Journal of Bodywork & Movement Therapies (2013) 17, 512—517

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FASCIA SCIENCE AND CLINICAL APPLICATIONS: HUMAN ANATOMY

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The anatomical and functional relation between gluteus maximus and fascia lata

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Received 1 September 2012; received in revised form 10 March 2013; accepted 4 April 2013

KEYWORDS
Gluteus maximus;
Myofascial insertion;
Fascia lata;
Iliotibial band

Summary There is not full agreement regarding the distal insertions of the gluteus maximus muscle (GM), particularly the insertions into the iliotibial band and lateral intermuscular septum. 6 cadavers, 4 males and 2 females, mean age 69 yr, were dissected to evaluate the insertions of the GM into the iliotibial band, fascia lata, lateral intermuscular septum and femur. The iliotibial band is a reinforcement of the fascia lata and cannot be separated from it. Its inner side is in continuity with the lateral intermuscular septum, which divides the quadriceps from the hamstring. In all subjects the gluteus maximus presented a major insertion into the fascia lata, so large that the iliotibial tract could be considered a tendon of insertion of the gluteus maximus. The fascial insertion of the gluteus maximus muscle could explain the transmission of the forces from the thoracolumbar fascia to the knee.

Introduction

In the literature, GM is described as the largest muscle of the human body (Standring, 2008; Encyclopædia Britannica, 2011; Van de graff 2002) having various functions (Eizenberg et al., 2008). Some studies have identified GM as having the largest capacity for external rotation of

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http://dx.doi.org/10.1016/j.jbmt.2013.04.004

the hip thanks to its insertion into the linea aspera of the femoral bone (Janecki, 1977; Preece et al., 2008). For Lieberman et al. (2006) fibers from the more cranial sites of origin primarily end in a thick laminar tendon that inserts on the iliotibial tract. The activity of the cranial portion is 'considerable' increases during jogging and running (Stern et al., 1980). Other studies have identified a role in hip flexion due to the insertion of the GM in the iliotibial tract (Sahrmann, 2002; Jonkers et al., 2003).

For Benninghoff (1994) the most important insertion of GM is the iliotibial band. Stern found that some fibers from deeper portions of the muscle insert onto the gluteal ridge of the femur, generally on the proximal 25% of the femur (Stern, 1972). If this is confirmed, the real function of GM has to be modified. Indeed the latest studies suggest the iliotibial band is just a reinforcement of the fascia lata (Stecco et al., 2008; Fairclough et al., 2006). Also for Terry et al. (1986) the iliotibial tract has to be considered together with the fascia lata, the lateral femoral intermuscular septum and the crural fascia as creating a combined musculo-ligamentous unit. Gerlach and Lierse (1990) also found that the lateral femoral intermuscular septum collaborates in the muscular force transmission to the bone.

It is evident that GM has various functions according to the fibers involved in the contraction. This previous Author report a complex function of the GM that are not possible to explain through the current anatomical description of its insertions.

The purpose of this study was to analyze the distal insertions of GM in embalmed cadavers to better understand how many fibers insert into the fascia lata, iliotibial tract and lateral intermuscular septum and ultimately understand if GM could be considered also a fascial tensor. This hypothesis is supported by Lieberman et al. (2006) who described that fibers from the more cranial sites of origin primarily end in a thick laminar tendon that inserts on the iliotibial tract.

Materials and methods

6 cadavers embalmed with formaldehyde, 4 males and 2 females, mean age of 69 years, were dissected on the posterior side of the thigh. All of the cadavers displayed normal skin appearance, without evidence of lesions over the thigh. The dissection was performed sequentially by layers. First, we removed the skin, tela subcutanea and the subcutaneous fat to reach the surface of the deep fascia or fascia musculorum. We dissected the deep fascia of the GM to evaluate the characteristics of this fascia and its relations with the muscle in the different areas. Then, a vertical incision of the GM belly was performed, from posterior superior iliac spine to ischial tuberosity, to separate the distal portion of the muscle from the proximal insertion. The distal portion of the muscle belly was manually tractioned in a cranial direction to evaluate the effect into the iliotibial tract and to observe whether specific lines of force into the fascia lata could be recognized. A specific dissection to evaluate the surface of insertion of the gluteus maximus into the iliotibial tract, fascia lata, lateral intermuscular septum and linea aspera of femur was then performed. Finally, a separation of the different sub-layers of the fascia lata in the proximal and in the distal portion of the thigh was performed, without the use of a scalpel, to evaluate where it is possible to isolate the single sub-layers and where there is a crossing interchange of collagen fibers.

Result

The gluteus maximus presents a deep fascia that covers both the superficial and deep surfaces of the muscle (Figure 1). This fascia is very thin and adherent to the muscle thanks to many intramuscular septa that depart from the inner surface of the fascia and that divide the muscle in numerous fascicles. To isolate the deep fascia from the muscle it is necessary to cut with a scalpel every single vertical septum of perimysium of the gluteus maximus. The gluteus maximus could be easily divided from the gluteus medius muscle thanks to the presence of a particular fascial structure, formed by a fascia adherent to the gluteus maximus muscle, a fascia covering the gluteus medius muscle and loose connective tissue in the middle. This fascial structure creates a perfect plane for permitting gliding, of the muscular fibers of these two muscles, which have different orientations, to act autonomously. Both fasciae give insertion, in their inner surface, to many muscular fibers of the gluteus muscles.

In all subjects, the fascia of the gluteus maximus muscle is continuous with the superficial layer of the posterior lamina of the thoracolumbar fascia. Distally, it continues with the fascia lata and the iliotibial tract. Medially it adheres to the periosteum of the sacrum, laterally it continues with the fascia of the tensor fascia lata muscle. The fascia lata covers all muscles of the thigh and appears as a thick, whitish layer of connective tissue, similar to an aponeurosis.

The fascia lata present a thicker region in the lateral and posterior-lateral side and it continues distally with the crural fascia. The fascia lata is easily separable from all the muscles of the thigh thanks to a virtually uninterrupted plane of loose connective tissue between the fascia lata and the muscle bellies, surrounded by their epimysium. There are three exceptions to this rule. In the distal thigh, the fascia lata gives origin to some muscular fibers of the vastus lateralis, with a mean value of 3 cm, (Figure 2a) and medialis, present in 100% of the surface of all the subjects evaluated (Figure 2b). The fascia lata also gives a small myofascial origin to the biceps femoris with a mean value of 4.25 longitudinal $\times$ 2.5 cm transversal (Figure 2c, Table 1).

In all subjects the vastus medialis presented a complete adhesion to the perimysium in the fascia lata along its entire surface. Strong intermuscular septa originate from the inner surface of the fascia lata and extend between the muscle bellies dividing the thigh into different compartments. The iliotibial tract is just a lateral reinforcement of the fascia lata, it is not possible to find a line of separation. On the posterior side, the majority of collagen fibers of the iliotibial tract are in continuity with the intramuscular septa that divide the quadriceps from the hamstring. The majority of muscular fibers of the gluteus maximus insert into the fascia lata, in particular at the level of the iliotibial tract, and into the lateral intermuscular septum (Figure 3).

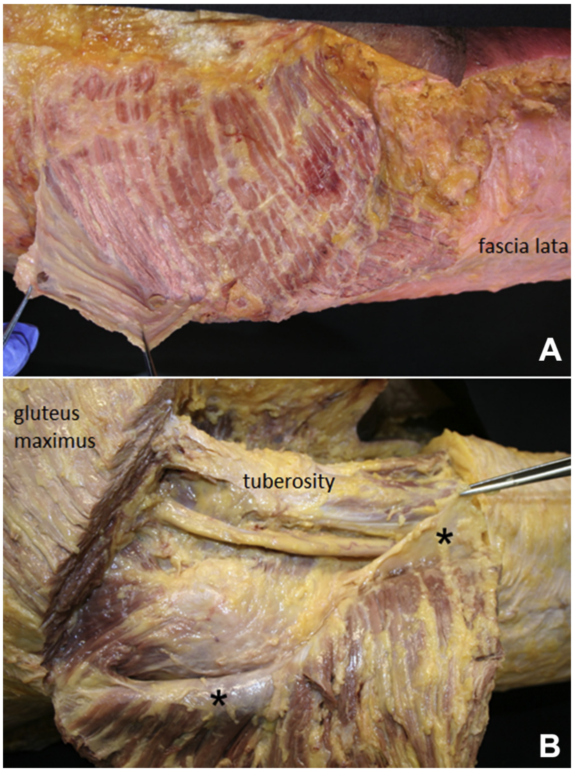

Figure 1 Posterior view of the left gluteus maximus and its fascia. In A: the deep fascia is adherent to the superficial surface of the gluteus maximus muscle thanks to the presence of many intramuscular septa. In this picture, the fascia has been sharply dissected to release the septa and allow reflection proximally and laterally at the lower left corner. In B: the gluteus maximus was cut and reflected distally and laterally. It is evident that there is a deep fascia (highlighted with an asterix) that is adherent to the inner surface of the gluteus maximus muscle. This fascia creates a plane of gliding between the gluteus maximus and the underlying structures.

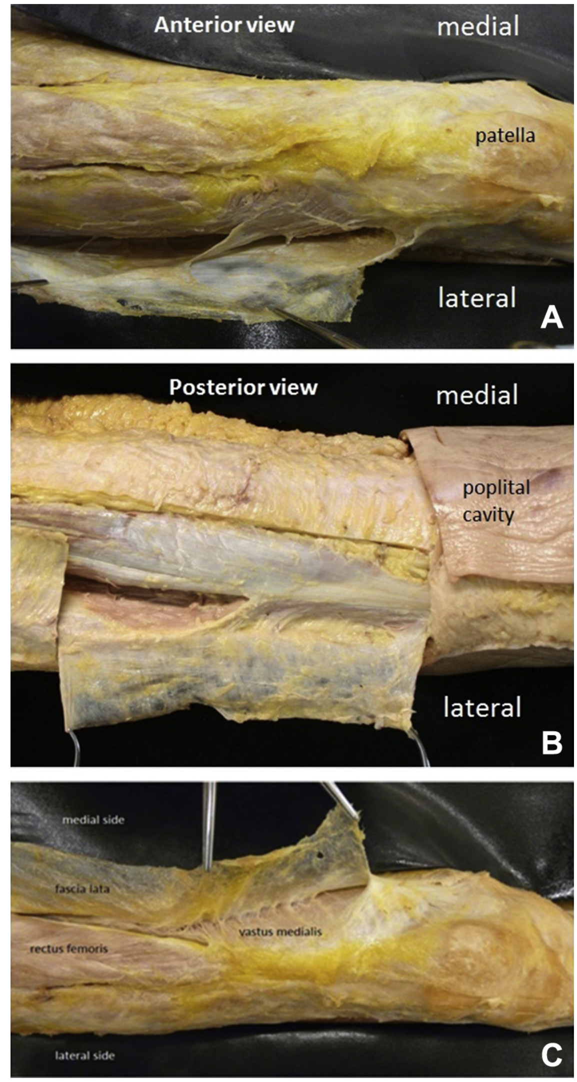

Figure 2 A: Anterior view of a right thigh (knee joint at right side) showing the myofascial origin of the vastus lateralis muscle from the inner surface of the fascia lata. B: Posterior view of a right thigh showing the myofascial origin of the biceps femoris muscle from the inner surface of the fascia lata. C: Medial view of the right thigh showing the continuity between the perimysium of the vastus medialis with the fascia lata.

In two subjects, some muscular fibers of the gluteus maximus merged in the aponeurotic portion of the vastus lateralis muscle. This area of insertion was 3.75 cm2 (1.5 cm in longitudinal direction, 2.5 cm in transversal direction) and was in the proximal-lateral surface of the vastus lateralis muscle (Table 2).

Distally, the iliotibial tract is attached to the lateral condyle of the tibia (Gerdy's tubercle), but it also provides an oblique myofascial expansion that passes over the patella, contributing to form the anterior knee retinaculum and stretching the crural fascia in a latero-medial direction.

Analysing the macroscopic aspect of the fascia lata, it is possible to see the multiple directions of the fibrous bundles forming the fascia. With a careful dissection, in the proximal third of the lateral side of the fascia lata, the two or three sub-layers of dense connective tissue that form the fascia could be divided and evaluated separately. This is possible thanks to the presence of thin layers of loose connective tissue that create a gliding system between these fibrous layers (Figure 4). In contrast, the distal two-thirds of the fascia lata can only be separated using sharp dissection. This is due to the presence of multiple collagen fibers that cross the layers.

Discussion

Our dissections seem to demonstrate that the gluteus maximus muscle is involved in transmitting only a small part of its force to the linea aspera of the femur via the lateral intermuscular septum, but also to a broad surface composed of the fascia lata, the iliotibial tract and the lateral intermuscular septum. This result confirms the previous description of Stern (1972). Thanks to the distal insertions of the iliotibial tract, the GM could be considered also an important vector for knee movements. The anatomical continuity could support the theory that the

Table 1 Myo-fascial insertion between medial third of the lateral side of the vastus lateralis and fascia lata (column A); distal third of the lateral side of the biceps femoris and fascia lata (column B).

Subjects	Myo-fascial insertion of the fascia late (+/− 0.5 cm)	Distal third of the lateral side of the biceps femoralis (in cm^2 longitudinal × traversal)
1 sx	2	4 × 2
1 dx	2.5	4 × 2
2 sx	4	5 × 2.5
2 dx	4	5 × 2.5
3 sx	1.5	3.5 × 3
3 dx	1	3.5 × 3
4 sx	4.5	5 × 3
4 dx	4	5 × 3
5 sx	2.5	4 × 2.5
5 dx	2.5	4 × 2.5
6 sx	3.5	4 × 2
6 dx	3.5	4 × 2

Table 2 Distal insertions of the gluteus maximus.

Subjects	Gluteus maximus insertion (+/− 0.5 cm)		
	Area (in cm^2)		Longitudinal surface (in cm)
	Proximal part of the linea aspra	Lateral portion proximal part of the vastus lateralis	Fascia lata (include the ileo tibial b and)
1 sx	1 × 1.5	0	7
1 dx	1 × 1.5	0	7
2 sx	0.5 × 1	1.5 × 2	5
2 dx	0.5 × 1	1.5 × 2	5
3 sx	1.5 × 2	0	6.5
3 dx	1.5 × 2	0	6.5
4 sx	1 × 1.5	0	6
4 dx	1 × 1.5	0	6
5 sx	1 × 1.5	1.5 × 3	6
5 dx	1 × 1.5	1.5 × 3	6
6 sx	0.5 × 1	0	7
6 dx	0.5 × 1	0	7

contraction of the GM always affects the iliotibial tract and all the fascia lata. this could explain why a hypertonicity of the gluteus maximus may cause an iliotibial band friction syndrome or, more generally, be related to knee dysfunction. So, in cases of iliotibial band syndrome (ITBS), or more generally in lateral knee pain, we suggest manual examination of the gluteus maximus and the tensor fasciae latae muscles, that are the main tensors of the iliotibial tract. Also Chen et al. (2006) have demonstrated with MRI that gluteal contraction causes a posteromedial displacement of the iliotibial tract, and that the resolution of the ITBS can only be achieved when the biomechanics of hip muscle function are properly addressed. Previous studies have demonstrated the innervation of the fascia lata (Stecco et al., 2007; Tesarz et al., 2011; Yahia et al., 1992). If these fascial receptors are sensitive to stress, it is possible

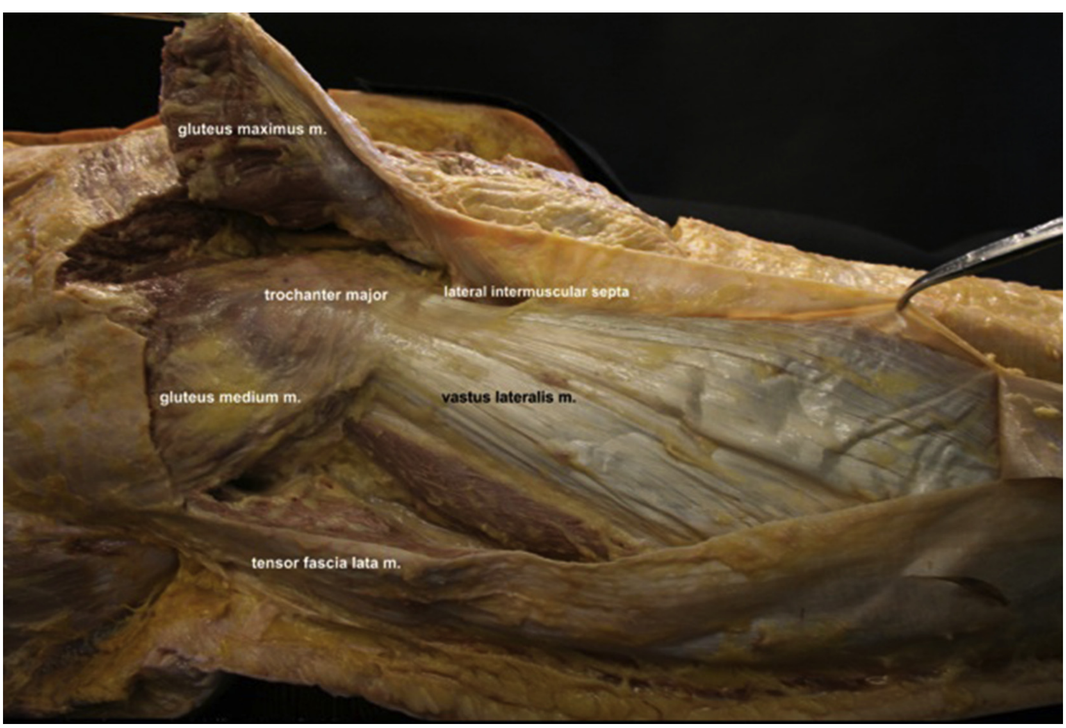

Figure 3 Lateral view of a left thigh with the central portion of the iliotibial tract reflected distally (to the right) showing the gluteus maximus insertion into the fascia lata and into the lateral intermuscular septum. Besides, the tendineous insertion of the vastus lateralis muscle into the great trochanter is clearly evident.

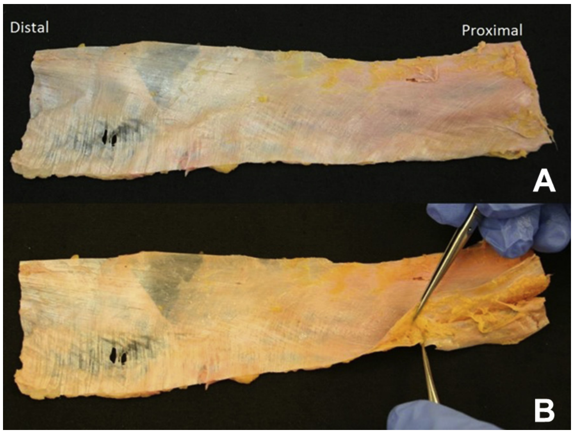

Figure 4 Lateral portion of the fascia lata from a left thigh. The multiple directions of the fibrous bundles forming the fascia lata are evident. In B: In the proximal one-third of the thigh, it is possible to separate the two fibrous layers forming the fascia lata thanks to the presence of loose connective tissue between the two layers.

that hypertonicity of the GM muscle may cause increased tension of the fascia lata, and symptoms that could be confused with a sciatica pain. These anatomical findings could explain the interesting case report presented by Sha et al. (2011) who described a case report of gluteus maximus tendon calcification combined with sciatica pain. The gluteus maximus muscle also has an important insertion into the thoracolumbar fascia, confirming the studies of Vleeming et al. (1995). He showed that the GM is linked anatomically to the lumbar paraspinal muscles via the thoracolumbar fascia, which allows load transfer from the spine to the pelvis (Figure 5). Our findings extend these results from the pelvis to the knee. Thanks to the insertions of the GM into the iliotibial tract and lateral intermuscular septum, the GM becomes important for the mechanical coordination of the lumbar spine, pelvic region and lower limb. So, the fascial insertion of the gluteus maximus muscle could explain the transmission of the forces from the thoracolumbar fascia to the knee, and consequently some types of pain radiation that are not explained from a neurologic point of view. For example, hypertonicity of the GM could explain both increased tension in the lumbar region, causing pain in the low back area, and in the lower limb, above all in the lateral region of the knee.

Figure 5 Distal portion of the thoraco-lumbar-fascia. The collagen fibers of the thoraco-lumbar-fascia are in continuity with the deep fascia of the gluteux maximus.

Conclusion

The distal insertions of the GM are more fascial then osseous. The insertions of GM into the fascia suggest that vastus lateralis and biceps work together to stabilize the part of the fascia lata that forms the intermuscular septum between hamstring and vasti. The septum becomes not a separating element, but it is in continuity with the fascia, to helping the movement coordination. This complex morphology of fascia permit emphasis of the role of the deep fascia in the mechanical coordination of different muscles via its multiple myofascial insertions.

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