NAJSPT

CLINICAL SUGGESTION

THE VALUE OF BLOWING UP A BALLOON

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ABSTRACT

Suboptimal breathing patterns and impairments of posture and trunk stability are often associated with musculoskeletal complaints such as low back pain. A therapeutic exercise that promotes optimal posture (diaphragm and lumbar spine position), and neuromuscular control of the deep abdominals, diaphragm, and pelvic floor (lumbar-pelvic stabilization) is desirable for utilization with patients who demonstrate suboptimal respiration and posture. This clinical suggestion presents a therapeutic exercise called the 90/90 bridge with ball and balloon. This exercise was designed to optimize breathing and enhance both posture and stability in order to improve function and/or decrease pain. Research and theory related to the technique are also discussed.

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INTRODUCTION

Many muscles used for postural control/stabilization and for respiration are the same, for example: the diaphragm, transversus abdominis, and muscles comprising the pelvic floor.[1-6] Maintaining optimal posture/stability and respiration is important and is even more challenging during exercise. Exercise increases respiratory demand (e.g. running) and limb movements (e.g. arms moving while standing still) increase postural demands for stabilization.[3, 7] Maintaining an optimal balance of these muscles for both respiratory and postural/stability roles is challenging. Many factors are potentially involved with suboptimal respiration and suboptimal (faulty) posture and may be associated with musculoskeletal complaints such as low back pain, and/or sacroiliac joint pain.[8] (Table 1)

One of the most critical factors, often overlooked by physical therapists, is maintaining an optimal zone of apposition of the diaphragm.[3, 9-11] The zone of apposition (ZOA) is the area of the diaphragm encompassing the cylindrical portion (the part of the muscle shaped like a dome/umbrella) which corresponds to the portion directly apposed to the inner aspect of the lower rib cage.[12] The ZOA is important because it is controlled by the abdominal muscles and directs diaphragmatic tension. When the ZOA is decreased or suboptimal, there are several potential negative consequences. (Table 1) Two examples include:

1. Inefficient respiration (less air in and out) because the transdiaphragmatic pressure is reduced.[11] The smaller the ZOA, there will be less inspiratory action of the diaphragm on the rib cage.[11]

2. Diminished activation of the transversus abdominis which is important for both respiration and lumbar stabilization.[11, 13]

In an athletic population, low back pain (LBP) is one of the most common reasons for missed playing time by professional athletes.[14, 15] Low back pain is defined as pain that occurs between the 12th rib and the gluteal fold. This region includes the osseous structures and soft tissue of the lumbar segments and the sacroiliac joints (SIJs).[16] The incidence of LBP has been documented to be as high as 30% in the athletic population, and in many cases pain may persist for years.[15] Low back pain is frequently correlated with faulty posture such as an excessive lumbar lordosis.[16,17,18] Excessive lumbar lordosis may be associated with over lengthened and weak abdominal musculature.[18-20] Poor neuromuscular control of core muscles (transversus abdominis, internal oblique, pelvic floor and diaphragm) has been described in individuals with SIJ pain[21] and in individuals with lumbar segmental instability, potentially adversely affecting respiration.[22]

Table 1. *Possible factors associated with suboptimal respiration and posture.*

Suboptimal Respiration and Posture
Decreased/suboptimal Zone of Apposition of diaphragm
Decreased exercise tolerance
Decreased intra-abdominal pressure
Shortness of Breath/Dyspnea
Decreased respiratory efficiency
Decreased expansion of lower rib cage/chest
Decreased appositional diaphragm force
Decreased length of diaphragm (short)
Decreased transdiaphragm pressure
Increased use of accessory muscles of respiration
Poor neuromuscular control of core muscles
Increased lumbar lordosis
Increased anterior pelvic tilt
Increased hamstring length
Increased abdominal length
Rib elevation/external rotation
Sternum elevation
Increased activity of paraspinals
Increased lumbar-pelvic instability
Low back pain
Sacroiliac Joint pain
Thoracic Outlet Syndrome
Headaches
Asthma

Rehabilitation programs prescribed by physical therapists with the goal of decreasing lumbar-pelvic instability via specific stabilization exercises have been shown to decrease LBP.[23, 24] These stabilization exercises utilize verbal and tactile cuing in order to educate the patient to voluntarily contract the transversus abdominis and multifidi via the abdominal drawing in maneuver (ADIM) in a variety of positions such as supine, sitting, sit to stand, standing and single leg standing.[25] Stabilization exercises have also included co-contraction exercises of the abdominals and lumbar extensor muscles.[26] In spite of decreasing LBP with stabilization exercises, the rate of recurrence of LBP,[15] suggests that there may be a missing component to traditional stabilization exercise programs. Traditional stabilization exercises that have included transversus abdominis, multifidi and/or paraspinal activation are not always sufficient to prevent future episodes of pain. Perhaps stabilization exercises that encourage an optimal ZOA of the diaphragm which in turn promotes optimal activation of the transversus abdominis may further help to address suboptimal respiration and posture which may be associated with LBP.

Richardson et al.[27] describe coordination of the Transversus abdominis and the diaphragm in respiration during tasks in which stability is maintained by tonic activity of these muscles. During inspiration, the diaphragm contracts concentrically, whereas the transversus abdominis contracts eccentrically. The muscles function in reverse during exhalation with the diaphragm contracting eccentrically while the transversus abdominis contracts concentrically. Hodges et al. noted that during respiratory disease the coordinating function between the transversus abdominis and diaphragm was reduced.[6] Thus, it is also possible that faulty posture such as over lengthened abdominals and excessive lordosis could reduce the coordination of the diaphragm and transversus abdominis during respiration and stabilization activities.

O'Sullivan et al.[21] studied subjects with LBP attributed to the sacroiliac joints and compared them to control subjects without pain. O'Sullivan et al. compared respiratory rate and diaphragm and pelvic floor movement using real time ultrasound during a task that required load transfer through the lumbopelvic region (the active straight leg raise test). Subjects with pain had an increase in respiratory rate, descent of their pelvic floor and a decrease in diaphragm excursion as compared to the control subjects, who had normal respiratory rates, less pelvic floor descent, and optimal diaphragm excursion. While O'Sullivan et al. concluded that an intervention program focused on integrating control of deep abdominal muscles with normal pelvic floor and diaphragm function may be effective in managing patients with LBP,[21] they did not describe strategies or exercises to achieve this goal.[21]

The purpose of this clinical suggestion is to discuss the clinical value for patients/athletes in performing an exercise called a 90/90 Bridge with Ball and Balloon by discussing the exercise as it relates to suboptimal respiration and posture.

ANATOMIC BACKGROUND

While the role of the Transversus abdominis in lumbar stability is well documented, less well known is the role of the diaphragm in lumbar stability. While the primary function of the diaphragm is respiration, it also plays a role in spinal stability.[3, 28] Hodges et al. conducted an electomyographic (EMG) study with five subjects who were required to rapidly flex their left arm at the shoulder (while in standing position) in response to a visual stimulus. The authors reported that the diaphragm is involved in the control of postural stability during sudden voluntary movement of the limbs.[3] Subsequently, Hodges et al. reported in an EMG study that the separate demands on the diaphragm to control pressures in the thorax for breathing and abdomen for stabilization of the lumbar spine can be combined; however when the demand for breathing increases, the role of the diaphragm in postural stability declines.[6]

The diaphragm is comprised of two separate muscles, the right hemidiaphragm and left hemidiaphragm, which are innervated by the right and left phrenic nerves respectively. The hemidiaphragm's proximal attachment site is the central tendon.[29] The section anterior and lateral to the central tendon attaches distally to the zyphoid process of the sternum and ribs 7-12 and is referred to as the costal border of the diaphragm. The overall shape of the diaphragm is a dome, with the apex (the central tendon) around the level of T8.[12, 30-32] The right hemidiaphragm attaches distally to the anterior portions of the first through third lumbar vertebrae (L1-3) and the left hemidiaphragm attaches distally on the first and second lumbar vertebrae (L1-2).[29] This section of the diaphragm is referred to as the crura. Of interest is the asymmetrical attachment of the diaphragm with the left hemidiaphragm attaching to L1-2 and the right portion attaching to L1-3.

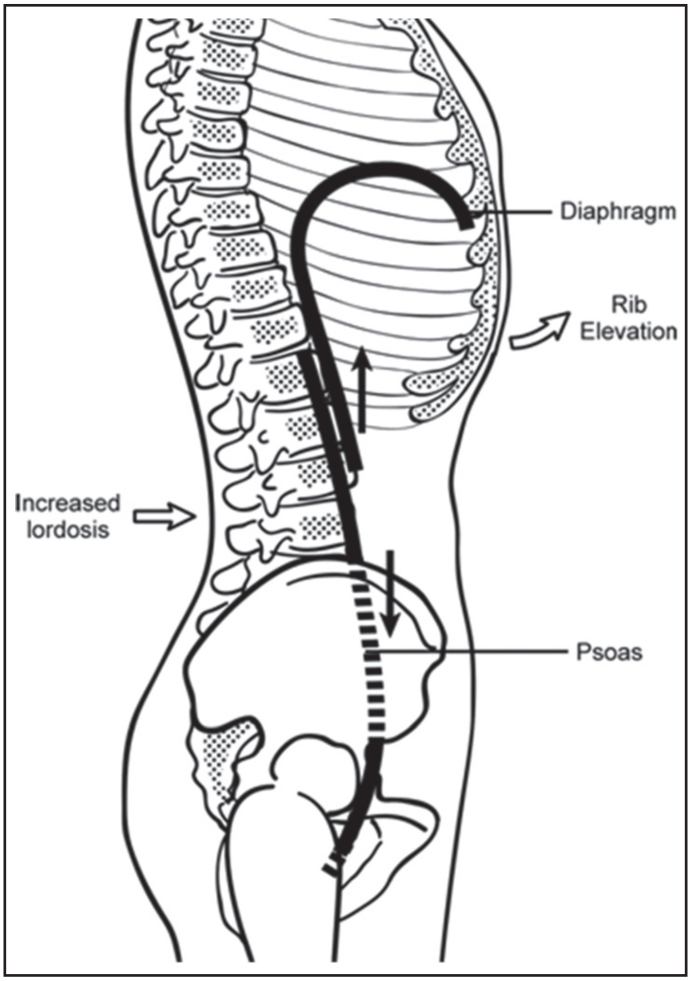

Figure 1. *Sagittal view of the Diaphragm. Note the psoas pull on the spine contributing to increased lordosis and faulty rib position. Copyright © Kyndall Boyle, 2007, used with permission*

During the inhalation phase of ventilation, the dome of the diaphragm moves caudally like a piston creating a negative pressure in the thorax that forces air into the lungs. This action is normally accompanied by a rotation of the ribs outward (external rotation) largely in part due to the ZOA.[12] (Figure 1) Apposition is a term that means multiple layers adjacent to each other.[33] The normal force of pull on the sternal and costal portions of the diaphragm would produce an internal rotation of the ribs. The ZOA creates an external rotation of these ribs primarily because the pressure in the thoracic cavity prevents an inward motion. The crural portion of the diaphragm assists the caudal motion of the dome. It also pulls the anterior lumbar spine upward (cephalad and anterior). Additionally, the abdominal muscles and pelvic floor musculature are less active to allow visceral displacement due to the dome of the diaphragm dropping. With exhalation, this process is reversed. Abdominal muscle activity compresses the viscera in the abdominal cavity, the diaphragm is forced cephalad and the ribs internally rotate. As exhalation becomes forced as during exercise, abdominal activity (rectus abdominus, internal obliques, external obliques, and transversus abdominis) will be increased.[34-36]

When the ZOA is optimized, the respiratory and postural roles of the diaphragm have maximal efficiency.[37] In suboptimal positions (i.e. decreased ZOA), the diaphragm has a decreased ability to draw air into the thorax because of less caudal movement upon contraction and less effective tangential tension of the diaphragm on the ribs and therefore lower transdiaphragmatic pressure.[38] This decreased ZOA is accompanied by decreased expansion of the rib cage, postural alterations, and a compensatory increase in abdominal expansion.[12] (Figure 2) As a result, adaptive breathing strategies can develop. One such adaptive breathing strategy would be to relax the abdominal musculature more than necessary on inspiration to allow for thoraco-abdominal expansion. This situation leads to decreased abdominal responsibility while breathing and can contribute to instability. This would reflect more upper chest breathing and less efficient diaphragm activity. If the body maintains this position and breathing strategy for an extended period of time, the diaphragm may adaptively shorten and the lungs may become hyperinflated.[37, 39, 40] Hyperinflation may also contribute to over use of accessory muscles of respiration such as scalenes, sternocleidomastoid (SCM), pectorals, upper trapezius and paraspinals in an attempt to expand the upper rib cage.[41-44] Again, without an optimal dome shape/position of the diaphragm or an optimal ZOA the body compensates to get air in with accessory muscles since the more linear/flat/short diaphragm is less efficient for breathing.[32]

CLINICAL SUGGESTION/SOLUTION

A therapeutic exercise that promotes optimal posture (diaphragm and lumbar spine position) and finely tuned neuromuscular control of the deep abdominals, diaphragm, and pelvic floor (lumbar-pelvic stabilization) would be desirable for patients with suboptimal respiration and posture which may

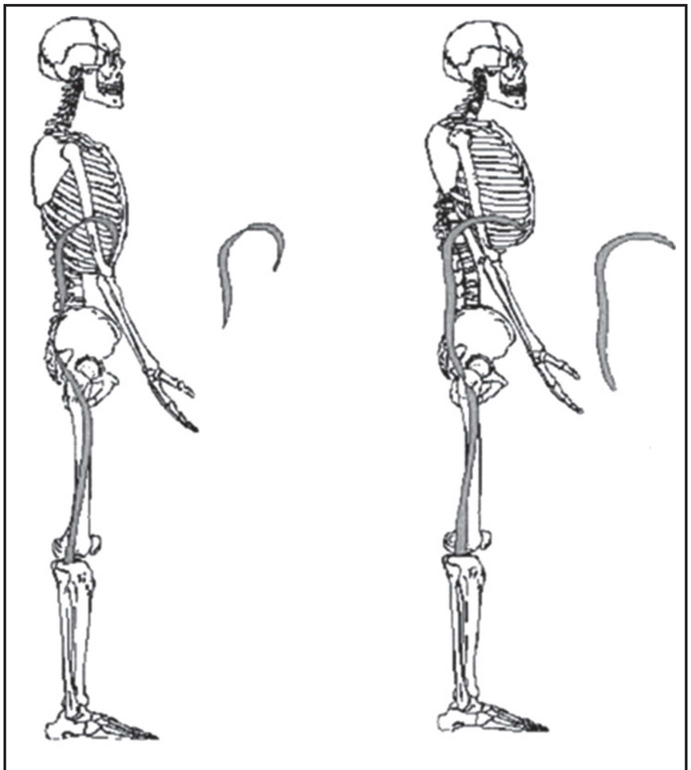

Figure 2. *Sagittal view of Postural Alignment associated with optimal and sub-optimal Zone of Apposition (ZOA) of the respiratory diaphragm.*
Optimal ZOA is depicted as a dome shaped diaphragm with bony segments in an ideal plumb line position. Suboptimal ZOA is depicted as a more linear/flat diaphragm and bony segments not in an ideal plumb line position, demonstrated by an increased lumbar lordosis and rib external rotation/elevation. Note the effects of suboptimal ZOA on the thoracic and cervical spine positions. Copyright © Postural Restoration Institute™ 2009, used with permission

be associated with musculoskeletal complaints i.e. LBP and/or SIJ pain. The 90/90 Bridge with Ball and Balloon technique developed by the Postural Restoration Institute™ was designed to help restore the ZOA and spine to a proper position in order to allow the diaphragm optimal ability to perform both its respiratory and postural roles.[45] The balloon blowing exercise (BBE) technique is performed in supine with the feet on a wall, hips and knees at 90 degrees and a ball between the knees. (Figure 3) This passive 90˚ hip and knee flexion position places the body in relative lumbar spine flexion, posterior pelvic tilt and rib internal rotation/depression which serves to optimize the ZOA and discourage lumbar extension/anterior pelvic tilt, paraspinal activity, and rib elevation/external rotation. When performed with active hamstring contraction the paraspinals are further inhibited due to the caudal pull of the hamstrings on the pelvis (specifically the ischial tuberosities) which further encourages lumbar flexion. Having a ball between the knees encourages adductor muscle activation (via hip adduction and internal rotation position) and co-contraction of the pelvic floor muscles (levator ani and coccygeus).

The patient/athlete is asked to hold the balloon with one hand and inhale through his/her nose with the tongue on the roof of the mouth (normal rest position) and then exhale through his/her mouth into the balloon. The inhalation, to about 75% of maximum, is typically 3-4 seconds in duration, and the complete exhalation is usually 5-8 seconds long followed by a 2-3 second pause. This slowed breathing is thought to further relax the neuromuscular system/parasympathetic nervous system and generally decrease resting muscle tone. Ideally the patient/athlete will be able to inhale again without pinching off the balloon with their teeth, lips, or fingertips. This requires maintenance of intra-abdominal pressure to allow inhalation through the nose without the air coming back out of the balloon and into the mouth.

The authors of this clinical suggestion hypothesize that the resistance of the balloon during exhalation requires an increase in abdominal musculature activation and therefore the ability of the abdominals to oppose the diaphragm and assist with maintaining an ideal ZOA may be enhanced. The activation/setting of the abdominals pulls the lower ribs down and in (caudad and posterior) and helps to inhibit/relax the paraspinals muscles (trunk extensors) which may help to decrease the patient/athlete's lumbar lordosis and pain in the paraspinal region through reciprocal inhibition. The abdominals do not produce any appreciable torque or motion in the spine and are functioning in this case as stabilizers of the ribs during breathing, not as prime movers. The rib motion (depression/caudad/posterior) optimizes the ZOA.

When the exercise is performed by the patient/athlete with hamstring and gluteus maximus (glut max) activation (hip extensors) the pelvis moves into a relative posterior pelvic tilt and the ribs into relative

Figure 3. *Instructions for Performance of the 90/90 Bridge with Ball and Balloon:*

1. *Lie on your back with your feet flat on a wall and knees and hips bent at a 90-degree angle.*
2. *Place a 4-6 inch ball between your knees.*
3. *Place your right arm above your head and a balloon in your left hand.*
4. *Inhale through your nose and as you exhale through your mouth, perform a pelvic tilt so that your tailbone is raised slightly off the mat. Keep low back flat on the mat. Do not press your feet into the wall, instead pull down with your heels.*
5. *You should feel the back of your thighs and inner thighs engage, keeping pressure on the ball. Maintain this position for the remainder of the exercise.*
6. *Now inhale through your nose and slowly blow out into the balloon.*
7. *Pause three seconds with your tongue positioned on the roof of your mouth to prevent airflow out of the balloon.*
8. *Without pinching the neck of the balloon and keeping your tongue on the roof of your mouth, inhale again through your nose.*
9. *Slowly blow out as you stabilize the balloon with your left hand.*
10. *Do not strain your neck or cheeks as you blow.*
11. *After the fourth breath in, pinch the balloon neck and remove it from your mouth. Let the air out of the balloon.*
12. *Relax and repeat the sequence 4 more times.*

depression and internal rotation. This pelvic and rib position helps to optimize abdominal length (decreases) and diaphragm length/ZOA (increases). The hamstrings are not being activated to extend the spine but to extend the hip, specifically to move the acetabulum on the femur into hip extension.[29] The glut max is also active for hip extension during the exercise, however the hamstring have a better mechanical advantage than the glut max for hip extension because of the increased lever arm (distal attachment site on the tibia which is more distal than the glut max's distal attachment site which is on the femoral shaft.[29] The glut max is a powerful muscle for hip external rotation because of the oblique fiber orientation.[29] Because the diaphragm and psoas pull less up and forward (cephalad and anterior) and more down and forward (caudad and anterior) respectively on the spine via hamstring and abdominal co-activation, the diaphragm and spine are able to achieve an ideal position. (Figure 2) During the second inhalation (after exhaling into the balloon for the first time), an optimal position of the spine and diaphragm can be maintained via the opposition of the abdominals due to the back pressure in the balloon. This inhalation effort with the balloon in the mouth and the ribs in a depressed/ internally rotated state will direct the air into the lungs to expand the apical area of the lungs, especially when an arm is raised above the head to help direct it there. When the ribs are held down and a second inhalation occurs, the surrounding soft tissue i.e. pectoralis muscle lengthens/stretches with chest expansion from air that fills the lungs as the distance between the pectoralis attachment on the ribs and sternum and on the humerus is increased. This apical chest wall expansion may be particularly beneficial for individuals with scoliosis, depressed shoulder girdles, or rounded shoulders.

The balloon resistance also requires more activation/contraction of the transversus thoracis (triangularis sterni) muscle which is active during forced exhalation.[46] (Figure 4) Additionally, the respiratory cycle with resistance, also requires lengthening and contractions of both the internal and external intercostal muscles which are active for both phases of respiration.[12]

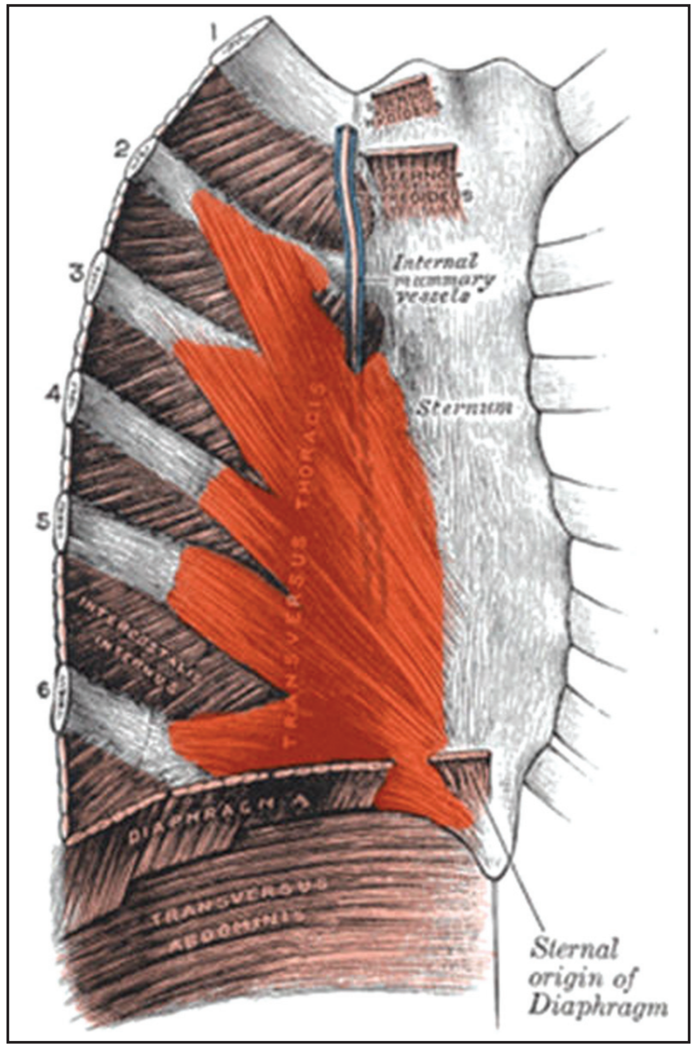

Figure 4. *Transversus Thoracis (Triangularis Sterni) muscle, located on the posterior sternum and ribs. Image from Wikipedia.com, accessed 8/16/2010.*

USE IN PHYSICAL THERAPY

Clinical experience with the BBE includes utilization of the exercise for both female and male patients (more females than males), ages 5-89 with a wide variety of diagnoses including: low back pain, trochanteric bursitis, SIJ pain, asthma, COPD, acetabular labral tear, anterior knee pain, thoracic outlet syndrome (TOS) and sciatica. Improved function and decreased pain has been noted with patients who were prescribed a BBE as part of their home exercise program in both published and non published cases. Published cases have included a female with right LBP and sciatica[47] a male with thoracic outlet syndrome,[48] and a male with asthma.[49] The female had 100% improvement in her function with an initial Oswestry Disability Index (ODI) score of 40% and a discharge ODI of 0%. This change exceeded the minimal clinically significant difference (MCSD) of 20%.[50] Her pain level also improved from an initial score of 9/10 to a discharge score of 0/10. Again this response exceeded the MCSD for the numerical pain scale which is a 2.5.[50] The patient with TOS also had remarkable improvement in his function and was able to avoid surgery and return to playing football. His initial Northwick Park Neck Pain Questionnaire[51] was 55.5% and at discharge it was 0%. This far exceeded the MCSD of 5%.[52] The goal for the male with asthma was to restore his ZOA with the BBE and manual restorative techniques. His spirometry scores improved from 1,800cc to 2,700cc on one visit and from 1,500cc to 3,200cc on a subsequent visit.[49] No other outcome measures were used.

The value of the BBE can be discussed at an anecdotal level through written reports and personal experience. A story in the local Omaha, NE newspaper described the unusual training utilized by the University of Nebraska women's volleyball team.[53] The training included the athletes blowing up balloons in order to relieve back and neck tension and prevent breath holding, both of which may restrict arm swing and reach. The training was directed by the physical therapist who developed the BBE, and currently serves as the biomechanical consultant to the University of Nebraska-Lincoln.[53]

DISCUSSION

Despite the BBE's use for a variety of patient populations, there is little data published on the efficacy of such an exercise. O'Sullivan reported the need for rehabilitation of lumbar-pelvic instability that includes integration of the diaphragm, deep abdominals and pelvic floor.[21] However descriptive studies to propose intervention strategies to integrate the diaphragm, deep abdominals and pelvic floor are lacking. Additionally, studies to investigate the efficacy of strategies are needed.[21, 37] The BBE is a specific example of an exercise that could be useful for integrating co-activation of deep abdominal muscles with pelvic floor and diaphragm during neuromuscular training and a wide variety of stabilizing maneuvers.

Lando et al. conducted a study of 25 subjects with severe chronic obstructive pulmonary disease (COPD) to investigate the influence of lung-volume reduction surgery on breathing.[37] Lando et al. reported that the subject's ZOA of the diaphragm was increased as a result of the surgery which increased their exercise tolerance and breathing efficiency.[37] This is one study that supports the value and benefit of obtaining optimal ZOA for breathing, which in this case was achieved via surgery. The asthma case report also supports the value of obtaining optimal ZOA for breathing which was achieved with conservative physical therapy techniques rather than surgery.[49] The BBE is a conservative exercise intended to assist a patient/athlete in obtaining optimal posture and respiration i.e. diaphragm (ZOA) and spinal position and neuromotor control (lumbar-pelvic stability). However, the BBE has not yet been studied or tested experimentally.

Future studies of the effects of a single BBE and/or training effects of multiple BBE's could include EMG for abdominal muscle, spirometry for changes in breathing parameters, real time ultrasound for diaphragm length and/or changes in abdominal muscle thickness. Additionally, future studies designed to describe changes in pain and function attributable to the BBE are needed to investigate the clinical efficacy of this promising therapeutic exercise technique.

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REFERENCES

1. Hodges P. Is There a Role for Transversus Abdominis in Lumbo-Pelvic Stability? *Manual Therapy.* 1999;4(2):74-86.
2. Hodges P, Gandevia S, Richardson C. Contractions of Specific Abdominal Muscles in Postural Tasks are Affected by Respiratory Maneuvers. *J Appl Physiol.* 1997;83(3).
3. Hodges PW, Butler JE, McKenzie DK, et al. Contraction of the human diaphragm during rapid postural adjustments. *J Phys.* 1997;505(2):539-48.
4. Sapsford RR, Hodges PW, Richardson CA. Activation of the abdominal muscles is a normal response to contraction of the pelvic floor muscles. In: International Continence Society Conference. Japan, 1998.
5. Hodges PW, Richardson CA. Contraction of the abdominal muscles associated with movement of the lower limb. *Phys Ther.* 1997;77(2):132-43.
6. Hodges PW, Heijnen I, Gandevia SC. Postural activity of the diaphragm is reduced in humans when respiratory demand increases. *J Physiol.* 2001;537(3):999-1008.
7. Grimby G. Respiration in exercise. *Med Sci Sports Exerc.* 1969;1(1):9-14.
8. Perri M. Pain and Faulty Breathing: A Pilot Study. *J of Bodywork and Movement Therapies.* 2004; 8:297-306.
9. DeTroyer A, Estenne M. Respiratory Anatomy of the Respiratory Muscles. *Clin Chest Med.* 1988;9(2):175-93.
10. Petroll WM, Knight H, Rochester DF. Effect of lower rib cage expansion and diaphragm shortening on the zone of apposition. *J Appl Physiol.* 1990;68(2):484-8.

11. Loring SH, Mead J. Action of the diaphragm on the rib cage inferred from a force-balance analysis. *J Appl Physiol.* 1982;53(3):756-60.
12. De Troyer A, Estenne M. Functional Anatomy of the Respiratory Muscles. *Clin Chest Med.* 1988;9(2): 175-93.
13. Bye PT, Esau SA, Walley KR. Ventilatory muscles during exercise in air and oxygen in normal men. *J Appl Physiol.* 1984;56:464-71.
14. Bahr R, Reeser JC. Injuries Among World-Class Professional Beach Volleyball Players. *Am J Sports Med.* 2003;31(1):119-25.
15. Bono CM. Current concepts review low-back pain in athletes. *JBJS.* 2004;86-A(2):382-96.
16. Vleeming A, Albert HB, Ostgaard HC, et al. European guidelines for the diagnosis and treatment of pelvic girdle pain. *Eur Spine J.* 2008;17:794-819.
17. Hodges PW, Richardson CA. Inefficient muscular stabilization of the lumbar spine associated with low back pain: a motor control evaluation of transversus abdominis. *Spine.* 1996;21:2640-50.
18. Christie H, Kumar S, Warren SA. Postural Aberrations in Low Back Pain. *Arch Phys Med Rehabil.* 1995;76:218-24.
19. Roncarati A, McMullen W. Correlates of low back pain in a general population sample: a multidisciplinary perspective. *J Manipulative Physiol Ther.* 1988;11(3):158-64.
20. During J, Goudfrooij H, Keessen W, et al. Towards standards for posture. Postural characteristics of the lower back system in normal and pathologic conditions. *Spine.* 1985;10:83-7.
21. O-Sullivan PB. Altered Motor Control strategies in Subjects With Sacroiliac Joint Pain During the Active Straight-Leg-Raise Test. *Spine.* 2002;27(1):E1-E8.
22. O'Sullivan PB. Lumbar segmental "instability": Clinical presentation and specific stabilizing exercise management. *Manual Ther.* 2000;5:2-12.
23. O'Sullivan PB, Phtyt GD, Twomey LT, et al. Evaluation of specific stabilizing exercise in the treatment of chronic low back pain with radiologic diagnosis of spondylolysis or spondylolisthesis. *Spine.* 1997;22(24):2959-67.
24. Rydeard R, Leger A, Smith D. Pilates based therapeutic exercise: effect on subjects with nonspecific chronic low back pain and functional disability: a randomized controlled trial. *J Orthop Sports Phys Ther.* 2000;36:472-84.
25. O'Sullivan PB. Diagnosis and classification of pelvic girdle pain disorders Part 1: A mechanism based approach within a biopsychosocial framework. *Man Ther.* 2007;12:86-97.
26. Cooke PM, Lutz GE. Internal disc disruption and axial back pain in the athlete. *Phys Med Rehabil Clin N Am.* 2000;11:837-65.
27. Richardson C, Hodges P, Hides J. Therapeutic exercise for lumbopelvic stabilization. New York: Churchill Livingstone, 2004.
28. Cresswell AG, Oddsson L, Thorstensson A. The influence of sudden perturbations on trunk muscle activity and intra-abdominal pressure while standing. *Exp Brain Res.* 1994;98:336-.
29. Moore KL, Dalley AF. Clinically Oriented Anatomy. 5 ed. Philadelphia, PA: Lippincott Williams and Wilkins, 2006.
30. Reid WD, Dechman G. Considerations when testing and training the respiratory muscles. *Phys Ther.* 1995;75(11).
31. Mead J. Functional significance of the area of apposition of diaphragm to rib cage. *Am Rev Respir Dis.* 1979;11:31.
32. Hruska R. Influences of dysfunctional respiratory mechanics on orofacial pain. *Dent Clin North Am.* 1997;41(2):211-27.
33. Thomas C. Taber's Cyclopedic Medical Dictionary. 16th ed. Philadelphia, PA: FA Davis Co., 1989.
34. Campbell EJM. An electromyographic study of the role of the abdominal muscles in breathing. *J Phys.* 1952;117:222-33.
35. Detroyer A, Estenne M, Ninane V. Transversus abdominis muscle function in humans. *J Appl Physiol.* 1990;68:1010-6.
36. Goldman JM, Lehr RP, Millar AB. An electromyographic study of the abdominal muscles during postural and respiratory manoeuvres. *J Neurol Neurosurg Psychiatry.* 1987;50:866-9.
37. Lando Y, Boiselle PM, Shade D, et al. Effect of Lung Volume Reduction Surgery of Diaphragm Length in Severe Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med.* 1999;159(3):796-805.
38. Celli B. Clinical and Physiologic Evaluation of Respiratory Muscle Function. *Clin Chest Med.* 1989;10(2):199-213.
39. Cassart M, Pettiaux N, Gevenois PA, et al. Effect of Chronic Hyperinflation on Diaphragm Length and Surface Area. *Am J Respir Crit Care Med.* 1997;156:504-8.
40. Laghi F, Tobin F. Disorders of the respiratory muscles. *Am J Respir Crit Care Med.* 2003 168;10-48.
41. Campbell EJ. The role of the scalene and sternomastoid muscle in breathing in normal subjects. An electromyographic study. *J Anat.* 1955;89:378-86.

42. Danon J, Druz WS, Goldberg NB. Function of the isolated paced diaphragm and the cervical accessory muscles in CI quadriplegics. *Am Rev Respir Dis.* 1979;119:909-19.

43. Moxham J, Wiles CM, Newhouse D. Sternomastoid muscle function and fatigue in man. *Clin Sci Mol Med.* 1980;59:463-368.

44. Robey JH, Boyle KL. Bilateral functional thoracic outlet syndrome in a collegiate football player. *N Am J Sports Phys Ther.* 2009;4(4):170-81.

45. Ebmeier J, Hruska R. Postural Restoration Institute Web site. 2010 [cited 2010 1-28-2010]; Available from: www.posturalrestoration.com.

46. Kendall FP, McCreary EK, Provance PG, et al. Muscles Testing and Function with Posture and Pain. 5th ed. Philadelphia: Lippincott Williams and Wilkins, 2005.

47. Boyle K, Demske J. Management of a Female with Chronic Sciatica and Low Back Pain: A Case Report. *Physiother Theory Pract.* 2009;25(1):44-54.

48. Robey J, Boyle K. Bilateral Functional Thoracic Outlet Syndrome in a College Football Player. *N Am J Sports Phys Ther.* 2009;4(4):170-81.

49. Coughlin KJ, Hruska RJ, Masek J. Cough-Variant Asthma: Responsive to Integrative Management and Postural Restoration. *Explore.* 2005;1(5):377-9.

50. Ostelo RWJG, deVet HCW. Clinically important outcomes in low back pain. *Best Pract Res Clin Rheumatol.* 2005;19(4):593-607.

51. Leak AM CJ, Dyer S, et al. The Northwick Park Neck Pain Questionnaire, devised to measure neck pain and disability. *British J Rheumatol.* 1994;33(5):469-74.

52. Klaber Moffett JA, Jackson DA, et al. Randomised trial of a brief physiotherapy intervention compared with usual physiotherapy for neck pain patients: Outcomes and patients' preference. *BMJ.* 2004;330(75):7482.

53. Chatelain D. Cook's Preparations Unusual But Effective. Omaha World-Herald 2005 December 17.