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Diagnosis and Management of Core Muscle Injuries

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Lower abdominal and groin injuries are among the most common causes of pain and lost playing time in sports. Treating these injuries requires understanding the anatomy of the core and how the various components interact. Every muscle of the core is subject to injury so therapeutic decision making depends on a precise diagnosis and an understanding of the natural history of that injury. In this review, we will describe the anatomy and pathophysiology of core muscle injuries in detail as well as the appropriate work-up and management.

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Introduction

Lower abdominal and groin injuries are among the most common causes of pain and lost playing time in sports.¹ Despite increasing recognition, these injuries remain poorly understood compared to other sports injuries. This is likely in part due to the diversity of organ systems that can give rise to lower abdominal or groin pain. Additionally, the lack of consistent nomenclature makes studying them difficult. By using categories based on the locations of pain, we do know that injuries of the upper leg, groin, and hip are among the most common injuries in sport.^{2,3,4} A recent weekly survey of soccer players found the weekly prevalence of “groin problems” to be 29%.⁵ We prefer the term *core injury*.^{10,11} The concept of “the core” was established by exercise and fitness experts and refers to the entire body from the chest to the mid-thigh. This classification allows for further subcategorization based on the anatomic structures involved. Specifically, there are 4 broad categories of core injuries: muscular, hip, back, and everything else.

Anatomy of the Core Muscles

A *core muscle injury* refers to damage to any skeletal muscle within the area between the chest and mid-thigh.⁷

These muscles are symmetrically arranged around the pubic bone and thinking about the anatomy this way helps one understand the pathophysiology of a lot of these injuries. The muscles that originate and/or insert onto the fibrocartilage plate covering the pubic bone play important roles in pelvic stability and constitute the harness that allows the torso to move with the legs. This central stability functionally anchors the pelvis so that more distal parts of the body can move efficiently. The rectus abdominis flexes the trunk and forms the anchor for considerable abduction and adduction, as well as internal and external hip rotation. Laterally, the rectus abdominis attaches to the obliques via pure fibrous connections, enveloping complexes of nerves and tiny vascular structures. Three adductors—the pectineus, the adductor longus, and the adductor brevis—insert onto the fibrocartilage of the pubic bone adjacent to the rectus abdominis and play a primary role in core stability. In the literature, previous adductor or groin injury is the most consistently identified risk factor for subsequent injury.^{8,9} We have found that distal scarring from a muscle belly injury can increase the forces applied at the pubic bone attachment and can accelerate a central injury. Other muscles, such as the iliopsoas and rectus femoris, can be involved as well. In a review of experience with over 8000 patients, these muscles were involved in 3% and 4% of cases, respectively.¹⁰ Describing the muscular injuries using the actual muscles involved allow patterns to emerge that will hopefully influence prevention and treatment.

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Physical Exam

A compulsive history and physical examination, and appropriate imaging are necessary to arrive at a complete diagnosis. Localized tenderness may sometimes help for specific diagnoses, although tenderness from diffuse bony or soft tissue inflammation may also cause confusion. Resistance testing with careful attention to the location of elicited pain can help identify involved muscles. Interpretation of each test involves 3 considerations: does the test cause pain? Does the resulting pain correlate to the muscle being tested? And does the resulting pain recreate the pain causing the athlete's disability? One must also consider that portions of the gastrointestinal, genitourinary, and gynecologic systems, lymphatics, blood vessels, and nerves also reside in the core. The importance of this group cannot be overstated since some of these diagnoses can be life threatening. A detailed history and physical examination will often provide enough evidence to expand the focus beyond the musculoskeletal system.

Core Muscle Injuries and Femoroacetabular Impingement

One must also consider the potential for hip joint involvement. In terms of physical exam, we prefer to examine the hips with primarily range of motion tests without interference from contraction of muscles. These include the standard flexion—abduction—external rotation and flexion—adduction—internal rotation tests plus other rotational or hyperflexion/hyperextension tests. Watching the hemipelvis lift off the bed during internal rotation allows for an appreciation of the levering effect of the femoral head on the pelvis in the presence of impingement. In our practice, 16% of patients have symptomatic intraarticular hip pathology in addition to muscular injury. Hip arthroscopists have described a similar overlap between femoroacetabular impingement and muscular injuries.^{11,12} Similarly, decreased hip range of motion has been identified as a risk factor for the development of chronic groin pain.⁹ One must be prepared to workup and treat both conditions when evaluating someone with groin pain.

Imaging

After completing a detailed history and physical exam, one must consider the muscles involved when selecting the next diagnostic tests; there is complex anatomy surrounding the pubic bone, all of which has the potential to contribute to an injury. Ultrasound can be useful in detailed visualization of structures but its use can be misleading in identifying hernias. The proximity of the inguinal canal to the caudal rectus abdominis attachment contributes to some of the confusion related to hernias. Normal inguinal fat occurs in the spermatic cords or round ligament. Likewise, retroperitoneal fat extending into the inguinal canal is commonly observed on MRI, but should not typically be considered a true hernia. If a true hernia is suspected, prone imaging and dynamic sequences with ultrasound or MRI can be used. As previously stated, laxity of the internal inguinal ring or floor of the inguinal canal is often

a byproduct, or secondary sign, of a more central injury involving the muscular attachments to the pubic bone. Because ultrasound is relatively inexpensive and widely available, it is often an appropriate next step. The presence of edema around the pubic bone or along the surrounding musculature, or signs of atrophy or laxity of the abdominal wall should prompt one to get an MRI with the “athletic pubalgia” protocol to better define the muscles involved.^{13,14}

Plain Radiographs

Because of the frequency of concomitant hip and core muscle injuries, we have made it a part of our routine practice to get plain films of the pelvis and hip. Documenting the presence of femoroacetabular impingement and hip dysplasia is useful in understanding and treating the acute injury, aids in the workup of future injuries or pain, and informs how an athlete should train with respect to injury prevention.¹⁵ Plain x-rays are also important in the detection of heterotopic ossification which occurs following platelet-rich plasma (PRP) injections and in the presence of old avulsion injuries.

In our practice, we routinely use MRI in working up groin pain. Many patterns of injury have emerged and we have, along with our radiology colleagues, established a nomenclature system for the MRI findings associated with core muscle injuries. The importance of defining all of the structures involved in an injury cannot be overstated. A poor quality MRI can be as misleading as an ultrasound. For example, MR imaging of core muscle injuries without appropriate dedicated images of the pubic bone will often show a diffuse haziness around the pubic bone. This is, reasonably, interpreted as a pubic bone stress fracture and the patient is made nonweight-bearing for months. Rest will almost certainly alleviate the symptoms but, if the injury is related to a muscular detachment, the pain will return upon resuming athletic activities.

MRI Findings in Core Muscle Injuries

The primary finding associated with core muscle injuries have been previously summarized.¹⁶ We place primary importance on the presence of fluid between the pubic bone and the overlying fibrocartilage plate, which typically necessitate surgical repair. The presence of a fluid signal between the pubic bone and the overlying fibrocartilage, which we refer to as a pubic plate detachment, can occur in the midline (Fig. 1A), laterally (Fig. 1B), extend posteriorly along the pubic ramus—which often correlates with perineal or buttock pain (Fig. 1C), and can be associated with loss of the distal rectus abdominis muscle mass (Fig. 1D) and scarring of the proximal adductors (Fig. 1E). The injuries tend to be progressive and the final stage of the injury is fracture of the fibrocartilage plate and retraction of the attached muscles along with a portion of the fibrocartilage—complete avulsions (Fig. 1F).

Nonoperative Treatment

Most core muscle injuries resolve with nonoperative management, but it is vital to recognize those that require surgical

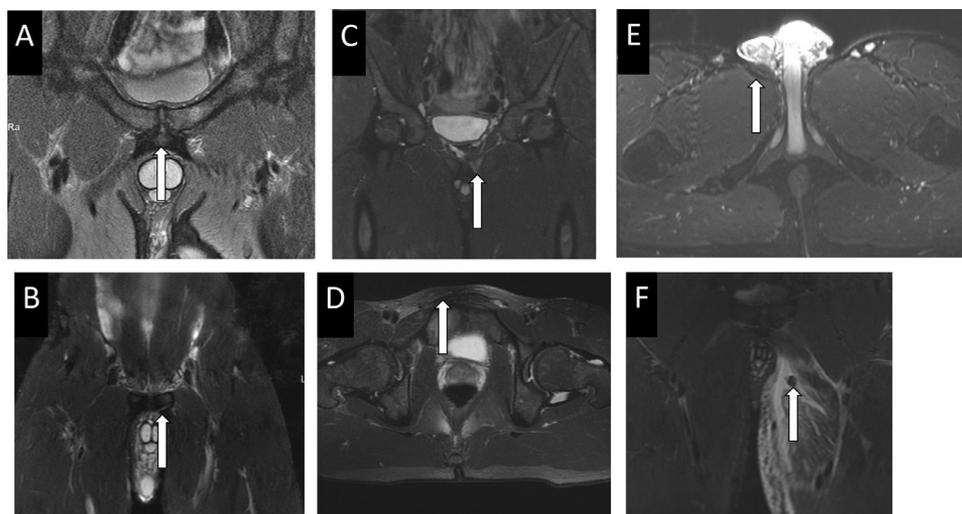


Figure 1 MRI findings of core muscle injuries. A midline plate detachment (A), lateral plate detachment (B), posterior extension of a plate detachment (C), loss of the distal rectus abdominis muscle mass (D), scarring of the proximal adductors (E), and complete avulsion of the pubic fibrocartilage (F).

repair. For certain peripheral injuries, nonoperative management is a first-line treatment. In many cases, it is also required due to special considerations in athletes. These include the timing within a season, concerns about coaching/front office decisions, and the influence of contract negotiations, in addition to the clinical factors. These factors must be considered in deciding when to employ aggressive temporizing procedures versus permanent solutions. In general, the first treatment of groin pain involves rest, ice, analgesics, anti-inflammatories, and depending on the resources available, manual therapy, ultrasound, infrared, etc. Success has been demonstrated in treating these injuries nonoperatively but comparison with surgical outcomes is difficult.⁶ Many practitioners prescribe physical therapy as a first-line treatment for core muscle injuries and there is controversy in the literature about the relative efficacy of physical therapy versus surgery. There are many published studies that demonstrate return to play following dedicated exercise programs designed to improve core muscle strength and proprioception.^{17,18,19} Classically, these injuries improve with rest but the pain returns upon resuming activities. This period of rest, however, is not a required component of the diagnostic workup and someone with signs and symptoms of a core muscle injury need not wait to start physical therapy or proceed with definitive repair.

Regarding the nonoperative approach to temporize a central core muscle injury, we prefer corticosteroid injections directly into the areas of injury and inflammation. Overall in our experience, about 80% of players with core injuries returned to high level play for the duration of the season and delaying definitive repair did not adversely affect postoperative outcomes. Other factors, however, such as the timing of the injection and the presence of clinically significant hip pathology are likely significant factors in determining whether this approach will be successful. To our knowledge, there are no outcomes studies for the use of corticosteroid injections to treat core muscle injuries, but they are widely used and the techniques

have been well described.²⁰ Pubic symphyseal or cleft injections have also been described and are widely used.²¹ We do not advocate the use of this technique as we have determined that these injections are effective only if the plate detachment is confluent with the pubic cleft. We are not aware of any studies comparing these techniques.

PRP has become a popular treatment for a variety of sports-related injuries including chronic groin pain. There are few published studies describing its use.^{22,23,24} In our practice, we have seen an increased incidence of prior PRP injections among the patient population and with it an increase in dense fibrosis and heterotopic bone formation at or near the area of injury within the adductor muscles. Prior to the introduction of PRP, similar ossification was a rare occurrence that only occurred in long-standing avulsions or previous surgical adductor division procedures. Nearly every patient with prior PRP injections has intense fibrosis and about half have heterotopic ossification, an example of which is shown in [Figure 2](#). There is certainly a selection bias when studying our patient population in that we tend not to see athletes with success from prior treatments, but this observation warrants a cautious approach to the use of PRP for core muscle injuries.

Operative Treatment

Most injuries that cause chronic lower abdominal and groin pain in athletes are not simply occult hernias or impinged nerves. They usually involve multiple muscles and there is significant interaction with the hip joints. Treatment should be directed towards restoring normal anatomy across the pubic bone. This often refers to the rectus abdominis and adductors and restoring the balance between the forces applied by these opposing muscle groups. That is not to say that these processes do not occur, but the presence of an indirect hernia sac does not rule out a muscular injury.

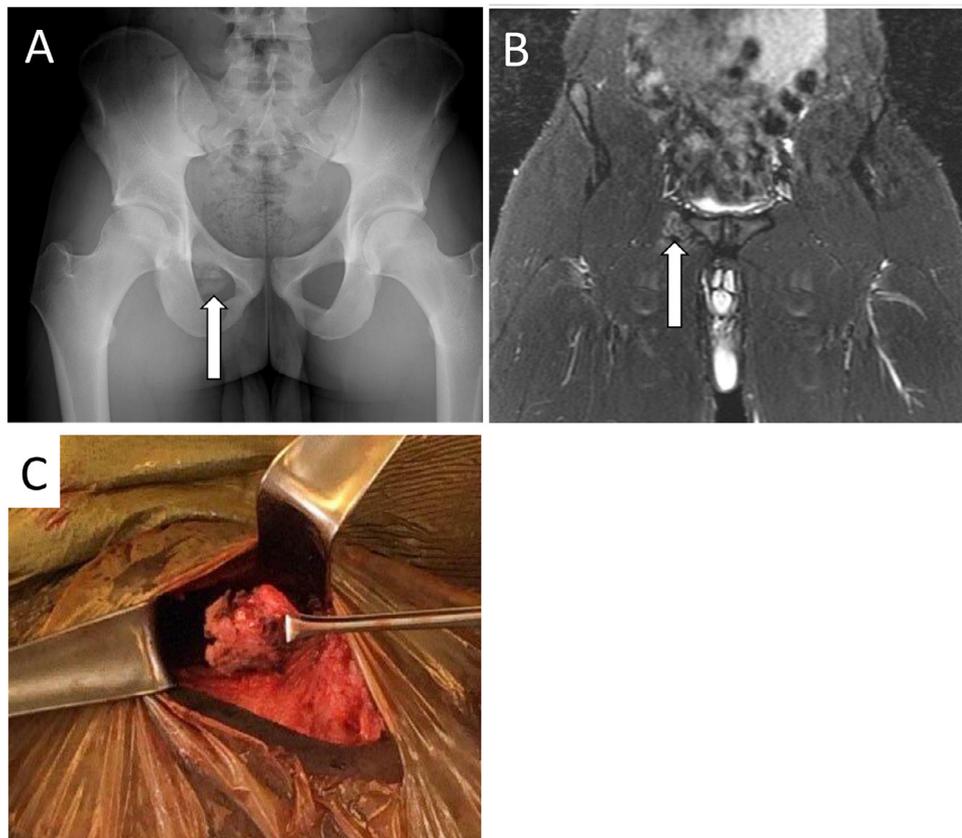


Figure 2 X-ray (A), MRI (B), and surgical specimen (C) demonstrating heterotopic ossification of the adductors following a PRP injection.

Disrupting the pubic bone attachment of the abdominal wall musculature can certainly result in laxity of the floor of the inguinal canal and internal inguinal ring. There have been numerous publications demonstrating success with treating this laxity as the primary culprit.²⁵ Mesh fibrosis seems to help stabilize the rectus abdominis at the pubic bone but this has not been demonstrated. In our practice, we regularly see patients with mesh-related inguinodynia and persistent pain from unresolved muscular injuries. The use of mesh in treatment of these injuries is widespread and is recommended by many leaders in the field.^{26,27}

Some advocate division of the adductor pubic bone attachments to decrease the forces on the pubic bone, with²⁸ or without²⁹ placement of inguinal mesh. We do not recommend this approach because of the importance of balancing the forces applied at the pubic bone by the rectus abdominis and adductors. Additionally, dividing the pubic bone attachments of the adductors may leave athletes with a functional weakness. Others have advocated nonoperative management of complete avulsions, arguing that this constitutes an “auto-release”. We have a large experience with treating core muscle avulsions, and, in our experience, athletes have done well with repair. We see an average of 100 patients with complete avulsions of 1 or more core muscles per year. In a previous study, we followed 53 athletes closely with weekly follow-up following surgical repair. Of that cohort, 68% had returned to play at 3 weeks, 83% had returned to play at 6 weeks,

and 94% at 15 weeks. Pain-free normal play increased from 4% after 3 weeks to 19% after 6 weeks, and to 77% after 15 weeks.

It is worth emphasizing that many core injuries involve elements other than the rectus abdominis and adductors. Careful consideration of all structures involved leads to appropriate management and this often means coordination with hip arthroscopists. As previously stated, 16% of patients in our practice have both a muscular and hip injury. In addition, pain related to psoas impingement can be treated by lengthening procedures at the level of the femoral attachment and/or at the level of the hip joint.³⁰ We have treated over 300 patients with combined hip arthroscopy and core muscle repairs with 88% of athletes returning to play by 6 months postoperatively.

Despite the variations in surgical technique, most publications report success with treating these injuries surgically.^{31,32,21,33} There is less controversy regarding the importance of physical therapy in the postoperative period and a progression to return to play. Surgical treatment of core muscle injuries is 1 part of what should be a comprehensive and multidisciplinary collaboration between athletic trainers, physical therapists, sports medicine physicians, radiologists, and orthopedic surgeons.

Postoperative Physical Therapy

It turns out that early activation of the core muscles following repair is essential. Immediately following repair, the 2

processes that are most likely to cause problems with return to play (scarring and loss of muscle tone) have already kicked in. Additionally, strengthen muscles together in functional groups (rather than in isolation) pay attention to the sequence of muscle activation, understand the harness that attaches to the pubic bone, and protect the harness. These principles apply to everyone and are important in preventing core injuries.

Conclusions

Core muscle injuries are common and treatable. In general, the more central (closer to the pubic bone) the core muscle injury, the more likely it is to require surgery. Common pitfalls include failing to appreciate all the structures involved in an injury (including the hips) and complications related to certain treatments like mesh placement and PRP injection. Detailed anatomic understanding is essential for successful diagnosis and treatment.

Conflicts of Interest

The authors declare no conflicts of interest and do not have any financial disclosures.

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