Rotational Instability Of the Midthoracic Spine Assessment and Management

Diane Lee. Published in Manual Therapy 1(5): 234-291

Diane Lee BSR FCAMT, Wednesday 29 March 2006 - 03:47:53

Recent research has enhanced the understanding of instability of the spine. The principles of this research has been incorporated into the evaluation and treatment of the unstable thorax. Rotational instability of the midthorax is commonly seen following trauma to the chest. Specific mobility and stability tests have been developed to detect this instability. The tests are derived from a biomechanical model of evaluation. Treatment is based on sound stabilization principles and although the segment will remain unstable on passive testing, the patient can be trained to control the biomechanics of the thorax and return to a high level of function.

IntroductionIn the literature pertaining to back pain, the musculoskeletal components of the thorax have received little attention. Research is sparse in all areas including developmental anatomy, normal biomechanics, pathomechanical processes, evaluation and treatment. And yet, midback pain is not uncommon. A biomechanical approach to assessment and treatment of the thorax requires an understanding of its normal behavior. A working model has been proposed (Lee 1993, 1994a,b) part of which is based on scientific research (Panjabi 1976) and the rest on clinical observation. This model requires validation through further research studies. The understanding of instability of the spine has been enhanced by recent research (Hides et al 1994, 1995, Hodges & Richardson 1995a,b, Panjabi 1992a,b, Richardson & Jull 1995, Vleeming et al 1995). The principles of this research have been incorporated into the evaluation and treatment of the unstable thorax. Rotational instability of the midthorax involves both the spinal and costal components of the segment. Specific tests have been developed (Lee 1993, 1994a,b, Lowcock 1990) to detect this instability and the management is based on sound stabilization principles (Richardson & Jull 1994).

AnatomyThe thorax can be divided into four regions according to anatomical and biomechanical differences. The midthorax is the topic of this paper and includes the T3 to T7 vertebrae, the third to seventh ribs and the sternum. Rotational instability of the thorax is most common in this region. A brief anatomical review is relevant in order to understand the normal mechanics and pathomechanics of rotation in the midthorax.The facets on both the superior and inferior articular processes of the thoracic vertebra are curved in both the transverse and sagittal planes (Davis 1959). This orientation permits multidirectional movement and does not restrain, nor direct, any coupling of motion when the thorax rotates. Neither do they limit the amount of lateral translation which occurs in conjunction with rotation (Panjabi 1976). The ventral aspect of the transverse process contains a deep, concave facet for articulation with the rib of the same number. This curvature influences the conjunct rotation which occurs when the rib glides in a superoinferior direction. A superior glide is associated with anterior rotation of the rib, an inferior glide is associated with posterior rotation. The posterolateral corners of both the superior and inferior aspects of the vertebral body contain an ovoid demifacet for articulation with the head of the rib. Development of the superior costovertebral joint is delayed until early adolescence (Penning & Wilmink 1987, Warwick et al 1989). In the skeletally mature, the costovertebral joint is divided into two synovial cavities, separated by an intra-articular ligament. Several ligaments support the costovertebral complex including; the radiate, costotransverse or interosseous ligament, lateral costotransverse ligament and the superior costotransverse ligament. Attenuation of some of these ligaments occurs when the midthorax is unstable. The anatomy and age related changes of the intervertebral disc in the thorax have received recent study. Crawford (1995) investigated a series of 51 cadavers aged from 19 to 91 and tabulated the incidence and location of degeneration, Schmorl s nodes and posterior intervertebral disc prolapse. The midthoracic region was found to have the highest incidence of degenerated discs and intervertebral prolapses. Wood et al (1995) found that 73% of ninety asymptomatic individuals had positive anatomical findings at one or more levels of the thoracic spine on magnetic resonance imaging. These findings included herniation, bulging, annular tears, deformation of the spinal cord and Scheuermann end-plate irregularities. While structural changes are common, their clinical consequences are unknown. It is hypothesized (Lee 1993, 1994a,b) that some changes must take place in the intervertebral disc for the thoracic segment to become unstable in rotation. These changes may occur prior to the onset of symptoms and predispose the patient to the development of instability.

Biomechanics of rotation In the cadaver, Panjabi et al (1976) found that rotation around a vertical axis was coupled with contralateral sideflexion and contralateral horizontal translation. Clinically, it appears that in the midthorax, midrange rotation can couple with either contralateral or ipsilateral sideflexion. At the limit of rotation, however, the direction of sideflexion has consistently been found to be ipsilateral. In other words, at the limit of axial rotation, rotation and sideflexion occur to the same side. It may be that the thorax must be intact and stable both anteriorly and posteriorly for this in vivo coupling of motion to occur. The anterior elements of the thorax were removed 3 cm lateral to the costotransverse joints in the study by Panjabi et al (1976).During right rotation of the trunk, the following biomechanics are proposed (Lee 1993, 1994a,b). The superior vertebra rotates to the right and translates to the left . Right rotation of the superior vertebral body 'pulls' the superior aspect of the head of the left rib forward at the costovertebral joint inducing anterior rotation of the neck of the left rib (superior glide at the left costotransverse joint), and 'pushes' the superior aspect of the head of the right rib backward, inducing posterior rotation of the neck of the right rib (inferior glide at the right costotransverse joint). The left lateral translation of the superior vertebral body 'pushes' the left rib posterolaterally along the line of the neck of the rib and causes a posterolateral translation of the rib at the left costotransverse joint. Simultaneously, the left lateral translation 'pulls' the right rib anteromedially along the line of the neck of the rib and causes an anteromedial translation of the rib at the right costotransverse joint. An anteromedial/posterolateral slide of the ribs relative to the transverse processes to which they attach is thought to occur during axial rotation.

When the limit of this horizontal translation is reached, both the costovertebral and the costotransverse ligaments are tensed. Stability of the ribs both anteriorly and posteriorly is required for the following motion to occur. Further right rotation of the superior vertebra occurs as the superior vertebral body tilts to the right (glides superiorly along the left superior costovertebral joint and inferiorly along the right superior costovertebral joint). This tilt causes right sideflexion of the superior vertebra at the limit of right rotation of the midthoracic segment . **Definition of instability**Instability can be defined as a loss of the functional integrity of a system which provides stability. In the thorax, there are two systems which contribute to stability - the osteoarticularligamentous and the myofascial. Snijders & Vleeming (Snijders et al 1992, Vleeming et al 1990a,b, 1995) refer to these two systems as form and force closure. Together they provide a self-locking mechanism which is useful in rehabilitation.   Form closure refers to a stable situation with closely fitting joint surfaces, where no extra forces are needed to maintain the state of the system.   (Snijders et al 1992, Vleeming et al 1995). The degree of inherent form closure of any joint depends on its anatomy. There are three factors which contribute to form closure; the shape of the joint surface, the friction coefficient of the articular cartilage and the integrity of the ligaments which approximate the joint. The costal components of the midthorax have considerable form closure given the shape of the costovertebral joints and the structure of the ligaments.   In the case of force closure, extra forces are needed to keep the object

in place. Here friction must be present.   (Snijders et al 1992). Joints with predominantly flat surfaces are well suited to transfer large moments of force but are vulnerable to shear. Factors which increase intraarticular compression will increase the friction coefficient and the ability of the joint to resist translation. The relatively flat zygapophyseal joints provide little resistance to lateral translation and rely on the form closure of the costal components and the myofascial force closure for stability. The muscles which contribute to force closure of the midthoracic region include the transversospinalus and erector spinae groups. These muscles will be addressed in rehabilitation of the unstable thorax.Panjabi has proposed a conceptual model which describes the interaction between the components of the spinal stabilising system (Panjabi 1992a,b). In this model, he describes the neutral zone which is a small range of displacement near the joint s neutral position where minimal resistance is given by the osteoligamentous structures. The neutral zone can be palpated during specific tests for stability. The range of the neutral zone may increase with injury, articular degeneration (loss of form closure) and/or weakness of the stabilising musculature (loss of force closure). When the thorax is unstable, the neutral zone is increased. Rotational instability of the thorax causes an increase in the neutral zone which is palpated during segmental lateral translation. The unstable segment has a softer end feel of motion, an increased quantity of translation and a variable symptom response. If the joint is irritable, the test may provoke pain. If the instability is long standing and asymptomatic, the tests are often not provocative. [newpage]

Clinical tests for lateral translation stability (rotation) To evaluate the stability of a midthoracic segment, it is necessary to first determine the available mobility in lateral translation. Left rotation/left sideflexion/right translation requires the left sixth rib to glide anteromedially relative to the left transverse process of T6 and the right sixth rib to glide posterolaterally relative to the right transverse process of T6 and the T5 vertebra to laterally translate to the right relative to T6. This motion is tested in the following manner. The patient is sitting with the arms crossed to opposite shoulders. 5). With the right hand/arm, the thorax is palpated such that the fifth finger of the right hand lies along the sixth rib. With the left hand, the transverse processes of T6 are fixed. With the right hand/arm the T5 vertebra and the sixth ribs are translated purely to the right in the transverse plane. The quantity, and in particular the end feel of motion, is noted and compared to the levels above and below. Next, the stability of the T5-6 spinal component can be evaluated by restricting the sixth ribs from gliding relative to their transverse processes and then applying a lateral translation force. No motion should occur when the ribs are fixed. This test stresses the anatomical structures which resist horizontal translation between two adjacent vertebrae when the ribs between them are fixed. A positive response is an increase in the quantity of motion and a decrease in the resistance at the end of the range. To test the T5-6 segment, the patient is sitting with the arms crossed to opposite shoulders. With the right hand/arm, the thorax is palpated such that the fifth finger of the right hand lies along the fifth rib. With the left hand, T6 and the sixth ribs are fixed bilaterally by compressing the ribs centrally towards their costovertebral joints. The T5 vertebra is translated through the thorax purely in the transverse plane. The quantity of motion, the reproduction of any symptoms and the end feel of motion is noted and compared to the levels above and below. When the segment is stable, no motion should occur. When unstable, the same degree of motion previously noted in the mobility test can be palpated.**Subjective and objective findings**Rotational instability of the midthorax can occur when excessive rotation is applied to the unrestrained thorax or when rotation of the thorax is forced against a fixed rib cage (seat belt injury). At the limit of right rotation in the midthorax, the superior vertebra has translated to the left, the left rib has translated posterolaterally and the right rib has translated anteromedially such that a functional U joint is produced. Further right rotation results in a right lateral tilt of the superior vertebra. Fixation of the superior vertebra occurs when the left lateral translation exceeds the physiological motion barrier and the vertebra is unable to return to its neutral position. Initially, the patient complains of localized, central midthoracic pain which can radiate around the chest wall. The pain may be associated with numbness along the related dermatome. Sympathetic symptoms including sensations of local coldness, sweating, burning and visceral referral are common. If the unstable complex is fixated at the limit of rotation, very little relieves the pain. All movements, especially contralateral rotation, and sustained postures tend to aggravate the pain. If the complex is not fixated, the patient often finds that contralateral rotation and extension affords some relief. Positionally, the following findings are noted when T5-6 is fixated in left lateral translation and right rotation (right rotational instability). T5&#64979;T6 is right rotated in hyperflexion, neutral and extension, the right sixth rib is anteromedial posteriorly and the left sixth rib is posterolateral posteriorly. All active movements produce a 'kink' at the level of the fixation, the worst movement is often rotation . The passive accessory mobility tests for the zygapophyseal and costotransverse joints are reduced but present. The right lateral translation mobility test is completely blocked.Prior to reduction of the fixation, the left lateral translation stability test of T5-6 is normal because the joint is stuck at the limit of left lateral translation. After the fixation is reduced, the stability test reveals the underlying excessive left lateral translation. The reduction restores the complex to a neutral position from which the amplitude of left lateral translation can be more effectively measured.If the segment is not fixated at the limit of lateral translation, then both the mobility and stability tests will reveal excessive left lateral translation. When the sixth ribs are compressed medially into the vertebral body of T5, there should be no lateral translation of T5 relative to T6. When the segment is unstable, excessive motion during this test is noted. Segmental atrophy of multifidus can be palpated bilaterally. In the lumbar spine, Hides et al (1994) found wasting and local inhibition at a segmental level of the lumbar multifidus muscle in all patients with a first episode of acute/subacute low back pain. In a follow-up study (Hides et al 1995), they found that without therapeutic intervention, multifidus did not regain its original size or function and the recurrence rate of low back pain over an eight month period was very high. They also found that the deficit could be reversed with an appropriate exercise program. This research is consistent with clinical observation of instability in the midthorax.**Treatment**If the segment is fixated at the limit of lateral translation/rotation, a manipulative reduction is necessary prior to the initiation of a stabilization program. When T5-6 is fixated in left lateral translation/right rotation the following technique is used.The patient is in left sidelying, the head supported on a pillow and the arms crossed to the opposite shoulders. With the left hand, the right seventh rib is palpated posteriorly with the thumb and the left seventh rib is palpated posteriorly with the index or long finger. T6 is fixed by compressing the two seventh ribs towards the midline. Care must be taken to avoid fixation of the sixth ribs which must be free to glide relative to the transverse processes of T6. The other hand/arm lies across the patient's crossed arms to control the thorax. Segmental localization is achieved by flexing and extending the joint until a neutral position of the zygapophyseal joints is achieved. This localization is maintained as the patient is rolled supine only until contact is made between the table and the dorsal hand. From this position, T5 and the left and right sixth ribs are translated laterally to the right through the thorax to the motion barrier. Strong longitudinal distraction is applied through the thorax prior to the application of a high velocity, low amplitude thrust. The thrust is in a lateral direction in the transverse plane . The goal of the technique is to laterally translate T5 and the left and right sixth ribs relative to T6. Following reduction of the fixation, the thorax is taped to remind the patient to avoid end range rotation. Stabilization is then required. If the segment is not fixated, stabilization is begun immediately. Physiotherapy cannot restore form closure therefore the emphasis of treatment must be on the restoration of force closure. The goal is to reduce the dynamic neutral zone during functional activities and to avoid the end ranges of rotation thus limiting the chances of fixation. This is accomplished through specific exercises augmented with muscle stimulation and EMG. The first group of muscles which must be addressed are the transversospinal (multifidus) and erector spinae groups. Essentially, the patient is taught to specifically recruit the segmental muscles isometrically and then concentrically while prone over a gym ball. Electrical stimulation can be a useful adjunct at this time. In sidelying, specific segmental rotation can be resisted by the therapist both concentrically and eccentrically to facilitate the return of multifidus function. The program is progressed by increasing the load the thorax must control. Initially, scapular motion is introduced, in particular lower trapezius work. The patient must control the neutral position of the midthorax throughout the scapular depression. The goal is to teach the patient to isolate scapular motion from spinal motion so that the scapula does not produce spinal motion during activities involving the arm. Once control is gained over the scapula, exercises involving the entire upper extremity may be added. By increasing the lever arm and then the load, the midthorax is further challenged. Gymnastic ball, proprioceptive, balance and resistive work can be integrated into the program as needed. The velocity of the exercises can be increased according the patient s work and recreation demands. Initially, the load should be applied bilaterally and then progressed to unilateral work. At the completion of the program, the patient should be able to isolate specific spinal extension without scapular motion and control both bilateral and unilateral arm motion throughout midrange. They are advised to avoid any activity which places the midthorax at the limit of rotation in the direction of their instability.**Conclusion**Instability of the thorax can be extremely debilitating but is a treatable condition. The segment remains statically unstable and the neutral zone, on passive testing, remains increased. Through appropriate training, the region can become dynamically stable and the neutral zone controlled. **References**

Crawford R J 1995 Normal and Degenerative Anatomy of Thoracic Intervertebral Discs. Proceedings of the 9th Biennial Conference of the Manipulative Physiotherapists Association of Australia. Gold Coast, Queensland, 24-29 Davis P R 1959 The Medial Inclination of the Human Thoracic Intervertebral Articular Facets. Journal of Anatomy 93: 68-74 Hides J A, Stokes M J, Saide M, Jull G A, Cooper D H 1994 Evidence of Lumbar Multifidus Muscle Wasting Ipsilateral to Symptoms in Patients with Acute/subacute Low Back Pain. Spine 19(2): 165-172 Hides J A, Richardson C A, Jull G A 1995 Multifidus Inhibition in Acute Low Back Pain: Recovery is Not Spontaneous. Proceedings of the 9th Biennial Conference of the Manipulative Physiotherapists Association of Australia. Gold Coast, Queensland, 57-60 Hodges P W, Richardson C A 1995a Neuromotor Dysfunction of the Trunk Musculature in Low Back Pain Patients. Proceedings of the World Confederation of Physical Therapists Congress, Washington Hodges P W, Richardson C A 1995b Dysfunction of Transversus Abdominis Associated with Chronic Low Back Pain. Proceedings of the 9th Biennial Conference of the Manipulative Physiotherapists Association of Australia. Gold Coast, Queensland, 61-62 Lee D G 1993 Biomechanics of the Thorax: a Clinical Model of In Vivo Function. Journal of Manual and Manipulative Therapy 1:1 13-21 Lee D G 1994a Biomechanics of the Thorax. In: Grant R (ed) Physical Therapy of the Cervical and Thoracic Spine, 2nd edn. Churchill Livingstone, New York ch 3 p 47-64 Lee D G 1994b Manual Therapy for the Thorax - a Biomechanical Approach. Delta Orthopaedic Physiotherapy Clinic 301 11950 80th Ave Delta BC V4C 1Y2 Lowcock J 1990 Thoracic Joint Stability and Clinical Stress Tests. Proceedings of the Canadian Orthopaedic Manipulative Physiotherapists, Orthopaedic Division of the Canadian Physiotherapy Association Newsletter November/December 1991 15-19 Panjabi M M, Brand R A, White A A 1976 Mechanical Properties of the Human Thoracic Spine. Journal of Bone Joint Surgery 58A: 642-652 Panjabi M M 1992a The Stabilizing System of the Spine. Part I. Function, Dysfunction, Adaptation, and Enhancement. Journal of Spinal Disorders 5(4): 383-389 Panjabi M M 1992b The Stabilizing System of the Spine. Part II. Neutral Zone and Instability Hypothesis. Journal of Spinal Disorders 5(4): 390-397 Penning L, Wilmink J T 1987 Rotation of the Cervical Spine - A CT Study in Normal Subjects. Spine 12 (8): 732-738 Richardson CA, Jull G A 1994 Concepts of Assessment and Rehabilitation for Active Lumbar Stability. In: Boyling J D, Palastanga N (eds) Grieve s Modern Manual Therapy, 2nd edn. Churchill Livingstone, Edinburgh, ch 51 p 705-720 Richardson C A, Jull G A 1995 Muscle Control - Pain Control. What Exercises Would You Prescribe? Manual Therapy 1(1): 2-10 Snijders C J, Vleeming A, Stoeckart R 1992 Transfer of Lumbosacral Load to Iliac Bones and Legs. Part 1: Biomechanics of Self-bracing of the Sacroiliac

Joints and its Significance for Treatment and Exercise. In: Vleeming A, Mooney V, Snijders C J, Dorman T (eds) First Interdisciplinary World Congress on Low Back Pain and its Relation to the Sacroiliac Joint. San Diego, CA, Nov. 5-6, 1992, 233-254

Vleeming A, Stoeckart R, Volkers A C W, Snijders C J, 1990a Relation Between Form and Function in the Sacroiliac Joint. Part 1: Clinical Anatomical Aspects. Spine 15(2): 130-132

Vleeming A, Volkers A C W, Snijders C J, Stoeckart R 1990b Relation Between Form and Function in the Sacroiliac Joint. Part 2: Biomechanical Aspects. Spine 15(2): 133-135

Vleeming A, Snijders C J Stoeckart, Mens J M A 1995 A New Light on Low Back Pain. In: Vleeming A, Mooney V, Dorman T, Snijders C J (eds) Second Interdisciplinary World Congress on Low Back Pain. San Diego, CA, Nov. 9-11, 149-168

Williams P, Warwick R, Dyson M, Bannister L H 1989 Grays Anatomy. 37th edn. Churchill Livingstone, Edinburgh

Wood K B, Garvey T A, Gundry C, Heithoff K B 1995 Magnetic Resonance Imaging of the Thoracic Spine. Journal of Bone and Joint Surgery 77A(11): 1631-1637

Posted by Mart de Kruijff, BSc. PT, MAS.O.M.T.