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New perspectives from the Integrated Systems Model for treating women with pelvic girdle pain, urinary incontinence, pelvic organ prolapse and/or diastasis rectus abdominis

D. G. Lee
Private Practice, White Rock, British Columbia, Canada

Abstract
The Integrated Systems Model (ISM) is an evidence-based approach that considers both pain and disability. It relates impairments found in systems to pain, and the impact of these impairments and pain on the synergistic function required for optimal strategies for performance and, ultimately, health. It is a model that applies to the whole person, rather than to a specific type of pain or impairment presentation, and thus, the ISM can be used across populations suffering from pain, impairment and disease. When treating women with pelvic girdle pain, urinary incontinence, pelvic organ prolapse and/or diastasis rectus abdominis, the ISM facilitates the clinical reasoning process that then determines where best to begin treatment (i.e. find the primary driver for each meaningful task) since no two women have the same story or goals (i.e. meaningful complaint), and each patient must be assessed and treated individually.

Keywords: diastasis rectus abdominis, Integrated Systems Model, pelvic girdle pain, pelvic organ prolapse, urinary incontinence.

Introduction

Increasingly, scientific evidence suggests that pelvic function is essential for the performance of almost every task, and this is particularly relevant for women suffering from pelvic girdle pain (PGP), urinary incontinence (UI) and/or urgency (overactive bladder), pelvic organ prolapse (POP), and diastasis rectus abdominis (DRA). However, how do we determine if the pelvis is the *cause* of the patient's primary complaint, i.e. the offender, or merely the *victim* of an impairment elsewhere? When treating the "whole person", the restoration of function and performance depends on being able to identify and treat the underlying source of the problem, and it is common to find that the pelvis is the "criminal" in some cases and the "victim" in others. The Integrated Systems Model (ISM) for pain and disability (Lee & Lee 2011) facilitates the clinical reasoning process that then determines when to treat the pelvis (and its contents) and when to treat elsewhere.

Correspondence: Diane Lee, Suite 300, 1688 152nd Street, White Rock (Surrey), BC, Canada V4A 4N2 (e-mail: dianelee@dianelee.ca).

The Integrated Systems Model

The ISM helps clinicians to determine the primary driver, or cause, when multiple sites of impairment are noted during any single task. This approach relies on sound clinical reasoning that considers the relevant research evidence to develop prescriptive treatment programmes that are unique to each individual.

The ISM approach evolved from the Integrated Model of Function (IMF) (Lee & Vleeming 1998), and was first introduced in 2007 as the System-Based Classification for Failed Load Transfer (SBCFLT) (Lee & Lee 2007; Lee *et al.* 2008). We have since recognized that using the word "classification" was limiting for this model because its primary purpose is not to place patients into homogeneous subgroups. In contrast, it is a framework that allows clinicians to understand and interpret the unique picture of each individual patient in the clinical setting in order to facilitate decision-making and treatment planning. The model provides a context to organize all the different types of knowledge needed (i.e. scientific, theoretical, professional craft, procedural and personal), and provides for the development and testing of multiple hypotheses as the multidimensional picture of the patient emerges. A multimodal treatment plan can then be designed that is based on the complete picture of individuals and their presenting problem(s).

The ISM allows clinicians to characterize all the components that contribute to what Ronald Melzack termed the "message that represents the whole body" as a flow of awareness (Melzack 2005, p. 87). It is an integrated, evidence-based model that considers disability and pain, as defined and directed by the patient's values and goals. The model relates impairments found in systems, underlying pain mechanisms and the impact of these impairments on the individual's current whole-body strategies for function and performance. Thus, the ISM analyses the patient's current whole-body strategies, determines the underlying reasons for those strategies, and relates these to current knowledge about the necessary state required in all systems to provide optimal strategies for function and performance, and ultimately, for health. As a systems-based model, it has the inherent flexibility to evaluate and integrate new evidence from research and innovative clinical approaches as these emerge. As a patient-centred model, it can continually adapt to the changing goals and values of the individual. Since the model applies to the whole person, rather than to a specific type of pain presentation or body region, it can be used across pain and disease populations, and is not only applied to patients with lumbopelvic pain or PGP. In the context of the lumbopelvic–hip (LPH) complex, the IMF (Lee & Vleeming 1998) fits within, and is encompassed by, the ISM. The IMF provides a way to subdivide patients with failed load transfer (FLT) in the LPH complex, such as those with a primary form closure, a force closure, or motor control or emotional deficit.

The broader ISM also considers how a patient could be subgrouped according to the primary systemic impairment from which he or she suffers, as well as the role that the rest of his or her body and mind plays in the observed FLT in the LPH complex. For example, is the primary impairment causing the FLT intrinsic to the pelvic girdle itself (pelvic-driven PGP),

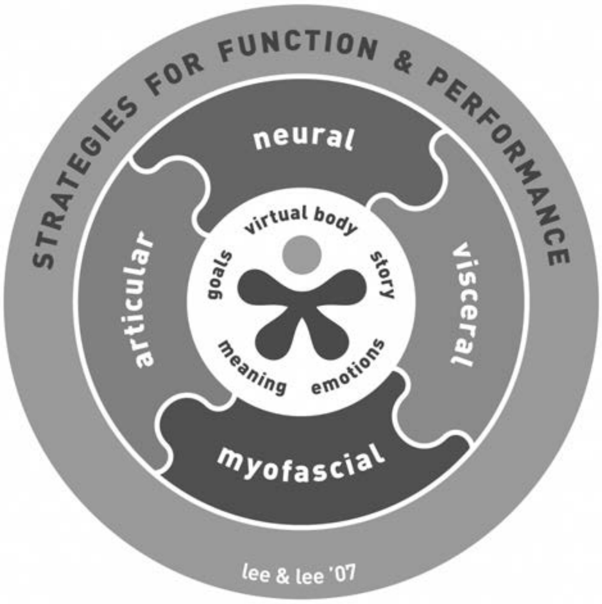

Figure 1. The Clinical Puzzle from the Integrated Systems Model (Lee *et al.* 2008).

extrinsic to the pelvic girdle (thorax- or foot-driven PGP) or caused by a negative cognitive/emotional state? There are four case reports that reflect each of these drivers of PGP in the online version of "Clinical reasoning, treatment planning, and case reports", Chapter 9 of the fourth edition of *The Pelvic Girdle: An Integration of Clinical Expertise and Research* (Lee 2011).

The ISM approach also considers the interaction and contribution of multiple systems (e.g. articular, myofascial, neural, visceral, hormonal and neuroendocrine). Therefore, while the model is based on the identification of the multi-system impairments that are the key drivers behind the problems facing the whole person, which could then be used to subgroup patients, its primary purpose is to provide a framework for weaving a unique tapestry that tells the patient's story. It also facilitates clinical reasoning "on the fly" as this story unfolds and the clinician begins to understand the significant pieces of the tapestry. When used reflectively, it is our goal that this model will facilitate, foster and promote the development of clinical expertise.

The Clinical Puzzle (Fig. 1) is a graphic conceptualization of the current ISM by Lee *et al.* (2008) that was originally part of the SBCFLT. It represents the person and their problem(s), and the systems that support optimal strategies for function and performance. The puzzle is used clinically for reflecting on key findings, and in teaching, as a tool for clinical reasoning and decision-making.

A key feature of the ISM approach is "finding the primary driver" when there are multiple sites of FLT. An FLT site is one that reveals non-optimal alignment, biomechanics and/or control (ABC) during any task being evaluated. For example, if the patient's primary complaints were PGP, perineal pressure (a possible symptom of POP) and intermittent stress UI (SUI) with lifting, then a suitable screening task would be to evaluate a squat (e.g. "Show me how you lift a heavy box"). As the individual performs this task, the therapist notes if the patient can maintain an optimal trajectory of the pelvis in relation to the lower extremities (i.e. the hip, knee and foot alignment, biomechanics, and control), an optimal trajectory of the thorax in relation to the lumbar spine, pelvis and base of support (i.e. thoracic ring control from thoracic rings 3 to 10 and segmental lumbar control), as well as optimal intrapelvic control (i.e. the sacroiliac joints and the pubic symphysis).

If several segments in the thorax, lumbar spine and pelvis fail to maintain optimal ABC, how do you know where to focus your first intervention? In the ISM approach, the "primary driver", i.e. the place to start treatment, is considered to be the first site that failed to transfer load optimally (as demonstrated by non-optimal ABC), and when a manual correction was applied to this area (e.g. to align the skeleton, facilitate optimal motion and/or control excessive movement), the function of the other sites of FLT improved during the evaluated task. Further tests are used to confirm or negate the initial hypothesis.

There are nine case reports complete with videos (online version only) in "Clinical reasoning, treatment planning, and case reports", Chapter 9 of the fourth edition of *The Pelvic Girdle* (Lee 2011), that further explain this approach. A case report by the present author that was presented at the ACPWH Annual Conference in Bristol, UK, on 21 September 2013 is outlined below.

Prevalence of pelvic girdle pain, urinary incontinence, pelvic organ prolapse and diastasis rectus abdominis

It is well known that the abdominal wall and pelvic floor play key roles in the function of the trunk, and that pregnancy and delivery can have a significant and long-lasting impact on this part of the body. Non-optimal postnatal strategies for the transference of loads through the trunk can create pain in a multitude of areas, as well as affect the urinary continence mechanism and support of the pelvic organs.

How common are these conditions in women? The prevalence of pregnancy-related PGP is difficult to determine from the literature when both low back pain (LBP) and PGP are combined. Wu *et al.* (2004) found a prevalence rate of 45% during pregnancy and 25% postnatally when both LBP and PGP were considered. When only severe pain was considered, the pregnancy prevalence rate dropped to 25%, which is consistent with the rate of 20% described by Albert *et al.* (2002). Most women go on to recover, with only 5–7% reported to have ongoing complaints (Ostgaard & Andersson 1992) with severe disability (8% according to Wu *et al.* 2004).

Urinary incontinence affects both nulliparous and parous women of all ages. Nygaard *et al.* (1994) reported that 28% of nulliparous elite athletes experience urinary leakage (the proportions are 85% for trampolinists, 67% for gymnasts and 50% for tennis players). In the last trimester of pregnancy, 48% of primiparous and 85% of multiparous women are incontinent of urine (Mørkved *et al.* 2003), and 92% of those incontinent at 12 weeks postpartum will still be incontinent at 5 years (Viktrup & Lose 2000). Some 5–7 years after delivery, 44.6% of women have some degree of incontinence (Wilson *et al.* 2002). Incontinence appears to increase with age: 16% of women aged 18–40, 33% aged 41–64 and 55% over 65 live with UI. It is the second most common reason, after dementia, for admission into assisted living (Mason *et al.* 2003).

One half of all parous women have some degree of symptomatic or asymptomatic loss of pelvic organ support, i.e. POP (Hagen & Stark 2011), and this condition also appears to worsen with age. Fifty per cent of those who have surgery for POP will experience a recurrence (Whiteside *et al.* 2004), and 30% of those will undergo a second surgical procedure within 2 years (Salvatore *et al.* 2010). One vaginal delivery increases the risk of developing POP by four, and two or more multiply it by 8.4 (Mant *et al.* 1997). Some 53% of women who undergo a forceps delivery have major defects in their pelvic floor muscles (PFMs) as a result (Ashton-Miller & DeLancey 2009), which is a risk factor for developing POP. Other risk factors for POP include denervation of the levator ani, hysterectomy (Altman *et al.* 2008) and excessive thoracic kyphosis (Mattox *et al.* 2000).

The Australian Longitudinal Study on Women's Health surveyed 28 000 women, and found that those who were pregnant experienced more back pain and incontinence than those who were not (Smith *et al.* 2008). In a much smaller sampling, Pool-Goudzwaard *et al.* (2005) noted that 52% of women reported a combination of LBP and PGP together with some form of pelvic floor dysfunction (e.g. incontinence, sexual dysfunction and/or constipation). Some 66% of women with DRA have at least one support-related pelvic floor dysfunction (Spitznagle *et al.* 2007).

These common conditions are clearly related, but why? A frequent feature of all clinical presentations is the failure to regain optimal strategies for transferring loads through the trunk for a wide variety of reasons including:

(1) articular system impairments, such as injury to either the sacroiliac joints and/or pubic symphysis;
(2) neural system impairments, such as pudendal nerve damage (leading to weakness in the PFMs), altered recruitment patterning (i.e. delayed, absent or asymmetric) of the deep muscles of the trunk [i.e. the transversus abdominis (TrA) and PFMs] and weakness of these same muscles;
(3) myofascial system impairments, such as tearing of parts of the levator ani from the arcus tendineus fasciae pelvis (anterior or posterior), and stretching of the linea alba and rectus abdominis (DRA); and
(4) visceral system impairments, such as lengthening of the uterosacral and cardinal ligaments supporting the superior aspect of the vagina, and altered tension in the broad and round ligaments and/or pubovesical ligaments supporting the bladder.

This list is only suggestive. Any structure in the abdomen or pelvis can drive non-optimal recruitment strategies and have an impact on how loads are transferred, and thus, further affect the structure and function of the various support mechanisms over time.

Role of the pelvic floor in pelvic girdle pain, urinary incontinence and pelvic organ prolapse

The pelvic floor unit (PFU) (Fig. 2) should be considered to be a functional neuromyofascial entity that extends via the obturator internus muscles from the left to right greater trochanters (Lee & Lee 2007). Optimal function of the PFU

Figure 2. Magnetic resonance imaging scan showing the connection between the levator ani muscle and the left and right obturator internus, and thus, the essential role of the arcus tendineus fasciae pelvis that connects this horizontal sling of pelvic support.

is required for voiding, defecation, sexual function, pelvic organ support and movement control/stability of the pelvis. The PFU works synergistically with the deep abdominal muscles and diaphragm, contributing to intra-abdominal pressure, and the various control mechanisms for the joints of the pelvis, lumbar spine and, indirectly, the lower thorax (Hodges *et al.* 2001, 2005, 2007; Sapsford *et al.* 2001; Neumann & Gill 2002; Pool-Goudzwaard *et al.* 2004).

Function of the PFU requires intact anatomy so that forces may be transferred through its fascial attachments. Optimal timing of contraction (motor control), as well as strength and endurance of contraction, are essential for joint control, urethral control and pelvic organ support. Given the role that the PFU plays in multiple tasks, it is not surprising that PFM training is recommended as the first-line of treatment for women with stress, urge or mixed UI, as well as POP (Dumoulin & Hay-Smith 2010; Fritel *et al.* 2010; Bø & Hilde 2013; Mørkved *et al.* 2013).

Even though the various muscles that comprise the pelvic floor have been investigated extensively, it appears we still have much to learn (Mørkved *et al.* 2013). Bump *et al.* (1991) noted that 25–40% of women have decreased cortical awareness of how to perform a proper pelvic floor contraction in response to a verbal command and often perform a Valsalva manoeuvre. Others may actually be able to contract and lift the levator plate, but still experience incontinence (Sherburn *et al.* 2005). A common clinical finding is that there is asymmetric activation of the various muscles comprising the levator ani (i.e. left/right and front/back).

The mechanisms that drive the asymmetric activation of the pelvic floor are interesting and these are the focus of the remainder of the present paper. With its approach to restoring optimal strategies for function and performance, the ISM appears to assist in re-establishing symmetry of activation, and thus, the function of the pelvic floor across a multitude of conditions including, although not limited to, PGP, UI and POP. One biologically plausible mechanism is that, if there are "twists" in the trunk, i.e. intrapelvic torsion (IPT) and intrathoracic segmental rotations/ring shifts, the nervous system recruits the deep muscle system asymmetrically, and when these "twists" are removed (i.e. the alignment is corrected), the recruitment pattern becomes symmetric immediately (D. Lee and L.-J. Lee, unpublished clinical observations). This mechanism will be highlighted through the lens of the ISM in the case report below. However, here are some key things to remember first:

(1) The nerve supply for the abdominal wall (including the TrA) is from T7 to T11 (i.e. the lower intercostal nerves, as well as the iliohypogastric and ilioinguinal nerves); therefore, altered function of the lower thorax can have an impact on the recruitment patterning/timing/tone of the abdominal wall.
(2) Co-activation of the PFMs and the TrA occurs in healthy subjects (Sapsford *et al.* 2001; Sapsford & Hodges 2001; Neumann & Gill 2002), and when the deep and superficial muscle systems work synergistically, loads are transferred through the trunk with no loss of joint control or joint mobility (i.e. with an optimal strategy). This synergistic activation of the TrA and PFMs is commonly lost in subjects with UI (Bø *et al.* 2009) and PGP.
(3) Women with UI and/or PGP have been found to use a pattern that braces or "grips" the lower thorax during an active straight leg raise, and this strategy was found to increase intra-abdominal pressure and depress the pelvic floor (Beales *et al.* 2009).
(4) Optimal strategies require and produce optimal ABC.
(5) To summarize the research evidence: motor control changes are variable across patients with pain, UI and POP. Specifically with regard to the population with LBP, compromised activity is often found in the deep muscles (i.e. the TrA, PFMs and deep fibres of the multifidus), while augmented activity is often found in the superficial muscles (i.e. the external and internal obliques, erector spinae and piriformis). The common link across all individuals is that the strategy is individual and task-specific, and has a wide variation in terms of which muscles will be involved. In all, the strategy is non-optimal for the task, and since the changes in recruitment are unique, we need to assess each patient individually. We can neither predict what pain will do, nor which impairments will cause pain.

Tiana's story: urinary frequency and stress urinary incontinence secondary to a seventh thoracic ring shift, and pelvic floor muscle strength and endurance deficit

Background
Tiana is a 25-year-old nurse who does CrossFit training between five and six times a week, and as a consequence of this high-intensity exercise, she has had multiple muscle strains and injuries. As her ability and training increased, she became aware of increasing urinary frequency. Tiana recently noticed that, if she did not void frequently, she experienced SUI, especially when performing tasks that load her trunk or increase her intra-abdominal pressure (e.g. box jumps). She is nulliparous.

Current meaningful complaints
Tiana's primary concerns included the increasing frequency of her need to void and the increasing incidence of SUI during her CrossFit training.

Cognitive beliefs
Tiana was worried about the impact that future pregnancies might have on her urinary continence.

These key complaints, beliefs and goals were entered into the centre of Tiana's Clinical Puzzle, which can be seen at the end of this case report (Fig. 12).

Meaningful task and screening tasks
Tiana's meaningful task was a box jump, and the tasks chosen to evaluate her strategy were standing posture and a squat task since each of these is directly related to her meaningful task (Fig. 3).

Standing
Tiana stood with her pelvis rotated in the transverse plane to the right (TPR right) and her

Figure 3. In the landing phase of the subject's box jump, her weight is more to the right of her base of support. Reproduced with the permission of the Diane G. Lee Physiotherapist Corporation.

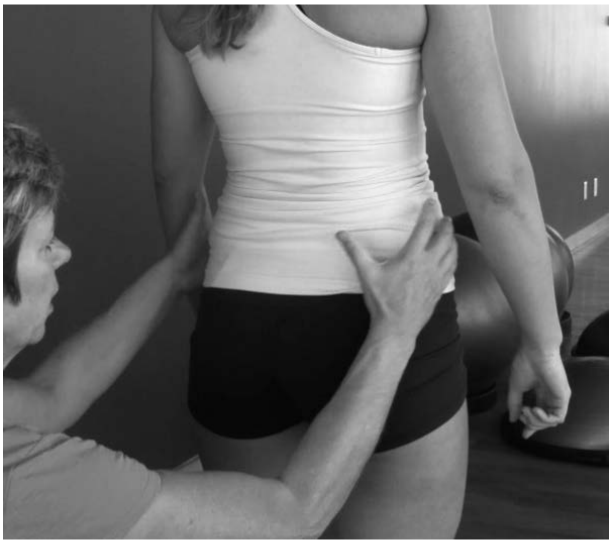

Figure 4. The subject's pelvic ring was rotated in the transverse plane to the right and associated with a right intra-pelvic torsion. Reproduced with the permission of the Diane G. Lee Physiotherapist Corporation.

pelvis in an IPT to the right (IPTR = the left innominate anteriorly rotated relative to the right innominate, and the sacrum rotated to the right) (Fig. 4). Her lower thorax (thoracic rings 8–10) was rotated to the left (TPR left lower), the seventh thoracic ring was shifted left and rotated to the right, and the sixth thoracic ring was shifted to the right and rotated to the left.

Correcting the alignment of the two thoracic rings (6 and 7) improved the pelvic position, while correcting the alignment of the pelvis made the thorax posture/position worse. This suggested that the thorax was driving the pelvic position, as opposed to the pelvis driving the thorax, and that further investigation of what

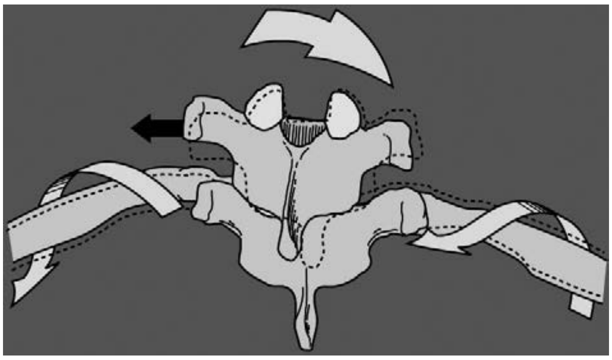

Figure 5. Biomechanics of a right rotation of a segmental thoracic ring. Right rotation is associated with left translation of the segmental thoracic ring (Lee 1993). The term "shift" is used when the translation is occurring when it should not. Reproduced with the permission of the Diane G. Lee Physiotherapist Corporation.

was causing the malalignment of the sixth and seventh thoracic rings was needed.

Squat

During a squat, the following sites of FLT (non-optimal ABC) were noted and the timing of when these failed was recorded:

(1) the seventh thoracic ring shifted further to the left and rotated to the right (the two motions are associated; Lee 1993) (Fig. 5), and the sixth thoracic ring shifted further to the right and rotated to the left before
(2) the left SIJ gave way (i.e. the left innominate anteriorly rotated relative to the sacrum), which is a sign of FLT (Hungerford *et al.* 2004).

When the alignment of the sixth and seventh thoracic rings was corrected, the left SIJ no longer gave way. When the left SIJ was controlled, the sixth and seventh thoracic rings continued to shift and rotate during the squat task, which is a sign of FLT. These findings suggested that the sixth and seventh thoracic rings were the primary driver, and that further assessment should focus on determining what was causing the loss of ABC of the sixth and seventh thoracic rings.

Supine active bent leg raise

This task was not related to Tiana's meaningful task of box jumping; however, for her to know if she was correcting her thoracic rings properly, it was useful as part of her exercise training. She found that more effort was required to lift her left leg (with the knee bent) than her right. No change in effort was noted when the twist was

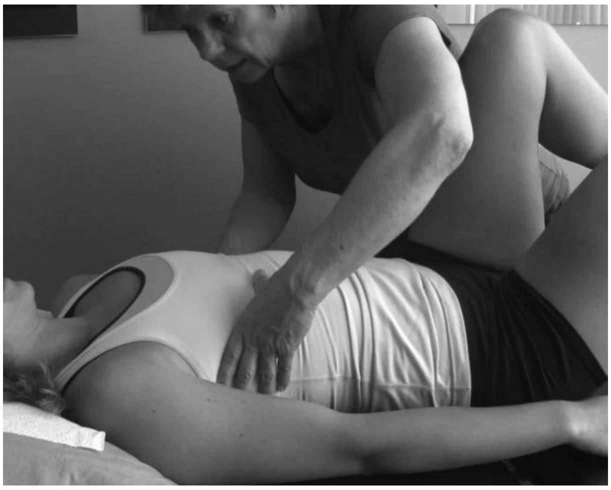

Figure 6. The active bent leg raise test was much easier for the subject to perform on her left side when the alignment of her seventh thoracic ring was corrected. Reproduced with the permission of the Diane G. Lee Physiotherapist Corporation.

taken out of her pelvis (IPTR). However, the task was much easier to perform when the seventh thoracic ring was corrected (Fig. 6). During this task, the sixth thoracic ring self-corrected when the seventh was aligned, and therefore, the focus of correction could be solely on the latter ring.

Hypothesis of the primary driver

Correction of the sixth and seventh thoracic rings improved performance with regard to Tiana's standing posture, the squat task and her ability to lift her left leg while supine; therefore, these thoracic rings were theorized to be the primary driver. Further system analysis (i.e. neural, articular, myofascial, visceral or a combination of the above) was required to determine what was causing the non-optimal alignment of the sixth and seventh thoracic rings across multiple tasks.

Vector analysis of the primary driver: the sixth and seventh thoracic rings

A resistant vector of force was felt from the left side of Tiana's upper abdominal wall when correcting the sixth and seventh thoracic rings. On palpation, increased tone was noted in the left external oblique (EO) muscle. The hypertonicity covered a number of thoracic rings and was regional, not fascicle-specific. However, the primary impact was on the seventh thoracic ring. A specific fascicle of the EO has the ability to anteriorly rotate one rib. However, this rib is part of the entire thoracic ring (Lee 1994), and therefore, when the rib anteriorly rotates on the

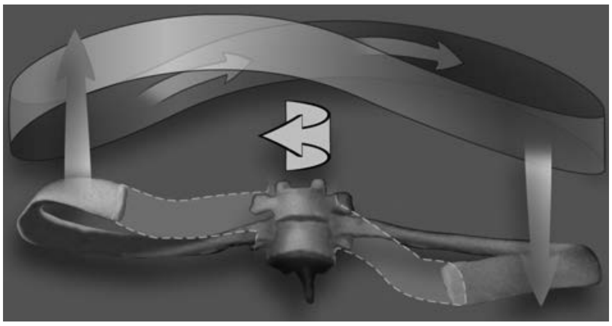

Figure 7. The left external oblique fascicle attaching directly to the left seventh rib can produce anterior rotation of this rib, and thus, right rotation of the entire seventh thoracic ring. Reproduced with the permission of the Diane G. Lee Physiotherapist Corporation.

left, it can potentially produce left translation and right rotation of the entire thoracic ring (Fig. 7). When the seventh thoracic ring was corrected, the sixth self-corrected, suggesting that the primary impaired thoracic ring was the seventh one.

The next question was: What is the impact of this increased tone in the left EO on the recruitment strategy of the entire abdominal wall? This led to the next part of the examination, a neural system analysis of the abdominal wall.

Neural system analysis of the abdominal wall

More palpable fascial tension was noted superficially on the left side of Tiana's lower abdomen, probably because of the increased resting tone of the left EO. When asked to contract her pelvic floor gently (i.e. a maximum voluntary contraction of no more than 10–15%), increased activation of the left EO was palpable as an immediate first response. Real-time ultrasound (RTUS) imaging revealed that, while the right TrA responded appropriately to this pelvic floor cue, the left did not (Fig. 8).

When the seventh thoracic ring was corrected manually, there was less superficial fascial abdominal tension, and a symmetrical activation of both the left and right TrA could be felt and seen via RTUS (Fig. 9).

Neural system analysis of the pelvic floor

A transabdominal, suprapubic anteroposterior RTUS imaging screen of the pelvic organs and fascial support system revealed asymmetry of the bladder when the pelvic girdle was resting in an IPTR (Fig. 10). A contraction of the pelvic floor appeared to increase this bladder asymmetry. When the seventh thoracic ring was manually corrected, thus neutralizing the position of the

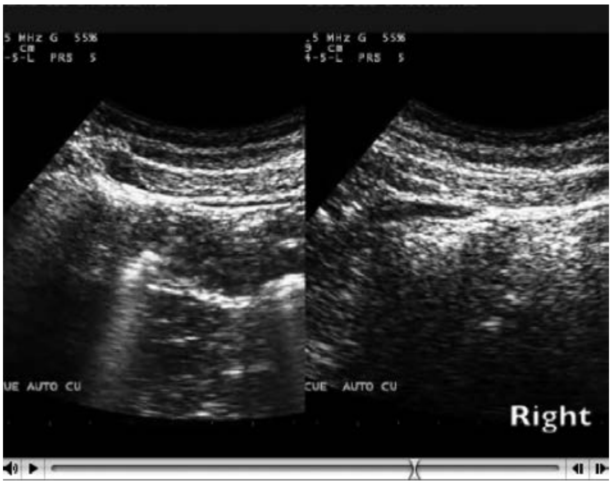

Figure 8. Screen capture from a real-time ultrasound imaging video of the left (on the left in this figure) and right (on the right) sides of the subject's abdominal wall during a response to a verbal cue for her to contract her pelvic floor. Note the difference in broadening and corseting of her transversus abdominis muscles.

Figure 9. The difference in the broadening of the left transversus abdominis after a verbal cue to contract the pelvic floor (on the left in this figure) when the seventh thoracic ring is corrected.

pelvis, the shape of the bladder was more symmetrical as was the pelvic floor lift (Fig. 11). A transabdominal, suprapubic sagittal view of the pelvic floor contraction did not reveal any asymmetry since only the midline of the bladder and pelvic floor are imaged with this orientation. However, a good lift in an optimal location for urethral and bladder support was noted.

A perineal RTUS view of Tiana's pelvic floor contraction when her pelvis was twisted (IPTR) revealed less lift (decreased amplitude) and less pelvic organ support during her cough (greater descent seen) compared to when her pelvis was in a neutral position.

Figure 10. Asymmetric bladder shape noted on real-time ultrasound imaging when the pelvis was in an intrapelvic torsion to the right.

Figure 11. The immediate change in bladder shape when the pelvic alignment is adjusted with the seventh thoracic ring correction.

Intravaginal examination of the pelvic floor

When Tiana's pelvis was in an IPTR, no activation of the left side of her levator ani was apparent on internal palpation (Grade 0) (Laycock & Jerwood 2001). The left side of her pelvic floor was not hypertonic in spite of appearing elevated on the RTUS examination. When her pelvic girdle position was neutralized, much better recruitment of the left side of her levator ani was immediately felt (Grade 3); however, Tiana could only hold this contraction for 5 s (endurance deficit). Some weakness and loss of endurance of the left side of the levator ani was still present in spite of removing the influence of the IPT on the recruitment strategy.

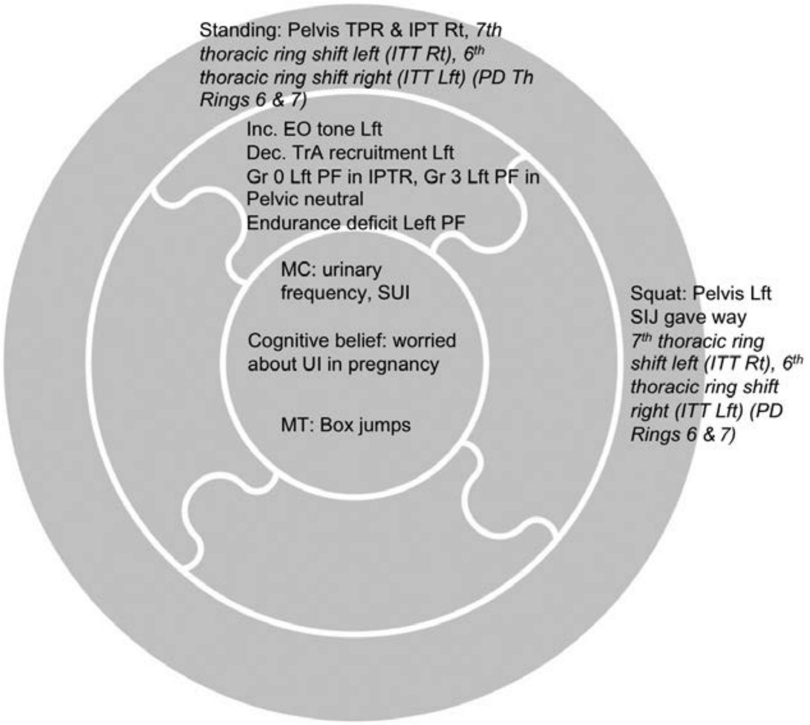

Figure 12. The subject's complete Clinical Puzzle: (TPR) transverse plane rotation; (IPT) intrapelvic torsion; (EO) external oblique muscle; (TrA) transversus abdominus muscle; (PF) pelvic floor; and (SUI) stress urinary incontinence.

Hypothesis about why Tiana experienced stress urinary incontinence during box jumps in CrossFit training

The hypothesis was that Tiana had an abdominal wall muscle imbalance (over-activation of the left EO and under-activation of the left TrA) that had created a primary seventh thoracic ring shift to the left (this ring is rotated to the right). This shift appeared to be driving the pelvis to rotate (TPR right and IPTR). There was insufficient activation of the deep muscle system (i.e. the left TrA and pelvic floor), and this was a probable cause of the loss of control of the left SIJ.

The mechanism that had altered the recruitment strategy of the left side of Tiana's pelvic floor was unclear. What was obvious was that the left side of her levator ani was not recruited when her pelvis was twisted (IPTR), and although activation improved when the twist of her pelvis was removed, there was an underlying strength and endurance deficit on this side of her pelvic floor.

Collectively, all of this was creating poor urethral, bladder, pelvic, and sixth and seventh thoracic ring support during tasks that increase loading through the pelvis and its organs, i.e. the box jump (Fig. 3). Tiana's complete Clinical Puzzle is shown in Fig. 12.

Treatment following the principles of the Integrated Systems Model: release, align, connect and move

According to the treatment principles of the ISM (Fig. 13), the first step was to release the vectors that were creating non-optimal alignment of the seventh thoracic ring and restore optimal recruitment synergies of the abdominal wall.

Release of the left EO:

(1) *Supine – hook-lying.* Align the seventh thoracic ring, and then breathe with a lateral costal expansion strategy for three or four breaths. Next, take the legs to the right on the inhale breath, hold and connect to the TrA and pelvic floor, and then exhale to return the legs to neutral for three or four repetitions (Fig. 14). After that, recheck the effort it takes to lift the left leg, which should be less.

Release and align:

(2) *Side-angle pose.* Position the left leg back and correct the seventh thoracic ring first. Next, unwind the IPTR, then rotate the thorax to the left to lengthen the left EO and hold this position for three breaths (Fig. 15).

Release, align, connect and move:

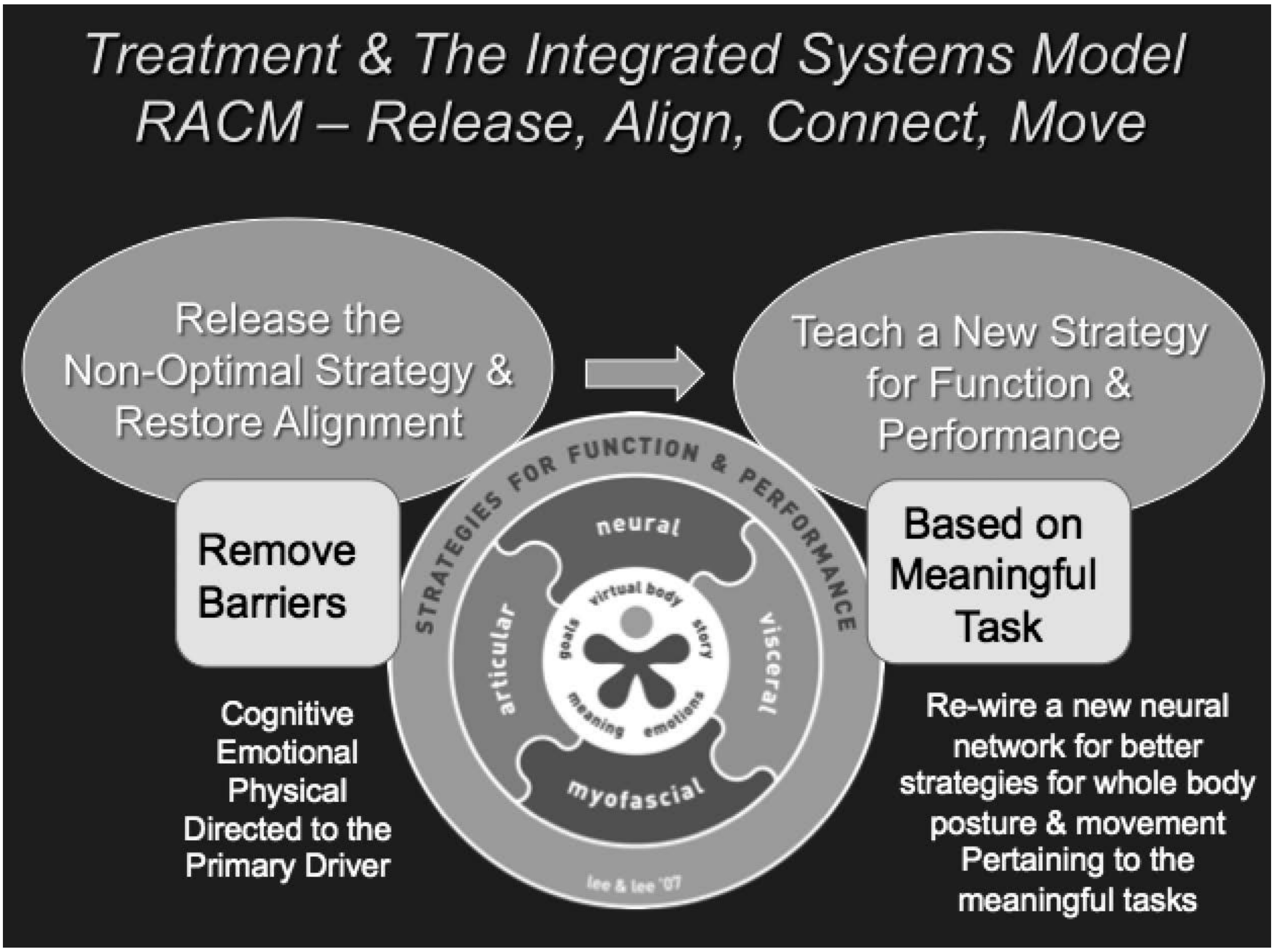

Figure 13. Treatment principles according the Integrated Systems Model approach (Lee & Lee).

Figure 14. Release technique and exercise for the seventh thoracic ring and the left external oblique muscle. Reproduced with the permission of the Diane G. Lee Physiotherapist Corporation.

Figure 15. Release and align exercise that focuses first on the seventh thoracic ring and then on the pelvis. Reproduced with the permission of the Diane G. Lee Physiotherapist Corporation.

(3) Correct the alignment of the seventh thoracic ring, activate the PFMs (feel for the contraction of the left side of the pelvic floor) and then perform three squats.

Tiana performed the three exercises outlined above before her CrossFit training workouts.

Strength and endurance training for the pelvic floor:

(4) *Left-side levator ani strength and endurance training.* Work up to 10, 10-s holds in pelvic neutral, three times per day for at least three or four times a week. Introduce both slow and fast contractions specifically for Cross-Fit training after 4–6 weeks. Continue with intensive specific PFM training for at least 8 weeks (Mørkved *et al.* 2003).

Follow-up plan:

(5) Reassess the symmetry of activation (motor control), and strength and endurance (performance) of the levator ani after 4–6 weeks, along with the ability to control the left SIJ, and the sixth and seventh thoracic rings, and maintain urethral closure during squats and box jumps. Progress PFM training and more-advanced thoracopelvic alignment exercises as necessary at that time.

Tiana's story, one in which non-optimal strategies in the thorax can drive the loss of thoracic and pelvic ring control, as well as urinary frequency/continence, is not uncommon, but such cases are often missed when patients are assessed "from the bottom up". Urinary frequency and incontinence can be caused by impairments that are far removed from the pelvic floor, and while local training of the PFMs and the deep muscle system is still relevant, the whole person and body have to be considered to enable optimal treatment of these conditions. The ISM provides an ideal framework for determining where to focus treatment when treating the whole person. Understanding the relationship between the thorax and the pelvis facilitates the development of a hypothesis, and subsequently, prescriptive, individualized treatment plans, rather than protocol or condition-driven ones.

Further information can be found online at the present author's website (www.dianelee.ca) and in the fourth edition of *The Pelvic Girdle* (Lee 2011).

Diastasis rectus abdominis, and the implications for the form and function of the trunk after pregnancy

It is well established that the TrA plays a crucial role in the optimal function of the lumbopelvic region, and that one mechanism by which this muscle contributes to intersegmental (Hodges 2003) and intrapelvic (Richardson *et al.* 2002) control is through fascial tension. Diastasis rectus abdominis has the potential to disrupt this mechanism and is a common postpartum occurrence (Boissonnault & Blaschak 1988; Spitznagle *et al.* 2007). Universally, the most obvious visible change during pregnancy is the expansion of the abdominal wall, and while most abdomens accommodate this stretch very well, others are damaged extensively (Fig. 16).

Figure 16. A woman who experienced significant damage to her skin, superficial fascia and linea alba during her second pregnancy. Reproduced with the permission of the Diane G. Lee Physiotherapist Corporation.

One structure that is particularly affected by the expansion of the abdomen is the linea alba, the complex connective tissue (Axer *et al.* 2001) that connects the left and right abdominal muscles. The width of the linea alba is known as the inter-recti distance and normally varies along its length from the xyphoid to the pubic symphysis. Beer *et al.* (2009) used RTUS imaging to measured the width of the linea alba in 150 nulliparous women aged between 20 and 45 years, and found the mean width to be highly variable, reporting 7 ± 5 mm at the xyphoid, and 13 ± 7 and 8 ± 6 mm at 3 and 2 cm above and below the umbilicus, respectively.

Mendes *et al.* (2007) showed that RTUS imaging is an accurate method for measuring inter-recti distance, and other researchers have used it to measure the behaviour of the linea alba during a variety of tasks (Coldron *et al.* 2008; D. Lee and P. W. Hodges, unpublished results). A diagnosis of DRA is commonly made when the inter-recti distance exceeds what is thought to be normal, but there is no standardized agreement as to what is typical.

There is little scientific literature on this condition. Boissonnault & Blaschak (1988) found that 27% of women have a DRA in the second trimester of pregnancy and 66% in the third. Some 53% of these women continued to have a

DRA immediately postpartum, and 36% remained abnormally wide at 5–7 weeks postpartum. Coldron *et al.* (2007) measured the inter-recti distance from the first day after childbirth to 12 months postpartum. These authors noted that this distance decreased markedly between day one and 8 weeks postpartum, and that, without any intervention (e.g. core training), there was no further closure at the end of the first year. In the urogynaecological population, 52% of patients were found to have DRA (Spitznagle *et al.* 2007). Some 66% of these women had at least one support-related pelvic floor dysfunction (e.g. SUI, faecal incontinence and/or POP). There are no studies to guide clinicians on what is the best treatment for postpartum women with DRA.

Clinically, it appears that there are two subgroups of postpartum women with DRA:

(1) those who are able to restore optimal strategies for transferring loads through the abdominal canister with or without achieving closure of the DRA through a multimodal treatment programme such as the ISM approach; and
(2) those who fail to achieve optimal strategies for transferring loads through the abdominal canister despite apparently being able to restore the optimal function of their deep muscles (i.e. an optimal neural system), but who do not experience loss of articular integrity of the SIJs or pubic symphysis (i.e. an optimal articular system), and in whom the inter-recti distance remains greater than normal (i.e. a non-optimal myofascial system); FLT is consistently found throughout the joints of the lower thorax, lumbar spine and/or pelvic girdle in multiple vertical loading tasks (e.g. single-leg standing, squatting, walking, moving from sitting to standing and climbing stairs).

The second subgroup of postpartum women appear to have sustained significant damage to the midline fascial structures, and sufficient tension can no longer be generated through the abdominal wall for resolution of function (Fig. 17). A surgical plication of the recti, along with an abdominoplasty to repair the midline abdominal fascia (the linea alba) and skin should be considered for this subgroup (Toranto 1988).

Recent studies of women with healthy (17 controls) and stretched (26 participants) abdominal walls have provided further data on the behaviour and morphology of the linea alba (D. Lee and P. W. Hodges, unpublished results) during a curl-up task. In the healthy controls, the linea alba demonstrated minimal deviation from the shortest line between the left and right rectus abdominis (distortion index) regardless of whether they pre-contracted the TrA during the curl-up task. Although the findings have to be validated, this suggests that these women were able to generate tension in the linea alba for effective transference of loads. Conversely, in 69% of the women with DRA, the linea alba became "distorted" from the initial rest position (i.e. wrinkled, saggy or domed) during the curl-up task, and while some could reduce this distortion by pre-contracting the TrA, others could not. Although further analysis is required, this finding suggests that there are two subgroups of women with DRA: those who will require surgery; and those who can be treated/trained to restore optimal strategies, and thus, the function and performance of the abdominal wall. Further clinical trials have been planned to enhance our understanding of this group of women with postpartum separation of the abdominal wall.

Figure 17. In some women with diastasis rectus abdominis, surgical repair should be considered only if optimal strategies for abdominal wall recruitment do not generate sufficient tension (force closure) to ensure that joint motion is controlled across multiple loading tasks. Reproduced with the permission of the Diane G. Lee Physiotherapist Corporation.

In the online version of the fourth edition of *The Pelvic Girdle* (Lee 2011), there are two case reports, complete with video clips, that describe the clinical findings and treatment of a pair of women: one has a non-surgical DRA; and the other eventually had her abdominal wall surgically repaired. We now understand that there are subgroups of this condition, and recognize that both further research and clinical expertise are needed to properly investigate and, thus, inform individuals with this very significant postpartum complication.

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Diane Lee graduated from the University of British Columbia, Vancouver, BC, Canada, with a BSc in Rehabilitation in 1976. She has been a fellow of the Canadian Academy of Manipulative Physiotherapy since 1981 and completed her certification in intramuscular stimulation in 2001. Diane is the owner, director, educator and physiotherapist of Diane Lee & Associates (www.dianelee.ca) in White Rock, BC. She is well known for her clinical work on the thorax and pelvic girdle. Diane has been a keynote and conference speaker at many meetings, including the World Congress on Low Back & Pelvic Pain. She has contributed chapters to several books and self-published the book The Thorax: An Integrated Approach *(2003).* The Pelvic Girdle: An

Integration of Clinical Expertise and Research *was first published in 1989 (Elsevier), and the fourth and latest edition (2011) presents a new model, the ISM, which is the foundation of Diane's series of courses. She holds the North American patent for an innovative sacroiliac belt, the Com-Pressor, and is the inventor and manufacturer of a new belt for pregnancy, the Baby Belly Belt. With respect to research, Diane is currently investigating the behaviour of the abdominal wall in women with DRA, and has received a grant from the Clinical Centre of Research Excellence at the University of Queensland, Brisbane, Queensland, Australia, to further these studies.*