Robert A. Donatelli

The Anatomy and Pathophysiology of the CORE

LEARNING OBJECTIVES

After studying this lesson, the reader will be able to do the following:

1. Define the hip and trunk CORE
2. Evaluate the CORE muscles and structure
3. Delineate the difference between local and global muscles on the back
4. Identify the muscles of the abdominal area that are considered stabilizing
5. Identify the spinal muscles that stiffen the spine
6. Evaluate the CORE dysfunction
7. Instruct patients in exercises designed to strength hip and trunk muscles
8. Identify the correlation between muscle weakness in the hip and lower extremity injuries

INTRODUCTION AND DEFINITION

This lesson defines the CORE, identifies the anatomical structures within the CORE, and discusses the pathophysiology of muscle imbalances.

For the purposes of this lesson the CORE is defined as a clinical manifestation in which a delicate balance of movement and stability occurs simultaneously. The author of this lesson describes the upper quadrant CORE to include the gleno-humeral joint and the scapulothoracic joint and the lower quadrant CORE to include the hip and trunk. This lesson discusses the function and special considerations of the muscles of the CORE. In addition, muscle imbalances and dysfunction of the CORE are discussed.

Speed is allegedly an innate talent and cannot be changed with training. However, muscle imbalances, joint restrictions, and pain may prevent the athlete from achieving his or her maximum innate abilities. The job of the sports-specific rehabilitation specialist is to identify deficits within the CORE and design a rehabilitation program to promote an increase in strength, power, and endurance specific to the muscles and joints that are in a state of dysfunction. Specificity of the rehabilitation program can help the athlete overcome musculoskeletal system deficits and achieve maximum potentials of his or her talents. A combination of power, strength, and endurance is critical for the muscles of the CORE to allow the athlete to perform at his or her maximum capabilities.

The lower quadrant CORE is identified by the muscles, ligaments, and fascia that produce a synchronous motion and stability of the trunk, hip, and lower extremities. The initiation of movement in the lower limb is a result of activation of certain muscles that hold onto bone, referred to as *stabilizers,* and other muscles that move bone, referred to as *mobilizers.* The muscle action within the CORE depends on a balanced activity of the stabilizers and mobilizers. If the stabilizers do not hold onto the bone, the mobilizing muscles will function at a disadvantage. The lack of harmony between the stabilizers and the mobilizers can result in muscle imbalances and injury.

Thirty-five muscles attach directly to the sacrum or innominate, or both. This lesson is not intended to describe the detailed anatomy of each of these muscles but rather to highlight the muscle groups and their specific application to movement and stabilization. In addition, the lesson presents evidence of how the muscle groups within the trunk and hip CORE are important to the athletes' performance and prevention of injuries. The CORE trunk muscles include the abdominals, thoracolumbar, lumbar, and lateral thoracolumbar muscles. The CORE hip muscles include the hip flexors, extensors, adductors, abductors, and internal and external rotators.

CORE MUSCLES OF THE TRUNK AND HIP

The CORE muscles of the trunk include the thoracolumbar muscles (longissimus thoracic pars thoracis, and the iliocostalis lumborum pars thoracis), the lumbar muscles (lumbar multifidus, iliocostalis lumborum pars lumborum, longissimus thoracic pars lumborum, intertransversarii, interspinalis and rotatores), the lateral thoracolumbar muscle, the quadratus lumborum, and the abdominal muscles (the transverses abdominis, rectus abdominis, internal and external oblique abdominals). Although the thoracodorsal fascia is not a contractile tissue, it does enhance CORE trunk stability as a result of the contraction of several trunk muscles attached to it.

The CORE hip muscles include psoas, iliacus, gluteus maximus, gluteus medius (anterior and posterior fibers), rectus femoris, and the hamstring muscle group. The external and internal rotators of the hip include a large group of muscles. These muscles are important to the hip and trunk for movement and stability. Lack of strength and power of the muscles noted as follows can contribute to injury of the lower extremity or reduced performance, or both.

External Rotators

The external rotators are the piriformis, superior/inferior gemellus, obturator internus and externus, quadratus femoris, gluteus maximus two thirds attached to tensor fasciae latae, iliopsoas, sartorius, and biceps femoris.

Internal Rotators

The internal rotators are the medial hamstrings, anterior portion of the gluteus medius, tensor fascia, iliotibial band, gluteus minimus, pectineus, and gracilis.

FUNCTIONAL ANATOMY OF THE MUSCLES OF THE TRUNK AND HIP

This section discusses the specific function of individual muscle groups within the CORE and their importance to performance in the athlete. Muscle is the body's best force attenuator. Eccentric control of rapid movement is critical for performance enhancement and prevention of injury. In addition, muscles create forces that play a role in the production of movement and in stabilizing of joints for safety and performance.

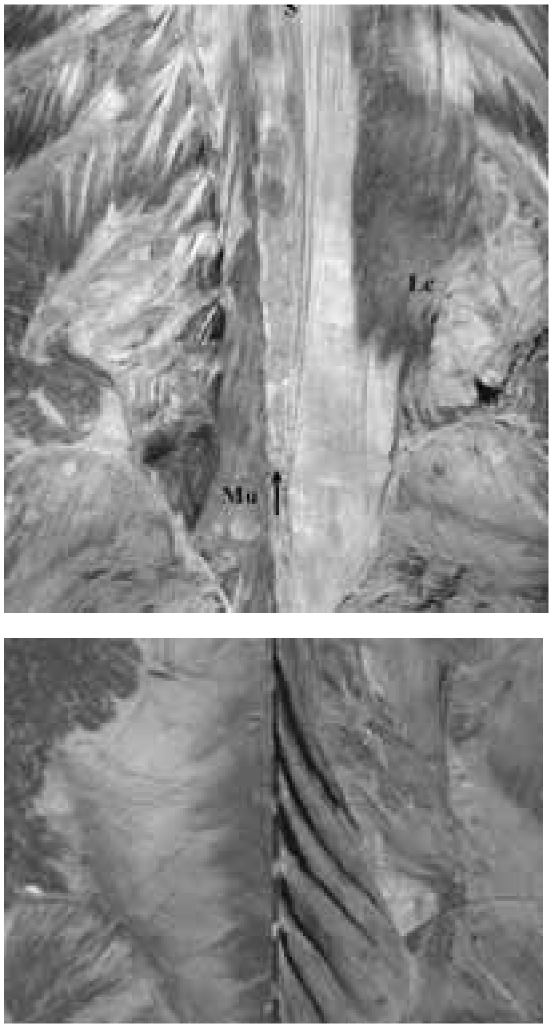
The physiological cross-sectional area (PCSA) of muscle determines the force-producing potential, while the line of pull and moment arm determine the effect of the force on movement and stabilization.[1] The small muscle of the thoracic and lumbar spine includes the intertransversarii, interspinales, and rotatores. These muscles have small cross-sectional areas and work through a small moment arm.[1] Their total contribution to rotational axial twisting and bending torque is minimal. Bogduk[2] and McGill[1] hypothesized that these small muscles may not predominate as mechanical stabilizers but instead have a proprioceptive role. The rotatores and intertransversarii muscles are highly rich in muscle spindles, 4.5 to 7.3 times more than the multifidus.[3] Muscle spindles are the proprioceptors of muscle. These receptors are stimulated by stretch.

The major extensors of the thoracolumbar spine are the longissimus, iliocostalis, and multifidus groups. According to Bogduk[4] and McGill and Norman,[5] the longissimus and iliocostalis are divided into lumbar and thoracic portions, longissimus thoracis pars lumborum and pars thoracic, and iliocostalis lumborum pars lumborum and pars thoracis (Figure 9-1, *A*). The pars thoracis component of these two muscles attaches to the ribs and vertebral components and has

Evidence-Based Clinical Application

The intertransversarii, interspinales, and rotatores are considered length transducers and therefore sense the positioning of each spinal motion. These structures are likely affected during active and passive end-range rotational movements, such as a baseball swing, a golf swing, passive stretch, or an end-range lumbar rotational mobilization technique.

A



B

Figure 1 A, Longissimus and Iliocostalis muscles. **B,** Multifidus muscle. (**A** From Willard FH: The muscular, ligamentous and neural structure of the low back and its relation to back pain. In Vleeming A, Mooney V, Dorman T, et al, editors: *Movement, stability and low back pain*, Edinburgh, 1997, Churchill Livingstone. **B** From Lee D: *The pelvic girdle: an approach to the examination and treatment of the lumbopelvic-hip region*, ed 3, Edinburgh, 2004, Churchill Livingstone. Courtesy Gracovetsky personal library.)

relatively short contractile fibers with long tendons that run parallel to the spine attaching to the sacrum and iliac crest. These muscles have the greatest extensor moment with a minimum of compression to the spine.[1] The lumbar components of these muscle groups have a line of pull that is not parallel to the spine but rather have a posterior and caudal direction that causes them to generate posterior shear and an extensor moment to the spine.[1] The multifidus muscles have a low density of muscle spindles and are involved in producing extensor torque with small amounts of twisting and side-bending torque.[1] The lumbar multifidus muscles span two to three spinal segments. Therefore their forces affect only local areas of the spine. The multifidus is a good example of a muscle that stiffens the spine, acting as a stabilizer (Figure 1, *B*) (Table 1).

Evidence-Based Clinical Application

Biering-Sorensen[6] showed that in young, healthy subjects the back extensors demonstrate the greatest endurance of all three muscles groups within the trunk CORE. In addition, decreased torso extensor endurance predicts those who are at greatest risk of developing back problems. Increased endurance of the back extensors is critical for the athlete for stability, prevention of injury, and improved performance.

The abdominals are an important part of the trunk CORE muscles. The three layers of the abdominal wall muscles (external oblique, internal oblique, and transverse abdominis) perform several functions. All three are involved in flexion because of their attachment to the linea semilunaris, which changes the line of pull of the oblique muscle forces to the rectus sheath, increasing the flexor moment arm (Figure 2).[7] The oblique abdominal muscles are mobilizers, involved with torso rotational forces and lateral bending.[7] Because the oblique abdominal muscles' role is to produce trunk rotational forces, they have been identified as an important CORE muscle in the baseball and golf swing. The rectus abdominis appears to be the strongest trunk flexor and is the most active during sit-ups and curl-ups.[8] The rectus is divided by fascial tissue. This has been referred to as the "beaded" effect (see Figure 2). Porterfield and DeRosa[9] have determined that the beaded rectus performs an additional role of lateral transmission of forces from the oblique muscles forming a continuous hoop around the abdomen, thus increasing stability to the spine.

The transverse abdominis has been the focus of many researchers. The muscle has been identified as an important stabilizer of the trunk because of its attachment into the anterior abdominal fascia and the posterior attachment to the lumbodorsal fascia (Figure 3). The resulting corset-like containment, described earlier, provides stiffness that assists with spinal stability. Richardson et al.[10] have demonstrated early activation of the transverse abdominis before arm and leg movements, thus signifying that the trunk must be stable before movement. In addition, a cocontraction of the transverse abdominis and the paraspinal muscles is assisted when the trunk is perturbed and a mass is added to the upper limb.[11]

Evidence-Based Clinical Application

Training the athlete to cocontract the transverse abdominis and the paraspinal muscles can be achieved while standing on an unstable surface and catching a medicine ball off a rebounder. This activity provides perturbing forces to the trunk while adding a mass to the upper limb.

The last muscle of the trunk CORE is the all-important quadratus lumborum (QL). The QL acts as a strong stabilizer by its attachment to each lumbar vertebra and the pelvis and rib cage. The functional aspects of the QL are unique. Specifically, the fibers of the QL have a large lateral moment arm via the attachments to the transverse processes, and thus the QL could support lateral shear instability, which may result from excessive compressive forces to the spine.[1]

McGill[12] determined that the QL hardly changes length during any spine motion, suggesting that when it contracts it is practically always isometric. The QL seems to be active during several different movement patterns, such as flexion-dominant, extensor dominant, and lateral bending tasks. The QL is an important stabilizing muscle for the lumbar spine in a wide variety of movements.[1]

Evidence-Based Clinical Application

The quadratus lumborum (QL) is an important stabilizer to the lumbar spine in many movement patterns important to improving the athlete's performance and prevention of injuries to the low back. Exercises designed to enhance the strength and endurance of the QL play an important role in the CORE program for the athlete. Isometric exercises would simulate the function of the muscle.

GLOBAL AND LOCAL MUSCLE SYSTEMS

As noted previously, the muscles described earlier can be classified as stabilizers or mobilizers. Richardson et al[10] has the best definition and description of trunk or lumbopelvic stability. The author of this lesson is in agreement that a stabilizing muscle acts as a dynamic process of controlling static position when appropriate to the functional movements. The dynamic process of stability allows the trunk to move with control in dynamic activities exemplified by athletes. Movement of the spine from flexion to extension should be a controlled sequence of intervertebral rotation and translation movements.[2] Bergmark[13] described the local stabilizing system as a group of muscles that have their origin or insertion on the lumbar

Table 1 CORE Muscle Tables

Trunk CORE Structures by Group	Stabilizing Action	Mobilizing Action
Thoracolumbar Muscles		
Longissimus thoracis		X
Iliocostalis lumborum		X
Lumbar Muscles		
Lumbar multifidus*	X	
Iliocostalis lumborum	X	
Longissiums thoracic	X	
Intertransversarii	Proprioception	
Interspinales	Proprioception	
Rotatores	Proprioception	
Lateral Thoracolumbar Muscle		
Quadratus lumborum	X	
Abdominal muscles		
Transversus abdominis*	X	
Rectus abdominis		X
Internal obliques (posterior fibers)	Posterior fibers	X
External obliques	X	X
Thoracolumbar fascia	Stabilizes via muscle attachment	
Myofascial Slings (transfer load UE ↔ LE)	**Muscles and Fascia**	
Posterior oblique sling	Lat dorsi	
	Glut max	
	Thoracodorsal fascia	
Anterior oblique sling	External oblique	
	Anterior abdominal fascia	
	Contralateral internal oblique	
	Hip adductors	
Longitudinal sling	Peronii	
	Biceps femoris	
	Sacrotuberous ligament	
	Deep lamina of thoracodorsal fascia	
	Erector spinae	
Lateral sling	Gluteus med/min	
	Tensor fascia latea	
	Lateral stabilizers of thoracopelvis region	

Hip CORE Structure by Group	Stabilizing Action	Mobilizing Action
Psoas (posterior fibers)	Posterior fibers	X
Iliacus		X
Gluteus maximus		X
Gluteus medius *posterior fibers and anterior fibers*	X	
Rectus femoris		X
Hamstrings		X
External hip rotators Piriformis, gemeli, obturator interior/exterior, quadratus femoris, gluteus maximus *(aspect attached to TFL),* iliacus, sartorius, biceps femoris	Piriformis, gemeli, oburator interior/exterior	X
Internal hip rotatores Med hamstrings, gluteus medius (*anterior fibers),*TFL, ITB, gluteus minimus, pectineus, gracilis	TFL ITB Gluteus medius (anterior fibers)	X

Table 1 CORE Muscle Tables—cont'd

Upper Quadrant CORE by Group	Stabilizing Action	Mobilizing Action
Scapulohumeral		
Supraspinatus	X	
Infraspinatus	X	
Teres major		X
Teres minor	X	
Subscapularis	X	
Long head of biceps	X	
Deltoids		X
Thoracohumeral		
Pectoralis major		X
Latissimus dorsi	X	X
Scapulothoracic		
Upper trap		X
Middle trap		X
Lower trap		X
Rhomboids	X	
Levator scap	X	
Serratus anterior		X
Pectoralis minor	X	

ITB, Iliotibia band; *TFL,* tensor fascia latea.
*Lumbar multifidus and transversus abdominis are local trunk stabilizers.

Figure 2 Linea semilunaris, which changes the line of pull of the oblique muscle forces to the rectus sheath, increasing the flexor moment arm. (From DeRosa C: Functional anatomy of the lumbar spine and sacroiliac joint. In Proceedings from the 4th Montreal Proceedings of the Interdisciplinary World Congress on Low Back and Pelvic Pain, Montreal, 2001.)

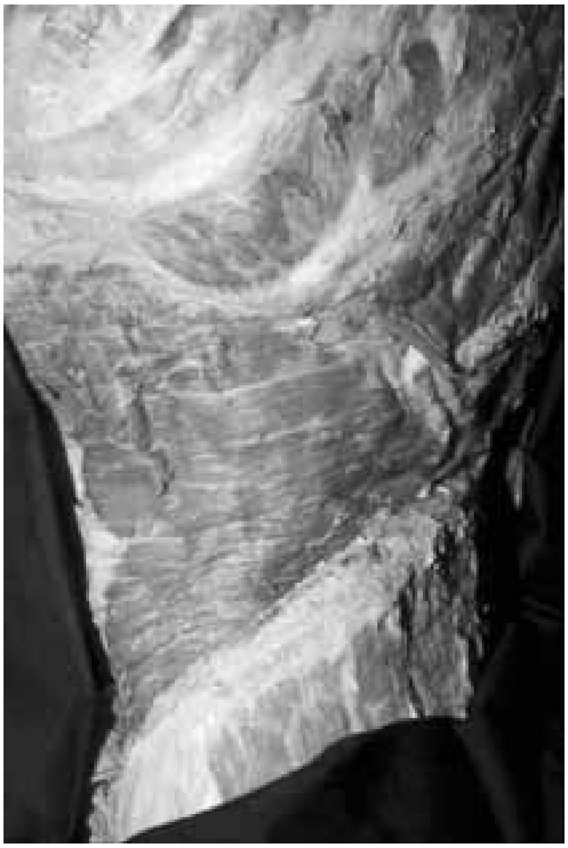


Figure 3 Transverse abdominis. (From DeRosa C: Functional anatomy of the lumbar spine and sacroiliac joint. In Proceedings from the 4th Montreal Proceedings of the Interdisciplinary World Congress on Low Back and Pelvic Pain, Montreal, 2001.)

vertebrae. These muscles are capable of controlling the stiffness of the spinal segments and postures of the lumbar spine. The lumbar multifidus with the segmental attachments is a prime example of a local muscle responsible for stiffening the lumbar segments. The posterior fibers of the obliquus internus abdo-minis and the transverse abdominis, which attach to the thoracolumbar fascia, form part of the local system. The medial fibers of the quadratus lumborum, iliocostalis lumborum pars lumborum, and the longissimus thoracis pars lumborum are also included in the local system (see Table 1).

The global muscle system includes the large, superficial muscles of the trunk that do not have direct attachment to the vertebrae. These muscles are the torque generators for spinal motion and act like guy ropes to control spinal orientation, balance the external loads to the trunk, and transfer load from the thorax to the pelvis.[10,13] The global muscles include the obliquus internus and externus abdominis, rectus abdominis, lateral fibers of the quadratus lumborum, longissimus thoracic pars thoracis, and iliocostalis lumborum pars thoracis (see Table 1).[13]

THE HIP CORE MUSCLES

Hip CORE muscle strengthening is an important part of the athlete's CORE program of exercises. The gluteus maximus and medius have always been considered strong stabilizers to the lumbar spine and pelvis. The gluteus maximus has a strong attachment to the thoracolumbar fascia proximally, and 80% of the gluteus maximus attaches into the iliotibial band distally. The gluteus maximus acts as a mobilizer. The gluteus maximus is an extensor and lateral rotator of the hip. In addition, the upper one half of the muscle abducts the hip, and the lower one half adducts the hip.[14] Decreased strength of the gluteus maximus in addition to decreased performance of the other posterior muscles of the hip, such as the gluteus medius posterior fibers, gluteus minimus, and the external rotators, compromise the control of the femur in the acetabulum. The anterior fibers of the gluteus medius abduct, medially rotate, and assist in flexion of the hip. In the clinical experience of the author of this lesson the anterior fibers of the gluteus medius are often found to be stronger than the posterior fibers of the gluteus medius in patients with lower extremity dysfunction. When testing the posterior fibers of the gluteus medius, the examiner must hold the leg in abduction and extension.

The piriformis muscle is a two-joint muscle extending over the sacral iliac joint and the hip joint. The piriformis extends, abducts, and externally rotates the hip. The obturator, internus and externus, and superior and inferior gemelli muscles are all lateral rotators. In the clinical experience of the author of this lesson, these lateral rotators frequently become weak. Nadler et al[15] indicated that alterations in side-to-side muscle strength might occur secondary to altered weight bearing, anthropometrics, lateral dominance, or gender. In this study athletes with previous lower extremity injury or low back pain were found to have differences in hip strength of the hip extensors and abductors, as compared with athletes without injury. Leetun et al[16] demonstrated that athletes who did not sustain an injury were significantly stronger in hip abduction and external rotation. Furthermore, analysis revealed that hip abduction and external rotator strength was the only useful predictor of injury status. A recent study by Tsai et al[17] demonstrated that the hip muscles play an important role in balancing the forces transferred between the lower body and upper extremities during the golf swing. Stronger hip muscles may provide better trunk stability. This study measured isometric hip abductor and adductor strength in golfers. A significantly stronger left hip abductor was found in the better golfers.

The semimembranosus and semitendinosus rotate the hip medially and flex and rotate the knee medially. The gracilis and pectineus muscles adduct the hip and internally rotate and flex the knee. The biceps femoris rotates the hip laterally and flexes and rotates the knee laterally. In the clinical experience of the author of this lesson, hamstring strains result from weakness of the CORE hip abductors, extensors, and rotators and CORE trunk muscles.

The psoas muscle function has been determined to be a primary hip flexor, along with the secondary hip flexor, the rectus femoris. The myoelectric evidence suggests that the psoas muscle activation is minimally linked to the spine demands.[8] The psoas counteracts the hip flexor torque created by the iliacus muscle. If the iliacus functioned alone, an anterior pelvic tilt force would force the spine into extension. The psoas provides stiffness between the spine and the pelvis and can be thought of as a stabilizer to the spine in the presence of a significant hip flexor torque.[1] The iliacus and psoas muscles produce compressive and anterior shearing forces to the spine.[13] Bogduk[18] points out that the psoas muscle is divided into anterior and posterior fibers. The posterior fibers arriving from the transverse processes of the lumbar vertebrae provide a compressive force to the spine, which is stabilizing. The anterior fibers make a larger contribution to hip flexion.

Evidence-Based Clinical Application

The iliopsoas participates strongly during sit-up exercises performed with the hips and knees flexed or extended.

The psoas muscle is activated during push-up exercises.

Maximum activity of the psoas occurs with resistance to hip flexion.[8]

FUNCTION OF THE TRUNK AND HIP MUSCLES

In the athlete the hip and trunk provide the stability and mobility needed to perform their sport. The greater the synchronization between the exact timing of the trunk muscles to stabilize movement and the hip muscles to create movement, the better the athlete performs with reduced risks of injury.

Trunk muscles transfer the forces to the hip and lower extremity. The trunk muscles are by design better stabilizers. Stiffness or stability of the lumbopelvic region is important for load transfer. The muscles of the trunk, pelvis, and lower limb, through a synchronized effort, provide a safe load transfer. The transfer of load protects the joints from the excessive forces of weight bearing, such as compressive and torsion forces. They provide a stabile spine and pelvis for the hip and lower leg to move against.

Performance in an athlete depends heavily on rotational movements of the trunk and hips. The initiation of powerful rotational movement, such as a baseball swing, golf swing, and tennis serve, occurs within the trunk and hips. Shaffer et al[19] demonstrated peak activity of the vastus medialis, hamstrings, gluteal muscles, erector spinae, and abdominal obliquus during a baseball swing. Watkins et al[20] indicated that the transfer of torque in an overhead-throwing athlete was achieved by the activation of the gluteus maximus, lumbar spine paraspinalis, and abdominal oblique muscles.

Watkins et al[20] emphasized the importance of hip and trunk muscles, the gluteus medius, the gluteus maximus, and lumbar spine erectors in stabilizing and controlling the loading response for maximum power and accuracy in golf swing. Tasi et al[17] demonstrated that significantly stronger left hip abduction strength was correlated with the more elite golfers and that hip strength in general was correlated to improved performance. Shaffer et al[1] established peak activity of the vastus medialis, hamstrings, gluteal muscles, erector spinae, and abdominal obliquus during a baseball swing. Watkins et al[21] confirmed the dynamic transfer of torque from the trunk to the lower extremity in professional baseball pitchers.

Several studies have demonstrated the capacity of the lumbar spine muscles to increase the spinal segmental stiffness.[22-25] Kaigle et al[22] demonstrated that combined activation of the muscles surrounding the spine including the multifidus, lumbar portions of the erector spinae, quadratus lumborum, and psoas stabilized the segmental movement in an injured segment. Goel et al[23] studied the effects of the action of the interspinalis, intertransversarii, the lumbar multifidus, and the quadratus lumborum. Activation of these muscles imparted stability to the ligamentous system, and the load bearing of the zygapophyseal joints increased. Panjabi et al[24] concluded that the intersegmental nature of the deep multifidus gave a significant advantage to the stability of the lumbar segment. Wilke et al[25] indicated that the multifidus was responsible for restricting the lumbar spinal range of motion in all directions except rotation.

In summary, the trunk and hip CORE muscles work together to attain a stable base around which movement occurs. A combined effect of the abdominals, back extensor muscles, and the lateral quadratus lumborum muscles provide the stability within the trunk to allow the hip muscles to develop explosive power. Isometric, concentric, and eccentric muscle contractions of the CORE muscles provide the movement and stability, through cocontraction of the agonist and antagonist muscles.

THE CONNECTION BETWEEN THE TRUNK AND HIP CORE TO THE UPPER QUADRANT CORE

For the purposes of this lesson, the muscles of the upper quadrant CORE include the rotators of the glenohumeral joint and scapula. On the basis of the author's clinical experience, the importance of rotation range of motion of the glenohumeral joint and the strength of the scapula and glenohumeral rotator muscles in the overhead-throwing athlete are critical in preventing injuries and improving performance. Monte et al[26] strengthened only the glenohumeral rotators in skilled tennis players and were able to demonstrate a significant increase in the velocity of the tennis serve. Wooden et al[27] demonstrated in teenage baseball pitchers a significant increase in ball velocity after strengthening the glenohumeral rotators.

Although more emphasis has been placed on the lower CORE for prevention and improvement in the ability to swing a golf club or a baseball bat, several studies have demonstrated an important role of the upper quadrant CORE.[28-30] Jobe et al[28] studied the muscle activity, in professional golfers, of the rotator cuff, deltoid, pectoralis major, and the latissimus dorsi muscles during a golf swing. The study used electromyo-graphic analysis and high-speed photography to determine the muscle activity during the phases of the golf swing. The study demonstrated that the subscapularis muscle was the most active of all the rotator cuff muscles throughout the swing. The supraspinatus, infraspinatus, and all portions of the deltoid muscle had low levels of activity throughout the swing. The most active mobilizers of the upper limbs during the golf swing were the pectoralis major and latissimus dorsi (Figure 4). The previously mentioned muscle groups seemed to provide power bilaterally to the golf swing. In another study, using electromyographic analysis of the shoulder muscles during a golf swing demonstrated similar results.[29] The infra-spinatus and supraspinatus muscles were active predominantly at the extremes of shoulder range of motion, and the deltoid muscles were again relatively noncontributory. Once again, the subscapularis, pectoralis major, and latissimus dorsi muscles were the propulsive muscles of the swing and maintained activity during acceleration and the forward swing. Finally, Kato et al[30] described the role of the scapular muscles in the golf swing. The study determined that the golf swing and uncoiling action require that the scapular muscles work in synchrony to maximize swing arc and club head speed. The anterior serratus muscle activity was the most active through all phases of the swing, which could indicate that fatigue could be an etiology of shoulder problems in high-demand golfers. Kato et al's study also indicated the stabilizing effect of the rhomboid and levator scapulae muscles during the majority of the swing.

Vleeming et al[31] and Snijders et al[32] described a connection of muscle systems that stabilize the pelvis between the thorax and legs. Four slings of muscle systems exist: (1) The posterior oblique sling contains the connection between the latissimus dorsi and the gluteus maximus through the thoracodorsal

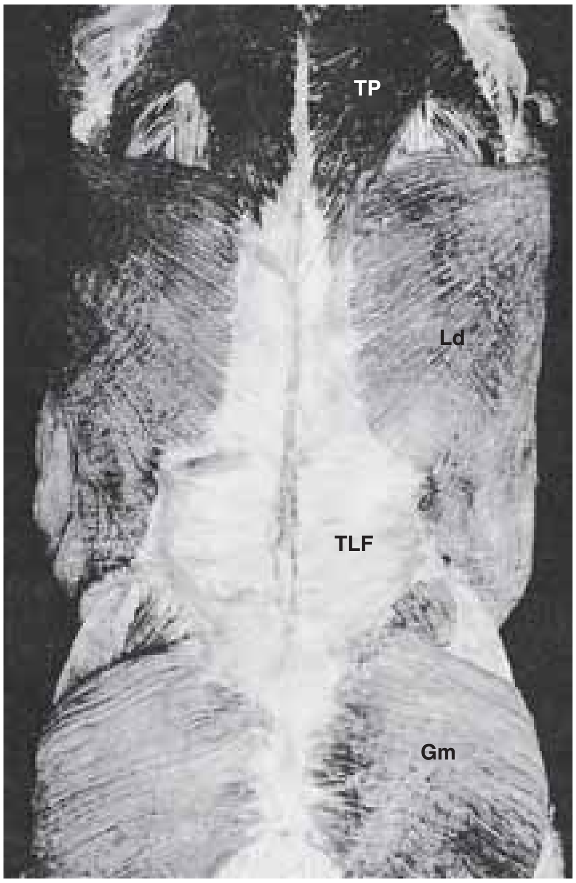


Figure 4 The latissimus dorsi is an important muscle to the posterior oblique sling, connecting the upper quadrant CORE to the lower quadrant CORE by its connection to the thoracolumbar fascia. (From Willard FH: The muscular, ligamentous and neural structure of the low back and its relation to back pain. In Vleeming A, Mooney V, Dorman T, et al, editors: *Movement, stability and low back pain*, Edinburgh, 1997, Churchill Livingstone.)

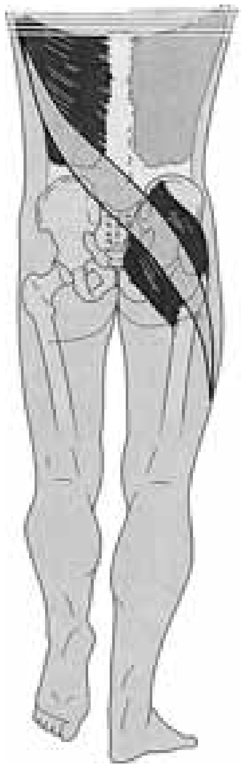


Figure 5 Posterior oblique sling contains the connection between the latissimus dorsi and the gluteus maximus through the thoracodorsal fascia. (Redrawn from Vleeming A, Pool-Goudzwaard AL, Stoeckart R, et al: The posterior layer of the thoracolumbar fascia: its function in load transfer from spine to legs, *Spine* 20:753, 1995.)

fascia (Figure 5); (2) the anterior oblique sling contains connections among the external oblique, the anterior abdominal fascia, and the contralateral internal oblique abdominals and the adductors of the thigh; (3) the longitudinal sling connects the peronei, the biceps femoris, the sacrotuberous ligament, the deep lamina of the thoracodorsal fascia, and the erector spinae; and (4) the lateral sling contains the gluteus medius/minimus and tensor fascia latea and the lateral stabilizers for the thoracopelvis region. These integrated muscle systems produce slings of forces that assist in transfer of load.

As previously noted, the posterior sling is the connection between the upper quadrant CORE and the lower quadrant CORE. Transfer of torque from the upper quadrant to the lower quadrant is important to the athlete. As noted earlier, the serratus and trapezius muscle groups are largely responsible for dynamic stability of the scapula as it moves through the shoulder range of motion. One could argue that the function and strength of the latissimus depends on the position of the humeral head on the glenoid. After evaluating numerous athletes, a clinical observation of this author demonstrates that scapula asymmetry alters the central position of the humerus on the glenoid and leads to muscle weakness of the glenohumeral rotators. Because the latissimus muscle is an internal rotator and depressor of the humeral head, posture of the scapula may be important to the mechanical advantage of the latissimus muscle in order to perform mobility and stabilizing roles within the shoulder and the trunk.

CORE DYSFUNCTION

The lower kinetic chain is a linkage system, which includes a series of joints, such as the ankle, knees, hips, and trunk, making possible the transmission of forces into the trunk and hips during running, jumping, kicking, and throwing. Dysfunction of any one of the joints within the lower kinetic chain linkage system may result in dysfunction elsewhere within the chain. Kinetic chain injuries may result from muscle imbalances, joint restrictions, and inadequate rehabilitation of previous injuries. Beckman and Buchanan[33] noted a significant delay in latency of the gluteus medius muscle in patients with chronic ankle instability as compared with normal controls. Devita et al[34] demonstrated alteration in firing of the proximal hip musculature in patients with anterior cruciate insufficiency. Jaramillo et al[35] found significant strength deficits of the ipsilateral gluteus medius in patients who had knee surgery. Yamamoto demonstrated an increased injury rate in individuals with weaker hamstrings and a decreased hamstring-to-quadriceps ratio.[36]

Nadler et al[37] demonstrated that only in female athletes the left hip abductors were weaker. This study indicated that female athletes had a more significant probability of requiring treatment for low back pain, secondary to the hip abductor weakness. The hip musculature plays a significant role in transferring forces from the lower extremity to the spine during upright activities and theoretically may influence the development of low back pain. Poor endurance and delayed firing of the hip extensors (gluteus maximus) and abductors (gluteus medius) have been noted in individuals with lower extremity instability and low back pain.[37-39] Hip extensors play a major role in stabilizing the pelvis during trunk rotation or when the center of gravity is grossly shifted.[37]

As previously noted, Leetun et al[16] demonstrated that CORE stability played an important role in injury prevention during sporting activities. Athletes who experienced an injury over the course of the season generally demonstrated lower CORE stability measures than those who did not. The results of the study indicated that in an athletic population, isometric hip strength measures, particularly in abduction and external rotation, are more accurate predictors of back and lower extremity injury than trunk endurance measures.[16]

Management of overuse injuries within the upper and lower limbs must include an assessment of CORE deficits, followed by the appropriate treatment. According to the clinical experience of the author of this lesson, patellofemoral pain, hamstring strains, lateral hip pain, chronic ankle sprains, and in some cases low back pain in the athlete result from lower-quadrant CORE muscle deficits. Mascal et al[40] reported that strengthening the hip, pelvis, and trunk musculature resulted in a significant reduction in patellofemoral pain and improved lower-extremity kinematics and the patients' ability to return to their original levels of function. The hip abductors, extensors, and internal/external rotators were the key muscles strengthened. Ireland et al[41] measured hip abduction and external rotation strength in 15 female subjects with patellofemoral pain. The subjects demonstrated 26% less hip abduction strength and 36% less hip external rotation strength than similar age-matched controls. Lastly, Sherry and Best[42] compared two rehabilitation programs in the treatment of acute hamstring strains. This study demonstrated that progressive agility and trunk stabilization exercises are more effective than a program emphasizing isolated hamstring stretching and strengthening in promoting return to sports and preventing a recurrence of the hamstring injury.

The literature is void of a relationship between overuse injuries of the upper quadrant CORE and muscle strength deficits. However, based on this author's clinical experience, assessment of muscle strength of the glenohumeral and scapula rotators is essential in the treatment of shoulder problems in the athlete.

SUMMARY

This lesson has identified the muscles of the upper and lower quadrant CORE (see Table 1). The upper quadrant CORE muscles include the rotators of the glenohumeral joint and scapula. The lower quadrant CORE comprises the muscles in the trunk and hip. In both cases the CORE is an area in which mobility and stability occur simultaneously. Electromyographic analysis and strengthening programs involving the muscles of the upper and lower quadrant CORE demonstrate that athletic performance is based on the mobilizing and stabilizing effect these muscles have on the shoulder, trunk, and hip.

Dysfunction of the upper and lower quadrant CORE can result in shoulder, elbow, low back, and lower limb pain and injuries. The author of this lesson has discovered through clinical observation that muscle imbalances within the CORE can be a major etiology of poor athletic performance, which can lead to injury. Strengthening of the upper and lower quadrant CORE muscles is oftentimes the major treatment approach for many overuse injuries identified in the athlete.

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