Athletic pubalgia: a detailed didactic approach

Poster No.: C-2375
Congress: ECR 2015
Type: Educational Exhibit
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Keywords: Athletic injuries, Education, Diagnostic procedure, Ultrasound, MR, CT, Musculoskeletal system, Musculoskeletal soft tissue, Anatomy
DOI: 10.1594/ecr2015/C-2375

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Learning objectives

The purpose of our educational exhibit is to:

1. illustrate the basic anatomy and imaging appearance of thigh and pelvic regions;

2. describe a systematic approach for the evaluation of such structures with magnetic resonance (MR) and dynamic ultrasound (US);

3. produce anatomical scheme with didactic purpose and show correlation with imaging findings.

Background

The term "pubalgia" is commonly used to identify a groin painful syndrome often observed in amateur and professional athletes who play in sports that need quick acceleration and deceleration, rapid changes in direction, kicking and frequent side-to-side movements.

Clinically, athletes frequently present with insidious unilateral chronic pain (weeks or months) in the inguinal region which may radiate to the scrotum and testicles or to the medial thigh, at the level of the adductor muscles origin. This symptoms are typically exacerbated by physical activity; they often recur and may lead to the premature termination of athletic careers.

The clinical presentation is often similar to that of the inguinal hernia but at physical examination in most cases there is no palpable hernia.

A precise clinical overview is often difficult because many different pathologic conditions, both of muscolotendinous and visceral origin, can lead to groin pain.

To date, there is no real consensus on the criteria for a reliable diagnosis, despite many studies have investigated this pathologic condition in order to find a clearer correlation between anatomy, imaging and symptoms.
Many authors use the term pubalgia to refer to a group of musculoskeletal lesions that occur around the pubic symphysis and that share similar mechanisms of injury and common clinical manifestations. The causal mechanisms of athletic pubalgia are poorly understood but many athletes have a spectrum of related pathologic conditions resulting from musculotendinous injuries and subsequent instability of the pubic symphysis.

The complex anatomy and biomechanics of the pubic symphysis region can create diagnostic confusion. It includes a number of interrelated muscle attachments that are located in close proximity to one another; the interrelation of these muscle attachments causes complex interactions between the forces exerted through the muscles across the pubic symphysis.

We will provide a practical but detailed approach with dedicated MR and dynamic US scan coupled with anatomic scheme, regarding each of the following structures: pubis, pubic symphysis, parasymphseal structures, rectus abdominis muscle, adductor longus, adductor brevis, adductor magnus, gracilis and pectineus muscles.

Findings and procedure details

1. IMAGING

A combined MR-US approach allows a detailed investigation of the anterior pelvis and groin. High-resolution ultrasound is an effective technique to accurately identify tendinopathies and muscle tears; in addition, dynamic evaluation adds several important information about biomechanics of the superficial structures around the pubic symphysis and can be also very helpful to exclude the presence of a true inguinal hernia, during a valsalva manoeuvre. The only disvantage of the ultrasound examination is the inability to demonstrate inflammatory and degenerative bony processes. A high-resolution ultrasound system with high-frequency probe (7-15 MHz) was used.

MR is currently considered optimal for the simultaneous assessment of osseous and soft tissue structures. 1.5 Tesla MR of the anterior pelvis with surface coils were performed; T1- and T2-weighted turbo-spin-echo (TSE) sequences were obtained, oriented along the three orthogonal planes.
Knowledge of the basic anatomy and imaging appearance of the musculoskeletal structures around the pubis is essential for the correct assessment of their injuries in symptomatic athletes.

2. NORMAL ANATOMY

PUBIC SYMPHYSIS

The pubic symphysis is an amphiarthrosis, a joint with a limited range of motion, composed of the two pubic bones, the interposed articular disk and four ligaments (Fig. 1 on page 12). There is no true joint capsule.

The pubic bone consists of three portions:

- the body articulates with the contralateral pubic bone by means of a quite irregular surface, covered by hyaline cartilage that is in very close contact with the fibrocartilaginous disk. It houses the pubic crest which arises from its medial upper margin and the pubic tubercle, an osseous process laterally located, on which the inguinal ligament attaches. From the pubic tubercle arises the pecten, a ridge that crosses the superior pubic ramus up to the arcuate line.

- the superior pubic ramus contributes to the formation of the anterosuperior portion of the acetabular fossa and the obturator foramen. The junction with the ilium is called iliopectineal eminence.

- the inferior pubic ramus forms the anteroinferior part of the obturator foramen.

The articular disk and four ligaments are the most important stabilizers of the joint.

- the articular disk is a fibrocartilaginous absorber interposed between the two pubic articular surfaces particularly important in dissipating axial and shear forces applied to the joint, together with the superior and inferior pubic ligaments.
• the **superior pubic ligament** is a bundle of collagen fibres that runs on the superior surface of the symphysis connecting the two pubic tubercles (Fig. 2 on page 13).

• the **inferior pubic ligament** (or arcuate ligament) is a thick fibrous band tense along the inferior margin of the joint. Some fibres blends superiorly with the articular disk and inferiorly with the aponeuroses of the gracilis and the adductor longus muscles.

• the **anterior pubic ligament** consists of a deep layer that merges with the articular disk (Fig. 3 on page 14) and a superficial layer that blends with the aponeurosis of the rectus abdominis and the external oblique muscles.

• the **posterior pubic ligament** is a thin bundle composed of few transversely oriented fibers, located on the posterior surface of the symphysis.

The most important functions of the pubis symphysis in athletes are:

- to stabilize the anterior pelvis (limited degree of motion);

- to protect the joint from injuries during walking and running (the wide contact surface of the joint allows a good distribution of the shear forces during movements and the two pubic rami transmit compressive forces generated at the symphysis to the ilium and ischium bones).

**MUSCLES**

A number of different muscles insert on and around the pubic symphysis, sharing similar mechanisms of injury and common clinical manifestations.

**Rectus abdominis muscle**

Proximal Origin: V, VI, and VII costal cartilage, inferior margin of the xiphoid process, costoxiphoid ligaments.
**Muscle belly:** superficially located in the anterior abdominal wall, near the linea alba (Fig. 4 on page 14 a,b,c); it is three times wider at the proximal origin from the lower rib cage than at the attachment on the pubis (*this fact may contribute to the greater frequency of rectus injuries near the pubic symphysis*).

**Distal insertion:** consists of a medial tendon, that inserts on the anterior pubic body (it merges with the anterior pubic ligament), and a lateral tendon, that attaches on the pubic crest and tubercle; the two components form a continuous fibrous band and they are not clearly observable (Fig. 5 on page 15). The distal attachment of the rectus abdominis muscle blends together with the proximal tendon of the adductor longus muscle to form a common fibrous aponeurosis that broadly attaches to the periosteum of the anterior aspect of the pubic body and that likely merges with the anterior pubic ligament and the interpubic disk (Fig. 6 on page 15). This common aponeurosis is located in close relationship with the superficial inguinal ring.

**Function:** the most important for maintaining the stability of the anterior pelvis (together with the adductor longus muscle); it provides muscle tone to the ventral abdominal wall, especially during straining; flexion of the trunk; antagonist to the diaphragm during respiration.

**Innervation:** lower costal and subcostal nerves (from the caudal six or seven thoracic nerve roots).

**Vascularization:** inferior epigastric arteries, subcostal artery, posterior lumbar arteries and deep circumflex iliac artery.

**External oblique abdominis muscle**

**Proximal Origin:** external surfaces and inferior borders of the V to XII ribs.

**Muscle belly:** the largest and the most superficial of the flat muscles of the lateral and anterior abdominal wall (Fig. 7 on page 16). It continues in a broad aponeurosis that occupies the anterior wall of the abdomen and takes part to the formation of the inguinal canal inferiorly (Fig. 8 on page 17).

**Distal insertion:** iliac crest, pubic tubercle, linea alba.
**Function**: rotation of the trunk; pull the chest downwards and compression of the abdominal cavity (valsalva maneuvre); limited actions in both flexion and rotation of the vertebral column.

**Innervation**: ventral branches of the lower six intercostal nerves and subcostal nerve on each side.

**Vascularization**: lower intercostal arteries (cranial portion), deep circumflex iliac artery and iliolumbar artery (caudal portion).

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**Internal oblique abdominis muscle**

**Proximal Origin**: dorsolumbar fascia of the lower back, anterior 2/3 of the iliac crest, lateral half of the inguinal ligament.

**Muscle belly**: the muscle belly is located deep to the external oblique and just superficial to de transverse oblique muscles. The muscle fibres are perpendicular oriented to that of the external oblique muscle.

**Distal insertion**: pecten pubis (via a conjoint tendon with the transversus abdominis muscle), inferior borders of the X through XII ribs, linea alba.

**Function**: antagonist to the diaphragm during respiration, same side rotation of the trunk (it acts with the external oblique muscle of the opposite side to achieve this torsional movement).

**Innervation**: lower intercostal nerves (VI-XI), subcostal nerve (XII) iliohypogastric nerve and ilioinguinal nerve.

**Vascularization**: subcostal arteries.

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**Transversus abdominis muscle**
**Proximal Origin**: Iliac crest, inguinal ligament, thoracolumbar fascia, costal cartilages VII-XII.

**Muscle belly**: it is so called for the direction of its fibers, the deepest of the flat muscles of the abdomen, located immediately beneath the internal oblique muscle.

**Distal insertion**: xiphoid process, linea alba, pubic crest and pecten pubis (via conjoint tendon with the internal oblique muscle).

**Function**: compression of the abdominal content providing thoracic and pelvic stability

**Innervation**: lower intercostal nerves (VI-XI), subcostal nerve (XII) iliohypogastric nerve and ilioinguinal nerve.

**Vascularization**: subcostal arteries.

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**Adductor longus muscle**

**Proximal Origin**: anterior margin of the pubic body, below the pubic crest (common aponeurosis with the rectus abdominis muscle) (Fig. 9 on page 17). The proximal tendon lies in close proximity to that of the gracilis muscle (Fig. 10 on page 18).

**Muscle belly**: the most superficial of the three adductor muscles (Fig. 11 on page 20), it lies lateral to the gracilis muscle, posterior and medial to the pectineus muscle (at the proximal third of the thigh) and deep to the sartorius, vastus medialis, vastus intermedius muscles (at the remainder two distal thirds).

**Distal insertion**: middle third of the femoral linea aspera.

**Function**: adduction of the thigh and also hip flexion and internal rotation.

**Innervation**: anterior branch of the obturator nerve (from the L2, L3, and L4 nerve roots).

**Vascularization**: adductors artery (from the deep femoral artery), femoral artery, medial femoral circumflex artery and descending genicular artery.
The adductor longus muscle is most often injured at its proximal myotendinous junction; being the blood supply relatively poor, at this level the tendon is less able to resist strain and repair itself. In particular, tears initially involve the anterior fibres, better developed than the posterior ones (more directly attached to the bone).

**Adductor brevis muscle**

**Proximal Origin:** anterior pubic body, inferior pubic ramus.

**Muscle belly:** it is located just below the external obturator muscle, posterior to the pectineus and adductor longus and anterior to the adductor magnus muscles (Fig. 12 on page 20).

**Distal insertion:** inferior 2/3 of the pectineal line, superior medial ½ of the femoral linea aspera cranial to the adductor magnus muscle.

**Function:** adduction of the thigh and also hip flexion and internal rotation.

**Innervation:** obturator nerve (from the L2 and L3 nerve roots).

**Vascularization:** adductors artery (from the deep femoral artery, medial femoral circumflex artery and obturator arteries).

**Adductor magnus muscle**

The large triangular belly of the adductor magnus muscle, deep located in the medial thigh (Fig. 13 on page 21), is composed of two components with different origins and functions.

**Adductor portion**

**Proximal Origin:** lower margin of the inferior pubic ramus (ischiopubic ramus).
**Muscle belly**: this fibres are more anterior and more horizontally oriented.

**Distal insertion**: gluteal tuberosity (medial to the insertion of the gluteus maximus muscle), medial femoral linea aspera, medial supracondylar line.

**Function**: adduction of the thigh and also hip flexion and internal rotation.

**Innervation**: obturator nerve (from the L2, L3, and L4 nerve roots).

**Vascularization**: deep femoral artery, medial femoral circumflex artery and popliteal vessels (posterior blood supply).

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**Ischiocondylar (or hamstring) portion**

**Proximal Origin**: ischial tuberosity.

**Muscle belly**: this fibres are vertically oriented.

**Distal insertion**: adductor tubercle of the medial femoral condyle.

**Function**: adduction of the thigh and also hip extension.

**Innervation**: tibial division of the sciatic nerve.

**Vascularization**: deep femoral artery, medial femoral circumflex artery and popliteal vessels (posterior blood supply).

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**Gracilis muscle**

**Proximal Origin**: symphysis pubis (anterior aspect), inferior pubic ramus.

**Muscle belly**: the most medial muscle, it lies medial to the adductor longus and brevis and anterior to the adductor magnus muscles (Fig. 14 on page 21).
Distal insertion: proximal anteromedial tibia (pes anserinus).

Function: adduction of the thigh, minor role in hip flexion and internal rotation, and also knee flexion.

Innervation: obturator nerve (from the L2 and L3 nerve roots).

Vascularization: adductors artery (from the deep femoral artery).

**Pectineus muscle**

Proximal Origin: pubic tubercle, superior pubic ramus (pecten pubis), portion of the iliopubic eminence.

Muscle belly: the rectangular belly overlies the adductor longus and brevis muscles (Fig. 15 on page 22).

Distal insertion: femoral pectineal line (between the lesser trochanter and linea aspera).

Function: adduction of the thigh and also knee flexion.

Innervation: femoral nerve (ventral portion), accessory obturator nerve (dorsal portion).

Vascularization: medial femoral circumflex artery and lesser contributions from obturator and femoral arteries.

3. BIOMECHANICS AND MECHANISM OF INJURIES

The complex anatomy of the pubic symphysis, with its interrelated muscle attachments located in close proximity to one another, reflect the complex biomechanics of this region.
The intimate relationship of this tendons produces complex interactions between the forces exerted through the muscles across the pubic symphysis.

During rotation and extension from the waist, the rectus abdominis muscle and the adductor longus muscle act as antagonists of one another. In physiological conditions, contraction of the rectus abdominis muscle produces posterior-superior traction of the pubic region with consequent elevation of the pubis (Fig. 16 on page 22). In contrast, the adductor longus muscle pulls down the pubis, applying an anterior-inferior force. The balance of this tangential opposed forces applied to the common aponeurosis is crucial for anterior pelvis stability.

An injury to one of the two tendons predisposes the opposing one to degeneration and tearing by both altering the biomechanics (repetitive unbalanced contractions) and interrupting the anatomic contiguity of the tendon insertions. The resulting instability of the pubic symphysis may produce not only lesions in other tendons around the pubis but also an inflammatory response, with osteitis and periostitis.

In many athletes tendon injuries are unilateral and sometimes can cause frank disruption of the rectus abdominis-adductor longus aponeurosis from its pubic attachment. Moreover, the lesion may extend into the pectineus and adductor brevis proximal insertion, or may propagate across the midline to involve the contralateral common aponeurosis.

Unbalanced stress on the abdominal wall muscles can produce a weakness of the posterior wall of the inguinal canal but the detection of a true palpable hernia is rare. Hernia-like symptoms may be related to the proximity of the injury site to the medial margin of the superficial ring of the inguinal canal or to lesion extension through the superficial inguinal ring.

Images for this section:
Fig. 1: The pelvis can be essentially considered a ring, composed of five bones the ilium, ischium, pubis, sacrum and coccyx. The ilium, ischium and pubis of each side articulate to form the "innominate bone" which frontally join the contralateral one by the symphysis pubis. The sacrum joins to the innominate bone by the sacroiliac joints.

Fig. 2: Coronal anatomical scheme of the symphysis pubis: note the superior and inferior (or arcuate) ligaments with the interposed fibrocartilaginous disk.
**Fig. 3:** Axial anatomical scheme of the symphysis pubis: note the anterior and posterior ligaments with the interposed fibrocartilaginous disk.

**Fig. 4:** (a) Coronal TSE-T1 weighted image of the anterior abdominal wall. Ra, rectus abdominis muscle; Oe, external oblique muscle; arrow, spermatic cord at the exit of the inguinal canal. (b,c) Axial TSE-T1 weighted image of the pelvis correlated with US axial
scan at the midline of the anterior abdominal wall. Note the rectus abdominis muscles of each side separated by the linea alba (white arrowhead).

**Fig. 5:** Axial TSE-T1 weighted images of the pelvis at the proximal (a), middle (b) and distal (c) third of the rectus abdominis tendon (white arrow). Pe, pectineus muscle; Ps, iliopsoas muscle; Sa, Sartorius muscle; Rf, rectus femoris muscle; °, femoral neurovascular bundle; *, spermatic cord; white arrowhead, pubic syphysis.
Fig. 6: Axial TSE-T1 weighted image of the pelvis correlated with US axial scan of the pubic region (a,b). At the symphysis pubis, the distal tendon of the rectus abdominis muscle (Ra) merges with the fibres of the anterior pubic ligament, the fibrocartilaginous disk and the adductor longus tendon to form a wide aponeurosis located just superficial to the symphysis. Pe, pectineus muscle; Ps, iliopsoas muscle; Sa, Sartorius muscle; Rf, rectus femoris muscle; Tf, tensor fascia latae muscle; Vl, vastus lateralis muscle; °, femoral neurovascular bundle; *, bony cortex of the pubic body-superior ramus; white arrowhead, pubic symphysis; P, pubis.
Fig. 7: Axial T1 weighted image (a) correlated with US axial scan (b) of the anterior-lateral abdominal wall. Note the aponeurosis of the external oblique muscle (white arrowheads) that takes part to the formation of the inguinal canal. Ra, rectus abdominis muscle; Oe, external oblique muscle.

Fig. 8: Anatomical scheme of the inguinal canal. The inguinal canal is a short cylindrical tunnel located in the anterior-inferior abdominal wall, lined by the three abdominal muscles: rectus (Ra), external oblique (Eo), internal oblique (Io) and transversus (Tr) abdominis. Different anatomical landmarks can be identified in the inguinal canal: the proximal opening (white arrow, deep inguinal ring), situated in the transversalis fascia, just superior to the inguinal ligament (empty arrowhead); the distal opening (white arrowhead, superficial inguinal ring) in the aponeurosis of the external oblique muscle; the anterior wall composed by the aponeurosis of the external oblique and internal oblique muscles; the posterior wall, formed by the transversalis fascia and the internal oblique-transversus abdominis conjoint tendon; the superior wall is formed by the internal oblique and transversus abdominis muscles; the inferior wall composed by the inguinal ligament. In males it houses the testicular vessels, the vas deferens, the genital branch of the genitofemoral nerve; in females, it contains the round ligament of the uterus and the ilioinguinal nerve.
Fig. 9: US longitudinal scan at the level of the pubic symphysis (P): note the close interconnection of the distal tendon of the rectus abdominis muscle (Ra) and the proximal tendon of the adductor longus muscle (Al).
Fig. 10: Anatomical scheme of the adductor muscles on the coronal plane (a) correlated to axial T1 weighted images of the pubis showing the proximal (b), middle (c) and distal (d) third of the adductor longus tendon. At the symphysis pubis (b) the adductor longus tendon fibres blends with that of the rectus abdominis muscle forming a fibrous band (white arrows) that lies superficial to the pubic joint; proceeding more caudally (c) the adductor longus tendon can be better appreciated as an hypointense structure (white arrows) located medially to the pectineus muscle belly. Note that at the root of the thight (d), the first visible belly of the adductors group is that of the adductor brevis muscle, while the adductor longus is still tendinous (white arrows). Pe, pectineus muscle; Ps, iliopsoas muscle; Sa, Sartorius muscle; Rf, rectus femoris muscle; Tf, tensor fascia latae muscle;
VI, vastus lateralis muscle; Eo, external obturator muscle; °, femoral neurovascular bundle; Al, adductor longus; Ab, adductor brevis; Am, adductor magnus; Gr, gracilis.

Fig. 11: (a) Axial T2 weighted image of the proximal thigh. (b) US longitudinal scan of the proximal adductors insertion (*): note the three muscle layers represented from superficial to deepest by the adductor longus (Al), adductor brevis (Ab) and adductor magnus (Am) muscles. Ps, iliopsoas muscle; Sa, Sartorius muscle; Rf, rectus femoris muscle; Tf, tensor fascia latae muscle; VI, vastus lateralis muscle; Gm, gluteus maximum muscle.
**Fig. 12:** (a) Coronal T1 weighted image of the proximal thigh (b) US axial scan of the medial compartment of the thigh. Eo, external obturator muscle; Gr, gracilis muscle; Al, adductor longus; Am, adductor magnus, *, ischio-pubic ramus.

**Fig. 13:** Axial T2 weighted image at the middle thigh. Gr, gracilis muscle; Sa, Sartorius muscle; Rf, rectus femoris muscle; Vi, vastus lateralis muscle; Vi, vastus intermedius muscle; Al, adductor longus muscle; Am, adductor magnus muscle; Hm, hamstrings.
Fig. 14: (a) Sagittal T2 weighted image of the pubic region. (b) US axial scan of the proximal medial thigh. Gr, gracilis muscle; Al, adductor longus; Ab, adductor brevis; Am, adductor magnus.

Fig. 15: (a) Axial T1 weighted image of the root of the thigh, with US axial scan (b). Pe, pectineus muscle; Ps, iliopsoas muscle; Sa, Sartorius muscle; Rf, rectus femoris muscle; Tf, tensor fascia latae muscle; Vi, vastus lateralis muscle; Eo, external obturator muscle; °, femoral neurovascular bundle; Al, adductor longus; Ab, adductor brevis; Am, adductor magnus; Gr, gracilis.
Fig. 16: Anatomical scheme of the biomechanics of the pubic region. The rectus abdominis (Ra) and the adductor longus (Al) muscles apply two opposite forces to the symphysis pubis during contraction. The close relationship between the common aponeurosis, most frequently involved in rotational and hyperextensional injuries, and the superficial inguinal ring (*) may explain the similarity of symptoms of athletic pubalgia and inguinal hernia. White arrow, inguinal ligament.
Conclusion

A combined MR-US approach allows a detailed investigation of the anterior pelvis and groin; in addition, dynamic evaluation adds several important information about biomechanics of such superficial structures. Knowledge of the basic anatomy and imaging appearance of these structures is essential for the correct assessment of injuries in symptomatic athletes.

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