An Anatomical Review

Muscular Control of the Lumbar Spine

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The lumbar spine has been the object of investigation since the era of Hippocrates. The lumbar spine consists of bone, cartilage, ligament, nerve, and muscle. The muscles provide the functional mechanism for movement and stability of the spine. They provide range of motion allowing for performance of many essential activities of daily living, work, and leisure. These muscles serve a secondary role protecting the underlying lumbar spinal components by absorbing axial forces. This role can have serious implications in the development of lumbar spinal pain syndromes. In this article we will discuss the attachments of the lumbar muscles and their direct and indirect action on the lumbar spine.

Keywords: Lumabar spine, Muscular control, Ligaments, Nerves, Muscle.

The lumbar spine is composed of bone, cartilage, ligaments, nerves, and muscle. These anatomical components give the spine form and function. The alignment of the lumbar spine is controlled by its bony and ligamentous structures. This architecture enables the lumbar spine to achieve its characteristic lordotic appearance. This form is given functional characteristics by actions of the lumbar spine muscles. These muscles are typically grouped into two different types: primary or secondary muscles. The primary lumbar muscles insert directly into the bony elements of the spine, resulting in control of spinal motion. The secondary lumbar muscles aid in lumbar motion without a direct insertion into the spinal bony structures. They control multisegmental gross movements and generate the force necessary to perform many functional activities (1).

The secondary function of the muscles surrounding the lumbar region is their protection of the lumbar discovertebral joints. The primary muscles act as stabilizers of the functional spinal units of the lumbar spine. They prevent extremes of range of motion, which have demonstrated to potentiate injury to the intervertebral disc. (2) Repetitive injury, over time, can set in motion the degenerative cascade of the lumbar disc resulting in the development of discogenic or facet mediated axial low back pain (2). The lumbar muscles protect the discovertebral joint by absorbing forces directed through the spine. If the loading forces were not dissipated, the intervertebral disc would bear the load with the eventual result of progressive, unremitting disc degeneration and the development of low back pain.

In this article we will discuss the basic anatomic attachments and actions of the muscles surrounding the lumbar spine. These muscles can be grouped in a number of ways. For our discussion, we will divide them into primary and secondary groups. Within each group we will divide the muscles into primary flexors, extensors, rotators, and lateral flexors.

Stability and movement are dependent on the coordination of the muscles surrounding the lumbar spine. Precise neural output allows for multiple muscles to act in concert providing for both gross and fine movements of the lumbar spine. This complex neural control is critical in providing a protective mechanism to the lumbar spine. Loss of this neuromuscular facilitation through disuse or injury can compromise the protective mechanism and result in excessive forces through the discovertebral segments. Ongoing research into this area should aide in designing a more effective rehabilitation program for low back pain patients.

The Thoracolumbar Fascia

The muscles of the lumbar spine are enclosed in the thoracolumbar fascia. The thoracolumbar fascia consists of three layers: the anterior, middle, and posterior layers (3-5). The anterior layer encases the psoas major and quadratus lumborum muscles. The middle layer arises from the tips of the transverse processes of the lumbar vertebrae and intervenes between the erector spinae and the quadratus lumborum, where it is continuous with the inter-transverse ligaments (5). The posterior layer covers the erector spinae and its aponeurosis. Of these three layers the posterior layer has the most important role in supporting the lumbar spine musculature.

The posterior layer consists of two laminae: a superficial lamina with fibers passing downward and medially and a deep lamina with fibers passing downward and laterally (6). The aponeurosis of the latissimus dorsi muscle forms the superficial layer. This contributes to the formation of the supraspinatus ligament via its insertion to the tips of the spinous process of L1 through L3 vertebrae. This posterior layer is well developed throughout the thoracic and upper lumbar region. It is usually absent in the lower lumbar segments. In the superficial lamina, the collagen fibers cross the midline and interface with the contralateral side (5).

The fibers of the contralateral latis-

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simus dorsi muscle that have crossed the midline form distinct bands of fibers emanating from the lower three lumbar spinous process to form the deep lamina of the posterior layer of the thoracolumbar fascia (5). At the fourth and fifth lumbar vertebrae the deep lamina attaches to the posterior superior iliac spine and anchors theses two vertebrae to the ilium. The fibers from the L3 vertebrae pass downward and laterally to blend with the raphe above the iliac crest (6).

Primary Muscles

There are two major groups of the lumbar extensors: the erector spinae and the multifidus muscles. The multifidus muscle covers the laminae of the lumbar vertebrae while the erector spinae covers the transverse processes posteriorly. The erector spinae in the lumbar region are primarily composed of the longissimus thoracis and the iliocostalis lumborum. The spinalis thoracic muscle intrudes into the lumbar region from the thoracic region. This muscle inserts into the first two or three lumbar spinous processes and offers little functional capability.

The erector spinae are a large muscle mass lying laterally to the multifidi (3). These muscles cover the entire lumbar spine and a major component of the thoracic region. In the thoracic spine there are two divisions of the erector spinae: longissimus thoracic and iliocostalis lumborum. The iliocostalis thoracis muscle divides them. In the lumbar spine these muscles form a common muscle mass and the divisions are separated by lumbar intermuscular aponeurosis (4). The lumbar fibers act directly on the vertebrae while thoracic fibers act indirectly on the lumbar spine. This indirect action is due to their insertion into the sacrum and ilium.

The most lateral muscle of the erector spinae is the iliocostalis lumborum. In adults this muscle consists of four fascicles that arise from the transverse processes of the L1-L4 spine, lower eight ribs, and the middle layer of the thoracolumbar fascia adjacent to the respective transverse processes (5). The iliocostalis lumborum lacks fascicle attachment to the L5 transverse process and is represented in the iliolumbar ligament posteriorly (5). Distally, these fascicles broaden and form overlapping insertions into the iliac crest laterally and medially to the sacrum (7).

Just medial to the iliocostalis muscle lies the longissimus muscle. It is the longest and thickest muscle of the erector spine group (3). The longissimus muscle can be divided into two groups: the longissimus thoracis pars lumborum and the longissimus thoracis pars thoracis. The longissimus thoracis pars lumborum consists of five fascicles that insert proximally into the dorsal aspect of the transverse process of each lumbar vertebra. These fascicles each arise from accessory process and the medial half of the posterior surface of the corresponding transverse process (5). The fascicle of L5 inserts directly into the posterior superior iliac spine and ilium (5, 8) and this is covered by the fascicles from L1 to L4. The fascicles from L1 to L4 become tendinous on their lateral surfaces. The confluence of their tendons forms the intermuscular lumbar aponeurosis, which attaches to the rostral end of the posterior superior iliac spine.

The longissimus thoracis pars thoracis consists of multiple individual muscle bellies that insert proximally into the posterior and medial aspect of all ribs and transverse processes of the T1 to T12 vertebrae (9). Each of these muscle bellies forms an individual caudal tendon, which passes inferiorly to insert into the lumbar and sacral spinous process, the dorsal surface of the sacrum below the insertion of the multifidus, and into the posterior superior iliac spine (4, 5). The side-to-side aggregation of these caudal tendons forms the medial half of a wide aponeurotic sheet known as the erector spinae aponeurosis, which covers the lumbar multifidus and longissimus thoracis (5). In the midline, the tendinous fibers of the erector spinae aponeurosis converge to form the supraspinous ligament.

The iliocostalis lumborum pars thoracis consist of small individual muscle bellies that arise on the lower eight ribs. Each individual muscle belly forms a flat tendon that inserts caudally into a linear area along the iliac crest with those from higher thoracic levels attaching medially and those from the twelfth rib attaching laterally (5). Laterally these tendons converge to form the lateral half of the erector spinae aponeurosis, which covers the lumbar fibers of the iliocostalis lumborum.

Bilateral contraction of the erector spinae results in an extension moment of the lumbar spine. This is its primary action. Unilateral control of lateral flexion moment of the lumbar spine is by the iliocostalis lumborum (3). This is influenced unilaterally by gravity and contralaterally by the contraction by the iliocostalis lumborum. The longissimus thoracis and iliocostalis lumborum are inclined backward and downward from their insertion and produce both sagittal and posterior rotation and posterior translation to their respective vertebrae. The thoracic fibers of the longissimus thoracis and the iliocostalis lumborum do not have direct action on extension of the vertebrae, but act to extend the thorax in relation to the pelvis. This is an indirect extension or antiflexion moment on the lumbar spine (5). The iliocostalis muscle receives innervation from the lateral branch of the lumbar dorsal rami. The intermediate branch of the lumbar dorsal rami innervates the longissimus muscle.

Deep and medial to the erector spinae muscles lies the multifidus. This muscle consists of short and long fibers. The short fibers attach proximally to the inferior edge of the dorsal lamina of each lumbar vertebra. Each muscle band consists of one or more fascicle, which are confluent with one another at their origin from the spinous process, but form individual attachments distally.

The large muscle fibers of the multifidus are arranged into five overlapping sheets of muscle (10). Fascicles from the L1 spinous process inserts into the mamillary process of L3 to S1 vertebrae. There is an additional fascicle that inserts on the posterior superior iliac spine (5, 9). Fascicles from the L2 vertebrae primarily insert distally into the L5 dorso-medial transverse process, S1 mamillary process, posterior superior iliac spine, and iliac crest (10). The L3 fascicles insert mostly into the upper lateral edge of the sacrum, dorsal sacroiliac ligaments, and the L5 and S1 mamillary processes. The L4 fascicles largely insert into the dorsal sacroiliac ligament over the intermediate and lateral third of the sacrum, but also attaches into the S1 mamillary process (5). The multifidus fascicles from the L5 vertebrae subsequently insert into the posterior-superior surface of the sacrum (9). Lewin et al (11) noted that the distal large fiber multifidus muscle may have attachments to the neighboring zygapophyseal joints. The primary action of the multifidus muscle is posterior sagittal rotation. The segmental attachments of the multifidus are specifically organized for exquisite control of each lumbar functional spinal unit (10). The multifidus has a secondary role as a stabilizer in rotation (12). This muscle serves as a weak lateral flexor to the ipsilateral side of the lumbar spine (12). It receives segmental innervation from the medial branch of the segmental lumbar dorsal rami.

The intersegmental muscles of the lumbar spine are the intertransversarii and the interspinales muscles. There are three distinct intertransversarii muscles. The intertransversarii laterales ventrales inserts proximally and distally into the lateral two-thirds of sequential transverse processes. The intertransversarii laterales dorsales lies just medial to and is much thinner in comparison to the intertransversarii laterales ventrales. The laterales dorsales inserts proximally to the accessory process and distally to the medial third of the superior dorsal edge of the adjacent transverse process below (9). The intertransversarii mediales attaches proximally to the accessory process, mamillary process, and mamillary-accessory ligament. Distally it inserts into the mamillary process of the vertebrae below (5, 13). Due to their small size and medial location, the intertransversarii muscles are weak posterior sagittal rotators and lateral flexors of the lumbar spine. Some researchers believe that these muscles serve more of a proprioceptive role for the spine (14). These muscles are postulated to create feedback positional information to the larger muscles of the spine that react to maintain proper spinal alignment (14). The intertransversarii lateralis muscles receive innervation from lumbar ventral rami while the intertransversarii mediales muscles receive innervation from the medial division of segmental lumbar dorsal rami.

The interspinales are small, thin, and quadrangular paired muscles that insert proximally into the lateral tip of the spinous process. They insert distally into the spinous process of the vertebra below. These muscles lie laterally to the interspinous ligament. Their primary action would involve posterior sagittal rotation. Their small size would limit them contributing to any significant movement. These muscles may also play a proprioceptive role similar to the intertransversarii muscles (10). The reason is that the intersegmental muscles carry high concentrations of muscle spindles (5). These muscles receive innervation from the medial branch of lumbar dorsal rami.

The quadratus lumborum is large, thin, and quadrangular shaped muscle that has direct insertions to the lumbar spine. It flanks the psoas major muscle and the superior insertion is into the twelfth rib. There are three major components or muscular fascicles to the quadratus lumborum: the inferior oblique, superior oblique, and longitudinal fascicles. The inferior oblique fibers arise from the iliac crest and iliolumbar ligaments and insert to the L1 trough L5 transverse process. They travel medially and upward to obtain their insertion. The twelfth rib is the insertion of the superior oblique fibers. These fibers insert upward and laterally. The longitudinal fibers insert into the iliolumbar ligament and the twelfth rib. The longitudinal fiber's origin is into the pelvis. Both the longitudinal and superior oblique fibers have no direct action on the lumbar spine. They are designed as secondary respiratory muscles to stabilize the twelfth rib during respiration. The inferior oblique fibers of the quadratus lumborum are generally thought to be a weak lateral flexor of the lumbar vertebrae. The quadratus lumborum receives innervation from branches of ventral rami at the T12 through L3 levels.

The psoas major is a long, thick muscle whose primary action is flexion of the hip. However, based upon its attachment sites into the lumbar spine there exists the potential to aid in spinal biomechanics. During anatomical dissections the psoas muscle has been found to have three proximal attachment sites: the medial half of the transverse processes from T12 to L5, the intervertebral disc, and the vertebral body adjacent to the disc (5, 15). The muscle fibers converge to form a strong tendon that crosses the pelvic brim to insert into the lesser trochanter of the femur (5). Based upon the muscle fibers angles of attachment the psoas major effects different motions on the lumbar spine. The primary action is lateral flexion of the lumbar spine (16). The muscle also enables extension to the upper lumbar segments and flexion of the lower lumbar spinal segments. When the lower extremity is in a fixed position (i.e., standing) the psoas major serves as an anterior rotator of the trunk to the contralateral side (17). The short moment arm of the psoas major is considered a weak flexor of the lumbar spine (15). More likely, the psoas major provides stability to the lumbar intervertebral segments. This stability sacrifices function to the lumbar discs. Increased stability will concomitantly cause increased compressive loads to the lumbar discs. These increased loads could potentially contribute to injury over time (16). The innervation for the psoas major muscle is from the branches of the second through fourth lumbar anterior rami.

Secondary Muscles

Although the abdominal muscles are not directly attached to the lumbar spine, they have a major role in controlling lumbar spine motion. The muscular fibers of the abdominal wall are the external and internal oblique muscles. They are involved in the formation of the rectus abdominis muscle. These muscles contribute to the generation of intra-abdominal pressure and have bony attachments that enable them to move the thorax in relation to the pelvis and exert indirect action on the lumbar spine (5, 6).

The external oblique muscle is a large, thin sheet-like structure on the lateral aspect of the anterior abdominal wall. This muscle's proximal insertion is into the lower six ribs. From this position it descends inferior and medially across the abdominal wall. The external oblique inserts distally into the iliac crest, linea alba, and pubis. The primary function of this muscle is flexion of the thorax (18). The obliquity of the external oblique muscle enables rotation of the spine to turn the anterior trunk to the opposite side (17).

Immediately deep to the external oblique lies the internal oblique muscle. Its proximal insertion is similar to the external oblique: the lower ribs and linea alba. Distally, the internal oblique inserts into the iliopsoas fascia, inguinal ligament, iliac crest, and thoracolumbar fascia. The internal oblique's primary action is flexion of the lumbar spine. In addition, it can act as a weak lateral flexor and rotate the spine to turn the anterior trunk to the same side (17). The ipsilateral internal oblique muscle and the contralateral external oblique muscle execute rotation. To produce pure axial rotation, a flexion moment must be counterbalanced by a simultaneous extension moment generated by the posterior lumbar muscles: the erector spinae and the multifidus (5). The external and internal oblique muscles both receive innervation from the lower intercostal nerves, iliohypogastric nerve, and ilioinguinal nerve.

The third muscle of the anterior abdominal muscle group is the transversus abdominis muscle. It arises from the in-

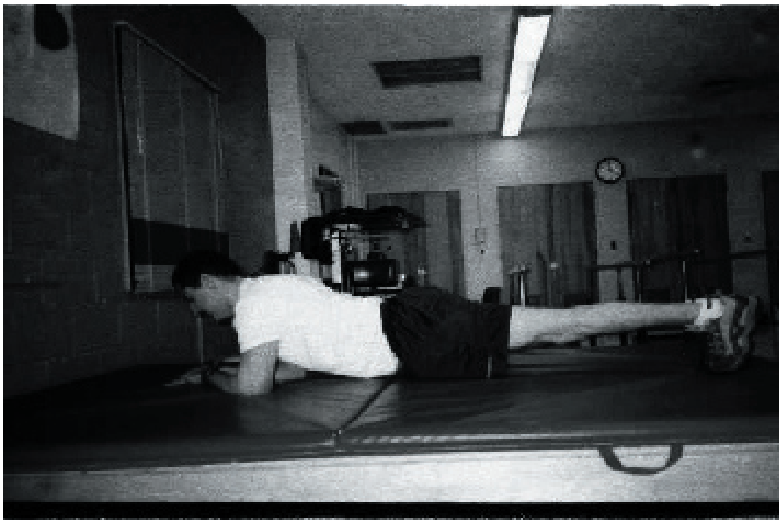

Fig 1. *Bridging technique for eccentric abdominal strengthening*

ner surface of the lower six costal cartilages and iliac crest. The middle fibers of the transversus abdominis arise from the lateral raphe of the thoracolumbar fascia. The criss-cross arrangements of these muscle fibers allow for a slight extension moment. During biomechanical and anatomical analysis of this muscle approximately 4Nm of extension force is contributed for moderate to heavy lifting (19).

The rectus abdominis is a paired, strap-like muscle of the anterior abdominal wall. This muscle inserts proximally into the fifth through seventh ribs and the xiphoid process. The rectus abdominis inserts distally into the pubic crest and ligaments of the pubic symphysis. Contraction of this muscle predominantly causes flexion of the lumbar spine (18). The rectus abdominis receives innervation from the lower intercostal nerves.

The general principles of the lumbar and abdominal muscles are to protect the spine and aid in our activities of daily living. The most important aspect is during lifting. Lifting involves active extension of the spine from a flexed position. This act is a combination of intra-abdominal pressure, the balancing of the flexion moment, exerted weight of the trunk, and the weight being lifted.

Intra-abdominal pressure is increased during the act of lifting. This increase in intra-abdominal pressure compresses the lumbar vertebral column and consequently the lumbar spine muscles. Recently, it has been found that contraction of the abdominal muscles increases intra-abdominal pressure and simultaneously exerts a flexion moment on the thorax (19). This flexion moment of the abdominal muscles on the thorax exceeds the extension moment produced by raised intra-abdominal pressure (19). Studies of abdominal strengthening exercises for treatment of low back pain have not been promising; even though people with back pain have been shown to have weaker abdominal muscles (5, 19) (Fig. 1).

Less than 35 kg during lifting is sufficient to exert an extension moment of the lumbar spine. The average strength of the lumbar spine is approximately 200Nm depending on age. The lumbar spine muscles are not strong enough to overcome the flexion moment during a heavy lift and usually need the muscles of the posterior hip and thigh (gluteus maximus and hamstrings) for this function.

The strengthening of back extension muscles through progressive resistance exercises is well documented (20). Gains in lumbar extension torque production using high-tech equipment have been reported after 12 weeks of training in healthy individuals and patients with chronic low back pain (20). Low-tech alternatives for lumbar exercise conditioning such as progressive floor exercises and prone extension exercises have been shown to improve endurance in patients with chronic back pain (21). Low-tech alternatives, however, require muscular strength that is lacking in debilitated patients. For example, the roman chair necessitates the patient lifting their weight against gravity, which is often not feasible for them. A program that encompasses strength and endurance training on a variety of different exercises may obtain optimum results. No single routine to date has been found to achieve the consistent results in patients with low back pain.

An important consideration to focus on is lateral flexion during asymmetric loading. The lateral flexors of the lumbar spine are the psoas major, quadratus lumborum, erector spinae, rectus abdominis, and the oblique muscles. In a laterally flexed position, the contralateral muscles are elongated. This may result in a higher force output and degree of activation. Huang et al studied the myoelectric responses of lumbar trunk muscles to static lateral flexion (22). Lumbar muscle activity was dependent on trunk position and loading. Of particular importance was the side of force applied. Myoelectric activity increased in most ventral and dorsal muscles contralateral to the side of lateral flexion and loading. On the ipsilateral side, the abdominal muscles demonstrated bilateral co-activation and appeared to contribute more to trunk stabilization in laterally bent positions than the other trunk muscles. This co-activation was larger in the unloaded position (22). Interestingly, they found in that the transverse abdominis muscle showed a relatively high level of activation, which increased with trunk lateral flexion in unloaded and loaded positions. In the unloaded position activity increased 5-25% and 13-48% in the loaded position (22). This research suggests that a rehabilitation program, which develops the lateral flexors, may aid in preventing low back pain.

Secondary Muscles: The Importance Of The Hip Musculature

Nicholas et al (23) described the link theory in which the ankle, knees, and hips act as a link system making possible the transmission of forces into the pelvis and spine during running, jumping, kicking, and throwing. Biomechanical studies have confirmed not only how the joints of the lower limb work together to transfer forces between limb segments during motion, but also how a compromised joint will lead to proximal and distal joint dysfunction (24-26). Many have proposed that any deficiency or alteration in the human link system will produce or aggravate disease either distal or proximal within the link (26-31). Despite the common perception of the existence of the kinetic chain or link theory, there is limited research in the peer-reviewed literature regarding this entity (29, 32-34). As an exact biomechanical model has not been completely defined at this time, research has focused on individual issues related to the kinetic chain like flexibility, strength, and their relationship to injury to define this phenomenon. Nadler et al (35), utilizing a timed 20-meter shuttle run, noted that in clinically asymptomatic NCAA Division I athletes, with a previous history of low back pain, were found to be significantly slower during performance of the timed 20-meter shuttle run compared to athletes without low back pain history. This finding suggests that athletes with a previous history of low back pain may have residual limitations within the lower extremity kinetic chain. The hip musculature theoretically plays a significant role within the kinetic chain with activation of the hip extensors, flexors and abductors required for all ambulatory activities, stabilization of the trunk/pelvis and in transferring force from the lower extremities to the pelvis and spine (36, 37).

The muscle groups involved in hip extension are semimembranosus and biceps femoris. The other hip extensors, which are directly involved in hip extension, can be divided into primary and secondary groups. The primary hip extensors include the gluteus maximus and hamstrings, which include the semitendinosus to the spinal column, include the erector spinae, quadratus lumborum, and multifidus. The gluteus maximus originates from the external surface of ala of ilium, including iliac crest, dorsal surface of sacrum and coccyx, and sacrotuberous ligament, and inserts distally through the iliotibial tract, into the lateral condyle of the tibia as well as onto the gluteal tuberosity of the femur (38). This muscle extends and laterally rotates the thigh, as well as extending the trunk from the flexed position. The semitendinosus muscle originates from the ischial tuberosity, and inserts distally to the medial surface of the tibia. It extends the thigh, and when the thighs and legs are flexed, it can extend the trunk. This muscle can also flex the leg and rotate it medially. The semimembranosus also originates from the ischial tuberosity, and inserts distally along the posterior part of the medial condyle of the tibia. Like the semitendinosus, it too extends the thighs, and when the thigh and leg are flexed, it can extend the trunk. This muscle can also flex the leg and rotate it medially. The biceps femoris has both a long and short head. Proximally, the long head originates at the ischial tuberosity, while the short head originates from the lateral lip of the distal half of the linea aspera and lateral supracondylar line. Both insert distally to the lateral fibular head region. This muscle extends the thigh, but can also flex the leg and rotate it laterally.

There are ten muscles attached from the pelvis to the lower extremities involved in flexion of the hip, which include the following: the psoas major and minor, iliacus, tensor fascia latae, sartorius, rectus femoris, pectineus adductor brevis and magnus and gracilis. In addition, there are four muscle groups of the abdomen, the rectus abdominis, internal and external obliques and transverse abdominis, which also assist in hip flexion.

The main hip flexors are the psoas muscles (38). The psoas major originates from the lateral aspect of the T12 to L5 vertebral bodies, intervertebral discs between them and transverse processes of L1-l5, and insert distally at the lesser trochanter of femur. It is the main hip flexor at the hip joint and also aids in stabilizing this joint. The psoas minor also originates from the lateral aspect of the T12 and L1 vertebrae and intervertebral discs, inserting distally at the pectineal line, iliopectineal eminence via the iliopectineal arch ligament. Like the psoas major, this muscle flexes thigh at hip joint, and aids in stabilizing this joint. The iliacus originates from the iliac crest, iliac fossa, ala of the sacrum, anterior sacroiliac ligaments and the capsule of hip joint, inserting distal to tendon of psoas major along the femur, inferior to the lesser trochanter. It also flexes the thigh at the hip joint, and aids in stabilizing this joint. The tensor fascia latae originates at the anterior superior iliac spine and anterior part of external lip of iliac crest, and inserts along the anterolateral aspect of lateral tibial condyle via the iliotibial tract. It abducts, medially rotates and flexes the thigh and aids in keeping the knee extended. The sartorius originates from the anterior superior iliac spine region and inserts along the superior aspect of the medial surface of tibia. It flexes, abducts and laterally rotates the thigh at the hip joint and flexes the leg at knee joint. The rectus femoris originates from the anterior inferior iliac spine and groove superior to the acetabulum, and distally inserts at the tibial tuberosity via the patellar tendon. The rectus femoris extends the leg at the knee joint, and helps the iliopsoas flex the thigh. The pectineus, adductor brevis, adductor magnus and gracilis do not play much of a role in spinal mechanics and therefore will not be discussed. Overall, the hip flexors help to stabilize the spine and pelvis through direct attachment, provide for motion in the sagittal plane (flexion) and may influence resting posture when contracted (e.g., increased lumbar lordosis with tight psoas major/minor).

The gluteus medius/minimus are the major stabilizers of the pelvis during single limb stance (39). The gluteus medius and minimus originate from the outer aspect of the ilium and the fascia of the gluteal aponeurosis and inserts into the outer aspect of the greater trochanter (38). Activation of these muscles prevents the Trendelenburg sign whereby the pelvis contralateral to the weightbearing extremity tilts downward during the stance phase of gait.

The hip musculature thus plays a significant role in transferring forces from the lower extremity up towards the spine during upright activities. Poor endurance and delayed firing of the hip extensor (gluteus maximus) and abductor (gluteus medius) muscles have previously been noted in individuals with lower extremity instability or low back pain (23, 32, 40, 41). Beckman and Buchanan (40) noted a significant delay in latency of gluteus medius muscle in those with chronic ankle instability as compared to normal controls. DeVita et al (42) noted an alteration in firing of the proximal hip musculature in people with anterior cruciate ligament insufficiency. Jaramillo et al (41) demonstrated significant strength deficits of the ipsilateral gluteus medius, in patients who had undergone knee surgery. Kankanaapa et al (43) and Leinonen et al (44) demonstrated poor endurance in the gluteus maximus in people suffering from chronic low back pain. Nadler et al (45) demonstrated a significant asymmetry in hip extensor strength in female athletes with reported low back pain. In a prospective study, Nadler et al (46) demonstrated a significant association between hip

Fig 2. *Testing hip extensor muscles*

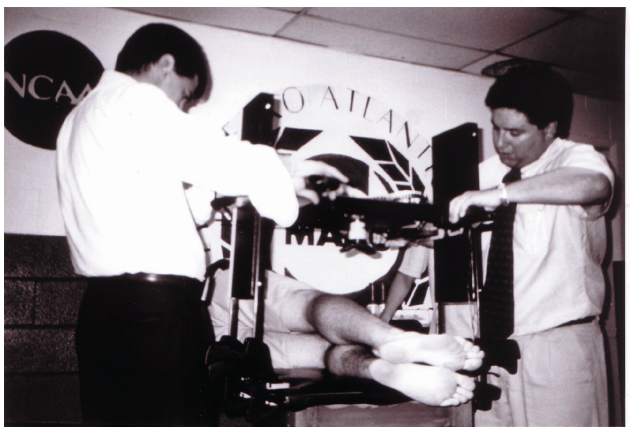

Fig 3. *Hip abduction strength testing*

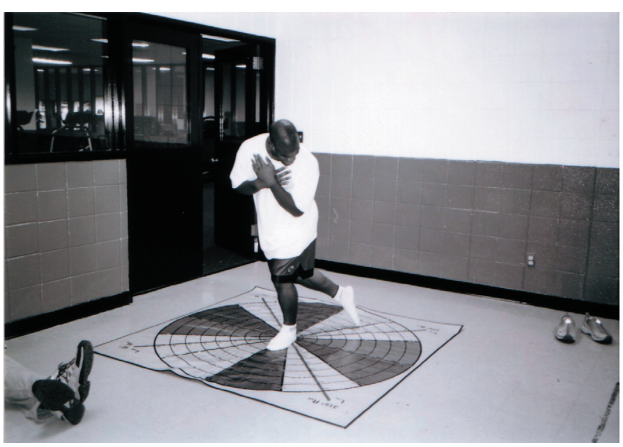

Fig 4. *Functional testing for core strength*

strength imbalance of the hip extensors measured during the pre-participation physical and the occurrence of low back pain in female athletes over the ensuing year (Fig. 2). Overall, the hip appears to play a significant role in transferring forces from the lower extremities to the pelvis and spine, acting as one link within the kinetic chain.

To address issues related to strength imbalance about the hip musculature, Nadler et al (47) evaluated the occurrence of low back pain both before and after incorporation of a core-strengthening program. Hip strength was measured during the pre-participation physical examination and low back pain incidence was monitored over the course of the study. Following the pre-participation physical, all athletes began a structured core-strengthening program targeting the abdominal, paraspinal, and hip extensor muscles. Though the incidence of low back pain decreased by 47% in male athletes this was not statistically significant, while the overall incidence of low back pain slightly increased in female athletes despite core conditioning. Though core-conditioning exercises did not change the incidence of reported low back pain, female athletes with hip abductor strength imbalance were more likely to have required treatment for low back pain suggesting the necessity for more gender-specific core-strengthening programs (Fig. 3). In addition, the exercises chosen for this study included only frontal and sagittal plane movements, which may have impacted upon the results. Future studies incorporating exercises in the transverse plane may help to solve the issue surrounding exercise and low back pain (Fig. 4).

Conclusion

The muscles of the lumbar spine are designed to allow for smooth, controlled movement in all functional planes. This motion is accomplished through the use of both segmental and polysegmental muscles. The polysegmental muscles are involved with major active movements requiring large amounts of force. The segmental muscles provide for minute changes in the spine. These changes most likely occur during minor active movements and in the preservation of posture. These smaller segmental muscles may also play more of a proprioceptive role than in generating motion. In fact, this role seems more likely based upon the attachment sites of these segmental muscles. Their placement is often intimately involved to the axis of motion, thereby leaving these muscles at a disadvantage for producing motion (48). The lumbar muscles have the ability to detect minute changes in motion quickly, allowing for correction of the spine by the polysegmental muscles.

More importantly for the field of pain medicine is the compressive effects and force absorbing abilities of the lumbar muscles. Based upon the gross anatomy of these muscles, our field continually strives to devise rehabilitation programs to increase the stabilizing, proprioceptive, and force absorbing capabilities of the lumbar muscles. At the same time we strive to diminish compressive effects to the lumbar intervertebral discs. This is the continuous battle that we face today in the physical rehabilitation of patients with acute or chronic lower back pain.

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