Sunny Hill Health Centre for Children

Proudly Presents

26th International Seating Symposium

Syllabus

March 11 – 13, 2010

The Westin Bayshore
1601 Bayshore Drive
Vancouver, BC

Sponsored by

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Breathing and Upright Posture: Simultaneous Needs

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Breathing and postural mechanics are intertwined [1, 2] and should not be handled separately when designing a person's wheelchair and seating system. Wheelchair and seating systems for the non-ambulatory patient need to address the problems of optimizing upright alignment (musculoskeletal alignment), mobility (neuromotor control of locomotion) and skin integrity (cardiovascular). Perhaps less obviously, the seating practitioner should also be evaluating how wheelchair positioning affects breathing mechanics and vice versa. This paper will focus on the unique aspects of breathing mechanics and the seated patient: establishing a link between breathing, postural control and postural alignment.

Soda-pop can model of postural control (Figure 1)
The aluminum shell of a soda-pop can is not structurally strong; easily crushed when empty or when the top is opened. However, when the can is intact, the internal pressures generated by the carbonated beverage make the aluminum can functionally quite strong and difficult to crush. Likewise, human skeletons are weak; easily crushed if the muscles supporting the skeleton, our "aluminum can", are unable to generate necessary internal pressures to counteract gravitational and atmospheric pressures acting upon it. [3, 4] Patients with profound weakness or paralysis such as in spinal cord injuries (SCI), suffer crushing forces upon their skeletons, overtime causing severe restrictions to the musculoskeletal system and internal organs, thereby restricting lung expansion. [5-7] The respiratory compromise is profoundly worse for children who acquire an SCI prior to the time of skeletal maturation as their developing skeletons are more adversely affected by gravity on their developing frames. [8]

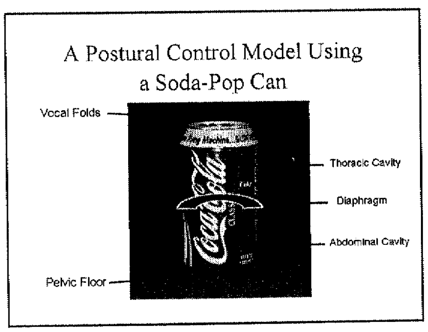

Figure 1: Soda-Pop Can Model

Posture, postural control, and breathing
A chronically slumped posture, the result of collapsing forces, can cause a multitude of postural deficiencies including: 1) a thoraco-lumbar kypho-scoliosis which compresses the anterior rib cage, often causing a mid trunk fold at the xiphoid process, thus restricting breathing mechanics, 2) a compensatory forward head position on top of the thoracic kyphosis which compromises swallowing mechanics thereby increasing the risk of aspiration and mechanically compromising the recruitment of accessory muscles for increased lung volumes, 3) a compensatory upper quadrant position including protracted scapula and humeral internal rotation, impairing shoulder mechanics as well as chestwall muscle recruitment for breathing, and 4) a posterior pelvic tilt with excessive hip external rotation

thus further compressing forces at the mid trunk and pelvic floor further impairing the diaphragm's mechanical advantage. [9] (Figure 2)

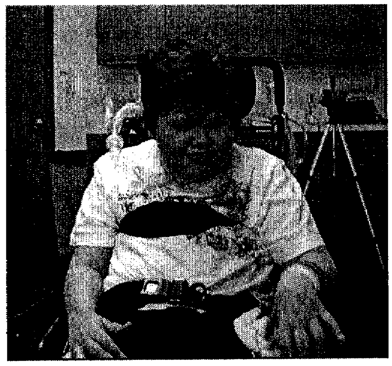

Figure 2: 13 ½ y/o male surviving resection of a brainstem astrocytoma at age 10 years old and then a left CVA secondary to an anoxic seizure at age 12 years old. Note his "collapsed" posture in wheelchair with compromised breathing mechanics. He was on a ventilator 24 hrs/day and was considered "failure to wean".

The diaphragm plays multiple simultaneous roles: maximizing inhalation, contributing to postural control, supporting gastrointestinal function (anti-reflux support and promoting lower GI motility), and aiding venous return. [3, 10, 11] Each one is as vitally important as the other. Positioning strategies needs to take these roles into consideration. The diaphragm needs pelvic floor and abdominal muscle support to create intra-abdominal pressures in order to stabilize the diaphragm's central tendon during inspiratory contractions. [12] This, in turn, supports the efficiency of the intercostal contractions above the diaphragm for maximizing inspiratory lung volumes. [13, 14] This coupling action between the diaphragm and intercostals produces greater drops in pleural pressures than either muscle alone. [15] Thus, preserving the mechanical advantage of both the diaphragm and the anterior chest wall is crucial for optimal breathing mechanics.

Recent studies specifically looked at the effect of positioning on breathing mechanics and lung volumes for normal subjects in a seated position. Landers showed that a collapsed posture (slumped) results in lower lung volumes in healthy adults. [16] Building upon those results, Lin evaluated pulmonary values in 3 sitting postures and 1 standing posture for 70 normal adults. [17] The subject's posture and lumbar lordosis significantly affected lung volume (spirometric values): 1) standing had the greatest lumbar lordosis and the highest pulmonary values, whereas 2) slumped sitting had the least lumbar lordosis and the lowest lung volumes. Of the 2 remaining sitting postures, pulmonary values were higher with a supported lumbar lordosis and ischial relief rather than just a normal posture with full ischial support and a flat back.

Considerations for supporting breathing mechanics and internal trunk pressures in a wheelchair posture

Taking alignment, trunk internal pressure regulation and the newest research in the biomechanics of breathing, it would compel the seating practitioner to consider breathing mechanics in their wheelchair prescription. For patients with a weak trunk, supporting a lumbar lordosis and maintaining an open anterior chest wall appears critical to maximizing lung volumes and diaphragmatic function. This translates into controlling sagittal plane alignment to minimize thoracic kyphosis and a collapsed anterior rib cage (supporting the mid trunk). Internal pressures may need support as well, especially intra-abdominal pressures.

Not all patients will benefit from the same solution. A few ideas will be presented that focus on respiratory mechanics. This author is not a seating expert, but rather a pediatric cardiopulmonary physical therapist looking at seating from a breathing mechanics/postural control perspective.

Figure 3: Now 15 years old, he is off of the ventilator during the day (central sleep apnea prevents nocturnal weans). A TLSO with abdominal cutout supports his postural alignment and breathing mechanics, while the Passy Muir © speaking valve re-engages his vocal folds thus restoring his pressure regulator at the "top of the soda-pop can". Note the improvement in his upper quadrant positioning as well as improved head and neck alignment.

Abdominal binders: For patients with weak or paralyzed abdominal muscles, an abdominal binder may help to restore intra-abdominal pressure for breathing mechanics and pelvic alignment. [18] More research needs to be done in this area, thus the appropriateness of a binder needs to be assessed on an individual basis. [19]

Passy Muir© or other Speaking Valves: Patients with tracheostomies who can tolerate a speaking valve will improve their ability to control intra-thoracic positive pressure because the vocal folds are restored as the expiratory pressure regulator. [20] (See Figure 3) By regulating intra-thoracic pressures, the valve allows graded exhalation, improves internal pressure support for postural control including improved upper extremity force production, improves bowel and bladder emptying, improves swallowing mechanics as well as its original intent to improve voicing.[21-23] Thus, the seating therapist should consider a speaking valve an adjunct to optimal seating for the patient with a tracheostomy.

TLSO: A thoraco-lumbo-sacral orthosis, also known as a "body jacket", controls the sagittal plane from the pelvis up to the upper chest. An abdominal cutout is needed for optimal diaphragmatic excursion.[24] (See Figure 3) An abdominal binder may also be needed for patients with abdominal muscle weakness. The TLSO also allows normal resting positions of the upper quadrant, head and neck if the mal-alignment was compensatory due to the flexed thoraco-lumbar spine and collapsed rib cage. The TLSO is most appropriate in pediatrics prior to skeletal maturation.[8] Other seating positioning strategies may be used for adult patients.

Chest straps and lateral trunk supports: A chest strap is a common and effective positioning device when the primary objective is to keep the patient safely in the wheelchair. However, a chest strap binds the chest down, encouraging a flexed spine and posterior pelvic tilt. (see Figure 2) This compromises the diaphragm and intercostal muscle coupling while further limiting postural control responses of the trunk. Lateral trunk supports are also common and effective positioning devices that can decrease scoliotic forces, but they do not control the sagittal plane. [25]

Tilt- in- space seating: although research shows decrease pressure over the ischium in patients with profound neurologic impairments who are positioned in a tilt-in-space wheelchair, [26] whether to use a tilt and the angle of the tilt must be carefully assessed because of the increased risk for aspiration and the potential for aspiration pneumonia.

Summary

Seating and positioning strategies are complex, taking multiple factors into consideration. This paper addressed the respiratory component of such a multi-system assessment using a soda-pop can model of postural support to explain the interactions between posture, postural control and breathing.

Suggestions were made that may more optimally support breathing mechanics, but in no way excludes other ideas from seasoned seating practitioners. More research is needed in this area.

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