Core Muscle Injuries

10

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The real magic of discovery lies not in seeking new landscapes, but in having new eyes. Marcel Proust [1].

Over the past half century, people have used a number of terms to describe the musculoskeletal injuries that affect the abdomen, pelvis and thighs of athletes. The terms reflect the various specialty disciplines of those who use them and obscure cohesive insight into the nature of these problems. In this chapter, my radiologist partner and I advise new eyes and propose nomenclature to represent new insight into the various problems. We base our request on our own clinical findings extracted from a large personal experience, coupled with some anatomical studies as well as observations of others. With respect to these injuries, we strive for the reader to embrace the above-cited Marcel Proust observation.

Historical Perspective

Dogma

The old, hard-line, dictator coach of the 1960s and 1970s (Fig. 10.1) embodies the state of our knowledge about groin injuries until recently. He knew that anyone who complained of them was *just not tough enough.* Most of us have probably had coaches like this. He was not thoughtful like Proust. He did not wonder what bothered the player, show empathy and then seek an answer. Most coaches back then were pretty powerful and just not like that. In fairness to those coaches, the fact was that most doctors in that era had no clue about this set of injuries. The pelvis remained a mysterious, forbidden area; and without a dependable fix for the injuries, there was really no purpose for a coach to think differently. He strove for team wins and most players with unfixable, disabling injuries contributed nothing to that.

Conflicts

The term "sports hernia" was around back then and deservedly had a bad name. The outcomes from hernia repair in athletes and others with inguinal pain were so predictably bad, it became verboten for general surgeons to perform repairs in the absence of demonstrable hernia. David C Sabiston, perhaps the most famous leader of American surgical training programs in that era, declared, "You shall surely fail your boards if you say you would do that" [2].

The clash between what the sports world saw as an obvious set of injuries and the medical world's failure to understand them generated a bewilderment bolstered by recent medical literature [3]. In 2006, the search terms *sports hernia* or *athletic pubalgia* yielded a total of only 12 articles using PubMed.com, while at the same time, the same key words produced over 100 articles on ESPN.com, the USA's leading sports website [4]. The same set of searches captured 15 different terms that described comparable, soft tissue sports injuries in the pelvis.

In an analogous web search in 2012, the number of terms describing these injuries grew to 50, not including 14 from the gynecologic literature. The scientific articles mushroomed to over 200. Most of the papers bundled the patients as if they had one common injury; and lacked detailed descriptions of histories and physical examinations. Several papers split out high thigh injuries from abdominal wall injuries.

Athletic Pubalgia

The multiplicity of injuries in one general location and the confusion over terms underscores the need for a unifying concept and nomenclature. The descriptive term "athletic

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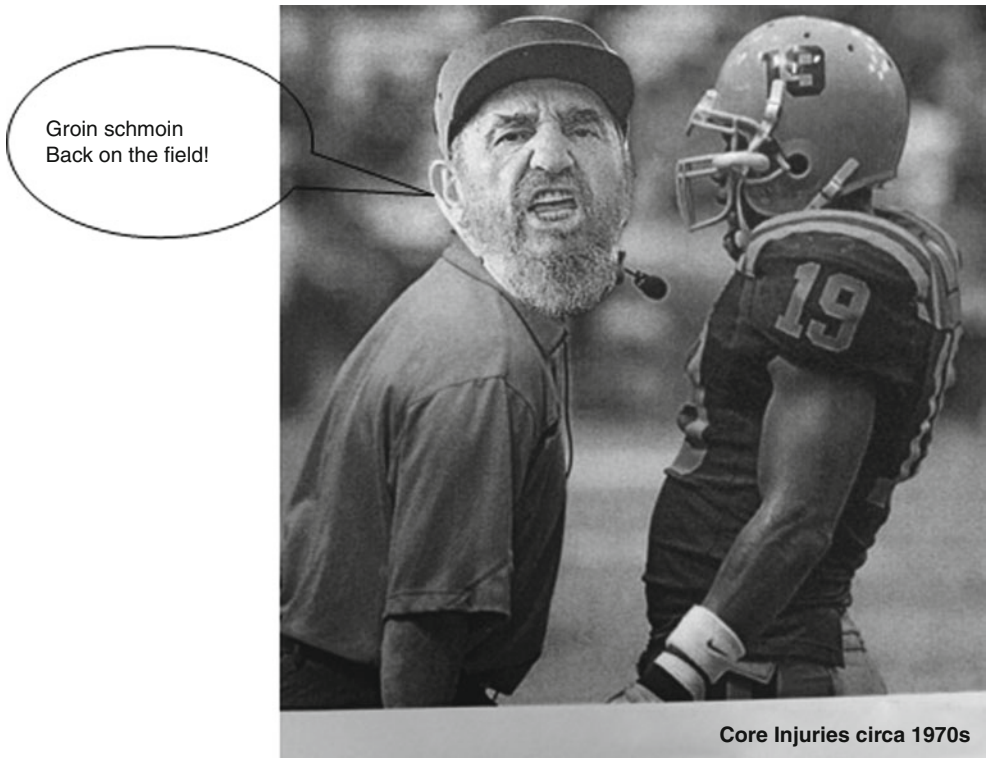

Fig. 10.1 State of knowledge about core injuries in the past

pubalgia" came from a 1991 article [5]; we sought an umbrella label without the word "hernia" for the complex pain near the pubic bone in these athletes. One specific injury could not possibly have explained the various clinical profiles of our patients. Experience over the past two decades [6] identified an even wider spectrum of pain and problems; the patients usually vaguely connected the pains. Pain occurred in a variety of muscles or muscle groups in the abdomen or thigh, often at multiple sites at the same time and with migration from one site to another over time. As encompassing as the term may be, *athletic pubalgia* does not easily roll off the English-speaking tongue so the press has not embraced the term. The French translation into a more enunciable "pubalgie" brings up a semantic issue. As accurate as the term may be, *athletic pubalgia* describes the anatomical region for these problems without connoting a unifying concept. As the reader shall see, the concept that connects the various pains and pathologies turns out to be simple.

Milestones in Recognition of a Dynamic Muscular Pathophysiology Around the Pubis

Let us summarize some of what has defrocked the myth that these are hernias. Keep in mind that the situation has grown more confusing because hernia repairs have had some success for specific injuries. Authors as far back as 1895 [7–10] speculated on a dynamic musculoskeletal nature to these injuries and on changes in the pubic bone that seemed to correlate with age and soft tissue injury. A 1924 article [10] even connects changes in the inferior aspect of the pubis to prior suprapubic injury. In 1981 Nesovic suggested a muscular imbalance in footballers in Yugoslavia [11] and subsequently devised a number of repairs for various injuries. I may have followed in suggesting this in publication [5], but Gilmore from the United Kingdom, and perhaps others, had been censuring the hernia theory years before that.

Seeking New Landscapes Versus Having New Eyes

After several early reports of successful experiences using new approaches [12–14], an outpouring of traditional hernia surgeons and then laparoscopic surgeons sought new frontiers for their tools [15–19]. Most of the reports suggested that pain rarely improved without surgery. Most of those articles provided limited follow-up; and several reported 100 % success rates – remarkable considering the wide variety of patients and absence of definitions. Consistent with those reports, in our own early experience with open and then laparoscopic hernia repair as primary treatment (circa 1988–1993), pain often improved. However, we were never satisfied with the results because athletes often persisted with some degree of pain [20, 21]. Thus, some success with hernia repair, as occurred years ago, plus an influx of hernia surgeons has brought some people back to the mistaken concept of hernia as the underlying factor.

Table 10.1 Changes in patient profiles over two decades

Patient profile	1986–1995	2003–2008
Female	Less than 1 %	15.2 %
Age (years)	24.7 (14–54)	28.6 (8–88)
Athletes	91.1 %	76.9 %
# of sports	15	32
Top sports	Soccer	Soccer, football, hockey
# of recognized syndromes	3	19 (121 different operations)
# of rehab/performance protocols	0	16

Data from Ref. [6]

Then team physicians, physical therapists, trainers, and others with experience treating players during competition wrote about the injuries [15], and some questioned the need for surgery. One paper narrowed the scope of patients to a certain type adductor injury and reported good success with a specific physical therapy regimen as primary treatment [22].

In 2008, we reported a large overall experience with these injuries characterizing the changes in the recognition and treatment over two decades (Table 10.1). The injuries were divided into a number of different categories based on the specific muscles involved, MRI and operative pathology. The pubis and its attachments were undeniably important. Not all the lesions needed surgery, and when appropriate, surgery nearly always fixed the problems. Soon afterwards, Mushawek [19] reported a minimal repair technique with 100 % "perfect satisfaction" at 4 weeks postoperatively. She described the ultrasonographic identification of an abdominal wall hernia as the common factor in the patients and at least one patient also had an adductor procedure. In 2011 Paajanen again achieved 100 % "perfect satisfaction" but this time with laparoscopic hernia surgery and at 12 months postoperatively [23]. Interestingly, Paajanen sometimes added some kind of adductor procedure to his repairs. As physicians, we are taught to challenge anything that is 100 %. On the other hand, like searching for gold, zeal comes from looking for something valuable and finding something shiny. Those startling results likely represent a combination of some success and zeal.

The literature remains confusing. The numerous articles advocate many different approaches. For example, one critical review of exercise therapy as treatment for groin pain in athletes found 468 articles on the subject, adjudged only 12 worthy of analysis, and determined that only 7 out of those 12 were reasonable in quality [24].

We found five relatively recent prospective studies (Table 10.2) [22, 23, 25–27]. Together, they reflect a lack of a unified theme. Holmich's trial [22] was randomized and prospective for two types of physical therapy for specific adductor injuries; the authors showed that an active training protocol was better. Our two studies [25, 27] were not randomized. This was not ethically possible in our patient population; plus, we chose to treat a number of patients non-surgically. In the first study, the overall two-year self-assessed success rate was 95.4 % after various types of surgery. Success was defined as at or better than pre-injury levels of play. Most in the other 4.6 % group were better but had concomitant hip or other problems not yet fully treated. The exact time frame for return to play was not assessed since many patients had surgery in the off-season. The second study [27] was on pelvic pain in women athletes. A variety of injuries separated into three categories: hip, core muscle injuries, and "other causes", and there was considerable overlap among the three groups. Surgery provided markedly superior results compared to non-operative approaches for the musculoskeletal injuries (Table 10.2). The other two prospective studies [23, 26] were randomized. Ekstrand and Ringborg [26] included 66 patients and randomized them to four different treatments, only one being surgical. The complex results are difficult to summarize, but only the surgery achieved satisfaction.

Table 10.2 Five prospective studies on groin pain in athletes

Author	Year	Study
Holmich	1999	68 patients randomized to two types of PT
Meyers	2000	157 non-randomized patients
Ekstrand	2001	66 patients randomized to four treatments
Meyers	2011	114 non-randomized women patients
Paajanen	2011	60 patients randomized to surgery vs. PT

In summary, a deluge of studies now shower the medical literature on this topic. The various authors write about a variety of injuries; and it is difficult to sort out the definitions and patient selection. Stated bluntly, the befuddling literature along with a lack of a common anatomic understanding emphasizes the urgency for new eyes.

The Old Eyes

One should not judge the above studies too harshly. They reflect the eyes of the various authors' trainings. Many of the papers touch on important observations and contribute to our having new eyes, by challenging the opacity of the pelvis and pelvic injuries.

For too many years, the pelvis has remained a mysterious anatomical region. The private nature of the pelvis has

something to do with this, but the main reason is that each of us, i.e. physician, surgeon, physical therapist, athletic trainer, etc., is biased by our own training. It is difficult to see beyond that. The urologist sees the pelvis as the ureters, bladder, testicles, etc. The general and colorectal surgeons think of this region as where the colon and rectum reside as well as some protrusions called hernias. Gynecologists see other things. It is easy to list other specialists. Orthopedists are probably best equipped to deal with the mechanics of these athletic injuries as they deal with bones and joints, but they have feared misdiagnosis of, or injury to the genitourinary, gastrointestinal and gynecologic structures.

The main point is that we all must realize the limitations imposed by our training. We need to cross specialties. We need new eyes.

New Eyes

The answer to the mystery is that no one has ever taught us well what lies alongside the essential organs and vessels in the pelvis. Alongside lays some important musculoskeletal anatomy. This portion of the musculoskeleton is our transmission like a car, or our foundation like a building. This is the core of our athleticism. Consider the *new building* analogy. If the foundation is our core, perhaps then the walls are our muscles. Maybe hernia repairs have a small degree of success because the mesh fibroses and fixates the muscles with its intense foreign body reaction; and despite its intended purpose, provides a slightly firmer connection to the foundation. And perhaps the cutting of sensory nerves and slight imbrication of musculature of "minimal repair" provides a quick coat of paint that makes the building look better in the short term but not necessarily the long term, and but does not make the building much sturdier. One may carry out this analogy in several directions.

As a busy liver surgeon at Duke University in the mid-1980s, the surgeon author became curious about this anatomy. As a hobby, he helped Drs. Frank Bassett and William Garrett with the sports teams and was seeing a number of players whose careers were cut short by exertional pelvic pain. He and a medical student studied in the fresh cadaver laboratory, the anatomy depicted in Fig. 10.2. In medical school the anatomy had seemed overwhelming. Armed with the recent memory of physical examinations on athletes who could no longer play, we were determined to think about anatomic function. Most of the athletes had multiple sites of pain elicited around the pubic symphysis.

In the lab, it became obvious that the pubic bone was in the middle of all this activity. We did a stupidly simple experiment (Fig. 10.3). From above the pubis, I took a Mayo scissors and cut through about 30 % of the right rectus abdominis attachment while the medical student put her

Fig. 10.2 Pelvic anatomy in a cadaver

index finger behind the three adductors that attach to the pubis and on top of the anterior edge of the inferior pubic ramus which has sharp, tooth-like projections. As I cut the rectus, the adductor muscles jolted posteriorly and jammed her finger into the pubic ramus teeth and she let out a scream, depicted by the tears in the figure.

Rather than worry whether she would ever use her finger again, we immediately made the observation that forces created by the weakened rectus abdominis were being transmitted below the pubic bone. The pubic complex was acting like a joint. We had caused instability of this pubic "joint." In further dissections, it became clear the rectus abdominis, pectineus, adductor longus and adductor brevis, were the most important structures in stabilizing the joint. Other muscles passing by the joint, such as psoas, rectus femoris and Sartorius provided additional support. A thick fibrocartilage plate lay on top of and congruent with the pubic bone connecting the muscles above and below. There was very little real tendon. The medical student's finger did recover.

Further experiments on fresh cadavers reaffirmed the dynamic nature of this region. For example, rectus abdominis divisions caused changes in either hydrostatic or strain gauge measured pressures inside the ball and socket hip joint. The cuts sometimes caused the needles to bend. In the absence of life, the precise values were not physiological. Nevertheless, the obvious changes meant that the entire region around and including the pubic bone acted in concert.

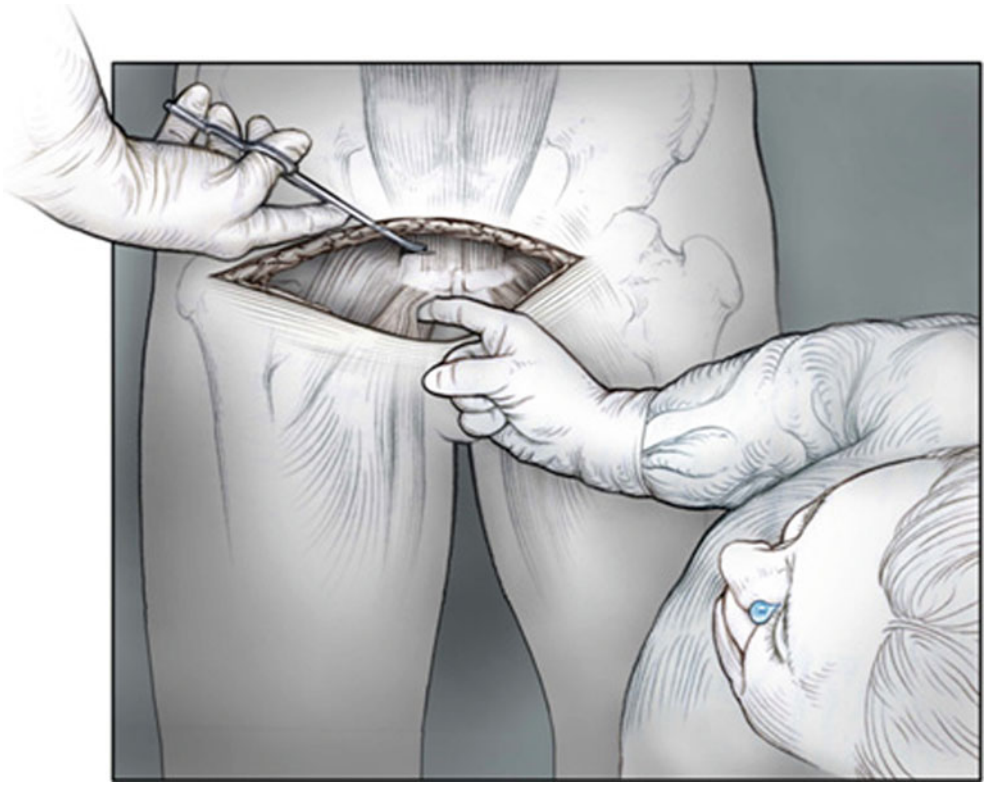

Fig. 10.3 Dissection of fresh cadaver with medical student. Note student's tears when her finger is pinched after partial rectus abdominis severance (reproduced with permission) (Artist – Rob Gordon)

Clinical Experience

These simple experiments were performed in the same era as trainers and physical therapists were recognizing more on-field, soft tissue pelvic injuries. Therefore, it seemed acceptable to perform surgical procedures on three long-injured players based on the sites of suspected pathology. Fortunately, the initial patients did well, and then more patients came.

Figure 10.4 shows the growth in patient experience. No doubt, the growth parallels an overall growth in the sports world's acknowledgement of the existence of these problems. One can notice that we were quite selective initially with respect to who underwent surgery. As we became more confident, we realized osteitis pubis was not generally a separate problem, and instead was a reaction to pubic instability; so we operated on a proportionately higher number of patients, reflected in the graph. Presently, more patients are coming with pure hip or other non-muscular causes of pain; plus we are recognizing more injuries that do not need surgery, accounting for the subsequent widening gap between surgeries and total consultations.

In a comparison of two decades of experience with these injuries [6], we chronicled a number of patterns in about 8,500 patients. While males still accounted for about 85 % of the injuries, distinct injuries became apparent in women. The median age of all diagnosed patients had increased, as well as the number of recreational athletes and sports. The paper recounted the development of 19 separate syndromes, 121 different operations, and 16 rehabilitation/performance protocols based on sites of pathology. It also documented a 15 % clinical and MRI correlation between "athletic pubalgia" and symptomatic hip pathology. We emphasize the huge diagnostic and therapeutic importance of this last observation.

History and Physical Examination

Clinical findings in the office remain our gold standard for precise diagnosis of these injuries [27]. Histories are conducted with careful attention to three sets of diagnoses: core muscle injury, hip, and other causes.

Because muscle injury results primarily from muscular disruption, the pain of core muscle injury is primarily exertional in nature. The athlete often anticipates the pain with initiation of specific forceful activities such as sprinting or changes of direction. The pain may affect normal activities such as coughing, sneezing, or rolling over in bed at night time. The pain may vary from side to side, depending on patterns of compensation, or involve multiple sites of soft tissue attachments such as the rectus abdominis, specific adductor or strap muscles. An inflammatory response of or around the pubis (osteitis pubis) sometimes accompanies the resultant instability and may cause tenderness or pain cessation of activities.

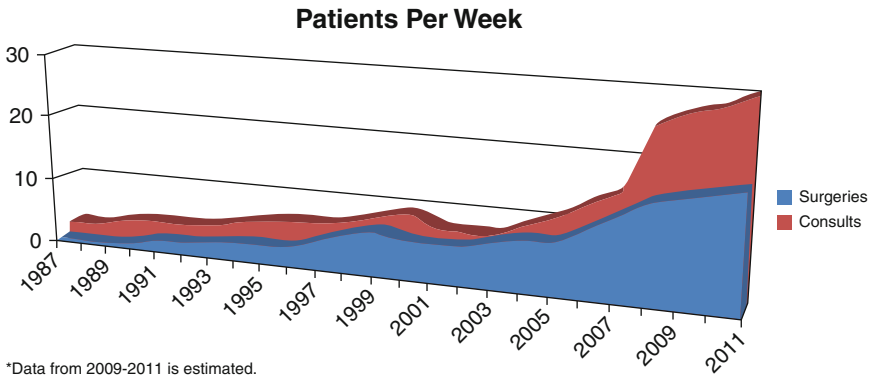

Fig. 10.4 Overall clinical experience (Data from 2009–2011 is estimated)

In contrast, patients with hip problems usually describe pain with or after minimal activity such as prolonged standing, walking or jogging, or with certain postures such as prolonged sitting, or going up and down stairs. Their pain may be more sporadic, often less predictable. Historical clues may signal the presence of both muscle and hip findings at the same time. Pains from "other causes" often have historical clues pointing to the genitourinary, gastrointestinal, gynecological symptoms or neurological systems. One's antennae should come up when the patient reports pain totally unrelated to physical activity. We cannot overstate the importance of past medical history. And one should beware that some patients with perilous other causes may have benign musculoskeletal injuries at the same time. In contrast with some other fields of medicine, the profound overlap of the three diagnostic "buckets" [6] indicates one should not necessarily be satisfied with just one diagnosis.

Physical examinations should be conducted with the same careful attention to the three categories of diagnoses. For core muscle injuries, we have developed resistance tests for each of the muscles attaching to or crossing the pubic symphysis or joint [28] (Fig. 10.5). Interpretation of each test involves three considerations: (1) Does the test cause pain? (2) Does the resultant pain correlate to the muscle being tested? And (3) Does the resultant pain re-create the pain causing the athlete's disability.

For the hip problems, the examination involves primarily range of motion tests without interference from contraction of muscles. These include the standard flexion-abduction-external rotation (FABER) and flexion-adduction-internal rotation (FADIR) tests, plus numerous other rotational or hyper flexion or hyperextension tests that could isolate anterior, posterior or lateral impingements or other pathology. Localized tenderness may sometimes help for specific diagnoses, although the tenderness form diffuse bony or soft tissue inflammation may also cause confusion.

Comprehensive physical examinations, sometimes with internal pelvic or rectal examinations, deserve particular attention for the detection of the "other causes." One must remember that other causes include both musculoskeletal problems including tumors as well as non-musculoskeletal diagnoses. It may be helpful to note that extreme pain with light touch may suggest the existence of CRPS (chronic regional pain syndrome), the more modern name for RSD (reflex sympathetic dystrophy) [29].

Fig. 10.5 Pectineus test

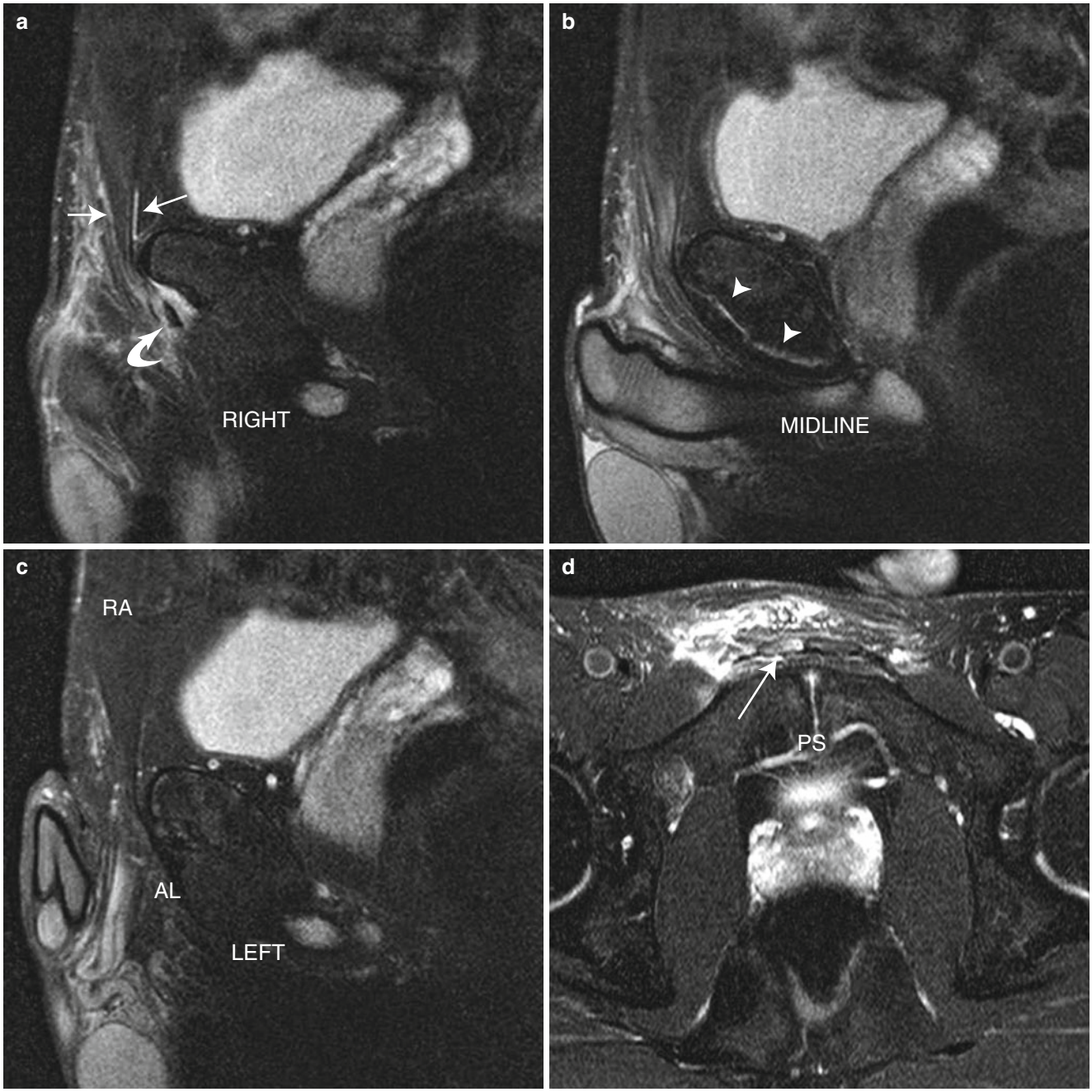

Fig. 10.6 Sequential sagittal MR images from a dedicated athletic pubalgia/core injury MRI protocol on a baseball catcher (**a**, **b**, **c**) show a detached rectus abdominis and torn adductor longus on the right (*arrows*) with an extensive midline pubic plate disruption (*arrowheads*) but normal rectus abdominis and adductor attachments on the left. An axial MR image (**d**) employing high resolution shows unilateral edema within and around the lower right rectus abdominis at the level of the pubic symphysis

Magnetic Resonance Imaging

The formulation of specific magnetic resonance imaging techniques for these injuries has opened many eyes. We initially showed a soft correlation of MRI with athletic pubalgia [30]. Then specialized pelvic MRI and MRI-hip arthrography became astoundingly accurate in demonstrating pathologic links with the histories and physical examinations [31, 32]. About 7 years ago, the radiologic co-authors designed a specialized technique for demonstrating most of these soft tissue injuries (Fig. 10.6) [33]. The technique resulted from imaging fresh cadavers, and determining the correct angles and ways to reduce bone interference so that attachments to the fibrocartilage pubic plate could be detected. The

Table 10.3 Clinical entities of core muscle injuries

Various core muscle injuries		
Syndrome	Defect	Possible indicated procedure
Unilateral RA/unilateral AD Adductor longus (AL) Adductor pectineus (AP) Adductor brevis (AB)	Tear and compartment syndrome (CS)	Repair and release
Pure AD syndromes	Normally CS	Release and/or repair
Bilateral RA/bilateral AD	Aponeurotic plate disruption; tear and CS	Repair and release
Unilateral/bilateral RA	Tear(s)	Repair
Osteitis pubis variant	Usually tears, CS, bone edema	Repair, release, steroid injection
Unilateral/bilateral	Combination tear(s) and CS	Repair(s) and release(s)
Iliopsoas variant	Impingement and bursitis	Release
Baseball pitcher hockey goalie	AD tear and muscle belly CS	Release
Spigelian and high RA	Tear	Repair
Rectus femoris variant	Impingement	Release
Female variant	Medial disruption; lateral thigh compensation	Repair and release(s)
Round ligament syndrome	Inflammation with tear	Repair and excision
Dancer's variant	Obturatorinternus/externus	Release(s)
Rower's rib syndrome	Subluxation	Excision and mesh
Avulsions	Usually acute adductor injury	Repair and/or release(s)
AD/RA calcification syndromes	Chronic avulsions	Excision, release
Midline RA variant	Tears and muscle separation	Repair
Anterior ischial tuberosity variant	Posterior perineal inflammation, gracilis, hamstrings	Release
AD contractures	Often associated with hip pathology	Release and hip repair
Other variants	E.g., gracilis, quadratus, iliotibial band	Variable

Adapted from Ref. [6]
Any of the soft tissues attached or crossing the pubic symphysis can be involved alone or in combination with other injuries. Note that a patient can have more than one variant
The above syndromes are listed in order of occurrence; highest to lowest
RA indicates rectus abdominis, *AD* adductor

technique uses surface coils and a send-receive body coil. The initially reported MRI sensitivity and specificity rates of 68 % and 100 % respectively for rectus abdominis injury and 86 and 89 % for adductor injury have improved with dedicated core muscle protocols This objective way of demonstrating injuries has provided convincing evidence of the multiplicity of soft tissue injuries as well as the overlap with ball-in-socket hip injuries. Similarly, MR arthrography has become increasingly sensitive in the diagnosis of intrinsic hip pathology, and increasingly accurate with employment of dedicated sensorcaine or lidocaine protocols.

Illustrative Cases/Studies

While we have described many distinct syndromes and procedures to repair the various injuries (Table 10.3), the main point is that many distinct injuries occur in the pelvis, involving soft tissues, bony anatomy or both. *This is not just one injury.* A pattern of injuries follows a set of forces normally symmetrically balanced around the pubis. The new eyes need to capture those dynamics. This appreciation then enables the identification of most of the problems as well as institution of appropriate therapy. Not all the diagnoses require surgery. Plus, a variety of established or alternative modalities may help treat or temporize the various problems depending on the specific injuries. When it comes to surgery, we usually perform direct repair with sutures or compartmental releases of overcompensating muscle groups, or a combination. Note that *release* to us means reducing pressure within a muscular compartment, usually with a set of epimysiotomies, and not division of muscles or tendons. We have devised a variety of compartmental decompressions depending on the particular pathologies.

The following represent several cases that portray part of the spectrum of problems:

Figure 10.7 shows a tear of the obturator externus in a professional ice hockey player during the recent playoffs. See all the edema extending into the more superficial adductor longus. The plate is spared. With steroid injection the day after injury, he was able to play 10 days after injury. The patient will likely not need surgery.

Figure 10.8 shows the imaging of what we call "baseball pitcher/hockey goalie syndrome" but in a National Football League middle linebacker. The injury is caused by fascicular disruption resulting in distal retraction of injured muscle and a compartment syndrome. This syndrome usually resolves with time, sometimes sped by a

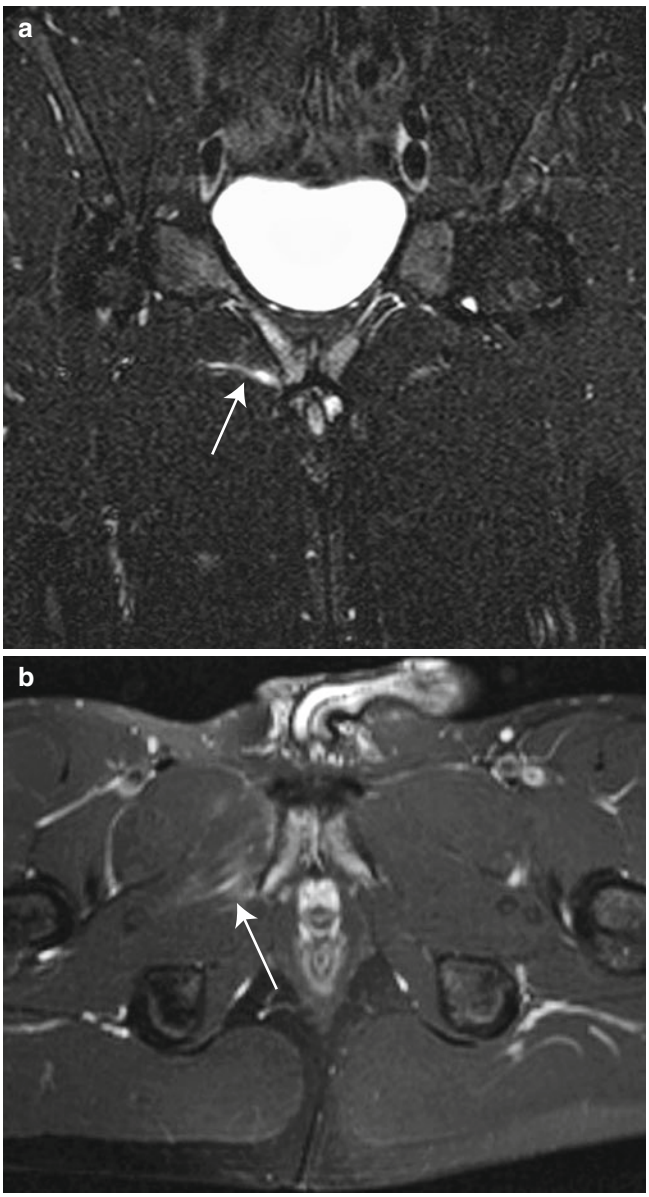

Fig. 10.7 Coronal (**a**) and axial (**b**) MR images from a hockey player show streaky edema following the distribution of the right obturatorexternus (*arrows*)

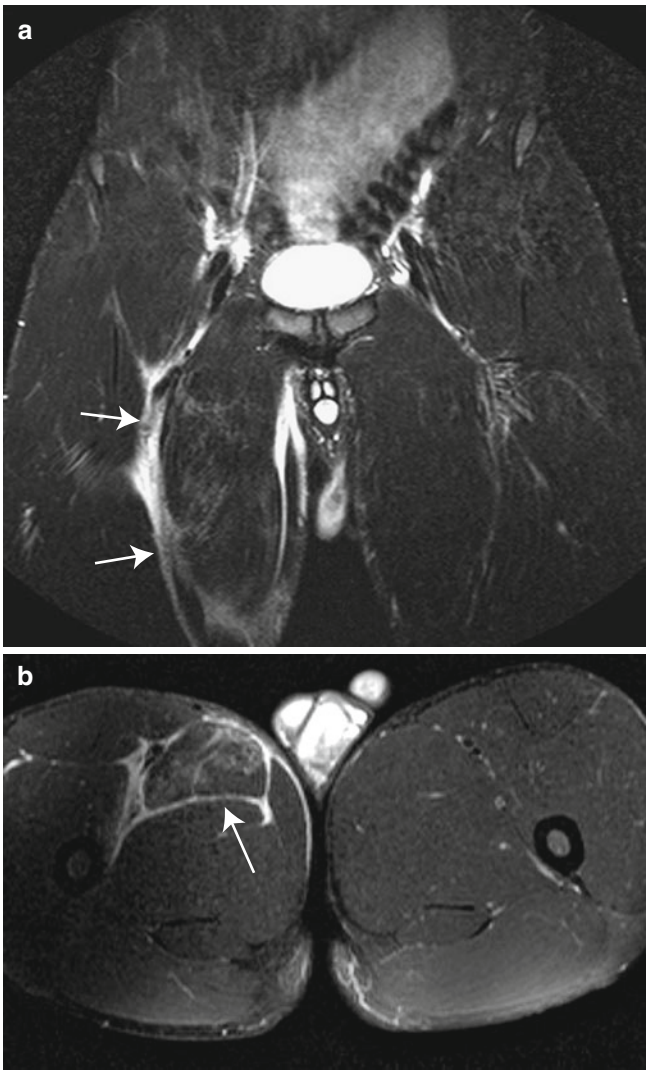

Fig. 10.8 Coronal (**a**) and axial (**b**) MR images show extensive feathery edema throughout the right adductor compartment with enlargement of the pectineus and adductor longus and perimuscular edema (*arrows*) characteristic of baseball pitcher/hockey goalie syndrome

steroid injection. In this case, the pain did not resolve, and he underwent a compartmental release and nerve decompression and returned to full play 4 weeks after surgery.

Figure 10.9 shows the magnetic resonance imaging of a star soccer player who had undergone an unsuccessful hernia repair with mesh. In fact, he never had a fibrocartilage plate injury and his original pain was entirely due to an intense stress reaction in the ischiopubic aspect of the acetabulum. Fortunately, he got better with 4 months of strict non-athletic activity. In the next off-season, he did end up undergoing removal of his mesh because of the pain and stiffness from the muscular fixation and fibrosis caused by the mesh.

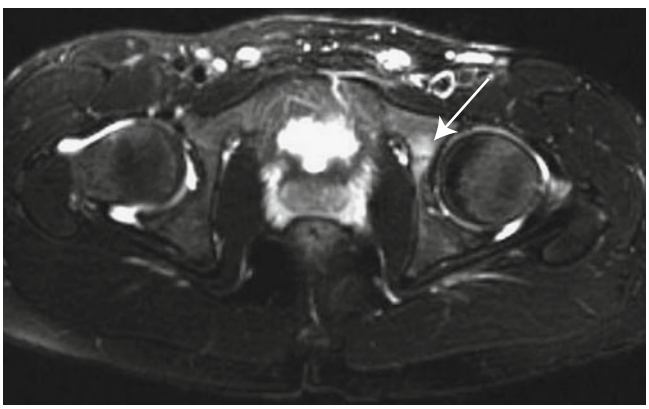

Fig. 10.9 Axial MR image from a soccer player with persistent pain after an unsuccessful mesh hernia repair shows bone marrow edema and a dark, linear lesion at the triradiate cartilage physis (*arrow*) typical for a stress fracture

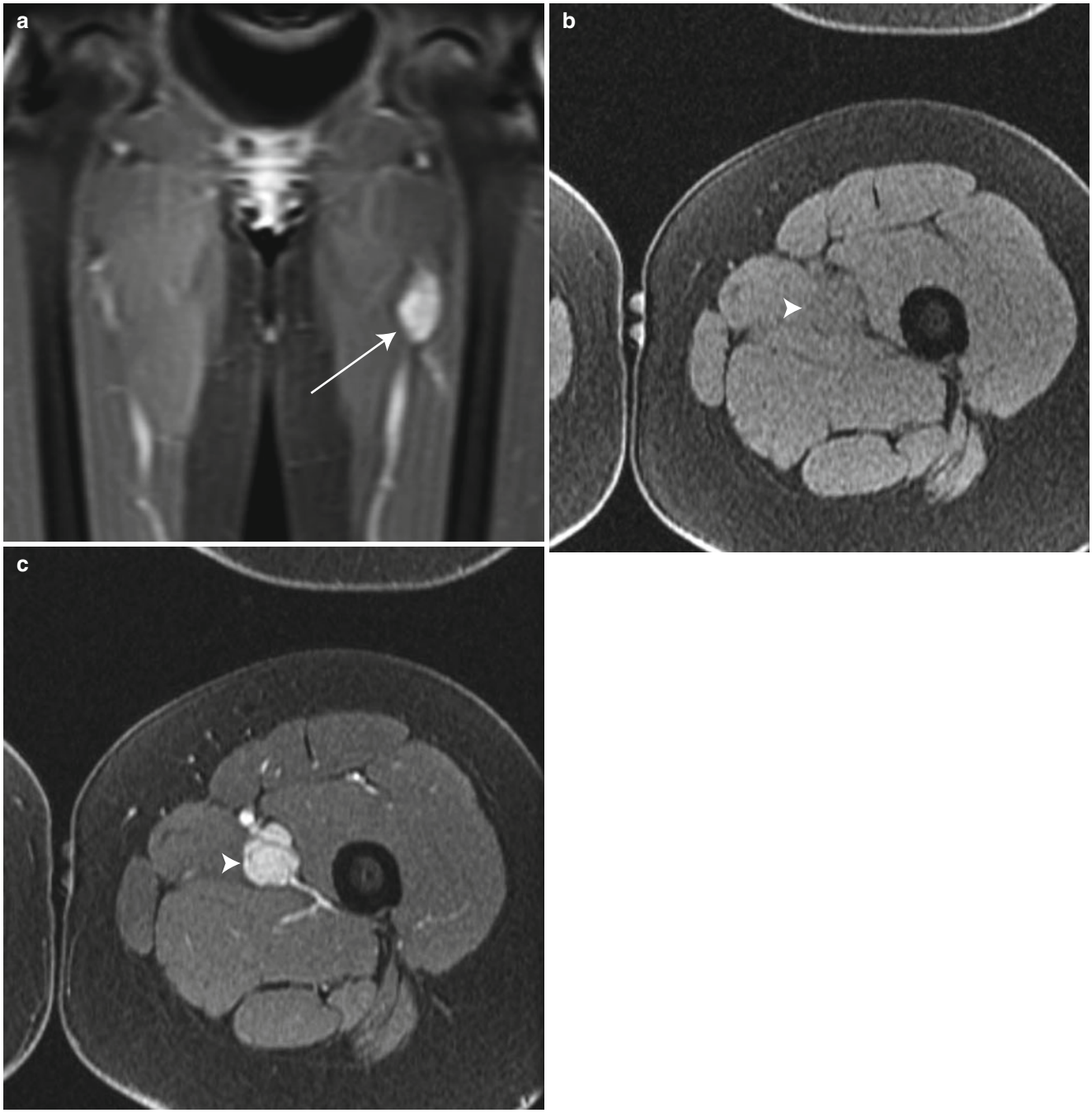

Fig. 10.10 A preliminary coronal localizer MR sequence (**a**) for a 15 year old volleyball player shows a mass within the left thigh adductor compartment (*arrow*). At this point, the MRI was altered to a soft tissue mass protocol. Pre (**b**) and post (**c**) contrast axial images of the left thigh show an enhancing intermuscular solid mass (*arrows*) with feeding vessels indicating an aggressive lesion, ultimately proven a sarcoma

Figure 10.10 is included to remind us of the scarier diagnoses that do occur in the core. This excellent volleyball player and daughter of a prominent football coach had adductor pain caused by this tumor, a usually lethal synovial cell sarcoma. Fortunately, the MRI field was widened, based on clinical examination, and the tumor was caught early. Nevertheless, it had already locally metastasized. She underwent radical resection to include femoral vein resection followed by irradiation and now healthy 6 years out and without recurrence.

Figure 10.11 illustrates what seems to be a common finding in these patients, the association of "osteitis pubis" and plate defects. This was the case in this high level basketball player's MRI. He underwent bilateral rectus

abdominis repairs and plate decompression and was competing in the Olympics 6 weeks later. Most patients need surgery for this. *Osteitis pubis* is usually associated with plate disruption related to core muscle detachment. We have followed three similar patients who did not undergo surgical correction. In each, the fluid accumulation initially was entirely between the fibrocartilagenous plate and the pubic bone. With continued athletic competition, the fluid subsequently got worse, crossed the bony cortex into the marrow and formed pubic symphysis cysts. This progression of findings raises the possibility that the pubis is subject to arthritis like the ankle joint. With injury and continued pressure in the two sites, fluid accumulation and the loss of congruency seems to lead to marrow changes and arthritis.

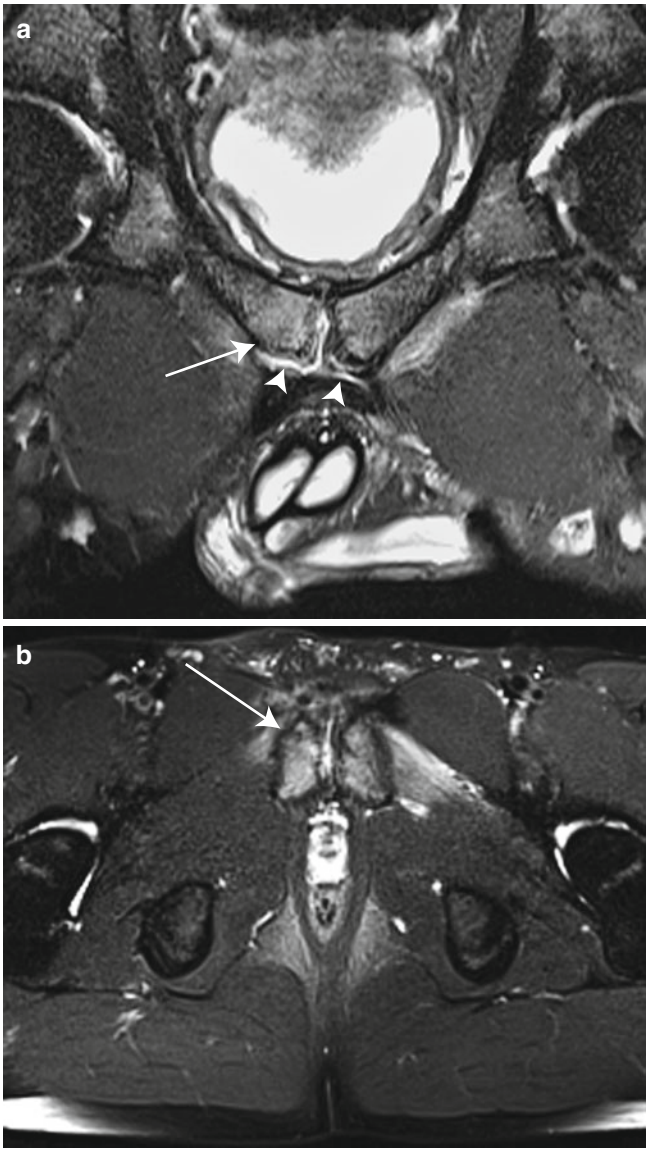

Fig. 10.11 Coronal oblique (**a**) and axial (**b**) MR images show bright bone marrow edema (*arrows*) on both sides of the pubic symphysis indicating osteitis pubis. A large detachment of the pubic plate (*arrowheads*) is also visible on the coronal oblique image

Finally, let us illustrate two more points. As mentioned, the recently published women athlete study [27] shows nicely how the causes of pelvic pain fall nicely into three categories: hip problems, core muscle injuries and "other problems" with important overlap. The women had a markedly different set of anatomic pathologies than men, almost certainly resulting from gender differences in anatomic structure. Then, the women had combination hip and core muscle injuries all chose to undergo both or neither surgeries, possibly reflecting a more determined group of athletes. The surgical group did extraordinarily better than the non-surgical group. This constellation of observations shows how much we still have to learn about these injuries. We have only begun to understand the risk factors and best treatments.

The second point is that we are seeing an increasing number of patients with persistent or recurrent pain after either "hernia repair" or "minimal repair" (Table 10.4). Fortunately, the success rate is high after re-operation and correcting the primary defects. Unfortunately, we are also finding that many of them were originally not suffering from core muscle injury.

New Nomenclature

For clarity and hopefully facilitation of new knowledge, we recommend a new nomenclature for these injuries. As mentioned, previous terms, most notably the ones using "hernia", have led to inaccurate diagnosis, suboptimal treatment and misconceptions about pathogenesis. The recom-

Table 10.4 Re-do surgery

Type of surgery	# of patients	Subsequent surgery		
		Core muscle	Hip	Other
"Minimal repair"	99	84	12	3
Hernia repair				
Open	123			
Laparoscopic	107			
Both	17			
Total	247	218	22	7
Total	**346**	**307 (87.3 %)**[a]	**34 (9.8 %)**	**10 (2.9 %)**

[a]Overall 1 year success rate for "re-do" core muscle surgery was 93.9 %

Table 10.5 New nomenclature (See text for definitions)

Core
Core injuries
Hip joint
Core muscles
Core muscle injury
Pubic symphysis
Pubic symphyseal joint
Pubic joint or pubic bone joint
Osteitis pubis
Primary osteitis pubis
Secondary osteitis pubis

mended nomenclature (Table 10.5) hopefully encourages fresh questions concerning the physiology and biomechanical pathogenesis. The recommended terms in this section are noted in italics. The nomenclature presupposes five tenets linking the anatomy to these injuries: (1) a spectrum of injuries; (2) a dynamic musculoskeletal nature; (3) the pubis at a center of motor activity; (4) a normal musculoskeletal equilibrium among the anatomic parts; and (5) a biomechanical importance of this region in the body's athleticism.

We recommend the term *core injury* to describe any of the afore-mentioned problems. The term *core* reflects what much of the lay and scientific literature already calls the core, the large block of musculoskeleton that includes the abdomen, pelvis, hip, proximal thigh and back. *Hip joint* refers to the ball-in-socket hip joint alone with its investing capsule, thereby excluding all the muscles outside this narrowly defined hip joint. C*ore muscles* then refer to all the muscles outside the hip joint in this region, and *core muscle injury* refers injury to any of those muscles or any combination of core muscles.

Because the pubis is the center of so much activity, this bone also deserves more distinct terminology. Descriptions of the bone in classic anatomical treatises [34, 35] create considerable ambiguity. Classically, the pelvis has two pubic bones, each divided into a body and two rami. Often "body" and "symphysis" are used interchangeably; yet, the dictionary definition of symphysis "site of fusion" and the term is also used in the singular to denote the site of fusion between the right and left bodies. Most adults still have a distinctly mobile, tiny space between the two pubic bones analogous to the sterno-clavicular joint or acromio-clavicular joint. We recommend this normal mobile space be called the *symphyseal joint*. The pubic symphyseal joint is lined by fibrocartilage and includes an innermost extension of the externally investing *fibrocartilage plate* often called a "disc". The injuries to the pubis may involve either or both pubic bodies, rami, or symphyseal joint. Therefore, we recommend embracing both the plural and singular usages of *pubic symphysis* in the following context. The singular term includes both bodies and the symphyseal joint taken as a whole. In contrast, the plural *pubic symphysis* describes each central pubic body as if it were detached from the other, in which case there are two pubic symphyses: the right and the left.

In distinction from the pubic symphyseal joint, we recommend the term *pubic joint* or *pubic bone joint* to describe all the motion around the pubic symphysis. This term does not satisfy one criterion of a classical orthopedic "joint"; it does not contain two or more juxtaposed bones. Activity around the entire pubis, however, is so balanced and involves so many more degrees of freedom than even the shoulder or hip joint, it deserves a simple designation. The term(s) effectively gets across the activity theme despite the non-fulfillment of that criterion.

We also recommend *osteitis pubis* to apply to any inflammation in or around any part of the pubic bone. The user of the term then has to specify how it is being used. For example, acute or chronic inflammatory changes may be seen in part or all of the pubic bone during imaging or anatomical dissections. Any or all of this may be called osteitis pubis. We would add an additional two modifiers: *primary* versus *secondary osteitis pubis.* Secondary osteitis pubis refers to pubic inflammation when there is an obvious cause for the reaction e.g. muscular injury or obstetrical symphyseal joint disruption. Primary osteitis then refers to discernible pubic inflammation for which no cause is apparent e.g. the non-athletic patient with severe, continual chronic pubic pain, tenderness and imaging findings of pubic inflammation but no other discernible disruption. Considering the two modifiers, some patients may not easily fall into either of the two categories.

Summary and Conclusions

In this chapter we have reviewed the literature and historical and clinical aspects of injuries to the soft tissues around the pubic bone, and made some frank observations. One of the more important ones is that as specialists in medicine, we need to be aware of the limitations of our training. We also propose a new nomenclature to facilitate a common understanding and new knowledge. For *core injuries*, we need to recognize two distinctly separate areas of motion: the *hip joint* and the *core muscles* that attach to or pass by pubic bone. The two joints act together in various ways. Already a fruitful area of research, the concept of *core muscle injury* creates a paradigm shift in how we must advance this field, one that crosses multiple specialties.

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