C. Application to ICF Model: Use ventilatory strategies to maximize mobility levels (participation) and respiratory health

II. CONCEPT DEVELOPMENT:

A. Based on normal motor development, anatomy, physiology, energy efficiency of movement, dual nature of breathing and moving, neuroplasticity, and 30+ years of observations

B. Research:

1. Hodges 2007: postural control, respiration and pelvic floor responses are related

2. Doidge 2007 (Chapter 3): Mike Merzenich’s developmental work on neuroplasticity in the 1980s & 1990s
   a) “Neurons that fire together wire together”
   b) “Neurons that fire apart wire apart”, or “Neurons out of sync fail to link”

3. Efficient recruitment of muscles for respiration
   a) Butler 2008 - recruitment of external intercostal muscles for inspiration are highly associated with an increased mechanical advantage (r² =0.99). Patterns varied significantly between subjects. Lots more to learn about the neuromotor recruitment for breathing and postural control!

   b) Froese 2006 – How you breathe differs by the strength of your diaphragm (3 healthy subjects paralyzed transiently and re-tested). Sidelying: Non-dependent lung moved more efficiently when paralyzed. Dependent lung moved more when healthy. IAP (intra-abdominal pressure) matters.
III. THE PRINCIPLES FOR VENTILATORY STRATEGIES: INTEGRATING ALL THE BODY SYSTEMS INTO FLUID, EFFICIENT MOVEMENTS

A. **Thoracic spine movements:** coordinated with respiration and determines the appropriate matching phase

1. **Extension:** usually paired with inhalation (sitting up, reaching up, etc.)
2. **Flexion:** usually paired with exhalation (squatting, reaching down, etc.)
3. **Research:** Lamberg & Hagins 2013
   
   a) Reaching up to an object while going onto tiptoes was highly associated with inhalation and increased lung volume.
   b) Coming down was highly associated with exhalation and decreased lung volume.
   c) Breath holding, if it occurred, occurred most frequently during the “hold” phase: of the high-placed object at the peak of the reaching task.
   d) Breath support may be used to increase trunk stability.

B. **Primary type of muscle contraction used during the motor task:** determines specific muscle contraction of the inspiratory or expiratory pattern

1. **Isometric vs. isotonic contraction**
   
   a) **isometric** (stability activities)
      
      (1) paired with breath holding (not valsalva)
      (2) static stability postural strategy: i.e. - reaching up to a high shelf and "fishing" around for something
   
   b) **isotonic** (movement activities)
      
      (1) paired with inhalation or exhalation pattern
      (2) dynamic stability postural strategy: i.e. - any activity that requires movement of the trunk (chest, spine, pelvis) such as standing up, sitting down, reaching, etc.

2. **Concentric vs. eccentric contraction**

   a) **concentric** - moving up into gravity
      
      (1) paired with a concentric breathing pattern; shortening of the muscle
      (2) think of lifting up a barbell. Your bicep muscle contracts concentrically. Apply the same concept to your chest muscles, i.e. all inspiratory patterns, forceful exhalation
   
   b) **eccentric** - coming back into gravity
      
      (1) paired with an eccentric breathing pattern; controlled lengthening of the muscle
      (2) think of lowering the barbell. Your bicep muscle contracts eccentrically by slowly lowering the barbell. Apply the same concept to your chest, i.e. speech, singing, humming, purse lip breathing or any controlled expiratory pattern
(1) Passive
   
   (1) paired with fairly passive, low demand, postural tasks like sitting in a chair, lying on a couch. Little or no effort.
   (2) Just the opposite... patients who passively exhale as they sit down and wind up “falling” into the chair. the task required more control, but thire breath support was a low control maneuver.

C. From the spine and muscle contraction information, match the breathing and sensory strategy to that specific motor task

1. Breathing Strategies

   a) Inhalation: always a concentric contraction
      
      (1) can be used to increase thoracic spine extension via more activation of upper accessory muscles
      (2) can be used to maintain a neutral spine or slight flexion via activation of a more diaphragmatic pattern

   b) Exhalation: can be many types of muscle contractions
      
      (1) passive: used during quiet breathing. Low "postural demand" on trunk muscles
      (2) eccentric: used during quiet, controlled (slow and intentionally prolonged) activities such as speech or other fine motor related activities
      (3) concentric: used to forcefully expel the air such as in coughing, yelling or any resistive activity that requires a concentric contraction of the abdominal muscles (generally more gross motor related activities)

2. Sensory strategies

   a) Eyes: lead the movement
      
      (1) eyes up - usually paired with inhalation
      (2) eyes down - usually paired with exhalation
      (3) Research: Bexander 2005: relationship of neck movements/amplitude and vision
          
          (a) Vision and head rotation was indeed linked. Muscle activation of neck rotators increased when vision matched the head movement, enhancing the neck movement response.
          (b) Relationship between vision and neck movement was observed in both static tasks and functional movements

   b) Auditory: influences muscle recruitment patterns
      
      (1) Louder, faster, higher pitch voices usually facilitates
          
          (a) more upper accessory muscle breathing
          (b) more upper thoracic trunk extension
          (c) a quicker inspiratory effort
          (d) Polla 2004 – diaphragm is composed of more Type 1 slow twitch fibers whereas the intercostals are composed of more fast twitch Type 2A, 2X & 2B fibers.
II. INCORPORATING CONCEPTS INTO FUNCTIONAL TASKS – EXAMPLES

A. In each of the following typical motor tasks:

1. Identify:
   a) The type of thoracic trunk pattern that is prevalent
   b) The type of muscle contraction that is prevalent

2. Based on this information, add:
   a) The most logical ventilatory strategy
   b) The most logical sensory stimulus

B. Rolling
   1. Rolling with flexion
   2. Rolling with extension

C. Reaching
   1. Reaching up
   2. Coming back down

D. Talking
   1. With activities

E. Dressing
   1. Shirts
   2. Socks

F. Transfers
   1. Assumption of standing and return to sitting (standing pivot)
   2. Sliding board transfer

G. Eating

H. Weight Lifting: (fallacies of the trade)
### Ventilatory strategies: Decision tree

<table>
<thead>
<tr>
<th>The Movement</th>
<th>Flexion</th>
<th></th>
<th>Extension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracic Spine Movement</td>
<td></td>
<td></td>
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<tr>
<td>Matching Respiratory Phase</td>
<td></td>
<td></td>
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<tr>
<td>Type of muscle contraction needed for that movement</td>
<td>Concentric</td>
<td>Eccentric</td>
<td>Passive</td>
</tr>
<tr>
<td>Matching Respiratory Response (ventilatory strategy)</td>
<td>Forced Exhalation</td>
<td>Controlled Exhalation</td>
<td>Passive Exhalation</td>
</tr>
<tr>
<td></td>
<td>yelling, coughing, grunting, blowing</td>
<td>talking, singing, humming, gentle pursed lip breathing</td>
<td>no effort, no control, simply “letting go”</td>
</tr>
<tr>
<td>Matching visual strategy</td>
<td>Eyes down</td>
<td>Eyes down</td>
<td>No preference</td>
</tr>
<tr>
<td>Matching audible strategy</td>
<td>Loud, low pitch, forceful, faster cadence voice</td>
<td>Smooth, softer, slower, sustained voice</td>
<td>No preference</td>
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<tr>
<td>SAMPLE: Reaching up to medicine cabinet</td>
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Mary Massery  
(847) 803-0803  
e-m: mmassery@aol.com  
website: www.MasseryPT.com
GROUP PROBLEM SOLVING: PUTTING IT ALL TOGETHER

I. INCORPORATE THE COURSE MATERIAL INTO THE FOLLOWING TYPICAL THERAPY ACTIVITIES

A. General passive ROM

B. Any upper extremity strengthening program

C. Any lower extremity strengthening program

D. Any developmental sequence activity

E. Upright posture activities (sitting or standing)

F. Instructions in transfers

G. Gait training

H. Gross motor functional skills: i.e. dressing, moving objects around in the home, etc.

I. Ventilatory functional skills: i.e. talking on the phone, coordinating breathing with eating, talking in a crowd, etc.

J. Wheelchair cardiopulmonary fitness training

II. CITE ONE EXAMPLE WHERE CONSIDERATION OF THE PATIENT'S RESPIRATORY SYSTEM WOULD NOT BE APPROPRIATE IN DEVELOPING HIS/HER THERAPY PROGRAM?
COURSE EVALUATION
Please Provide Feedback on the Presentation.

Lecture content: Comments:

Superior - Good - Fair - Poor

Lab content: Comments:

Superior - Good - Fair - Poor

Overall Presentation: Comments:

Superior - Good - Fair - Poor

Were the handouts and A-V materials valuable? YES NO

How?

Did the course meet your expectations? YES NO

How?

What were the course's strengths and weaknesses?

Thank you for your valued input.

NAME (optional):_________________________ Discipline:_________________________

Mary Massery (847) 803-0803 e-m: mmassery@aol.com website: www.MasseryPT.com