Please cite this article as:

Lee LJ. The Thoracic Ring Approach – A New View of the Thorax. No. 145, Winter 2013, In Touch journal, an official publication of Physio First, the Journal for Physiotherapists in Private Practice (UK).
The Thoracic Ring Approach – a new view of the thorax

Dr Linda-Joy (LJ) Lee PhD FCAMPT MCPA
Synergy Physiotherapy, Vancouver, Canada
Associate member of the Centre for Hip Health and Mobility, Vancouver, Canada.
Honorary senior fellow, University of Melbourne (Faculty of Medicine, Dentistry and Health Sciences), Australia.

This article is based on the content of the two lectures Linda-Joy (LJ) Lee will be presenting at our 2014 Conference and is published here as a taster to whet your appetite for what promises to be an excellent weekend, with an exciting line up of lectures to keep you and your practice updated clinically and commercially.

Learning outcomes
1. Understand new perspectives on the integrated nature of the thoracic spine and ribcage as a “thoracic ring,” and the inherent flexibility of the thorax and need for neuromuscular control for optimal function.
2. Understand some of the mechanisms that explain why dysfunction in the thorax, whether painful or pain-free, can be the underlying driver for pain anywhere in the body; based on anatomy, neurophysiology, and biomechanics.
3. Understand how The Thoracic Ring Approach enables the clinician to determine when and when not to treat the thorax in order to relieve pain and restore optimal function to the whole person.

Introduction
The thorax is essential for respiration, while ensuring the effective transfer of forces and loads in multiple planes to facilitate optimal whole body function and performance. Clinicians have long recognised that the thorax can be the silent, but underlying, cause for problems elsewhere in the body and that, while patients may not complain of thoracic pain, there may be impairments in the thorax that either refer pain to other regions or contribute to inappropriate loading of other structures in the kinetic chain. Most commonly, the hypothesis is that a stiff thorax creates excessive forces and pain in adjacent areas such as the lumbar spine, the neck, and the shoulder girdle and upper extremities (McConnell 2005; Cleland et al 2007; Bergman et al 2002). This belief that the main dysfunction in the thorax is one of stiffness correlates with a treatment focus on increasing mobility in this region, using techniques such as mobilisation, manipulation, soft tissue and myofascial release, muscle energy, and dry needling. Indeed, in a survey of UK manual therapists, the thoracic spine was the area of the spine most frequently manipulated (Adams & Sim 1998).

Research on the benefits of thoracic spine treatment is limited and provides conflicting insight into when treatment will improve outcomes. For example, investigations into the impact of treating the thoracic spine in patients with neck pain demonstrated that, while some patients experienced positive outcomes, there were adverse responses to thoracic spine treatment with 33% of the manipulation group and 30% of the mobilisation group reporting aggravation of symptoms, muscle spasm, and headache (Cleland et al 2007).

Clearly, while some patients can benefit from treatment to the thoracic spine, others do not, so how does the clinician best determine if treating the thorax will positively affect a patient’s problem?

There are multiple mechanisms by which a dysfunctional thorax, whether painful or pain free, can be the “primary driver” for pain and problems elsewhere in the body – for conditions as varied as hip impingement, Achilles tendinopathy, recurrent hamstring strains, and pelvic girdle pain to shoulder impingement, neck pain, “core” muscle dysfunction and incontinence. In the individual patient, a clinical reasoning approach based on a broader understanding of the thorax and its role in whole body function is needed to determine if the thorax is the true underlying cause, or “driver” of the patient’s problem, whether it be pain, disability, and / or decreased performance.
The Thoracic Ring Approach (Lee LJ 2011, 2012) incorporates the most current research in the thorax and provides innovative clinical assessment and treatment skills for the thorax as a three-dimensional series of "thoracic rings". The approach also considers the multiple links between the thorax and all other regions of the body and proposes multiple mechanisms by which the thorax can drive pain or problems elsewhere in the body. Meaningful Task Analysis (MTA) (Lee LJ 2008; Lee LJ and DG 2011) integrates manual assessment skills with functional movement analysis to provide a clinical reasoning framework that enables the clinician to decide whether treatment to the thorax will facilitate resolution of the patient's problem.

Why a "ring"?

In both research and clinical realms, the thoracic spine and ribs are commonly considered as separate entities, with separate assessment and treatment techniques for each (Giles & Singer 2000; Lee DG 1994; Malland 1964; Mitchell & Mitchell 2002). However, multiple articulations and strong ligaments connect the ribs to their related thoracic spinal segment (Standing 2008) and recent kinematic data support that the thoracic spine does not move independently of the ribs in function. Subtle uniplanar changes (flexion/extension) in thoracic spine alignment have a significant impact on the three-dimensional shape and movement of the ribcage (Lee et al 2010).

It is thus proposed that, where there are anterior attachments, the true functional spinal unit of the thorax is a "ring" (Lee LJ 2003, 2005, 2013; Lee LJ et al 2010; Molnar et al 2006). For example, the 5th thoracic ring comprises the right and left 5th ribs and their anterior attachments to the sternum, the T4-5 thoracic vertebrae and the T4-5 intervertebral disc (Lee DG 1994; Lee LJ 2003, 2005; Lee & Lee 2008). Each typical thoracic "ring" has 13 articulations (Standing 2008) and the 136 joints in the unique architecture of the thorax provide significant mobility. It is a commonly held view that the thoracic spine is inherently stiff and stable due to the presence of the ribcage (Geelhoed et al 2006; McConnell 2005; Takeuchi et al 1999), yet this belief is supported by minimal data.

The intact thorax is mobile in all planes; biomechanical data support that the primary movement of the thorax is rotation (transverse plane motion), followed by lateral bending (coronal plane motion) (Lovett 1905; Gregersen & Lucas 1967; Watkins et al 2005). In terms of ROM for trunk rotation, the thorax provides the majority of movement, with a minimum of 6-9 degrees per segment (White & Panjabi 1990), compared to the 1-3 degrees of rotation available per lumbar segment (Bogduk 1997). The thorax is the centre of rotation for the trunk, essential for the production, modulation and transmission of rotational torques. The capacity for movement at each segment, together with the requirements for control of upright posture and respiration, involves co-ordination of muscle activity by the central nervous system (CNS) to meet these demands.

Thus, the evidence supports that the thorax is, in fact, inherently flexible in nature and where there is movement there are requirements for neuromuscular control that must be considered.

These are similar to those described for other regions of the spine (Hodges 2003), but with an additional consideration due to the anatomy (Lee LJ 2013), including:

- **Intra-ring control**: motion between the joints of each ring
- **Inter-ring**: motion between the rings (intersegmental)
- **Inter-regional**: motion between the thorax and the other body regions, i.e. the thorax and pelvis, thorax and head, thorax and shoulder girdle, thorax and hips, thorax and feet, etc.
- **Postural equilibrium**: control of the thorax, both segmentally (inter-ring) and regionally, contribute to control the body’s centre of mass over the base of support.

The muscular complexity of the thorax is architecturally suited for control of the thorax, which is governed by the neural control system. Based on anatomical attachments and research from other areas of the spine, it has been proposed that the deep segmental muscles such as thoracic multifidus and the intercostals are architecturally suited to control inter-ring and inter-ring motion (Lee LJ 2003b), while the more superficial, multi-segmental muscles connecting the thorax to other regions are suited to control inter-regional motion. Recent studies support that the CNS uses complex mechanisms for control in the thorax. During tasks that create perturbations to the thorax in the sagittal plane (flexion/extension), the deep multifidus and superficial longissimus are similarly recruited throughout the thorax to control challenges to stability. In contrast, when challenges to stability occur in the transverse plane, the plane of greatest mobility in the thorax, the CNS controls the deep multifidus and superficial longissimus differentially for control of opposite rotational perturbations to the thorax. Thus, the need for complex co-ordination of the deep and superficial thoracic paraspinal muscles is determined by the presence of rotational forces (Lee et al 2006, 2009, 2010).

Patients can present with various patterns of altered muscle recruitment and activity, or non-optimal strategies for control, in the thorax. The most common direction for poor control is related to rotational forces (Lee LJ 2003). Owing to the coupling of a contralateral segmental lateral translation with rotation (Lee DG 1994), loss of rotational control can also be manifest as poor control of lateral translation forces, e.g. different agility in left vs. right direction for cutting sideways in sports drills. Similarly, loss of rotational control can be coupled with loss of lateral bending control.

A new view of the thorax: a flexible structure requiring fine control

Shifting from the paradigm that the thorax is stiff and requiring mobilisation, to one where the thorax is flexible and requiring optimal neuromuscular control provides greater insight into why the thorax can drive distal problems. It moves us away from the concept that the thorax is static, stiff box that stays rigid during tasks, but rather is a dynamic stack of rings, much like a "slinky" or shock-absorbing spring.
If we consider the 10 thoracic rings and the significant mobility available at each level, there are multiple patterns of dysfunction that can present, depending on the patterns of neuromuscular imbalance.

Early observations of poor segmental control in the thorax were made in patients experiencing problems with arm loading tasks, e.g., during swimming, driving, lifting, who presented with a variety of symptoms, including thoracic pain, scapular pain, shoulder impingement pain, neck pain, low back pain, pelvic girdle pain (Lee LJ 2003, 2005, 2007). These patients demonstrated lateral translation and rotation of thoracic segments on initiation of arm movements related to symptom provocation during MTA. Identification of the specific poorly controlled segment was best determined by thoracic “ring palpation” along the lateral aspect of the ribs in the mid-axillary line. This is applied farthest from the axis of rotation of the thoracic segment where there is greater amplitude of motion compared to palpation points centrally at the vertebra (Figure 1).

Figure 1: Palpation of the upper thoracic rings, slightly anterior to the mid-axillary line. Detection of motion at the lateral sides of the thoracic ring reflects vertebral motion due to strong anatomical connections between the ribs and the thoracic spine (Lee LJ 2003, Keene 1906). From the Thoracic Ring Approach

In addition to poor thoracic ring control during MTA, other areas in the body also demonstrated non-optimal biomechanics or control, e.g., scapula dyskinesia, humeral head translation, etc., and some of these areas would correlate with symptoms. For example, a swimmer with right pelvic girdle pain would demonstrate failed load transfer (FLT) at the right SIJ and experience posterior pelvic girdle pain during a left prone arm lift simulating a swimming stroke. Upon initiation of the arm movement, a left “shift” (left lateral translation / right rotation) of an upper thoracic ring, e.g., 4th ring would be palpable and occur before the loss of pelvic control. Gentle but specific manual support to the 4th thoracic ring can be applied to facilitate optimal biomechanics and motion control of the thoracic ring during task performance. (Lee LJ 2003; Keene 1906) (Figure 2).

Figure 2: Correction of a lower thoracic ring during resisted arm flexion to determine whether restoring optimal biomechanics and neuromuscular control to the thoracic ring will result in positive change for the meaningful task, and whether the thoracic ring is the driver for the patient’s shoulder problem

In cases where the underlying driver for the patient’s problem is the thorax, this “ring correction” improves task performance, changes pain and other symptoms, decreases the effort required to lift the arm, and creates optimal biomechanics and control in the other areas of the kinetic chain that previously demonstrated non-optimal loading (Lee LJ 2003, 2005, 2007). The right posterior pelvic girdle pain in our swimmer would disappear, the pelvis would show no loss of control, and the arm lift would feel light and easy to perform. This can often elicit a subjective “wow” response from the patient, correlating to the positive change in their experience of their body while performing the task. The response to thoracic ring correction can then be compared to the response to the manual support and correction of other areas showing non-optimal alignment, biomechanics or control, i.e., neck, scapula, glenohumeral joint, pelvis. If the thorax is the true underlying driver, then corrections to other areas would make no change to, or even worsen, task performance or symptoms.

Many patients with poor thoracic control have no complaints of thoracic pain (Lee LJ 2005). However, based on the findings and the clinical reasoning approach described above, treatment directed at the thorax can result in positive outcomes for both function and resolution of pain in distal regions. This involves releasing hypertonic and overactive muscles related to the driving thoracic ring with specific thoracic ring treatment techniques combined with thoracic ring taping for support, and neuromuscular training with cues and a specific progressive exercise program to restore both segmental ring control and inter-regional control during functional loading related to the patient’s meaningful task (Lee LJ 2003).

The long superficial muscles have specific fascicles of attachment that can impact on one ring more than others and, if these muscles become dominant and are not balanced by activity in the deep segmental ring muscles, altered patterns of thoracic ring motion occur. These patients can appear to have stiffness of the thoracic spine during trunk movements, due to hypertonicity in the superficial
trunk muscles. This is consistent with studies that demonstrate that mobilisation and manipulation techniques affect change via neurophysiological mechanisms that alter muscle tone and activity (Biolosky et al 2009). It explains why it is a common experience for therapists and patients alike to have to perform release, mobilisation and manipulation techniques for the thorax repeatedly. While these techniques temporarily change neuromuscular resting tone and compression across joints, allowing greater movement, without exercise and training to change strategies for all levels of thoracic control, the old patterns of muscle hypertonicity return, creating stiffness that will require treatment again.

Since these early clinical observations, The Thoracic Ring Approach has been used with a variety of patient populations to determine if the thorax is the underlying cause and to treat a wide range of conditions and problems effectively. A key feature of the approach is the use of MTA, which uses whole body functional movement analysis during tasks that are painful or goal-related to determine whether or not the thorax is the primary driver (Lee LJ 2008; Lee LJ and DG 2011) (Figure 3).

![Figure 3: Meaningful Task Analysis - triangle pose for yoga. Manual assessment of the behaviour of the thoracic rings during functional movement to determine if FLT occurs and then correction of any areas of FLT permits determination of whether or not there is a thorax driver for performing the task. Notice the difference in trunk range of motion with the thoracic ring correction (right photo) as compared to no ring correction (left photo).](image)

When there is loss of optimal sequencing, force modulation and synergy between the muscles around the thoracic ring, between the rings and between the ten rings and other regions of the body, non-optimal loading of multiple different structures and regions of the body can occur. Pain can occur anywhere in the body, together with other non-optimal experiences such as sensitisation of the sympathetic nervous system, incontinence, decreased ease of movement, and inability to reach performance related goals. Based on clinical experiences and integration of the available research, multiple mechanisms have been proposed to explain how the thorax drives distal problems. While it is beyond the scope of this article to discuss them all, consider the following ways the thorax links to the rest of the body.

Direct attachments to other regions

Given the multiple connections myofascially to neighbouring regions, different patterns of non-optimal control for the thoracic rings can, because of the direct muscle attachments, have different impacts on their related areas. In patients with non-optimal thoracic ring control, compromised activity in the deep segmental muscles, e.g. multifidus, intercostals, at the levels of non-optimal control has been noted, associated with specific hypertonic fascicles in the erector spine muscles such as spinals, longissimus and iliocostals, that can be traced up to their origin at the same thoracic ring level.

Figures 4-6 illustrate a biologically plausible mechanism to explain how this imbalance of activity in the thoracic muscles results in a poorly controlled thoracic ring and can have specific effects on the lumbar spine segments and control of the sacroiliac joint. Commonly, the imbalances in control of the thoracic ring in the upper thorax involve hypertonicity of the muscles between the thoracic rings and the scapula and clavicle. Therefore, as the ring rotates the shoulder girdle is often pulled into rotation, which may present as one scapula elevating and the other depressing, and poor scapular or glenohumeral joint control on loading. Considering the muscular complexity within and around the entire thorax, many more patterns of imbalance can occur.

![Figure 4: Purple short lines represent the deep thoracic multifidus and intercostals which are proposed to be segmental controllers for the thoracic ring. Yellow lines represent the right thoracic longissimus muscle based on Macintosh & Bogduk (1991). In pain-free individuals, there is complex CNS control of the deep segmental thoracic multifidus and superficial thoracic longissimus when rotational forces are present. When these muscles are optimally balanced, they contribute to rotational balance of the thoracic ring (Lee et al 2009). NB: in this schematic all thoracic rings are represented as a rectangle but 13 articulations are present in each of these rings. The pelvis is represented as one block but has three articulations.](image)
specific thoracic rings and the lumbar vertebrae, sacrum, and innominate. Reproduced with permission from Macintosh JE, Bogduk N. The attachments of the lumbar erector spinae. Spine 1991;16(7):783–792. Spine by Lippincott, Williams & Wilkins in the format reprint in a journal via Copyright Clearance Centre

**Figure 5a:** If there is loss of tone or activity in the deep segmental ring muscles at one thoracic ring, then relative dominance of the thoracic longissimus is present (orange line). Alternately, the thoracic longissimus can be facilitated and dominant, resulting in a relative decreased contribution from the deep segmental muscles. In these situations, excessive activity of the specific thoracic longissimus muscle fascicle has specific compression, rotation and lateral translation consequences on the thoracic ring (left translation and right rotation) as well as on the lumbar vertebrae related to the specific distal attachments.

**Figure 5b:** Insight into potential mechanisms for thoracic driven low back and/or pelvic girdle pain. This figure shows attachment sites of individual fascicles of the thoracic portions of longissimus thoracis and iliocostalis lumborum, illustrating the direct links between

**Figure 6:** If the thoracic portion of the iliocostalis lumborum is relatively more affected than the longissimus, the balance of forces around the right sacroiliac joint would be impacted more than the lumbar spine.

**The thorax and “the core”**

The thoracic rings provide attachment points and innervation (T7 to L1/2) for all layers of the abdominal muscles (Standring 2008). Rotation of a thoracic ring and the related compensatory counter-rotations through the rest of the thorax will affect afferent input into the segments related to abdominal wall innervation which could drive dys-synergies between the layers of the abdominal wall and asymmetrical function of the abdominal wall. Alternately, asymmetrical activation of the abdominal wall may occur in order to counter the induced trunk rotation, and compensatory twists in the rest of the trunk, from non-optimal ring control. It is common to find subgroups of patients with abdominal wall dysfunction who are unable to retain optimal function and symmetry of the abdominal wall without treatment to the thoracic ring dysfunction (Lee LJ 2004, 2007) (Figures 7, 8).

**Figure 7:** The thoracic rings are a common underlying cause for
dys-synergies of the abdominal wall, lumbar, multifidus and pelvic floor. With verbal cues designed to elicit a bilateral symmetrical contraction of transversus abdominis, there is a response from the left transversus abdominis, but no response on the right. Changing cues, effort, and paying more attention to the right side do not change the ability to recruit the right transversus abdominis.

Figure 8: When the driving (3rd and 4th) thoracic rings are corrected, the same cues result in immediate recruitment of the right transversus abdominis in a symmetrical manner with the left transversus abdominis, symmetry of recruitment is restored. In thoracic-driven abdominal wall dysfunction, transversus abdominis contraction occurs in response to a cue directed to control of the thoracic rings, not in response to abdominal wall cues.

The links between the thorax and abdominal wall also provide insight into possible mechanisms for how thoracic dysfunction can contribute to incontinence and other pelvic floor disorders. Excessive and asymmetrical contraction of superficial muscles, such as the external obliques (EO), changes in diaphragm activity (attaches to the lower six thoracic rings) and depression of the scopulae restrict mobility and compress the thorax, affecting the balance between intra-thoracic and intra-abdominal pressure, and create increased pressure in the lower abdomen ("pressure belly"). In response to the increase in intra-abdominal pressure, the pelvic floor muscles can become hypertonic, unable to respond to rapid changes in intra-abdominal pressure and contributing to pain syndromes and/or stress urinary incontinence (SUI). Women with SUI have been found to have hypertonicity in the pelvic floor muscles and the external oblique muscle, which attaches to the 5th thoracic ring (Smith et al. 2007b). Pelvic floor activity is also linked to abdominal muscle activity (Sapsford et al. 2001) and the pelvic floor may become asymmetric in relation to asymmetric abdominal muscle function, providing further insight into how treatment to the thoracic rings can change the ability of patients to recruit and relax their pelvic floor, and to regain symmetrical contractions when there is asymmetry of pelvic floor contraction present (Lee LJ 2004).

Role in control of postural equilibrium
The thoracic rings can segmentally and multi-segmentally move into lateral translation and rotation to control the centre of mass over base of support (postural equilibrium) in the coronal and transverse planes. This may explain why non-optimal neuromuscular control of the thoracic rings results in altered medio-lateral and rotation forces through the lumbar spine, pelvis, hips, knees, ankles and feet (Lee LJ 2008). Figures 9 and 10 illustrate the impact of correcting a 4th thoracic ring on the distribution of forces through the foot.

Figure 9: a) Example of a patient with right plantar foot pain during running. During left step forward, the right foot demonstrates lateral weight bearing on push-off, with varus forces at the ankle. At initiation of the step forward, the 4th thoracic ring is felt to translate left, creating a segmental right rotation. Optimally, the upper thorax should rotate left, and therefore the movement of the 4th thoracic ring is non-optimal. The resultant left shift of the thorax over the base of support requires the compensatory varus at the ankle to neutralise the centre of mass over the base of support. b) Close up of the impact on the right foot of the early left translation of the 4th thoracic ring.

Figure 10: a) Correction of the 4th thoracic ring during the left step forward task results in optimal weight bearing through the right ankle and foot during push-off, and reduction of the patient's symptoms. The thorax can drive distal problems in the hip, knee, ankle and foot because of rotational mechanisms and the effect that lateral translation of the thorax has on the centre of mass relative to the base of support. b) Close up of the right foot in push off in response to the 4th thoracic ring correction. Note the significantly improved position.

Rotational links
Loss of rotational control of a thoracic ring creates the need for compensatory rotation in the regions above and below, throughout the body in order to maintain the desired body position and trajectory for the task. For example, in a sagittal plane movement such as a squat, if the 4th thoracic ring translates left and rotates right on initiation of the movement, rotation must occur in other areas of the kinetic chain in order to maintain a forward gaze position and keep the feet parallel. These rotational forces are non-optimal for a sagittal plane movement, and require muscles around the compensatory joint complexes to activate in asymmetrical patterns. This results in altered timing and activity.
in multiple muscles and altering of forces across structures in the entire body.

The regions of the body that have greatest range of rotation movement to compensate for non-optimal rotational control are the atlantoaxial joint (Cl-2), the thoracic rings (1-10), the hip joints, and the subtalar joints. Links between thoracic ring dysfunction and problems in these areas have been observed clinically. For example, subgroups of patients with hip and groin pain are thorax driven. If the 4th thoracic ring shifts left during a squat, the upper thorax moves into right rotation, creating a rotational perturbation. Often the compensation occurs at the opposite (right) hip, which translates anteriorly to facilitate a left counter-rotation of the pelvis. In order to keep the knee tracking over the foot, increased muscular forces are required around the right hip to counter the medial force created by the pelvic rotation and by the left lateral translation of the thorax relative to the pelvis. Furthermore, the left translation of the thorax shifts the centre of mass more onto the left leg. This reduces the need for activity in the right gluteal muscles (medius and maximus), further affecting control of right hip loading. In thorax driven hip problems, exercises to strengthen the right gluteus medius will not result in recruitment of this muscle during a functional squat or one leg stance if the thoracic ring left translation is not corrected.

Summary

There are multiple mechanisms by which a dysfunctional thorax, whether painful or pain-free, can be "the primary driver" for pain and problems anywhere from the head to the toes. In the patient, a clinical reasoning approach based on a broader understanding of the role of the thorax in whole body function is needed to determine if the thorax is the true underlying cause, or "driver" of the patient's problem.

Current assessment and treatment techniques need to be interpreted in the context of the functional unit as the thoracic ring. The thorax is not inherently stiff but rather flexible and needling control. Both clinical and research evidence support that neuromuscular control plays an important role in optimal function of the thorax and, therefore, treatment needs to include ways to train optimal patterns for both segmental ring control and integration of the thorax into whole body function. Clearly more research is needed. In the meantime, The Thoracic Ring Approach (Lee LJ 2011, 2012) proposes new manual techniques for assessment and treatment of thoracic rings, along with new exercise approaches for segmental and integrated thoracic ring control and loading to reach functional and performance goals. By assessing the response to thoracic ring corrections during meaningful task analysis, the clinician can determine if treating the thorax will positively affect a patient's problem. Non-optimal strategies for movement and control in the thorax can drive recurrent and chronic problems in other areas of the body. In fact, the thoracic rings may just be the missing link to your patient's recovery and improved performance.

Figures 1, 2, 3, 4, 5a, 6, 7, 8, 9 and 10 reproduced with permission from Linda-Joy Lee Physiotherapist Corp

References


Hodges PW. Neumechanical control of the spine. Department of Neuroscience. Stockholm, Sweden, Karolinska Institute, 2003


Lee LJ. Motor control of the thorax and relationship to the lumbopelvic region; PhD proposal, University of Queensland, Australia, 2004


Lee LJ. The role of the thorax in pelvic girdle pain. Presented at the 6th Interdisciplinary World Congress on Low Back and Pelvic Pain, Barcelona, Spain November 7-10, 2007

Lee LJ. The essential role of the thorax in restoring optimal function. Keynote presentation at the 2008 Orthopaedic Symposium of the Canadian Physiotherapy Association, Montreal, Canada, October 2008

Lee LJ. Discover the role of the thorax in total body function: Introduction to the "Thoracic Ring Approach" (course notes). Bergen, Norway 2011
Lee LJ. The essential role of the thorax in whole body function and the "Thoracic Ring Approach", assessment & treatment videos. ljlee.ca: 2012
Lee LJ. Motor control and kinematics of the thorax in pain-free function. University of Queensland, Australia, 2013
Lee LJ, Lee DG. An integrated multimodal approach to the thoracic spine and ribs in: Magee et al, Pathology and Intervention in Musculoskeletal Intervention. Elsevier 2008
Lee LJ, Chang AT, Coppiekers MW, Hodges PW. Changes in sitting posture induce multiphasic changes in chest wall shape and motion with breathing. *Respiratory physiology & neurobiology* 2010;170(3):236-245
Lee LJ, Coppiekers MW, Hodges PW. En bloc control of deep and superficial thoracic muscles in sagittal loading and unloading of the trunk. *Gait & posture* 2011;33(4):588-593
Macintosh JE, Bogduk N. The attachments of the lumbar erector spinae. *Spine* 1991;16(7):783-792
Maitland GD. *Vertebral manipulation*. London, Butterworths 1964
Molnar S, Mono S, Kiss L, Csermey T. Ex vivo and in vivo determination of the axial rotational axis of the human thoracic spine. *Spine* 2006;31(26):E984-991
Sapsford RR, Hodges PW, Richardson CA, Cooper DH, Markwell SJ, Jull GA. Co-activation of the abdominal and pelvic floor muscles during voluntary exercises. *Neuromuscul and Neurosurg* 2001;20(1):31-42

**About the author**

Dr. Linda-Joy (LJ) Lee is recognised internationally as a skilled educator, presenter and clinician. Her interest in trunk stability, motor control of the thorax, and the relationship of the thorax to lumbopelvic problems led her to complete a PhD at the University of Queensland. LJ is the creator of the innovative Thoracic Ring Approach and known for her unique way of looking at total body function in meaningful tasks related to function or performance to find the driver, or true underlying cause, for clients’ problems. These concepts have become key features of The Integrated Systems Model (ISM) (LJ Lee, Diane Lee).

In addition to publication of her own research and clinical ideas in peer-reviewed journals and books, LJ is an Associate Editor for the *British Journal of Sports Medicine*, a specialized consultant for Roving Australia, an Associate Member of the Centre for Hip Health and Mobility (Vancouver, Canada) and an Honorary Senior Fellow at the University of Melbourne, Australia (Faculty of Medicine, Dentistry and Health Sciences). She mentors a team at her clinic, Synergy Physiotherapy (www.synergyphysio.ca) in North Vancouver, Canada.

**Address for correspondence**

**Linda-Joy Lee**

www.ljlee.ca
email: ljlee@ljlee.ca