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PREVENTION & REHABILITATION: Practical Paper

Thoracic ring function, movement efficiency and injury prevention

Understanding the relationships between, and within, integrated systems and body regions and the consequences of impaired function of one on another is complex. In this issue of JBMT, Morley and Traum (2019) report that casting the trunk from the 7th thoracic ring* to the pelvis:

> "has statistically significant effects on the energy used during running and on the vertical movement of the center of mass. A running style that causes the body to use more energy is inefficient and can lead to earlier onset of fatigue". They suggest "It can make the runner more prone to overuse injuries".

* The term "thoracic ring" refers to the named thoracic vertebra and its accompanying ribs and sternal/costal cartilaginous attachments - see Fig. 2 below for illustration.

Does this study have any clinical implications? In other words, is 'casting of the trunk' seen in clinical practice? Multiple studies have shown that motor control changes in response to pain are highly variable and the consistent finding is a redistribution of muscle activity with deep muscles becoming inhibited and superficial muscles augmented (Hodges and Smeets, 2015). This redistribution of activation has clinically been found to impact congruent rotation of the thoracic rings, and while all the thoracic rings may not be impacted, many are; and this essentially 'casts' the trunk.

As Morley and Traum (2019) show, this may have performance and injury-risk ramifications. Through optimizing spinal kinematics, the individual may realize their athletic potential and mitigate risk of injury through the effect of cumulative stresses.

Also in this issue, Hernandez et al. (2019) note that a

> "combination of core muscle activation exercises and conventional treatment was more effective in short-term pain reduction in patients with knee OA". "The lumbopelvic-hip complex or "core" can be described as a muscular box consisting of the abdominals, the paraspinals and glutes, the diaphragm, the pelvic floor and the hip girdle musculature. The core controls trunk position and pelvis related movement, optimizing the production, transfer, and control of force and motion to the distal segments of the kinetic chain".

The paraspinals connect the first thoracic ring to the lumbar spine and pelvis (MacIntosh and Bogduk, 1991) and the abdominals connect the 5th thoracic ring to the lumbar spine and pelvis, and these are the same muscles noted to have redistribution of muscle activity (Hodges and Smeets, 2015). They can potentially limit mobility, and reduce control, of the thoracic rings, lumbar spine and pelvis in the presence of pain.

Many health practitioners specialize in varying aspects of thorax disorders, including physiotherapists, manual therapists, chiropractors, osteopathic practitioners, massage therapists, respiratory therapists and respirologists, cardiac physiotherapists, cardiologists, and exercise physiologists. Treatment is often based on the practitioner's training and experience. The thorax is an integrated system, as well as being integrated with the whole body/person. Therefore, understanding what comprises optimal function and how to assess and manage the thorax is fundamental to all forms of treatment for multiple conditions. Furthermore, understanding the impact of sub-optimal function of the thorax on other systems and body regions, can facilitate and expedite appropriate care, particularly for complex presentations and those experiencing persistent pain.

There is limited research on both the biomechanics of the thorax and its contribution to multiple pain states and conditions. The rib cage and the 13 joints per typical thoracic ring (Lee, 1994) pose significant methodological challenges for investigating segmental biomechanics both within and between the thoracic rings. Many of the ex vivo studies investigating mobility and/or control of a thoracic ring use cadaveric specimens without an intact rib cage, and while this is occasionally seen in clinical practice (rib removal), it is not the most common clinical presentation. Consequently, these studies are limited for application to clinical practice.

In 1993 a clinical model of in vivo biomechanics of the thorax was proposed (Lee, 1993). This biomechanical model was derived from clinical observations with consideration of the available evidence. Sizer et al. (2007) noted that:

> "In vivo studies are clinically applicable but lead to challenges in controlling extraneous variables that include motor and postural control, as well as tissue adaptation anatomical and circadian variability; applied preload forces the degree of thoracic kyphosis and scoliosis; and technical difficulty in measuring spinal coupling."

However, these variables are the clinician's reality and practitioners are expected to interpret movement behavior with these variables in situ. They conclude by noting that:

> "The lack of a common coupling pattern may merit individual clinical assessment for each patient examined".

How should clinicians interpret the movement findings of the thorax noted on assessment? What are the normal, or optimal, biomechanics for the thorax? What is abnormal? To date, the highest ranked level of evidence (a systematic review (Sizer et al.,

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2007)) does not provide clinicians with a biomechanical model against which to compare the patient's movement results. So, while it is acknowledged that the thorax plays a key role in optimal function of the trunk (including the head and neck), upper and lower extremities, respiration, digestion, and continence, practitioners still rely on clinical models of proposed alignment (posture), biomechanics and control for assessment and management of the thorax in multiple pain states and conditions.

1. Is the thorax contributing to your patient's presentation?

Assessment of the thorax follows the same fundamental principles for assessment of any other region of the body. The essential examination includes both subjective and objective components and then clinical reasoning of the examination findings to formulate an individualized treatment plan.

1.1. Hearing the story and how it is told – the subjective examination

Assessment begins not only by learning the details of the patient's story (onset of symptoms, timeline of events, aggravating and relieving activities, presence of any macro or microtrauma, medical considerations etc.) but actually hearing *how* the story is told (See Fig. 1). This helps to identify the pain mechanism (nociceptive, neurogenic, nociplastic), and any emotional barriers (fears, anger, anxiety) that may need to be addressed. Asking the patient what they believe to be the problem provides information on their cognitive beliefs (memories of past experiences of self or others, consideration of what other health practitioners have told them), that can potentially impede recovery. The meaningful complaint (the symptom that the patient is going to use to determine 'Am I better?') is derived from hearing their story, as is the meaningful task.

Meaningful tasks are those that aggravate the meaningful complaint, or tasks that the patient would like to be able to do better (e.g. sit without pain, run, elevate their arm, turn their head, not leak urine when they cough etc.). So, now the clinician knows what is bothering them and what they are unable to do. How does this direct what to assess? Specifically, how does this information help to guide the examination to determine if the thorax requires treatment?

In addition, it may also be useful to determine a positive focus beyond the presenting complaint; a performance goal, dream or ambition (Wallden and Chek, 2018). This serves to provide a positive context and focus for engaging in a return toward optimal function as opposed to (or in addition to) a goal to simply compensate or to "get out of pain" (see Fig. 1).

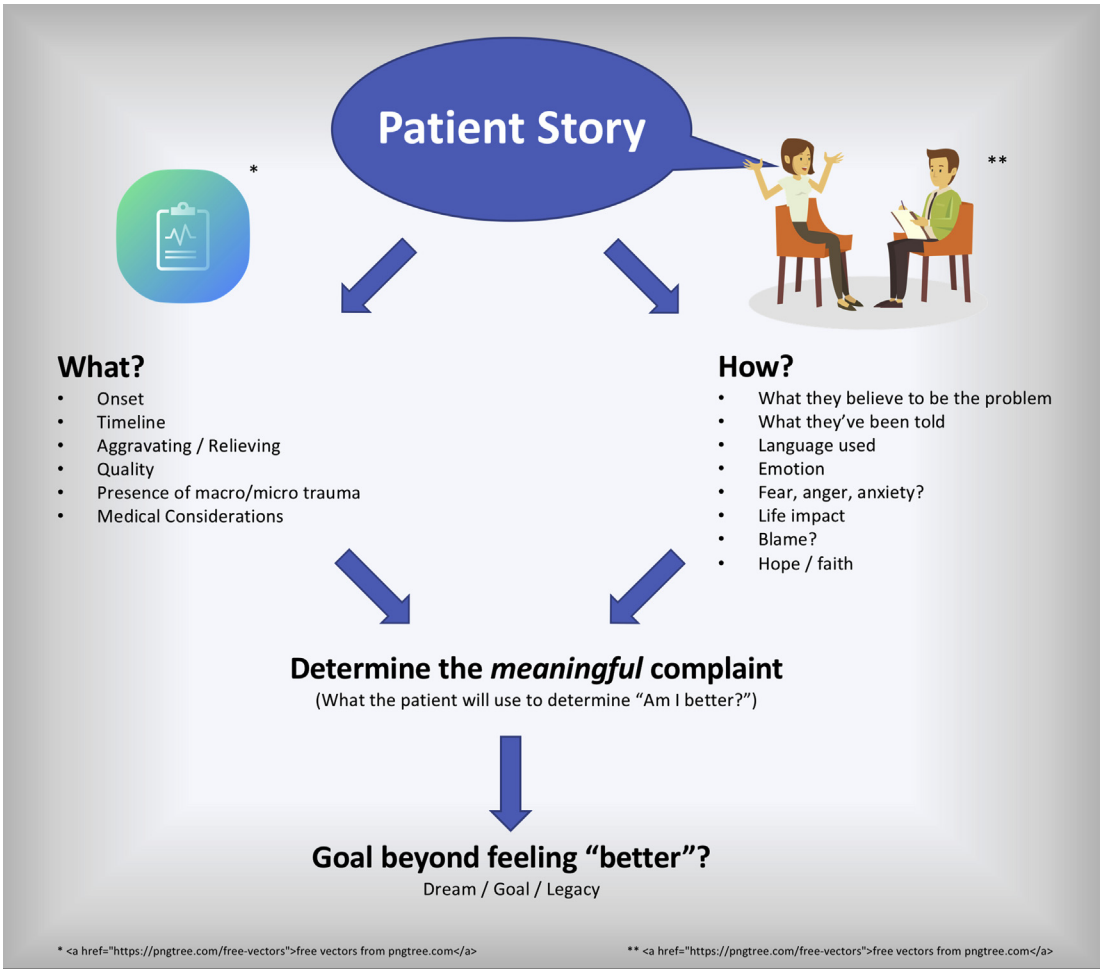

Fig. 1. The Two Sides of the Coin in the Consulting Process: Traditionally, much of the clinical focus in patient consultation has been on the "What?" - the objective aspects of the patient story, but current understanding places significant value on the "How?" – the subjective aspects of the patient story. Specifically, determining the individual's Meaningful Complaint is key to understand what it is that will determine "Am I better?", and beyond this initial goal (often the driver for that individual to consult a healthcare professional) is a key focus on something "bigger than" their pain – a positive, life-affirmative dream or ambition beyond the presenting complaint.

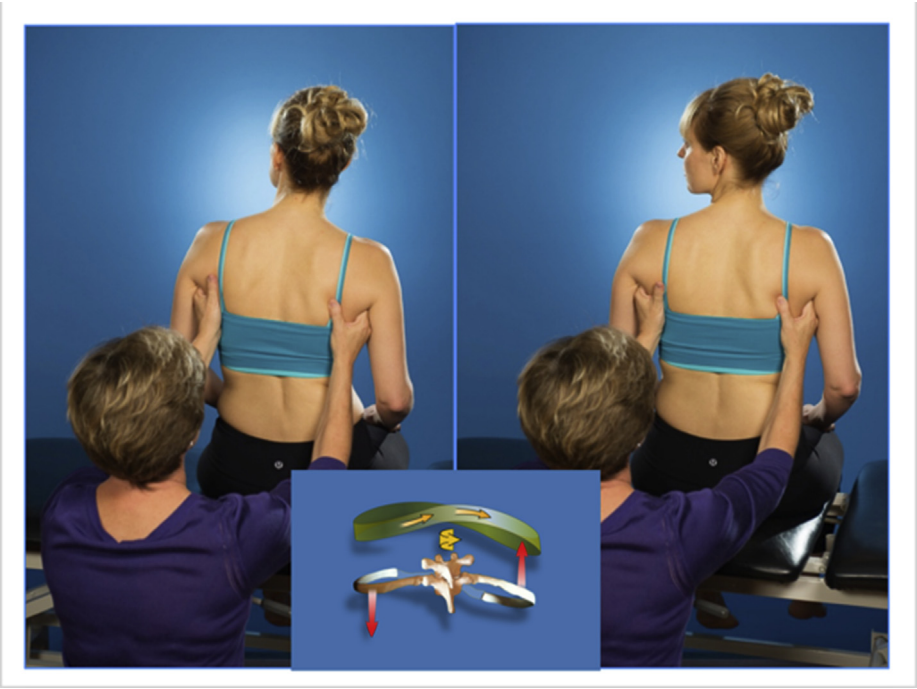

Fig. 2. Left: The therapist is monitoring the biomechanics of the mid-thoracic rings (3–6) in the mid-axillary line as the patient rotates her head and neck to the left. Optimally, the mid-thoracic rings should rotate to the left. See the inset picture for the required osteokinematics and arthrokinematics of the mid-thoracic rings during this task. Note the available range of left head and neck rotation. The 4th thoracic ring starts right rotated/left translated and fails to left rotate/right translate during this task. In this region of the thorax, right rotation couples with right side-flexion (Lee, 2015) thus the noted depression of the right scapula. Right: The starting position of the 4th thoracic ring can be corrected (thus ruling out an articular restriction) and when the active range of motion for left rotation of the 4th thoracic ring is facilitated during left rotation of the head and neck the range of motion for this task increased and the patient's experience was positive. Additionally, note the change in posture of both the mid-thorax and right scapula. While not perfect, it is much better and suggests that further assessment to determine what is causing the sub-optimal alignment and biomechanics of the 4th thoracic ring is relevant for improving the ability of this patient to turn their head to the left.

1.2. What tests to include in the assessment – objective examination

The specific tests that comprise the individual objective examination are directed by key findings from the story, or the subjective examination. Neurological tests for conduction/reflexes and neural, or dural, mobility can be applied if the story suggests there has been possible compromise or irritation of these structures.

Subsequently, screening tasks are chosen based on how they specifically relate to the patient's meaningful task(s) and goals. For example, if the meaningful task is to be able to sit and work on the computer without low back pain (LBP), then the following screening tasks would be pertinent to include in the objective examination:

1. Sitting posture in a similar chair that brings on the LBP and the squat task to evaluate how they got into the chair.
2. Seated bilateral arm elevation just to the level that they need to manipulate the keys on the keyboard (simulating computer work).

If the meaningful task is to be able to put a box on a high shelf without impingement pain in the right glenohumeral joint, then the following screening tasks would be more relevant to assess:

1. Standing unilateral full arm elevation (initially right arm (if right hand dominant) followed by left arm reaching up and across the chest to the bottom of a box).
2. Head and neck extension (to look up to the shelf) in isolation then followed by head and neck extension combined with arm elevation.

If the meaningful task is to be able to run without urinary leakage, none of the previous screening tests would be appropriate. Relevant screening tasks for running would include:

1. Standing step forward – initiated by the left and right lower extremities.
2. Standing thoracic rotation without and then with arm elevation to 30° (simulating the arm and thorax action required for optimal running biomechanics).
3. Thoracic rotation in step forward lunge position.

For each of these screening tasks, the starting position of the individual thoracic rings (posture and alignment) is determined to facilitate valid interpretation of the task findings. Subsequently, the task is performed and the behavior (alignment, biomechanics and control) of each thoracic ring is assessed (manual palpation and visual observation). To interpret the findings, one needs to have an understanding of what is required of that specific thoracic ring for that task. Should it move, and how should it move (active mobility testing for that task) or should it not move (motion control testing)? If it does not move when it should or if it moves when it should not, then this thoracic ring is behaving in a sub-optimal manner for the task being assessed and further tests are required to determine if the sub-optimal thoracic ring alignment, biomechanics and/or control are relevant to the clinical picture. The entire thorax can be screened quite quickly during this initial scan to determine which segmental thoracic ring(s) require further testing.

1.3. Is the sub-optimal behavior of a thoracic ring clinically relevant?

Subsequent tests for the thoracic ring(s) that demonstrate sub-optimal alignment, biomechanics and/or control for the screening

task include:

1. Passive mobility testing of the thoracic ring
   a. Can the starting position of the thoracic ring be manually corrected (Lee, 2003)? If so, this rules out an articular system impairment such as fibrosis or fixation.
   b. Does this manual correction of the thoracic ring alignment, combined with facilitation of the requisite biomechanics and control (active assisted range of motion) for the task being assessed improve the:
      i. Performance of the task (measured by an objective increase in range of motion, strength and other functional considerations) and/or the
      ii. Patient's experience of the task (reduction in subjective symptoms, ease of performance)?
2. Once the specific thoracic ring, or rings is found which, when corrected, result in the best improvement in both performance and experience of the screening task, assessment of the four systems (articular, neural, myofascial, visceral) that can potentially create sub-optimal alignment, biomechanics and/or control of the specific thoracic ring(s) is done.

Which system is assessed depends on the specific 'vector of pull' felt on both correction and release of the thoracic ring. Space constraints prevents a complete description of all four systems in this paper, but, to clarify the fundamentals of this part of the assessment, consider the difference in the behavior of a thoracic ring that is impacted by a stiff joint (articular system impairment) versus a joint that is restricted by over-activation of specific fascicles of the long muscles of the trunk (neural system impairment).

a. Articular system impairments (i.e. fibrosis, joint fixation) prevent correction of the thoracic ring and no improvement in the screening task occurs until mobility of the impaired joint(s) of the thoracic ring is restored. When an attempt is made to manually correct this thoracic ring, marked resistance is felt; the 'beginning and end feel' of motion is very hard. Specific passive arthrokinematic joint mobility tests for the relevant zygapophyseal and costotransverse joints are required to determine the underlying impairment(s). These findings then direct treatment. When there is a history of trauma to the thorax, specific intra- and inter-ring control tests should be performed to rule in/out a loss of passive system integrity or form closure.
b. Neural system impairments (over- or under-activation of any muscle that attaches to the thoracic ring) are a more common finding and result from redistribution of muscle activity and changes in motor output as a consequence of pain secondary to macro or microtrauma (Hodges and Smeets, 2015). In this instance, the thoracic ring can be manually corrected, and this correction often results in improvement in both the performance of the screening and meaningful task as well as the patient's experience while performing the task (Fig. 2).

When manually correcting the relevant thoracic ring (or combination of rings), resistance is felt both on initiating the correction (beginning feel) and on its release. The location, direction and length of the force vector felt during both correction and release suggest the muscles to be assessed for over-activation. When the neural system (altered motor control) is determined to be the underlying system impairment of the specific thoracic ring(s) further tests to analyze the recruitment strategies of the segmental and multi-segmental muscles pertaining to that specific ring during the specific screening task are indicated in order to plan treatment (Lee D 2018, 2019). As with the active mobility changes illustrated in Fig. 2, passive arthrokinematic joint mobility tests may also often reveal altered mobility findings which can be misinterpreted unless they are performed with the thoracic ring corrected to a neutral starting position.

In summary, to determine if sub-optimal alignment, biomechanics and/or control of the thorax is contributing to the patient's pain state and/or condition, an understanding of how the thorax should perform during tasks related to the patient's story is required. Then, tests for active mobility, passive mobility and control can be applied to the specific thoracic ring(s) found to be behaving in a sub-optimal manner during a specific screening task based on the meaningful task that is related to the patient's goals. If the thorax is relevant to the clinical picture, correcting its alignment, biomechanics and control will make an immediate difference in function, performance and the patient's experience.

As Morley and Traum (2019) and Hernandez et al. (2019) demonstrate, the thorax can be recognized clinically to be a contributor in multiple pain states, conditions and function. Once the skills are acquired to determine individual thoracic ring alignment, biomechanics and control, then assessment of the thorax can easily be incorporated into a whole body/person evaluation in a timely manner. Poor thoracic function is found in most musculoskeletal conditions, but it is not always necessary to treat it. When it is relevant to the clinical or performance picture, the fundamental orthopedic assessment tests for posture, movement and control will reveal the underlying system impairment, which then directs the intervention.

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Diane Lee*, Matt Wallden

* Corresponding author.
E-mail addresses: dianelee@dianeleephysio.com (D. Lee), matt@mattwallden.com (M. Wallden).

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