Pressure!

- Successful coordination of postural stability and respiratory mechanics depends on how well the patient with SCI:
  - Generates trunk pressure
  - Regulates trunk pressure
  - Maintains trunk pressure
  - In both the thoracic (ITP) and abdominal cavities (IAP)

Pressure!

- Recumbent / upright
- Pediatric / adult

How does it relate to breathing mechanics . . .
What Supports the Skeleton?

The “Soda-Pop Can” Model of Postural Support

A Postural Control Model Using a Soda-Pop Can

- Closed System
- Positive pressure from internal can is > atmospheric pressure
- Pressure creates functional strength to an otherwise weak external structure

A Postural Control Model Using a Soda-Pop Can

- Vocal Folds
- Thoracic Cavity
- Diaphragm
- Abdominal Cavity
- Pelvic Floor

Positive Pressure Compromised

- Pop-top Opened
- External Pressure > Internal Pressure

Potential Results:

Collapsed Skeletal and Internal Organ Alignment and Structure

New definition of “Core”

- Core stability extends from the vocal folds on top to the pelvic floor on the bottom of the trunk, and includes every muscle in between!
- The trunk muscles, including the diaphragm, function simultaneously as postural and respiratory muscles.
- Therefore, balance is related to breathing
  - Balance is more perturbed with chest breathing than diaphragm breathing (Hamaoui 2010)
  - Balance is more perturbed with increased effort of breathing (Kuczynski 2008)
Application to SCI

- Schillo 2009, 2014, Vazquez 2013:
  - Breathing biomechanics are impaired following SCI, and may include paradoxical breathing, rib stiffness, leading to increased work of breathing, decreased cough effectiveness, & presents with long term increased respiratory risk.
- Summary: Breathing, postural control, and the pressure needed for optimal function, cannot be assessed and treated separately and are especially important considerations for patients with neuromuscular conditions that affect breathing.

Emerging Research

- Vocal folds / glottal structures
  - The gate-keeper of pressure regulation and concurrent postural control
    - Hagins 2006
      - glottal control influenced IAP
    - Orlikoff 2008
      - glottal tone increased proportionately with increased UE loading
    - Massery 2013
      - glottal control influenced small balance perturbations

Procedure

- The 7 breathing/voicing conditions included
  - 1 glottis naturally open condition
  - 2 glottis forced-open conditions
  - 2 partially open glottis (voicing) conditions
  - 2 glottis closed (breath-hold) conditions

The Top of the Can

- Are YOUR vocal folds really related to postural demand?

STAND UP AND SEE FOR YOURSELF!

Methods and Materials

- 12 subjects
- Gentle perturbations were created with a chest harness, anterior-posterior cables/pulleys and electro-magnetic weights.

Peak horizontal linear displacement of the thorax during perturbation trials

- Peak horizontal linear displacement of the thorax during perturbation trials
Peak horizontal linear displacement of CoP during perturbation trials

<table>
<thead>
<tr>
<th>Breathing condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximal inspiration / hold</td>
<td>Maximal inspiration, then breath-hold</td>
</tr>
<tr>
<td>Normal expiration / hold</td>
<td>Normal expiration, then breath-hold</td>
</tr>
<tr>
<td>Counting out loud</td>
<td>Normal expiration, then airway left open (no breath hold)</td>
</tr>
<tr>
<td>Sigh</td>
<td>Sigh (H sound)</td>
</tr>
</tbody>
</table>

**CLINICAL PROBLEM: Kevin, 13 y/o**
Brainstem tumor at 10 y/o. Anoxic episode with L CVA at 12 y/o with profound R weakness including R diaphragm

- Failure to wean from the vent.
- Weak diaphragm; chest muscles are inhibited by tight chest strap, which . . .
- Inadvertently limits potential for intercostal & neck accessory muscle breathing, and . . .
- Lap belt placement encourages a posterior pelvic tilt, which . . .
- Increases trunk flexion and forward head posturing which increases aspiration risk

NO WONDER HE COULDN'T WEAN OR SAFELY SWALLOW!

**Add the vocal folds to the full equation:**
Kevin and Dad in early standing

- Without PMV, Kevin’s knees buckled easily.
- Clinical tip: I made Kevin count (engaging vocal folds for proximal control).
  - Sneaky . . ☺☺
- Kevin needed PMV for postural stability.

**Where do we go from here?**

- **Research:** PMVs in SCI and other NM populations
  - Voice
  - Trunk control / Balance
  - Swallow
  - Limb force production / pushing
  - Does the inclusion of a PMV:
    - Improve motor function (ADLs): increased participation?
    - Improve breathing mechanics: increased respiratory health?
Managing Pressures
The rest of the can

- Abdominal binders
  - Increase IAP and postural stability
  - Increase FVC
  - Boaventura 2003, Wadsworth 2012, Cornwell 2014
  - Conflicting outcomes on voicing
    - Wadsworth 2012, Cornwell 2014

- Abdominal compression for cough
  - Using air stacking to increase lung volume, adding abdominal compression during forced exhalation, significantly increased PCFR
    - Torres-Castro 2014

Managing Pressures
The rest of the can

- Wheelchair positioning and PFTs
  - Increased FVC with lumbar lordosis in sitting
    - Landers 2003, Lin 2006

- TLSOs
  - Manage spinal alignment, especially lumbar lordosis
  - Abdominal cutout improves respiratory function
    - Frownfelter 2014 – increased FVC with cutout
  - Add abdominal binder over cutout
    - Massery 1991 – case report

TLSO abdominal cutouts improve PFTs

20 healthy adults, 3 conditions:
1) No brace (control)
2) Brace, no abdominal opening (traditional TLSO)
3) Brace, with abdominal opening (allowing abdominal excursion during breathing)

TLSO: No abdominal opening
TLSO: abdominal opening

TLSO abdominal cutouts improve PFTs: Conclusions

- TLSOs restrict pulmonary function in healthy adults.
- An abdominal cutout in the TLSO increased pulmonary function, especially with activity, suggesting that cutouts should be considered when fabricating TLSOs for individuals with compromised breathing such as with neuromuscular disorders, scoliosis, or spine surgery.
- Research needed in SCI population

TLSO abdominal cutouts improve PFTs

Major Findings

- Wearing a TLSO reduced PFTs compared to controls (not wearing a TLSO) both at rest and after exercise (12 minute walk test) (p < 0.001).
  - May not result in decreased PFTs for SCI, but has not yet been tested in this population

- Novelty: PFTs increased with TLSOs with abdominal cutouts compared to traditional full-contact TLSOs
  - FVC increased at rest (p = 0.007) and after exercise (p = 0.025) with an abdominal cutout
  - FEV1 increased after exercise (p = 0.02) and was near significance at rest (p = 0.053), with an abdominal cutout

Jacob
Long Term Effects
MELISSA (3 y/o): BIRTH TRAUMA C5 SCI

Jacob

MELISSA 3 YEARS OLD

MELISSA 6 YEARS OLD

MELISSA 6 YEARS OLD

MELISSA 6 YEARS OLD
The entire trunk is a functional unit simultaneously supporting upright postural alignment and control, and respiration.

References

### References


