The greater trochanter triangle; a pathoanatomic approach to the diagnosis of chronic, proximal, lateral, lower pain in athletes

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ABSTRACT

Chronic pain experienced in the proximal, lateral, lower limb may arise from the femoro-acetabular joint, from the muscles and tendons that act upon it, from any of the structures that traverse the area, and from more remote structures such as the lumbar spine.

The aetiology of pathology in this area is not confined to either trauma or overuse. As a result many different sporting activities may have a causal role.

Without a clear clinical/pathological diagnosis, the subsequent management of chronic groin pain is difficult. The combination of complex anatomy, variability of presentation and the non-specific nature of the signs and symptoms makes the diagnostic process problematic.

The paper proposes a novel educational model based on pathoanatomic concepts. Anatomical reference points were selected to form a triangle, which provides the discriminative power to restrict the differential diagnosis, and form the basis of ensuing investigation.

This paper forms part of a series addressing the three-dimensional nature of proximal lower limb pathology. The 3G approach (groin, gluteal, and greater trochanter triangles) acknowledges this, permitting the clinician to move throughout the region, considering pathologies appropriately.

Proximal lower limb pain is a cause of significant morbidity in athletes.[1–4] Trauma to the hip joint and bony structures of the hip may result in direct injury or chronic degenerative change.[5] Overload or overuse injury of muscle, tendon, ligament or enthesis/apophysis at or around the femoro-acetabular joint may all result in chronic hip pain.

Pain localised to the lateral thigh may represent pathology within the femoro-acetabular joint,[6] or more superficial structures like the iliotibial band[7] or trochanteric bursa. Differentiation of joint pathology from that of the structures responsible for its movement may be difficult due to the complexity of movement at the joint. Radicular pain generated in the axial spine may also complicate an already busy area.[8]

The corollary to this is when pathology arising from the hip joint and structures around it manifests as pain in the groin, buttock and distal leg.[6] We must therefore consider these structures when investigating any proximal lower limb pain.

This paper sets out a method based on pathoanatomic principles for a systematic examination of the chronically painful proximal lateral lower limb. This enables the clinician to discriminate more easily between pathological conditions and target their management to specific diagnoses.

THE GREATER TROCHANTER TRIANGLE

The specific anatomical landmarks and borders of the greater trochanter triangle are set out in fig 1.

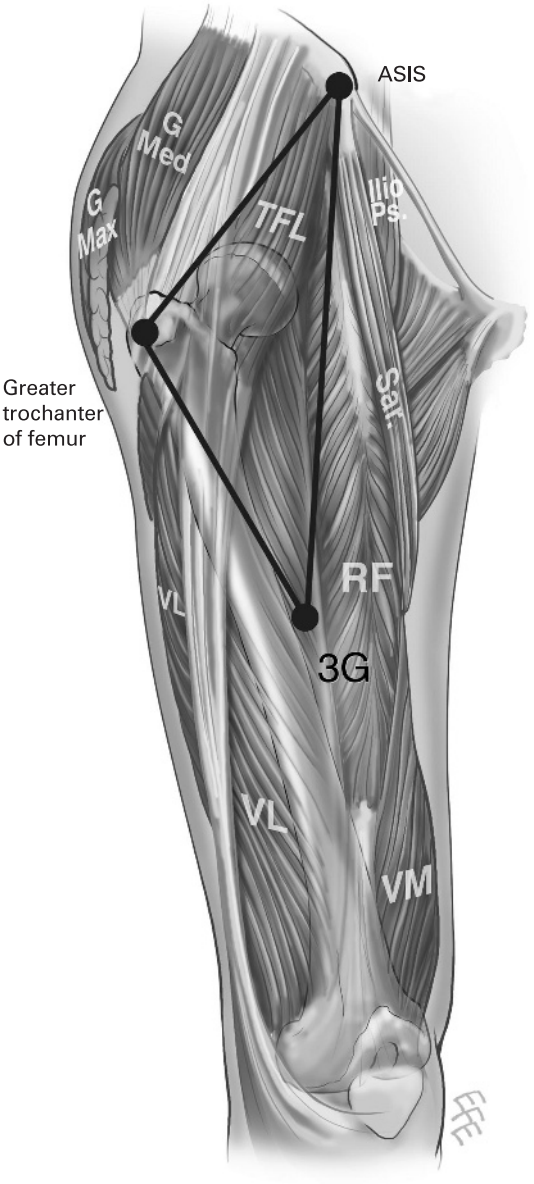

Figure 1 The greater trochanter triangle: ASIS, anterior superior iliac spine; 3G, the 3G point; G Max, gluteus maximus; G Med, gluteus medius; TFL, tensor fasciae latae; Ilio Ps., Iliopsoas; RF, rectus femoris; VL, vastus lateralis; VM, vastus medialis.

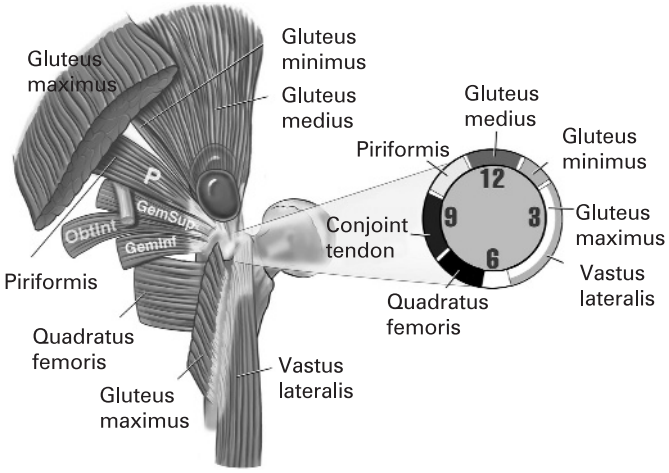

Figure 2 Greater trochanter clock face: P, piriformis; GemSup, gemellus superior; GemInf, gemellus inferior; ObInt, Obturator internus.

Apex points of the groin triangle

- Greater trochanter of femur (GT)
- Anterior superior iliac spine (ASIS)
- 3G point

The 3G point

From anthropometric measurements, the authors defined a new reference point at the apex of the triangle. This point was termed the "3G point" in reference to the three-dimensional pathology and the **g**roin, **g**luteal and **g**reater trochanteric regions. The relationship of this point in the anterior coronal plane was the mid-distance point between ASIS and the superior pole of the patella, and in the posterior coronal plane double the distance from the spinous process of L5 lumbar vertebrae to the ischial tuberosity in the line of the femur.

Anatomical relations of the borders of the greater trochanter triangle

The anterior superior iliac spine (ASIS) is the salient physical landmark when the lower limb is viewed in the lateral decubitus position. From this position, it marks the most anterior projection of the structures responsible for abduction, extension and lateral rotation of the hip, namely the gluteals, and tensor fascia latae. It is the origin of sartorius and the inguinal ligament. The iliac crest and the ASIS together act as anchor points for the thoracolumbar fascia and its continuation the fascia lata of the thigh. Just inferior to the ASIS lies the anterior inferior iliac spine (AIIS), the origin of the rectus femoris muscle. Inferior and anterior to the ASIS, the lateral femoral cutaneous nerve may be compressed as it passes beneath the inguinal ligament.

The greater trochanter of the femur is palpable in most subjects; pain at the trochanter may be localised to one of the structures inserting into it. Palpatory anatomy of these structures is difficult due to the overlying iliotibial band and gluteus maximus. We present a schematic representation of these insertions in fig 2. The authors recognise the variability of structures in this area, having based diagrams on cadaveric studies performed prior to this paper.[9] Viewing the greater trochanter as a "clock face", muscles insert as follows: gluteus medius and its underlying bursa at 12, gluteus minimus and its underlying bursa at 1, gluteus max overlaps the area to insert from 2 to 6 with vastus lateralis arising outside this. Quadratus femoris insert between 7 and 8, the conjoint tendon of the gemelli and obturator internus at 8–10 and the rounded tendon of piriformis at 10–11.

Superior border of the greater trochanter triangle

The line between the greater trochanter and the ASIS forms the superior border of the triangle. Though gluteus minimus is not palpable, the line runs parallel to the body of the muscle. This line transects the other gluteal muscles and tensae fascia latae (TFL). Gluteus minimus is the deepest and most lateral of the three gluteal muscles; it arises from the outer surface of the ilium between the anterior and the inferior gluteal lines inserting into the greater trochanter as shown in fig 2. The gluteus medius lies above this, arising from the outer surface of ilium between the posterior and anterior gluteal lines. Together with gluteus minimus it abducts and rotates internally or externally the hip joint, depending on the position of the femur and which part of the muscle is active.[10 11] Both muscles are fundamental in maintaining an upright trunk position when the contralateral foot is raised during walking. Gluteus maximus arises from the iliac wing behind the posterior gluteal line, including the iliac crest, from the posterior layer

Table 1 Pathoanatomic approach; within the greater trochanter triangle (adult) (diagnoses appear in order of frequency in an athletic population)

Define and Align	Pathology	Listen and Localise	Palpate and Recreate	Alleviate and Investigate
Within the triangle (adult)	Femoro-acetabular impingement	Mechanical symptoms, clicking ± locking.	Impingement test.[6]	Plain film x-ray, magnetic resonance imaging ± arthrogram.[13]
	Labral injury			
	Osteoarthritis	Insidious onset, night pain.	Limited ROM, especially internal rotation.[14]	Plain film x-ray.
	Femoral stress fracture			
	Neck	Groin pain.	Hop test.[15]	Plain film x-ray, isotope bone scans, magnetic resonance imaging.
	Shaft	Proximal thigh/knee pain.	Fulcrum test.[16]	Plain film x-ray, isotope bone scan, magnetic resonance imaging.
	Inflammatory conditions	Features of systemic inflammation.	Systemic manifestations of particular condition.[17]	Plain film x-ray, ultrasound-guided joint aspiration.
	Septic arthritis	Systemic inflammatory response.	Inability to weight bear, limited range of motion, ± sepsis.[18]	Plain film x-ray, fluoroscopically/ultrasound-guided joint aspiration.
	Avascular necrosis of femoral head	Mechanical symptoms more prominent than functional limitation.	Limited range of motion.[19]	Plain film x-ray, magnetic resonance imaging.
	Tumour	Systemic "red flags", absence of appropriate physical stressors.[20]	May mimic stress fracture.[20]	Plain film x-ray, computerised tomography (CT)/ magnetic resonance imaging,[21] biopsy.

Table 2 Pathoanatomic approach; within the greater trochanter triangle (paediatric) (diagnoses appear in order of frequency in an athletic population)

Define and Align	Pathology	Listen and Localise	Palpate and Recreate	Alleviate and Investigate	Define and Align
Within the triangle (Paediatric)	Acute transient synovitis	Male. Refusal to weight bear. Poorly localised pain. Viral precipitant.	3–6 years	Well, non-toxic, variable range of motion.	Diagnosis of exclusion, to be monitored to exclude septic arthritis.[22]
	Apophysitis/avulsion fracture	Associated injury/event.	<18 years[23]	Point tenderness.[24]	Plain film x-ray,[25] computerised tomography (CT).[26]
	Perthes' disease	Male, associated knee pain.	4–9 years	Decreased range of movement of hip, abduction and internal rotation ↓ Joint effusion.[27]	Plain film x-ray, antero/posterior (AP), lateral, and comparative views.[27]
	Slipped capital femoral epiphysis	Overweight, male, 30% cases bilateral.[28]	12–15 years	Decreased range of motion of hip, abduction and internal rotation ↓. Limb shortening, external rotation of hip.[29]	Plain film x-ray, antero/posterior (AP), lateral, and comparative views.
	Septic arthritis	Refusal to weight bear. Systemically unwell.	All	Unwell, toxic, variable range of motion.	Temp >38.5, CRP >20, ESR >40, refusal to weight bear, leucocytosis >12.[22] Plain film x-ray, joint aspiration, isotope bone scan.
	Congenital dysplasia	Delayed mobilising/limp, walking on tip-toe.[30]	All	Limb length discrepancy, unilateral symptoms, limitation of abduction.[30]	Ultrasound, x-ray.
	Tumour	Night pain, systemic "red flags", absence of appropriate physical stressors.[20]	All ages	Systemic features, may mimic stress fracture.[20]	Plain film x-ray, magnetic resonance imaging.[21]

of thoraco-lumbar fascia, the posterior surfaces of the sacrum, coccyx, and sacrotuberous ligament and from the fascia covering gluteus medius (the gluteal aponeurosis). It inserts into both the greater trochanter and the iliotibial band, acting as a hip extensor and lateral rotator, and assists in adduction.

Moving from the ASIS to the greater trochanter, the structures encountered are:

Superficial
- Tensae fasciae latae (TFL)
- Gluteus maximus
- Gluteus medius
- Gluteus minimus

Deep
- Trochanteric bursae
- Piriformis
- Gemellus
  - superior
  - inferior
- Obturator internus

Anterior border of the greater trochanter triangle

The anterior border of the triangle is the line from the ASIS to the apical point. This corresponds to the force vector for abduction of the hip (tensae fascia latae and gluteus maximus), and the manifestation of this force in the fascia latae in the form of the iliotibial band, the anterior border of which is palpable on abduction of the hip. The iliotibial band (ITB) or tract is a lateral thickening of the fasciae latae in the thigh. Proximally it splits into superficial and deep layers, enclosing tensor fasciae latae and anchoring this muscle to the iliac crest. The Psoas arises as a series of slips, each of which arises from the adjacent margins of the vertebral bodies and the intervening discs from the lower border of T12 to the upper border of L5. The iliacus arises from the upper two-thirds of the concavity of the iliac fossa and the inner lip of the iliac crest, as well as the ventral sacro-iliac and iliolumbar ligaments and the upper surface of the lateral part of the sacrum. The two muscles converge and pass downwards and medially beneath the inguinal ligament over the hip joint and into the lesser trochanter of the femur. The passage of this conjoined tendon over the hip joint is facilitated

Table 3 Pathoanatomic approach; superior to the greater trochanter triangle (diagnoses appear in order of frequency in an athletic population)

Define and Align	Pathology	Listen and Localise	Palpate and Recreate	Alleviate and Investigate
Superior to the triangle	Myofascial trigger points in gluteus medius and tensae fasciae latae	Gluteal and lateral leg tightness and discomfort ± accompanying lateral knee pain.	Restricted movement/strength in affected muscle.[31] Tender "trigger" points palpable within muscle.[18 19]	Dry needling effective in relieving trigger points.[32]
	Greater trochanter pain syndrome Gluteus medius tendinopathy	Weakness in stance phase of walking and/or running, climbing stairs.[33]	Trendelenberg test 72% sensitive, 76% specificity.[34]	Ultrasound.[35]
	Trochanteric bursitis	Boggy feel and swelling.	Pain on rising/standing.[34]	Ultrasound, relief of pain by local anaesthetic injection.[36]
	Apophysitis; iliac crest	Age group (13–25 years),[23] activity load.	Point tenderness,[24] painful Trendelenberg.[4]	Plain film x-ray,[25] computerised tomography (CT).[26]

Table 4 Pathoanatomic approach; posterior to the triangle (diagnoses appear in order of frequency in an athletic population)

Define and Align	Pathology	Listen and Localise	Palpate and Recreate	Alleviate and Investigate
Medial to the triangle	Hamstring tendinopathy	Sudden pain in buttock/posterior thigh. Walking painful.[37]	Tenderness of muscle belly or tendon from common origin.	Magnetic resonance imaging,[37] association between proximity of muscle defect to ischial tuberosity and recovery.[38]
	Referred pain	Diffuse ache, may not have back pain.	"Lasègue" straight leg raise (sensitivity 72–97%, specificity 11–66%).[39] Braggard's sign (94% +ve).[40]	Response to lumbar mobilisation,[41] guided nerve root injection,[42] magnetic resonance imaging.
	Ischial tuberosity apophysitis	Age group 15–25 years.[23] Shooting pain following high-energy kick or change of direction.	Pain standing on one leg and Hop test,[39] associated deep buttock pain.	Plain film x-ray, magnetic resonance imaging.[43]
	Piriformis tendinopathy	Hamstring origin pain with gradual rather than sudden onset and/or sciatic referred pain.	Tenderness over sciatic notch and aggravated by flexion, adduction, and internal rotation (Lasègue sign) of the hip[44]; also FAIR test,[45] Pace Test.[39]	Ultrasound-guided injection.[46]

by the iliopsoas bursa, which is in some cases in direct communication with the hip joint. Rectus femoris arises via a direct head from the anterior inferior iliac spine and a reflected head arising from the superior acetabular rim and joint capsule.

Moving from lateral to medial the structures encountered are:

- TFL & iliotibial band
- Iliopsoas
- Vastus lateralis
- Rectus femoris

Posterior border of the greater trochanter triangle

The posterior border of the triangle is the line from the greater trochanter to the apical point. Structures lying beyond this which require differentiation as casual agents for lateral thigh pain include the small hip rotators such as piriformis, the gemelli, obturator and quadratus femoris, the ischial tuberosity and hamstring origins and referred pain from the lumbar spine. Other major structures encountered in this area include the sciatic nerve; this leaves the pelvis through the greater sciatic foramen, below the piriformis muscle, and descends between the greater trochanter of the femur and the ischial tuberosity. Initially deep to piriformis, it runs inferiorly and laterally posterior to the ischium, crossing over the nerve to quadratus femoris. Inferior to piriformis, it lies deep to gluteus maximus. It passes inferiorly crossing obturator internus, the gemelli and quadratus femoris. The ischial tuberosity gives rise to the hamstring group of muscles, semimembranosus, semitendinosus, and the long head of biceps femoris.

Within the greater trochanter triangle

Within the triangle the main focus of our attention is the femoro-acetabular joint. This ball and socket joint sacrifices range of movement for stability. When considering pathology of the joint we must consider not only the articular surfaces but also the underlying bone, soft tissue structures such as the synovium and acetabular labrum, and surrounding structures such as the capsule, bursae and muscles. The acetabular labrum acts to provide secondary stability to the bony constrained hip joint.[12] Though the morphology of the labrum varies, it is from 2 to 3 mm thick and extends the same distance beyond the acetabular socket.

A pathoanatomic approach using the greater trochanter triangle

The diagnostic process of history and examination is often abbreviated. There is a growing tendency to rely on investigational studies as the initial diagnostic step (e.g. a MR scan to check for an ACL rupture). The authors propose a four-step approach to the diagnostic process, emphasising history and examination and limiting investigation to the final step as follows.

Step 1: Define and align

Define the points of the triangle on the patient: ASIS, greater trochanter, and 3G points. If needs be mark these on the skin, align these points to visualise the borders.

Step 2: Listen and localise

Listen to the patient's history and obtain as many discriminating factors as possible. Localise the pain in relation to the triangle. From patient symptoms and careful palpation, assigning the pain to a location on the triangle is a large step towards making a pathoanatomic diagnosis. We must now proceed to differentiate between the different causal possibilities for the pain according to its position on the triangle.

Table 5 Pathoanatomic approach; anterior to the greater trochanter triangle (diagnoses appear in order of frequency in an athletic population)

Define and Align	Pathology	Listen and Localise	Palpate and Recreate	Alleviate and Investigate
Anterior to the triangle	Iliopsoas syndrome	Pain on forced hip extension, unrelated to knee position. Pain above and below inguinal ligament.	Thomas test.[47]	Ultrasound ± guided local anaesthetic injection.[48] Magnetic resonance imaging.[49]
	Iliotibial band friction syndrome	Associated snapping at hip joint, lateral knee pain.	Ober's test,[39] reproduce snap.	Ultrasound, dynamic view.[35]
	Rectus femoris tendinopathy	Pain hip flexion worse with knee flexion.	Flexion contracture test.[47]	Magnetic resonance imaging.[49]
	Neuropathy, lateral femoral cutaneous nerve	Altered skin sensation.	Paraesthesia/dysaesthesia over superficial area of lateral thigh.	Local anaesthetic infiltration to anterior iliac superior spine. Nerve conduction studies.[50]

Step 3: Palpate and recreate

Palpate the identified area; a careful examination is of course mandatory. Recreate where possible the patient's pain. Though not always popular, this has many valuable implementations. The different manoeuvres/examinations employed to generate this pain can be very helpful; we must never forget that, in an athletic population, exercise is one of the most powerful of these tools. To describe individual manoeuvres in detail is beyond the scope of this text so we have limited our descriptions to those manoeuvres not well described in the literature.

Step 4: Alleviate and investigate

Where a number of anatomical structures are in close proximity, clinical presentations can be very similar. The manner in which pain can be removed may be very helpful. A decrease in pain following abstinence from aggravating activity is revealing. If a distinct structure can be identified, the elimination of symptoms following guided injection of local anaesthetic into the structure is invaluable. The authors recognise that a number of conditions discussed in this text may only be diagnosed definitively following radiological investigation; in these instances the most discriminative, evidence-based investigation is recommended.

Specific scenarios using a problem-oriented approach

The diagnostic stepwise approach using the greater triangle is summarised in tables 1–5. The triangle is used to localise the pathology to a particular area. We refer the reader to the specific table relating to that border of the triangle. This provides a differential diagnosis, and clarifies the most discriminative evidence-based tests.

Internal (within the triangle)

Pathology of the hip joint often defies clinical distinction. The distance of the joint from the surface, the close proximity of the structures involved, and different conditions representing different stages in a clinical spectrum, help explain why. In this section discriminative signs are quite limited, so history and clinical may be even more important than normal.

Dividing them according to an adult and paediatric population facilitates further stratification of the pathologies encountered within the triangle. The hip, be it adult or paediatric, is prone to inflammatory infective and degenerative processes, the latter in particular due to the large compressive loads transmitted during ambulation, through its articular surfaces.

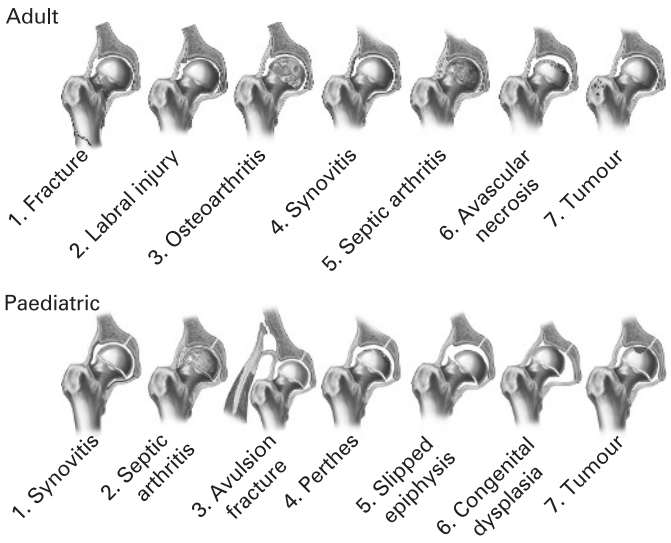

Figure 3 Within the greater trochanter triangle; adult and paediatric.

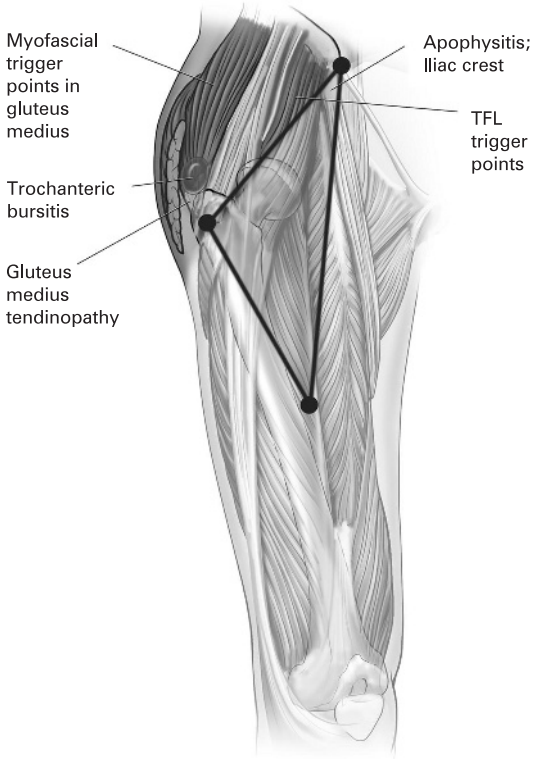

Figure 4 Superior to the greater trochanter triangle.

Irregular morphology of the acetabulum, or the femoral head/neck, may disrupt the labrum, resulting in pain, functional limitation, and ultimately joint degeneration.

The presence of the femoral epiphysis and the numerous secondary ossification centres in and around the hip make the diagnosis and treatment of the paediatric and adolescent hip dissimilar to that of the adult. A slipped upper femoral epiphysis, if untreated, has a high probability of being problematic later on in life; the limping child or adolescent must be fully investigated.

Superior

Superior to the line drawn between GT and ASIS lies the iliac crest and the muscles and fascia, which attach therefrom. The most common presentation of pain in this region is that of myofascial trigger points. These are amenable to dry needling or transverse friction myotherapy; it should be acknowledged that this may be the result of a problem elsewhere. The trigger points may lie superficially in gluteus maximus or tensor fasciae latae, or deeper in gluteus medius and gluteus minimus.

Posterior

Beyond the posterior border of the triangle lies an area where poorly differentiated pain is common. The complex anatomy around the greater trochanter, the most superior point of this region, highlights the complexity of the area. The confluence of the small muscles of the gluteal area, piriformis, the gemelli and obturator internus, all insert here and due to their depth below the gluteal muscles differentiation between them is problematic.

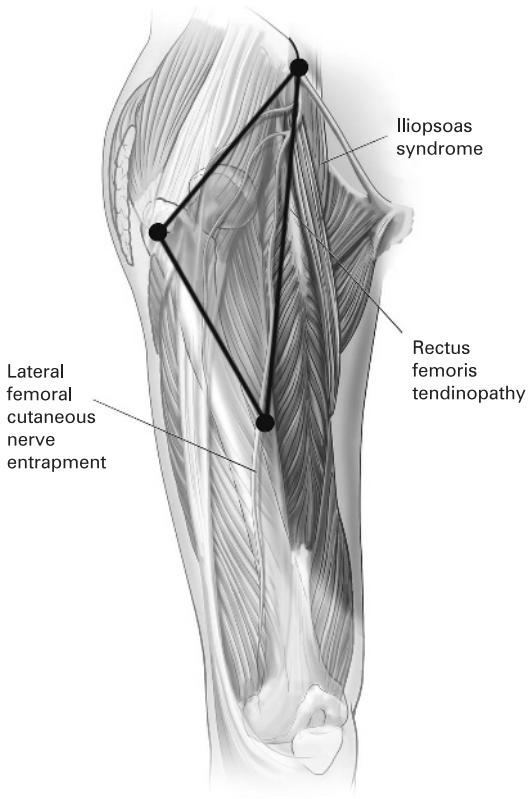

Figure 5 Anterior to the greater trochanter triangle.

Anterior

For the purposes of this paper we consider only the structures that need to be differentiated from femoro-acetabular pathology. The origin of rectus femoris (straight head at the anterior inferior iliac spine and reflected head at the upper border of the acetabulum and joint capsule), the insertion of the conjoint tendon of iliopsoas (at the lesser tuberosity having passed over the hip joint) and intimate nature of the relationship of the iliotibial band and the hip joint mean that they are all potential causal agents in this area.

CONCLUSION

This paper presents a method of teaching the causes of chronic pain in the lateral proximal lower limb. By offering a systematic means of limiting the differential diagnosis through history examination, diagnostic manoeuvres and, where necessary, directed investigation, this method may help the less experienced clinician in the diagnostic process.

What this study adds

- This paper outlines a novel educational approach to the categorisation of pathologies in the proximal lateral lower limb in an athlete.
- Pain-generating structures are categorised according to their anatomical position, around a triangle based on easily located anatomical landmarks.
- This categorisation, with accompanying high-quality diagrams, focuses the diagnostic process. Discriminative questioning and evidence-based examination presented in tabular form facilitate accurate differential diagnosis.

The greater trochanter triangle is one section of the "3G" approach to teaching the causes of chronic pain in the proximal lower limb. This paper should therefore be read in conjunction with the gluteal and groin triangle papers to fully address the three-dimensional nature of the region.

We recognise that experience, expertise and a thorough knowledge of the anatomy of an area cannot be supplanted in any complete understanding of the pathologies there encountered. This educational tool provides a means of differentiating the pathologies encountered, by virtue of their anatomical position, in the proximal lateral lower limb.

Competing interests: None.

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