The Aponeurotic Roots of the Thoracolumbar Fascia

F.H. Willard, Ph.D, J.E. Carreiro, D.O

Introduction

Thoracolumbar fascia is a complex arrangement of connective tissue sheets enveloping the low back and reaching over the sacrum. It has received several detailed anatomical and biophysical studies of recent (Hu and others, 2010); however, the function of this complex system of interconnected tissue is still illusive. Part of the problem lies in our inability to understanding how these layers integrate into the body to promote stability and facilitate motion. In this article we will review the major muscle groups and their associated fascial and aponeurotic sheaths that give rise to what is termed the thoracolumbar fascia (TLF). From these anatomical relationships a functional implication can be proposed.

Dissection of the Thoracolumbar Fascia

The fibromuscular layers of the lumbosacral region are arranged in a stacked array progressing from superficial to deep. Figure 1 presents a posterior view of the lower back of a 91 year-old male. The skin and pannicular (subcutaneous) fascia have been removed and the underlying structures stripped of their investing fascia to expose the latissimus dorsi and its associated aponeurosis, the superior aspect of the gluteus maximus and its aponeurosis as well as the fusion of these aponeurotic sheets to form the posterior layer of the TLF. In Figure 2, the latissimus dorsi and its aponeurosis have been removed to demonstrate the paraspinal muscles - iliocostalis laterally and longissimus medially -and the formation of the aponeurosis of the erector spinae.

In the next step, the lateral two paraspinal muscles and their aponeurosis were removed (Figure 3) sparing just the inner most laminae of these muscles (Ic and Lo in the figure) to mark their position. The three white arrows in Figure 3 indicate the medial border of the aponeurosis of the transversus abdoiminis. At this border, the aponeurosis splits contributing to three separate layers: the outermost layer to which it fuses is the aponeurosis of the erector spinae (present on the right side of this figure), the innermost layer is the anterior layer of TLF (not seen in this figure) and the remaining layer - termed the middle layer of TLF - passes between the paraspinal muscles and the quadratus lumborum. The removal of the aponeurosis of the erector spinae reveals the underlying multifidus, the third and most medial muscle of the lumbar paraspinal group. The thin white fascial bands seen crossing the multifidus muscle on a diagonal represent its attachment sites to the deep surface of the aponeurosis of the erector spinae.

In Figure 4, additional portions of the ilocostalis (Ic) and the longissimus (Lo) have been removed to expose the middle layer of TLF. Portions of the middle layer have been removed to expose the dorsal rami of the spinal nerves as they course through the middle layer.

Finally, in Figure 5 (which involves a second specimen) all paraspinal muscles and the dorsal rami have been removed. Exposed are the lumbar zygapophyseal joints and the transverse processes of the lumbar vertebrae. The middle layer of TLF, derived from the aponeurosis of the transversus abdominis, is seen attaching to the tips of the transverse processes. In between the transverse processes, an arch is seen in the aponeurotic attachment. It is through this arch that the dorsal ramus gains entrance into the middle layer of the TLF. The irregular dense connective tissue (fascia) that normally fills the arch, surrounds the ventral rami and invests the psoas has been removed to expose these structures. This investing fascia represents the anterior layer of the TLF.

The muscles of the lumbosacral spine

Four major muscle groups are positioned about the lumbosacral spine. Based on their geographic arrangement these groups are: superior posterior, inferior posterior, anterior and deep muscles. The superior posterior group consists of the iliocostalis, longissimus and multifidus, while the inferior posterior group contains gluteus maximus and medius and biceps femoris. The anterior group is composed of the rectus abdominis, external and internal obliques and transversus abdominis. Finally, the deep group consists of the psoas and quadratus lumborum. An additional muscle extends its influence into the lumbosacral region and that is the latissimus dorsi. This muscle effects lumbar region by way of its expansive aponeurosis that fuses to the aponeurosis of the erector spinae muscles. The detailed descriptive anatomy of each member of these muscle groups is presented in numerous textbooks of anatomy (Clemente, 1985; Standring, 2008) and is beyond the scope of this review; however key features regarding the contribution of these muscles to the aponeurotic roots of the TLF will be presented.

Superior posterior group - The three muscles of the superior posterior group are arrayed in longitudinal bands positioned medial to lateral in the lumbar region (Figures 1, 2 and 3) . The medial most muscle, multifidus, begins at L1 and extends into the sacrum and is separated from the other two muscles by a fascial septum thus creating an isolated muscle compartment. The other two muscles, iliocostalis and longissimus, course from the cervical region to the crest of the ilium. In the cervical and thoracic regions these two muscles are separated by fascial septae, however, in the lumbar region the two muscle frequently fuse together to form one large muscle termed the sacrospinalis (REF). Incomplete fascial septae partially separating the two muscles in the lower lumbar region can often be seen on MR imaging.

In the upper lumbar region, the iliocostalis and longissimus (or sacrospinalis muscle) forms a large, flattened aponeurosis that extends to the crest of the ilium inferiorly and the lumbar spinous processes medially. In its medial projection, the aponeurosis of the erector spinae muscles covers the posterior (outer) surface of the multifidus. These outer laminae of the multifidus have strong attachments to the inner surface of the aponeurosis. These attachments can be seen as whitish colored diagonal lines in Figure 3.

Inferior posterior group - Three large muscles of the lower extremity are related to the posterior aspect of the TLF. The superior and medial borders of the gluteus maximus arise from a flattened band of connective tissue termed the gluteal aponeurosis (Figure 1 and 6). This sheet of fibers extends upward from the superior border of the gluteus maximus to reach the crest of the ilium and medially from the attachment of the gluteus maximus to blend with the TLF over the sacrum. Internally, the gluteal aponeurosis forms an attachment site for the gluteus medius. The inferior and medial border of the Gluteus maximis attaches to the outer layer of the sacrotuberous ligament. This ligament also act as an attachment site for the biceps femoris. This latter muscle has a superiorly directed tendon whose inferior fibers attach to the ischial tuberosity and superior fibers attach to the outer layer of the sacrotuberous ligament (Figure 7). This outer band of fibers covering the sacrotuberous ligament represents an inferior extension of the TLF from the sacrum.

Anterior group - In the abdominal region, a multilayered fibromuscular band extends from the anterior midline around the torso to attach to the fascias of the lumbar spine. Laterally the band consists of three muscles, the external and internal oblique are superfical and the transversus abdominis forms the deep layer. Anteriorly all three muscles form aponeuroses that combine and then split forming the rectus sheath, this latter structure houses the rectus abdominis (Figure 8). Inferiorly these muscles form the inguinal ligament and superiorly they attach to the ribs with the transversus abdominis interdigitating with muscular slips from the thoracoabdominal diaphragm. The posterior border of the transversus abdominis ends by forming an aponeurosis

that quickly splits into two layers, the anterior most layer merges with the epimysium of the posterior surface of the quadratus lumborum and together these structures form what is termed the middle layer of the TLF; ultimately this structure attaches to the transverse processes of the lumbar vertebrae (Figure 9). The posterior most layer of transversus aponeurosis passes superficial to the paraspinal muscles to merge with the aponeuroses of the erector spinae and of the latissimus dorsi to form the posterior layer of the TLF.

Deep group - Two musclesrelated to the lumbar spine are found deep in the posterior body wall: the psoas and the quadratus lumborum (QL). The lateral border of the QL is is approached by the aponeurosis of the transversus abdominis, which subsequently divides to surround this muscle (Figure 9). The layer passing posterior to the QL is termed the middle layer of the thoracoabdominal fascia and the layer anterior to the QL is termed the anterior layer of the thoracoabdominal fascia. Both of these layers fuse with the epimysium of the QL. The middle layer of the thoracoabdominal fascia is thick and substantial, eventually attaching to the transverse processes of the lumbar vertebrae; the anterior layer is little more than an epimysium. The psoas is positioned anterior to the QLand its epimysium also fuses with the anterior layer of the TLF. It is through this fused investing fascia between the psoas and QL that the ventral rami of the lumbar plexus pass after exiting the distal opening of the intervertebral foramina. The dorsal rami of the spinal nerve enter the medial aspect of the middle layer of TLF and course in a lateral direction prior to entering the paraspinal muscles.

The Thoracolumbar Fascial Complex

Definition of fascia

Gray's Anatomy states "dissectable, fibrous connective tissue of the body, other than the specifically organized structures tendons, aponeuroses, and ligaments, are called fasciae"(Gray, 1948) This definition of fascia was introduced under C.M. Goss as editor of the American version of Gray's Anatomy in 1948 and it was maintained by Clemente in the most recent edition (Clemente, 1985). The definition as stated above is relatively clear in its exclusion of tendons, ligaments and aponeurosis from the term "fascia"; it also goes on to describe the investing nature of most fascia providing a packing substance around muscles, tendon, ligaments, and aponeuroses as well as visceral organs. A similar definition of fascia is offered in the English version of Gray's Anatomy (Standring, 2008) where fascia is also described as having collagenous fibers which are generally interwoven as opposed to the parallel array of fibers seen in tendons, ligaments and aponeuroses.

Muscles, tendons, ligaments, aponeuroses, cartilage & bone are covered by a continuous layer of investing fascial

Like any other muscles in the body, the paraspinal muscles are contained in a fascial skeleton;the outer most layer of which is histologically termed epimysium (Figure 10). In gross dissection, epimysium is termed the deep investing fascia of the muscle. It is composed of irregular dense connective tissue arranged in interwoven bands or sheets wrapping around the body of the muscle. From the epimysium, thin septae extend inward to divide the body of the muscle into fasciculii. In turn, delicate strands of connective tissue, termed endomysium extend inward from the perimysium to form a matrix surrounding individual muscle fibers. A similar situation exists in tendons, ligaments and aponeuroses where the outer layer of investing fascia is termed the "epitenon". When a tendon arises from a muscle, the epimysium blends into the epitenon; when that tendon attaches to a bone the epitenon blends with the periosteum. Thus investing fascias of all muscles, tendons, ligaments, and aponeuroses are interconnected forming a large fascial matrix. In the axial body, the three-dimensional structure of this matrix can be depicted as two elongated cylinders of fascia, separated by the vertebral column (Figure 11). The column anterior to the vertebral bodies contains the hypaxial muscles and associated

structures while that posterior to the vertebral bodies contains the epaxial (paraspinal) muscles and their associated structures.

Aponeuroses are different and distinct from investing fascia

Apnoeuroses are very succinctly defined in the 1948issue of Gray's Anatomy(Gray, 1948); here I quote:

> "Aponeuroses are fibrous membranes, of a pearly white color, iridescent, and glistening, which represent very much flattened tendons. They consist of closely packed, parallel, collagenous bundles, and by this characteristic may be differentiated from the fibrous membranes of fascia which have their collagenous more irregularly interwoven."

The text goes on to elaborate on how the aponeurosis, like a tendon, is part of the muscle, is in the direct line of pull from the muscle and is further differentiate from fascial membrane that enclose (invest) or guide the muscle. Multiple muscles can end in one aponeurotic sheet, similarly, an aponeurotic sheet can split to surround other structures such as muscles or bone. When this happens, the epitenon surrounding the aponeurosis blends with the epimysium of the muscle or the periosteum of the bone. Aponeuroses function to diffuse the tension generated by a muscle contraction over a wider range of territory than can be accomplished by a tendon or ligament.

The investing fascias and the surrounding aponeurotic sheaths form a complex structure in the lumbosacral region

The investing fascia of the epaxial musclesattaches laterally to the transverse processes of the vertebra; on the midline posteriorly it attaches to the spinous processes thus the posterior fascial tube is subdivided into two parallel tubes, left and right (Figure 11) by the spinous processes and interspinous ligaments. Overall, the fascial walls of these cylinders have been termed vertebral fascia, however regional names exist. The TLF begins superiorly as a regional delineation of the vertebral fascia (irregular connective tissue composing the epimysium of the paraspinal muscles). In the thoracic region it simply covers the paraspinal muscles, while in the lumbosacral region, this layer of fascia and its nomenclature, become extremely complex. The vertebral fascia covering the iliocostalis and longissimus blends into the epitenon of the aponeurosis of the erector spinae muscles and then becomes compresses between that aponeurosis and the overlying aponeurosis of the latissimus dorsi. Laterally this aponeurotic complex is joined by the aponeurosis of the transverse abdominis to form the "posterior layer of the TLF" (Figure 9) Eventually all of these aponeurotic layers fuse to form a thick, inseparable composite sheet below the level of S2 (Figure 2 and 6). This composite (stllltermed posterior layer of the TLFis continuous laterally with the gluteal aponeuosis and inferiorly with the sacrotuberous ligament and the tendon of the biceps femoris (Figure 7).

Aponeurotic sheaths of the lumbar spine

Several aponeuroses have been mentioned in the definition of TLF. A brief description of these structures will be presented.

Aponeurosis of the erector spinae muscles - The iliocostalis and longissimus muscles extend from the cervical and thoracic regions inferiorly to reach the crest of the ilium. As these muscles enter the lumbar region, they form an aponeurosis on their superficial aspect. Medially this structure attaches to the spinous processes of the lumbar vertebrae (Figure 2 and 9) and the superspinous ligament. Laterally the aponeurosis attaches to the crest of the ilium in the region of the posterior superior iliac spine (PSIS) and inferiorly it contributes to the composite of TLFbelow S2.

Aponeurosis of the latissimus dorsi - The latissimus dorsi is a large flat muscle arising from the humerus and spreading across the posterolateral aspect of the torso (Figure 1). As it approaches the midline the muscle forms a large flat aponeurosis that attaches to the spinous processes of the midthoracic to lower lumbar vertebrae. This aponeurosis (termed the posterior layer of the TLF) also continues into the sacral region where it fuses with the underlying aponeurosis of the erector spinae muscles (Figure 9). The combined aponeurotic sheet attaches to the crest of the ilium in the region of PSIS and extends inferolaterally to join the gluteal aponurosis as well as inferiorly to form the outer layer of the sacrotuberous ligament, eventually reaching the ischial tuberosity.

Aponeurosis of the transversus abdominis - As the transversus abdominis approaches the lumbar spine it forms an aponeurosis that quickly splits to surround the quadratus lumborum (Figure 9). The posterior lamina of this division is by far the more substantial structure and it forms the middle layer of the TLF; the anterior layer blends with the epimysium of the QL. The middle layer of TLF remains as an aponeurosis and extends medially to the transverse processes of the lumbar vertebrae. In between the transverse processes the aponeurosis forms a series of arches with the concaved aspect of the arch facing the lumbar vertebrae and associated intervertebral discs (Figure 05). It is through this arch that the dorsal ramus of the spinal nerve gains access to the middle layer of TLF between the QL internally and the paraspinal muscles externally.

Aponeuroses of the oblique muscles and the rectus sheath - All three of the abdominal muscles form aponeurotic sheets anteriorly. These sheets combine together and then spilt to house the rectus abdominis muscle. The details of this arrangement are well described in numerous textbooks of anatomy. Structurally there are some similarities between the anterior arrangement of these aponeuroses to surround the rectus abdominis and the formation of the aponeurosis of the transversus abdominis posteriorly and its separation to surround the QL (Figure 9).

Aponeurosis of the gluteal muscles and the fascia lata - The medial attachment of the gluteus maximus involves the outer layer of the sacrotuberous ligament, an aponeurotic layer along the sacrum that extends by the PSIS to follow the curvature of the crest of the ilium (Figure 6). This entire aponeurotic layer is an extension of the TLF covering the sacrum (Figure 12). The gluteal aponeurosis covers the gluteus medius, acting as an attachment site for this muscle as well.

Possible implications of the posterior fusion of aponeurotic sheets

Based on biomechanical studies, the transversus abdominis and associated oblique muscles have been described as a contractile bandage, pulling the anterior portions of the blade of the ilium (ASIS) toward each other, thus increasing the pressure in the two surfaces of the sacroiliac joint and thereby stabilizing the pelvis in upright posture(Pel and others, 2008).This self-locking mechanism will only work if another force prevents the posterior aspect of the innominate bones from moving laterally as the anterior crest moves inward. An unchecked lateral movement in the posterior ilium would allow a splaying the posterior portion of the sacroiliac joint, stressing the sacroiliac ligamentsand destabilizing the pelvis.

Here we are suggesting that the composite portion of the TLF, which is the thickest portion of this structure and a region that is most consistent with the histological definition of an aponeurosis, is best positioned to accomplish the task of resisting lateral movement of the PSISs. With the PSIS of the ilia anchored in place by the TLF, contraction of the transversus abdominis would be able to compress the sacroiliac joint.

As seen in the modified CT scan of the pelvis (Figure 13), inward movement of the ASIS (arrow over the abdominal muscles) would attempt to rotate PSIS laterally. Tensioning of the TLF (arrows overlying the TLF) would resist this motion allowing the anterior medial force to translate into increased pressure on the SIJ (arrows at the SIJ). Interestingly this model places great emphasis on the condition of the multifidus muscle in the sacrum. In the sacral region the multifidus occupies the space bounded anteriorly by the sacrum, laterally by the ilia andposteriorly by the TLC (Figure 14). Weakening or fatty involution of this muscle would relax the TLF thus allowing more lateral displacement of the ilia with resulting destabilization of the sacroiliac joint. Conversely, contraction of the muscles in thesurrounding aponeurotic sheets (Figure 15) would be expected to enhance the tension on the TLF further stabilizing the jointas seen in biomechanical studies (Vleeming and others, 1995)and on EMG studies (van Wingerden and others, 2004). This proposed model of TLF function needs to be thoroughly investigated through biomechanical experimentation.

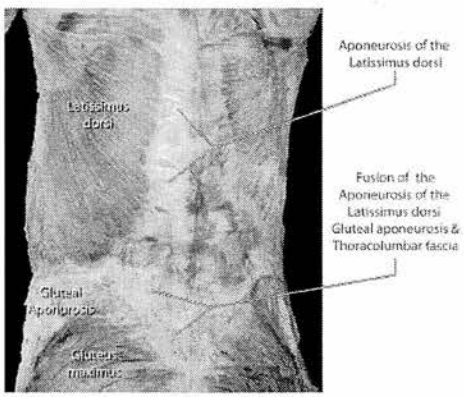


Figure 1 A superficial dissection of the back. The skin, subcutaneous fascia and investing fascia of the latissimus dorsi have been removed to expose the latissimus dorsi and its aponeurosis.

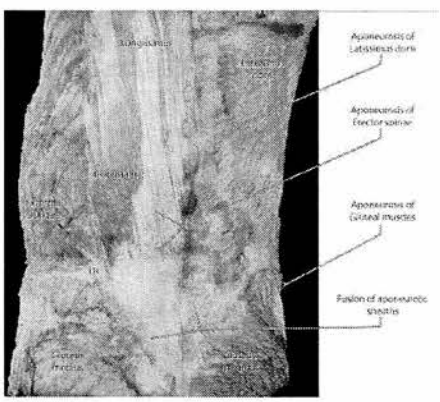


Figure 2 Dissection of the erector spinae muscles. The latissimus dorsi has been removed from the left side of the specimen to expose the longissimus and iliocostalis along with their aponeurosis.

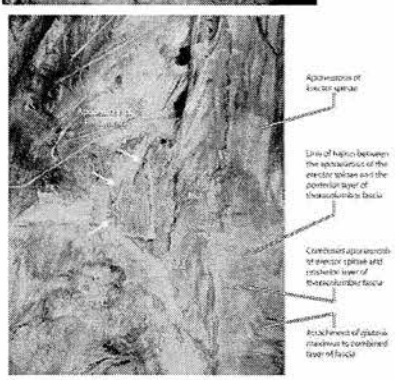


Figure 3 Dissection of the aponeurosis of the transversus abdominis I. In this view all but the deep laminae of iliocostalis and longissimus have been removed along with the aponeurosis of the erector spinae muscles. The aponeurosis of the transversus abdominis is seen laterally; its medial border divides to surround the quadratus lumborum (not shown) and the paraspinal muscles. The white arrows mark the cut border of the aponeurosis as it surrounds the deep laminae of the iliocostalis (Ic) and longissimus (Lo). Medial to the longissimus is the multifidus muscle (Mul).

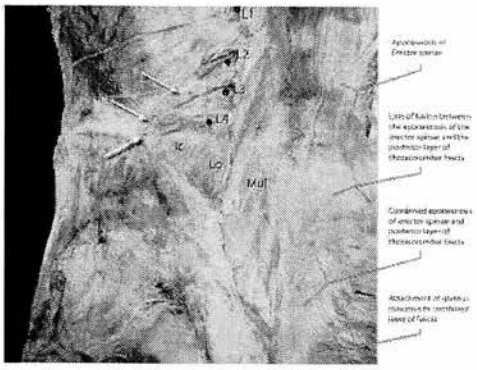


Figure 4 Dissection of the aponeurosis of the transversus abdominis II. In this view additional bands of the iliocostalis (Ic) and longissimus (Lo) have been removed to expose the underlying layer of fascia. This fascia is termed the middle layer of the thoracolumbar fascia and is derived from the aponeurosis of the transversus abdominis.

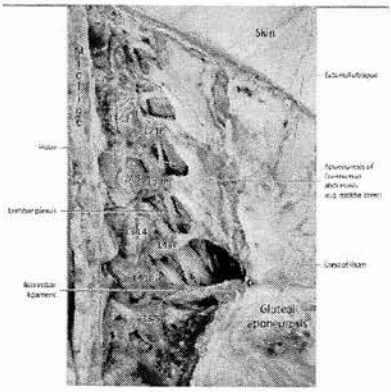


Figure 5 Deep dissection of the aponeurosis of the transversus abominis. The erector spinae muscles and the multifidus have been complete removed to expose the facet joints, transverse processes and the aponeurosis of the transverse abdominis. This portion of the aponeurosis of the transversus abdominis is termed the middle layer of the TLF. The ventral rami of the lumbar plexus and the psoas muscle can be seen deep to the arches of the aponeurosis of the transversus abdominis.

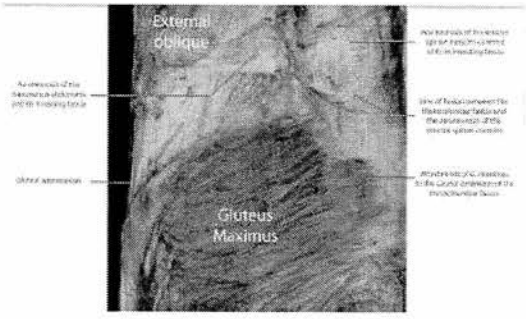


Figure 6 Superficial dissection of the gluteal region. The skin and subcutaneous fascia have been removed to reveal the attachment of the gluteus maximus and the gluteal aponeurosis. In addition the aponeurosis of the latissimus dorsi has been removed to expose the aponeurosis of the erector spinae muscles. A curved line is seen on the aponeurosis of the erector spinae muscles where it fused inseparably with the aponeurosis of the latissimus dorsi. This combined or fused portion of the TLF lies at the level of PSIS and below.

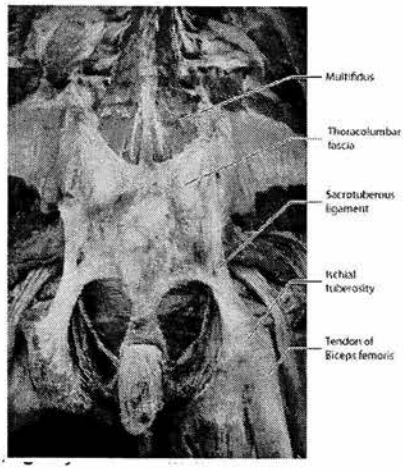


Figure 7 A deep dissection of the gluteal and sacral region. The gluteus maximus and medius have been removed. The multifidus is seen lying between the two ilia at the level of PSIS. The TLF covering the multufidus is seen to be continuos with the outer layer of the sacrotuberous ligament.

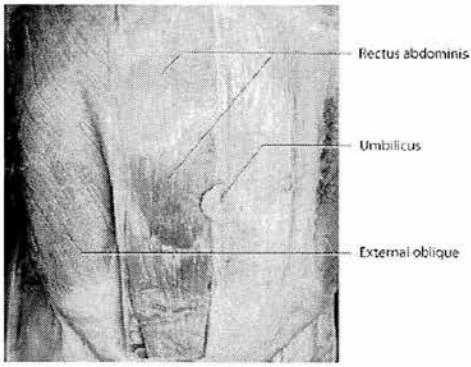


Figure 8 A superficial dissection of the anterior abdominal wall. The external oblique is seen to form an aponeurosis that subsequently contributes to the rectus sheath. These is a similarity between this relationship and the splitting of the aponeurosis of the transversus abdominis to surround the quadratus lumborum and the paraspinal muscles (See Figure 9).

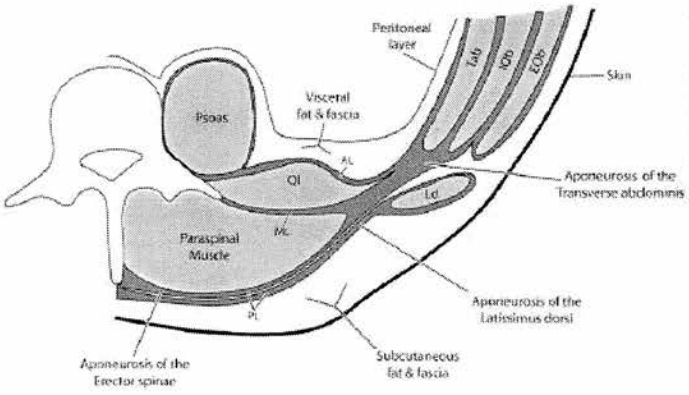


Figure 9 An axial plane diagram of the aponeurosis of the transversus abdominis in the lumbar region. The aponeurosis the atissimus dorsi is seen to overlie the aponeurosis of the erector spinae muscles. A thin layer of investing fascia, termed an epitenon, separates these two structures.

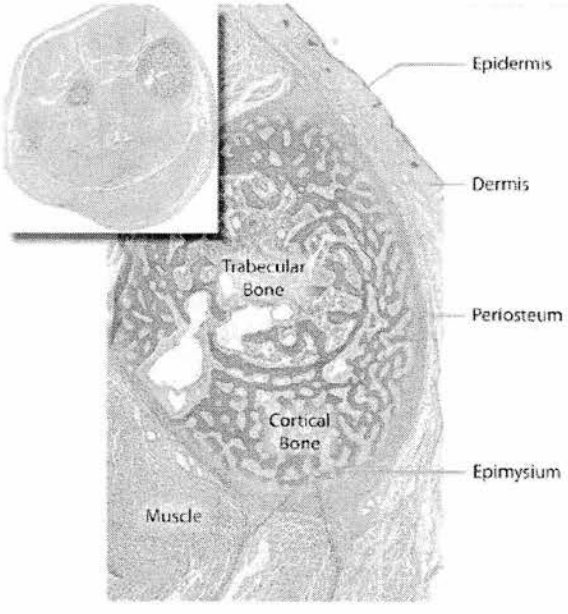
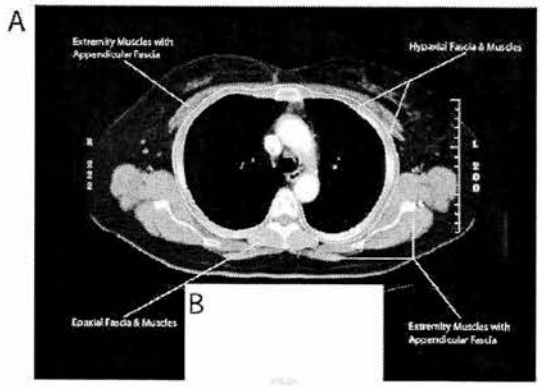


Figure 10 A histological section taken through a fetal limb. (Section from the University of Michigan Histology Website). This section demonstrates the continuity between investing fascias such as the epimycium of muscle and the periosteum of bone.



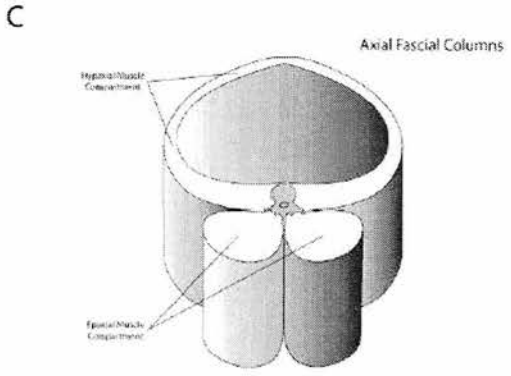


Figure 11 The axial cylinders of fascia surrounding the human torso. Image A is a axial plane CT scan of the thorax. Image B is a diagram outlining the hypaxial and epaxial cylinders of fascia surrounding the torso. Finally, image C is a hree dimensional model of these two fascial columns. The vertebral column is the midline junction of the two fascial columns.

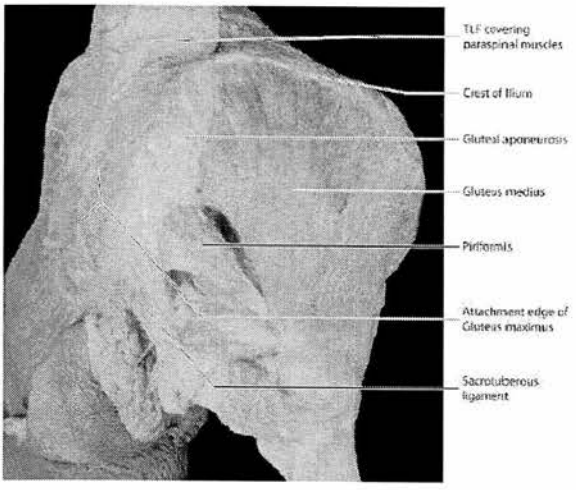


Figure 12 A posterior oblique view of a deep dissection in the gluteal region. The gluteus maximus has been removed. s dissection demonstrates the continuity of the TLF with the gluteal aponeurosis and with the scarotuberous ligament.

Figure 13 An axial plane CT scan of a male pelvis pproximately at the level of PSIS. The sacroiliac join is indicated by the two opposing black arrows. The body of the multifidus muscle is seen between the two ilia. The TLF covering the multifidus is indicated by the double curved line. This portion of the TLC is composed of the fused aponeuroses of the erector spinae and the latissimus dorsi (see text for further explanation).

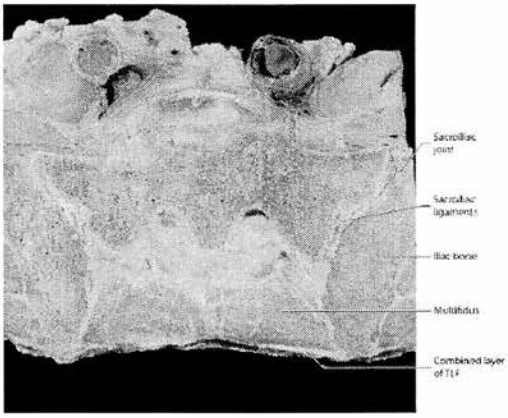


Figure 14 An axial plane section taken through the sacrum demonstrating the multifidus muscle with the overlying layer of TLF. This portion of the TLC is composed of the fused aponeuroses of the erector spinae and the latissimus dorsi.

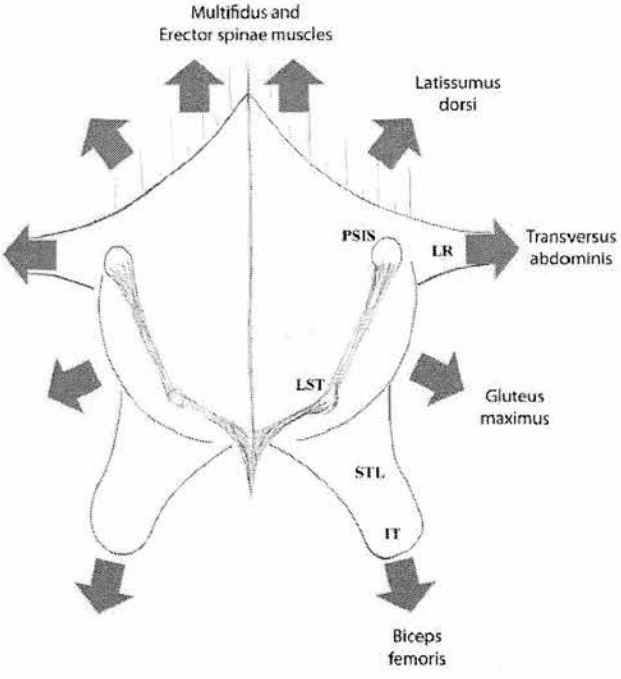


Figure 15 Model of the TLF and its ssociated muscle and aponeuroses. This is a posterior view of the sacral region. The TLF and its associated aponeuroses have been dissected off of the pelvis and flattened in the schematic diagram. The central region of the diagram represents the combined region of the aponeuroses that contribute to the TLF. This region is the thickest and best positioned to resist lateral movements of PSIS. The posterior superior iliac spine (PSIS) and the lateral sacral tubercle (LST) are shown to be connected by the long dorsal sacroiliac ligament. The aponeurosis of the Transversus abdominis forms the lateral raphe (LR) and the sacrotuberous ligament (STL) is seen ending on the ischial tuberosity (IT).

References

1. Clemente CD. 1985. Gray's Anatomy of the Human Body. Philadelphia: Lea & Febiger.
2. Gray H. 1948. Anatomy of the Human Body. 25th ed. Philadelphia: Lea & Febiger.
3. Hu H, Meijer OG, van Dieen JH, Hodges PW, Bruijn SM, Strijers RL, Nanayakkara PW, van Royen BJ, Wu W, Xia C. 2010. Muscle activity during the active straight leg raise (ASLR), and the effects of a pelvic belt on the ASLR and on treadmill walking. J Biomech 43(3):532-9.
4. Pel JJ, Spoor CW, Pool-Goudzwaard AL, Hoek van Dijke GA, Snijders CJ. 2008. Biomechanical analysis of reducing sacroiliac joint shear load by optimization of pelvic muscle and ligament forces. Ann Biomed Eng 36(3):415-24.
5. Standring S. 2008. Gray's Anatomy, The Anatomical Basis of Clinical Practice. 40th ed. Edinburgh: Elsevier Churchill Livingston.
6. van Wingerden JP, Vleeming A, Buyruk HM, Raissadat K. 2004. Stabilization of the sacroiliac joint in vivo: verification of muscular contribution to force closure of the pelvis. Eur Spine J 13(3):199-205.
7. Vleeming A, Pool-Goudzwaard AL, Stoeckart R, van Wingerden J-P, Snijders CJ. 1995. The posterior layer of the thoracolumbar fascia: its function in load transfer from spine to legs. Spine 20(7):753-8.