Variable space distribution of the structures forming the muscle and fascia system in the lumbar region of trunk. Implications in the biomechanics of trauma and legal medicine

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Abstract: The dissection of dorsal regions of trunk on embalmed cadavers, offered the authors the opportunity to point out the variable space distribution of the muscle and fascia structures in the lumbar region. The authors noticed the existence of a discrepancy between the classic descriptions and their personal observation and thus, consider that: 1. the muscle fascicles of the common sacral-lumbar muscle mass have a layer by layer lamellar space distribution with direct insertions on transverse processes and secondary insertions on spinous processes of vertebrae; 2. fascia and aponeurosis structures that take part to the formation of regional osseous-fibrous comoartments converge to a “fascia knot” located at the lateral border of lumbar muscles together with the posterior aponeurosis of abdominal muscles and of latissimus dorsi muscle. Implications of lumbar muscle and fascia system in the static and biomechanics of trauma as well as forensic implications are discussed.

Key Words: trunk, fascia and muscle structures, biomechanics.

The action of mechanical forces on human body frequently determines reactions from muscle and fascia system in the dorsal region of trunk. The contraction of back muscles that is secondary to those forces, contributes to sufferance of thoracic-lumbar spine with implications in the biomechanics of vertebral and medullar trauma. The purpose of the paper is to draw the attention towards the particular space distribution of the muscle fiber fascicles and on their relations to the osseous, fascia and aponeurosis structures in the lumbar region of trunk.

The lumbosacral musculature is classically described as a compact, strong muscular mass, located in the lumbosacral region and representing the incipient portion of the erector spinae muscles[1, 2]. The origins of its muscular fascicles are described as being on the spinous processes of the last lumbar vertebrae, on the median sacral crest and the back of the sacrum, on the posterior third of the iliac crest and on the deep side of the thoraco-lumbar fascia (lumbosacral aponeurosis, lumbosacral fascia, thoraco-lumbar aponeurosis: denomination difference depending on the author)[2-5]. A common view the authors share with the classical literature is describing the strong cranial insertion of the muscle fascicles on the outer posterior regions of the last ribs, continued with the muscular columns (iliocostal, longissimus, and spinal)[6, 7]. The latter ones go along the rib cage and the vertebral grooves up to the cervico-cephalic region, maintaining the straightness of the spine and of the trunk itself. There were also no dissenting discoveries regarding the quadratus lumborum muscle.

The fascial system partitioning the lumbar region, together with the lumbar spine, creates osteofibrotic pouches in which the muscles of the lumbar region

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are comprised and at the same time separated among themselves[8, 9]. These fasciae are described in the human anatomy literature[10, 11], as well as in some of the surgical literature[12, 13], as arising from the lateral edge of the lumbar musculature, from where they are continuing the posterior aponeuroses of the broad abdominal muscles. According to these classical descriptions, the posterior aponeuroses of the broad abdominal muscles, once reaching the lateral edge of the lumbar muscles, remain overlapped with one another, keeping their individuality and being fixed together through fibrous connective tracts. The external abdominal oblique muscle is described in the literature as having no posterior aponeurosis[2, 4]. Posterior aponeurosis of internal abdominal oblique muscle would pass over the posterior side of the lumbosacral muscle mass, getting inserted between it and the latissimus dorsi muscle aponeurosis and also inserting on the spurious processes tips of the lumbar vertebrae. Only the posterior aponeurosis of the transverse abdominal muscle would suffer a triplication. A layer of this triplication would insert up to the spinous processes level, passing between the posterior aponeurosis of internal abdominal oblique muscle and the posterior face of the lumbosacral muscle mass; the middle layer of this triplication would insert between the anterior face of the lumbosacral muscle mass and the posterior side of the square lumbar muscle to the lumbar transverse apophyses on which they get inserted; the third layer of triplication would insert between the front of the square lumbar muscle and psoas muscle, from which it derives the fascia that passes in front of the psoas muscle. The posterior superficial fascial system of this region entered the literature under different names by different authors, including thoraco-lumbar aponeurosis, thoraco-lumbar fascia, and lumbosacral fascia[2, 4, 5, 7]. Following the results of dissections and micro-anatomical exams we will make some observations which represent the views of this paper’s authors.

MATERIALS AND METHODS

We dissected seven refrigerated corpses, preserved with a mixture of glycerin, ethanol, and phenol. Three cadavers were between 25 and 30 years old at time of death, and 4 cadavers were between 50 and 70. Pictures were acquired with a Sony DSC-N1, 8.1 megapixels camera and a Sony DCR-HC-28 camcorder. Some fragments were collected (for staining and micro-anatomical study) from the lateral edge of the lumbar musculature, where the fascial system elements are very adherent to each other. The fragments’ sections were performed in the transverse plane along the longitudinal axis of the trunk. The fragments were fixed in 10% buffered formalin and enclosed in paraffin, then hematoxylin and eosin (H&E) stained. Micro-anatomical images were acquired with a NIKON EOS 600 microscope and image processing was performed with Lucia Net software.
Figure 1. A-D: Stratigraphic dissection; E-H: Fascial node; E: 1. Aponeurosis of latissimus dorsi muscle; 2. Posterior aponeurosis of external oblique muscle; 3. Aponeurosis of internal oblique muscle; 4. Aponeurosis of transversus abdominis muscles; 5. Fascial “knot”; 6, 8, 9. Fascia derived from the fascial knot; 7. Sacrum-lumbar fascia of common lumbar muscle mass; 10. Common lumbar muscle mass; 11. Quadratus lumbarum muscle; 12. Psoas muscle; F-G: 1. Bundles of muscle fibers; 2. Collagen fibers; H: 1. The point of junction the connective tissue fibers diverge in a fan-like shape, including in its structure areas of muscular tissue. A-D: Macrophotographs taken with Sony DSC-N1, 8.1 megapixels Camera and a Sony DCR-HC-28 camcorder. E-H: Microanatomical images were acquired with a Nikon EOS 600 Microscope and image processing was performed with Lucia Net Software.
latissimus muscle. Its lower and medial points of insertion coincide with those of the superficial aponeurosis. The upper side is continued with muscle fascicles; its irregular superior-lateral outline shrinks quite quickly toward the spine and upward it doesn’t reach the upper limit of the superficial aponeurosis. (Fig. 1A) The lateral edge of this fascia extends neither to the lateral edge of the lumbar musculature nor to the interfascial adherence situated at this level. Some authors call this the tendinous fascia of the lumbosacral muscle mass. Its connective fibers are parallel to each other and from the bottom up, a totally different direction from that of the connective fibers of the two fascial elements which are superimposed in the superficial plane overlying its surface. The origin of its own connective fascicles, their direction, their upper limit and their consistency determined us to consider this fascia as the true lumbosacral fascia.

Longitudinal sectioning of this fascia, parallel to the lumbar spinous processes tip approximately half an inch lateral to them, reveals how the muscular fascicles of the lumbosacral muscle mass are structuralized in depth. Stratigraphically, they are arranged in a lamellar fashion from the surface into depth, like other muscles that produce a strong and over-sufficient contracture (e.g., the masseter muscle) (Fig. 1B: 1. Sacral-lumbar common muscular mass, paramedian sectioned. It can be observed the lamellar stratigraphic disposition of component muscle fascicles; 2. Deep aspect of latissimus dorsi muscle aponevrosis; 3. Transverse-spinous muscles). In addition, we noticed a very easy cleavage plane consisting of a layer of lax connective tissue between the medial side of the lumbosacral muscle mass and the lateral side of the spinous processes with the transverse-spinous muscles (Fig. 1C: 1. Sacral-lumbar common muscular mass, covered by the sectioned sacral-lumbar fascia, laterally tractioned; 2. Medial fascicle, kept from common sacral-lumbar mass; 3. Transverse-spinous muscles; 4. Connective lax tissue (detail) interposed between medial aspect of sacral-lumbar common muscular mass and transverse-spinous muscles).

This cleavage plane covers the entire medial face of the lumbosacral muscle mass, separating it from the transverse spinal muscles, beginning from the sacrococcygeal region, right up to the T12-L1 spinous processes. In the lower portion, the origin of the muscle fascicles of the lumbosacral muscle mass occupies the lateral side of the posterior face of the sacrum and the posterior third of the iliac crest, the medial portion of the posterior face of sacrum being occupied by the origin of the fascicles of a strong transverse-spinous muscle. This has a triangular shape pointing up toward the lumbar spinous processes (Fig. 1D: 1. Deep aspect of sacral-lumbar aspect; 2. Sacral lumbar common muscular mass sectioned and folded cranial and caudal; 3. Transverse-spinous muscles; 4. Costal apofisis where deep medial fascicles of sacral-lumbar common muscular mass, have been sectioned; 5. Lumbar quadratus muscle covered by thoracic-lumbar fascia; 6. Inferior border of thoracic-lumbar fascia; 7. Lumbar-costal ligament; 8. Fibrous raphe, where fascias that originater from anterior-lateral join closely toghether, then trifurcate in order to participate in the formation of costal-fibrous lodge of sacral-lumbar common muscular mass; 9. Posterior fascicles of external oblique muscle).

From the deep lumbosacral fascia, muscle fascicles of the superficial plane of lumbosacral muscle mass are quite easy to dissect, except some areas with transversal trajectory (Fig. 1D). In the case of a preserved, prone-positioned cadaver, these linear areas of muscle fascicles insertion determine the formation of linear depressions on the superficial face of the lumbosacral fascia (Fig. 1A). We believe this type of insertion of muscle fascicles supports the hypothesis that the role of lumbosacral fascia is more to partially cover and to “anchor” the lumbosacral muscle mass at the tip of the lumbar spinous processes and at the median sacral crest. As a result, we consider that it stabilizes the spinous processes during lumbosacral muscle mass contracture, dissipating the strong contraction force way from them. Entering through the plane of cleavage and lifting the medial face of the lumbosacral muscle mass laterally, we discover very strong fascicular insertions of the lumbosacral muscle mass on the lumbar transverse processes. From the posterior costal edge cranially, these muscular fascicles get continued with muscle columns (iliocostal, longissimus, spinal), concurrent with classical descriptions.

Sectioning and lifting the lumbosacral muscle mass caudally and cranially, we came along a very strong fascia that separated the front of the lumbosacral muscle mass from the posterior face of the square lumbar muscle. It derives from the lateral edge of the lumbar musculature, where all the regional fascial system components are very adherent and impossible to be dissociated from one another. The authors called this place the fascial "node". Medially, this fascia inserted on the lumbar transverse processes, and cranially on the XIIth rib. Its lower edge doesn’t get to the iliac crest (as classically described), being unable to make a complete separation between the fascicles of the lumbosacral muscle mass and those of the lumbar square muscle. Thus, in the lower portion, the fascicles (that originated from the iliac crest) of the two muscles are interwoven, forming at this level a unitary, whole, compact mass. Considering the limits and consistency of this fascia, we consider it to be legitimately called “thoracolumbar fascia”, name attributed sporadically by some authors, while others often use this term in a more comprehensive way to include the lumbosacral fascia and the dorsal aponeurosis (thoracolumbosacral), which belongs to the latissimus dorsi. In the classical anatomical literature [1, 2, 4], this fascia is treated as representing the middle layer of the posterior aponeurosis triplication of the transverse abdominal muscle. A third fascial layer thinner than the previous one (as classically described) starts from the lateral margin of the lumbar musculature and passes in front of the lumbar square muscle up to the vertebral column,
the fascial layer that passes in front of the psoas muscle also deriving from it. This fascial layer is described in the literature as the anterior sheet of the posterior aponeurosis triplication of the transverse abdominal muscle.

We believe the following to be valid assumptions derived from these stratigraphic dissections. The posterior aponeuroses of the broad abdominal muscles get to the lateral edge of the lumbar musculature at this level the muscle fascicles of the latissimus dorsi continue all of a sudden with its aponeurosis, which is very adherent to the subjacent fascial system at this point; in this particular place, all aponeuroses reaching the lateral margin of the lumbar musculature are impassably adherent among themselves. This place is the starting point for three aponeurotical layers of different consistency and strength, reaching the vertebral column and with it creating true osteofibrotic pouches which partition and include the muscles bearing different names. The anatomy literature maintains these three aponeurotic layers are continuing the posterior aponeuroses of the broad abdominal muscles up to the vertebral column and these posterior aponeuroses, at the lateral edge of the lumbar musculature, would remain overlapped between them maintaining their individuality and being fixed together by fibrous tracts. However, this type of arrangement should provide a very easy separation through dissection between them. Moreover, in the case of a very strong contraction developed by the lumbar musculature in a living person, their dissociation would be almost inevitable.

In order to understand the way of action of this fascial system at the lateral edge of the lumbar musculature, we performed serial histological sections, using common stainings (H&E), in the transversal plane on the longitudinal axis of the trunk from the impassable adhesion area of the fascial system. The proposed “fascial node” nomenclature was reinforced by the microscopic findings. At 28x, we see the fasciae that reach the lateral margin of the lumbar musculature are accompanied at this level by microscopic muscular fascicles. These muscular fascicles are sectioned under variable angles and bounded in compartments by thick bands of collagen fibers (Fig. 1F: 1. Bundles of muscle fibers cut at various angles; 2. Collagen fibers). At 70x, we notice the helicoidal path of the muscular fascicles which are separated between them by connective tissue strips, which follow the helicoid path of the muscular fascicles.

Back at 28x, we observe a musculo-connective structure belonging to the incipient portion of the latissimus dorsi muscle aponeurosis (thoracolumbosacral aponeurosis) (Fig. 1G: 1. Muscular and connective tissue structure belonging to the aponeurosis of the latissimus dorsi muscle); the fascicles of this structure retain the same spatial spiroid arrangement and after describing an arc of a circle they are heading toward the junction site with the musculo-connective fascicles previously described. At the junction site, the fibrous fascicles are divergently distributed in a fan shape, including islands of muscle fascicles (Fig. 1H: 1. At the point of junction, the connective tissue fibers diverge in a fan-like shape, including in its structure areas of muscular tissue). In this manner it is accomplished a fusion of structures that come and go from this fascial "node", at its level the constitutive fibrous connective elements having a spiroid spatial arrangement in different planes.

These micro-anatomical exams prove that the posterior aponeuroses of the broad abdominal muscles at the edge of the lumbar musculature lose their individuality, and their fibrous and microscopic muscular fascicles are three-dimensionally "interwoven" with each other in a fascial "node". The fibrous fascicles from the initial lateral portion of the latissimus dorsi muscle aponeurosis also join this "weave", before they are individualized medially up to the medio-spinal line as the thoracolumbosacral dorsal aponeurosis. From this fascial “node” are going in a individualized way towards the medial, up to the vertebral column, the three aponeuroses layers classically described as being in continuation of the posterior aponeuroses of the broad abdominal muscles and which partition the lumbar region musculature, maintaining it into osteofibrotic pouches. It is true that the fibrous fascicles of these aponeurotical layers derive from the fibro-connective fascicles of the posterior aponeurosis of the broad abdominal muscles, but the micro-anatomical exams do not show that their individuality would continue the individuality of these aponeuroses. After having the lumbar musculature structuralized as a musculature that develops strong and over-sufficient contraction, we consider it is precisely the existence of this fascial "node" on the lateral edge of the lumbar musculature which prevents dissociation of the aponeuroses during muscle contraction, and the presence of the fasciae derived from the fascial "node" maintain the musculature in the osteofibrous pouches during contraction.

The strong insertions of the lumbar musculature are on the posterior third of the iliac crest and on the transverse processes of lumbar vertebrae and less on the spinous processes. On the spinous processes they are only "hooked" through the tendinous fascia of the lumbosacral musculature joint (the true lumbosacral fascia in the authors’ opinion), their insertion on the deep side of the fascia being quite light, contrary to any expectations and classical descriptions. Moreover, between the medial side of the lumbosacral muscle mass on the one hand and the lateral side of the spinous processes with transverse spinal muscles on the other hand, there are no adhesions but an easy cleavage plane occupied by lax connective tissue. As a result, we consider that, during the lumbosacral muscle mass contraction, the strong action is exerted on the transverse processes and less on the spinous processes. This type of structuralization would explain the high frequency of lumbar spine pathology in individuals who are making extended efforts in different situations of motion or body positioning, as well as in those who develop prolonged stationary contracture. The existence of the cleavage plane
between the medial side of the lumbosacral muscle mass and the lateral face of the spinous processes, could allow an easy access to the vertebral blades with minimal tissular destruction and dissociation of the transverse-spinous muscles, in the case of making a longitudinal incision of the lumbosacral fascia, approximately 1 to 1.5 cm (half an inch), para-sagittal to the tip of the spinous processes.

References


CONCLUSIONS

The structuralization of the lumbosacral muscle mass allows a strong and over-sufficient contracture in the lumbar region, which acts strongly on the transverse and less on the spinous processes.

Knowledge of an existing cleavage plane between the medial face of the lumbosacral muscle mass on one hand, and the lateral side of the spinous processes with transverse-spinal muscles on the other hand, allows for an easier and smoother surgical approach of the vertebral blades with minimal tissue destructions.

In the authors’ opinion, the regional fascial system partitioning the lumbar musculature into osteofibrotic pouches, derives from a fascial “node” situated at the lateral margin of the lumbar musculature, the meeting place for the posterior aponeuroses of the broad abdominal muscles.

We propose an alternative nomination for the fascial system of the lumbar region (Fig. 1E). The thoracolumbosacral superficial aponeurosis represents the latissimus dorsi muscle aponeurosis; the lumbosacral fascia represents the tendinous fascia of the lumbosacral muscle mass, as classically described; the thoracolumbar fascia is represented by a fascia of considerable consistency, derived from the fascial “node”, which passes through the anterior side of the lumbosacral muscle mass and the posterior side of the lumbar square muscle unto the lumbar transverse processes on which it inserts.

Whether this kind of musculo-fascial structuralization is ubiquitous or only of a certain frequency, it will be determined by subsequent studies. Depending on future works, more in-depth reconsideration of bio-dynamic studies could prove necessary both for knowledge and prevention of lumbar spine pathology in certain categories of individuals, as well as for innovation in rehabilitation medicine.