Skeletal Radiology (2019) 48:1991–1997
https://doi.org/10.1007/s00256-019-03249-2

SCIENTIFIC ARTICLE

Incidence and implications of fracture in core muscle injury

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Received: 19 February 2019 / Revised: 15 May 2019 / Accepted: 16 May 2019 / Published online: 6 June 2019

Abstract

Objective To determine the pubic bone fracture incidence and associated injury patterns in patients with core muscle injury.

Materials and methods Ninety-three consecutive patients with core muscle injury protocol MRI showing rectus abdominis-adductor longus aponeurotic plate injuries from June 2007 through August 2017 were independently analyzed in blinded fashion by two musculoskeletal radiologists for the presence or absence of pubic bone fracture. A variety of other osseous and soft tissue injury characteristics were recorded. Pain duration prior to MRI and return to play time were taken from the clinical record. Statistical analysis included fracture incidence as well as the association of fracture with other injury characteristics, duration of pain, and return to play time.

Results Eighty-seven men and six women with a mean age of 34.4 years (range, 16–66 years) were included in the study cohort. Overall fracture incidence was 18.3% (17/93) including 13 fatigue fractures of the pubic body and four elevated cortical fractures/fragments. After correction for multiple comparisons, no strong association was identified with osseous or soft tissue injury characteristics, pain duration, or return to play time.

Conclusions Pubic fractures—particularly fatigue fractures—are a common co-existing injury in patients with a wide range of core muscle injury patterns. The presence of fracture did not have a strong correlation with injury patterns, pain duration, or return to play time but may have implications for patient management.

Keywords Core muscle injury · Athletic pubalgia · Sports hernia · Fracture · Athlete · MRI · Radiology

Introduction

Groin injuries represent 2–5% of all sports injuries and—when grouped with lower abdominal injuries—are among the most common causes of pain and lost playing time in sports [1–3]. An important entity resulting in groin pain is core muscle injury, formerly known as sports hernia or athletic pubalgia. Core muscle injury refers to damage to any skeletal muscle between the chest and mid-thigh, with a focus on the musculature that originates or inserts onto the fibrocartilage plate on the pubic bone. These muscles play important roles in pelvic stability and allow the torso to move with the legs [4]. The main stabilizers at this location include the rectus abdominis and adductor longus which join to insert on a common aponeurotic plate anteriorly at the pubic symphysis [4]. During core rotation and extension, these muscles are relative antagonists with the rectus elevating the anterior pelvis and the adductor depressing it. Injury of one component results in abnormal biomechanical forces on the opposing muscles and tendons, leading to further injury at the aponeurosis and tenoperiosteal attachments and potential for osteitis pubis and pelvic instability [5].

Core muscle injury most commonly occurs in athletes participating in soccer, ice hockey, and Australian Rules football but can affect both elite and recreational athletes [1, 6, 7]. The twisting and turning as well as imposed differential load shift in these sports repeatedly stresses the pubic symphysis and its supporting musculature [2, 8]. MRI is often utilized for evaluation and the imaging findings are well described, including injury to the aponeurotic plate as well as the rectus abdominis or adductor longus muscles and tendons [6, 8–11].

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While previous research has detailed the soft tissue injury patterns, we hypothesized that the same repetitive shear and abnormal biomechanical forces transmitted through the pubic symphysis in core muscle injury may also place the patient at risk for pubic body fatigue-type stress fracture. The presence of a co-existing fracture may be under-recognized in core muscle injury and substantially change the athlete's treatment and rehabilitation plan. To our knowledge, no work had been done to investigate this incidence.

Our objective was to determine the pubic bone fracture incidence and associated injury patterns in patients with core muscle injury.

Materials and methods

This Health Insurance Portability and Accountability Act compliant study was approved by our institutional review board with a waiver of informed consent for the retrospective review of medical records. Patients were identified by a search of the picture archiving and communication system (PACS) including all core muscle injury protocol MR examinations between the dates of 6/1/2007 and 8/30/2017. Patients were included in the study if they had an aponeurotic plate injury. Exclusion criteria were patients without an aponeurotic injury or with pubic symphysis infection.

Patient demographics were recorded including age, gender, and sport (if applicable). Pain duration prior to MRI and return to play time were then recorded from the medical record. The pain duration was often an estimate and, when available, was taken directly from the clinical notes when the provider documented that the patient had pain for a specific amount of time prior to the first appointment. The return to play time was also often estimated. When available, this time was recorded as the time from the first clinical note with groin pain as the primary complaint to the clinical note that stated the patient had returned to their primary sport, were able to perform their previously limited activities (especially for older patients) or their symptoms had resolved.

MR imaging

All MRI examinations were performed within the same health system. All examinations utilized a core muscle injury protocol consisting of the following sequences: coronal short tau inversion recovery (STIR) large field-of-view through the pelvis, axial T2 fat-suppressed small field-of-view centered at the pubic symphysis, sagittal T2 fat-suppressed through the pubic symphysis, oblique coronal STIR and T1 parallel to the pubic symphysis, and oblique axial T2 fat-suppressed and proton density (PD) perpendicular to the pubic symphysis. Studies were performed on both 1.5-T (78/93) and 3.0-T scanners (15/93). Specific imaging parameters for 1.5 and 3.0 T are included in Tables 1 and 2, respectively.

Image evaluation

All studies were independently reviewed in blinded fashion by two musculoskeletal radiologists, an attending with 2 years of experience and a fellow. Discrepancies in findings were resolved by consensus.

The primary endpoint was to identify the presence or absence of pubic fracture (cortical fracture/fragment, pubic body, or pubic ramus). Pubic body/ramus fractures were defined as hypointense fracture lines on T1 or PD and T2-weighted imaging with surrounding bone marrow edema (Figs. 1 and 2). A cortical fracture/fragment was defined as an elevated fracture fragment at the pubic symphysis with the co-existing aponeurotic plate injury extending to bone at that location. Normal apophyses were identified and not included in this category.

Multiple additional areas were evaluated for associated injury patterns including osseous, myotendinous, and aponeurotic plate injury characteristics. Osseous evaluation of the pubic symphysis included the presence or absence of bone marrow edema (unilateral or bilateral), subchondral sclerosis, osteophytes, subchondral cysts, and pubic symphysis fluid (defined as T2 signal within the pubic symphysis equivalent to that of the bladder). Myotendinous evaluation focused on the rectus abdominis and adductor longus with recording of tendinosis (thickening with increased intrinsic signal), strain (surrounding edema),

Table 1 MR imaging parameters (1.5 T)

	Field of view	TR	TE	Echo train length	Matrix	NEX	Bandwidth
Cor STIR	Body width	5000	44	8	256 × 192	2	25
Ax T2 FS	20 × 20	3000	60	8	256 × 192	2	15
Sag T2 FS	24 × 24	4000	68	8	256 × 192	2	15
Obl Cor T1	24 × 24	600	20	4	256 × 192	2	15
Obl Cor STIR	24 × 24	4850	40	8	256 × 192	2	8
Obl Ax T2 FS	20 × 20	3000	60	8	256 × 192	2	15
Obl Ax PD	20 × 20	3000	25	8	256 × 256	2	15

Table 2 MR imaging parameters (3.0 T)

	Field of view	TR	TE	Echo train length	Matrix	NEX	Bandwidth
Cor STIR	Body width	5000	40	9	320 × 192	2	31
Ax T2 FS	20 × 20	3000	60	8	320 × 224	2	41
Sag T2 FS	24 × 24	4000	80	20	320 × 224	2	31
Obl Cor T1	24 × 24	600	20	4	320 × 224	2	31
Obl Cor STIR	24 × 24	4850	40	9	320 × 224	2	31
Obl Ax T2 FS	20 × 20	3000	80	20	320 × 224	2	41
Obl Ax PD	20 × 20	2200	20	5	320 × 224	2	31

partial tear (surrounding edema and partial fluid signal within tendon/partial disruption of fibers) and complete tear (complete disruption) (Fig. 3). Given the short length of the rectus abdominis tendon, it was combined with the muscle and analyzed as a myotendinous unit while the adductor longus was divided into muscle and tendon. Finally, evaluation of the aponeurotic plate injuries included side (right, left, bilateral), region on the pubic symphysis (upper one half, lower one half, or both), size in millimeters (medial-lateral and cranial-caudal), as well as presence or absence of a secondary cleft sign as defined by Brennan et al. [10] (Fig. 2).

Statistical analysis

Statistical analysis was performed in R 3.4.2 (R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria), including the “Hmisc package” (Frank E Harrell Jr., with contributions from Charles Dupont and many others. (2017). Hmisc: Harrell Miscellaneous. R package version 4.0-3). The proportion of patients with fracture was reported with 95% confidence intervals. The Chi-squared test or Fisher’s exact test (categorical variables) and the Wilcoxon rank sum test (continuous variables) were used to analyze the association of other osseous and soft tissue injury characteristics with pubic body fracture with the Benjamini–Hochberg method used to adjust for multiple comparisons. All statistical tests were two-sided with a significance level of $p < 0.05$.

Results

The PACS search yielded a total of 100 consecutive patients from June 2007 to August 2017. When the images were reviewed, seven patients were subsequently excluded (one with pubic symphysis infection and six without true rectus abdominis-adductor longus aponeurotic plate injuries). Thus, the study cohort included 93 patients, 87 men and six women, with a mean age of 34.4 years (range, 16–66 years).

The 93 patients consisted of 47 recreational athletes (including high school), 22 college athletes, 12 “high-level” athletes, and 12 non-athletes or unknown. The college athletes included 11 football, six soccer, two track, two basketball, and one baseball player and the “high-level” athletes included six marathon runners, four Ironman triathletes, one Olympic trial runner, and one military member.

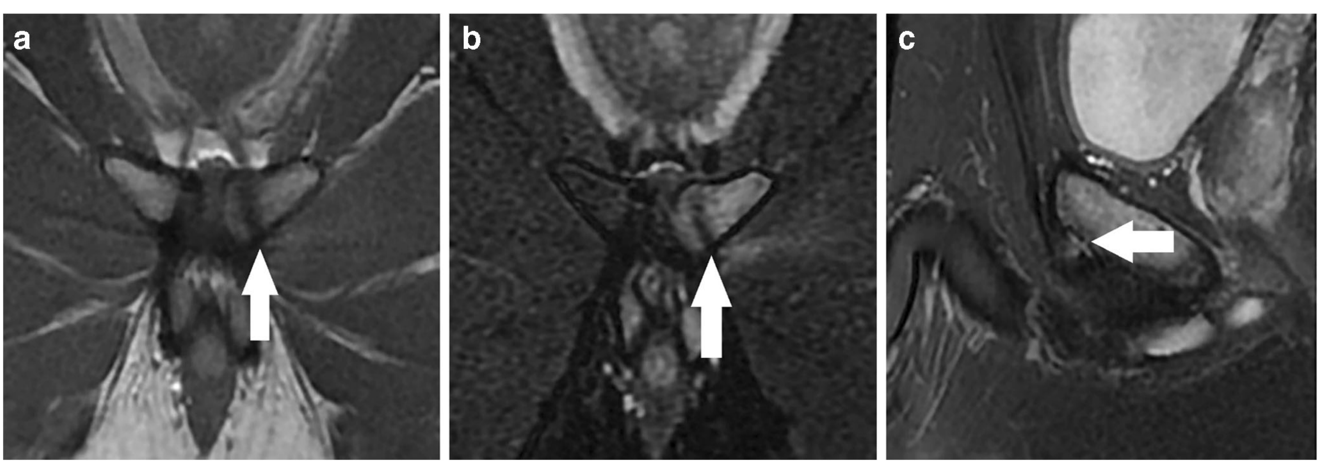

Fig. 1 A 38-year-old male presenting with left groin pain. Oblique axial proton density (**a**) and T2 fat-suppressed (**b**) MR images demonstrate a vertically oriented hypointense fracture line (*arrows*) through the left pubic body with surrounding bone marrow edema. Sagittal T2 fat-suppressed image through the pubic symphysis left of midline (**c**) demonstrates the co-existing aponeurotic plate injury (*arrow*)

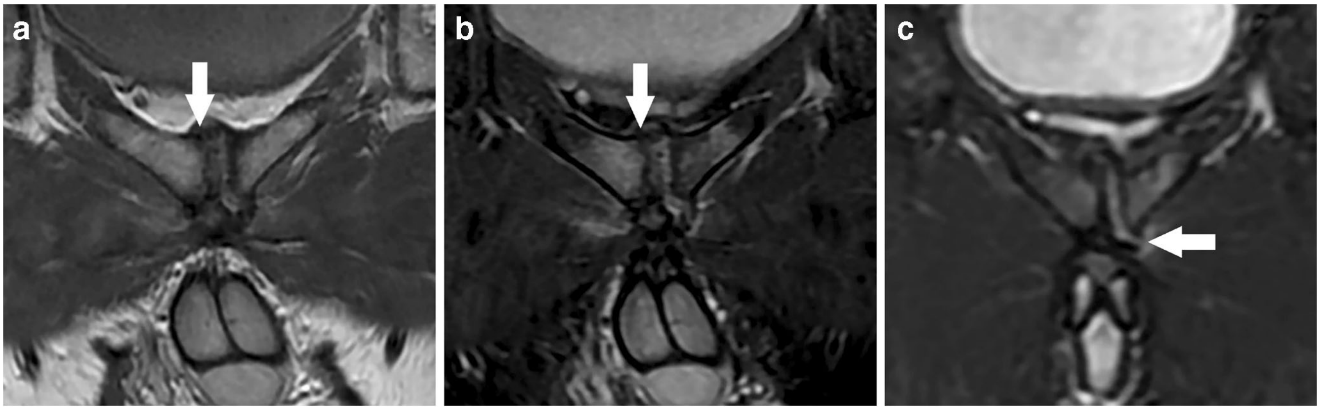

Fig. 2 A 50-year-old male presenting with chronic groin pain. Oblique axial proton density (**a**) and T2 fat-suppressed (**b**) MR images demonstrate a vertically oriented hypointense fracture line (*arrows*) through the right pubic body with surrounding bone marrow edema. Additional oblique axial T2 fat-suppressed image (**c**) in the same patient demonstrates a co-existing left secondary cleft sign (*arrow*)

The overall incidence of fracture was 17/93 (18.3%) with 13/93 (14.0%) pubic body and 4/93 (4.3%) cortical fractures/fragments. A single predominantly pubic body fracture extended slightly into the ipsilateral superior pubic ramus but there were no isolated pubic ramus fractures. All fractures occurred in males ranging from 17 to 54 years of age (mean 29.8 and median 24 years).

When looking at the distribution of fracture by sport, 5/17 (29.4%) occurred in college athletes (three football, one basketball, and one track) and 12/17 (70.6%) fractures occurred in other athletes (both high-level and recreational) including four runners, three basketball, one hockey, one football, one baseball, one Ironman triathlete, and one water skier. These findings are summarized in Table 3.

Given the low number of cortical fractures/fragments, only pubic body fractures (13/93) were analyzed for correlation with associated injury patterns, pain duration, and return to play time. After correction for multiple comparisons, no statistically significant associations were present. Results are summarized in Table 4.

Discussion

A relatively high incidence of fracture (18.3%) was present in our cohort of patients with core muscle injury; however, there was no clear association with any particular osseous or myotendinous injury pattern, pain duration, or return to play time.

Two theories exist to explain the mechanism of stress fracture. The first states muscle fatigue results in increased asymmetric force distribution resulting in compressive and tensile vectors across the bone. The combination of forces creates shear, which is countered by contraction of the muscles on the tensile side in order to distribute the forces more uniformly (stress shielding). As there is continued muscle fatigue, this protective mechanism is lost and the bone then bears the largest share of force, eventually resulting in fracture [12]. An alternative theory contends repetitive contraction of muscle at the insertion generates enough force to cause a stress-induced injury [12].

In the setting of core muscle injury, the rectus abdominis and adductor longus act as relative antagonists during motion.

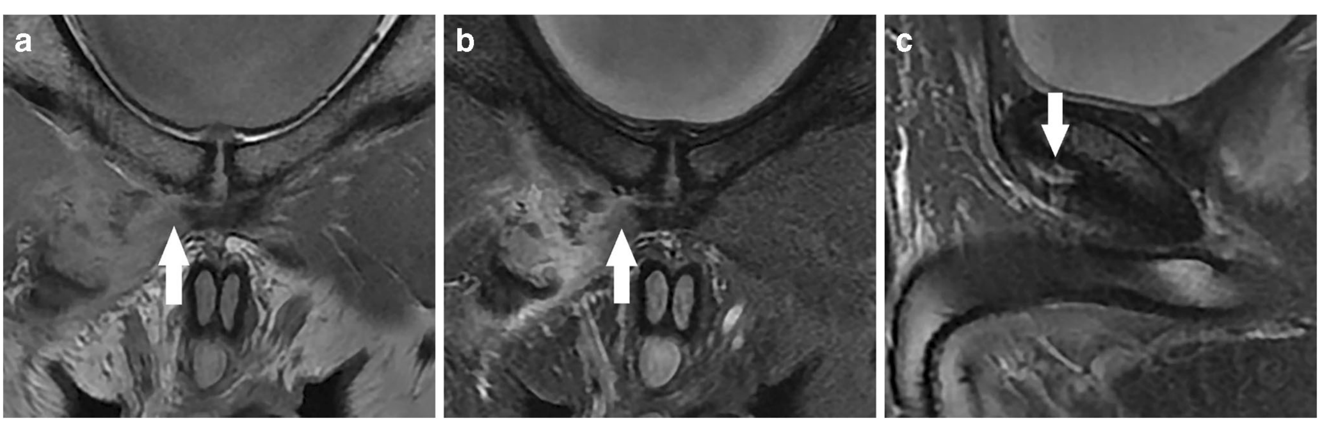

Fig. 3 A 33-year-old male presenting with right groin pain. Oblique axial proton density (**a**) and T2 fat-suppressed (**b**) MR images demonstrate a complete tear of the right adductor longus tendon from its attachment at the pubic body (*arrows*). Additional sagittal T2 fat-suppressed image (**c**) demonstrates the co-existing right aponeurotic plate tear (*arrow*). No associated fracture was present in this instance

Table 3 Fracture incidence

	All patients ($n = 93$)	Patients with fracture ($n = 17$)
Mean age in years (range)	34.4 (16–66)	29.8 (17–54)
Gender		
Male	87	17
Female	6	0
College athlete	22	5
Football	11	3
Soccer	6	0
Track	2	1
Basketball	2	1
Baseball	1	0
"High-level" athlete	12	4
Marathon runner	6	2
Ironman triathlete	4	1
Olympic trial runner	1	1
Military member	1	0
Recreational athlete	47	8
Runner	14	1
Soccer	10	0
Basketball	4	3
Hockey	4	1
Baseball	2	1
Football	2	1
Softball	2	0
Ultimate frisbee	2	0
Bicycling	1	0
Bowling	1	0
Curling	1	0
Martial arts	1	0
Racquetball	1	0
Swimming	1	0
Water skiing	1	1
Non-athlete or unknown	12	0

Especially in athletes, a large amount of torque is placed upon the pelvis at this location. When one of the muscles is injured, abnormal biomechanical forces are placed on the opposing muscle [13]. This imbalance creates shearing forces across the pubic symphysis leading to continued injury of the aponeurosis and myotendinous unit [1, 9, 14].

While certain sports and activities caused both types of injury in our population, we speculate the specific forces resulting in fracture or myotendinous injury are different. While this could be the continuum of a single injury, we did observe severe aponeurotic plate injuries with no fracture and vice versa with mild aponeurotic plate injuries demonstrating a concurrent fracture.

The presence of a fracture associated with core muscle injury may have important implications for patient management. Pubic fractures normally require at least 4–6 weeks of rest and avoidance of the pain-associated activity [1, 7]. Assessment of risk factors for low bone density such as the female athlete triad or low vitamin D levels is undertaken. Athletes can then proceed with gradual return to sport as symptoms allow with most showing complete healing within 3 to 5 months [1].

The degree of active rehabilitation may vary in cases of core muscle injury without fracture. Injuries to comparably well-vascularized areas such as the myotendinous junction may benefit from early physical therapy while injuries to the poorly vascularized tendon attachment and aponeurosis are often prescribed a longer period of rest prior to advancing activity and return to sport [1, 7]. Pubic symphysis steroid injections, while well tolerated and often effective in cases of core muscle injury and osteitis pubis [15], are relatively contraindicated in cases with a concomitant pubic fracture

Table 4 Injury characteristics, pain duration prior to MRI, and return to play time for patients with and without pubic body stress fractures

Injury characteristics	Fracture (13/93)	No fracture (80/93)	*p* value
Osseous			
Marrow edema	13/13	62/80	0.51
Sclerosis	7/13	41/80	1
Osteophytes	7/13	50/80	1
Subchondral cysts	1/13	18/80	1
Pubic symphysis fluid	3/13	28/80	1
Rectus abdominis myotendinous unit			
Tendinosis	0/13	3/80	1
Strain	1/13	4/80	1
Tear	0/13	3/80	1
Adductor longus muscle			
Strain	7/13	18/80	0.34
Tear	0/13	3/80	1
Adductor longus tendon			
Tendinosis	1/13	10/80	1
Strain	6/13	10/80	0.16
Tear	0/13	17/80	0.51
Aponeurotic plate			
Side			0.97
Bilateral	6/13	30/80	
Left	6/13	27/80	
Right	1/13	23/80	
Region			1
Upper one-half	6/13	30/80	
Lower one-half	3/13	18/80	
Both	4/13	32/80	
Secondary cleft sign	6/13	48/80	1
Size			
Right (medial-lateral)	5–25 mm	3–32 mm	0.79
Right (cranial-caudal)	9–44 mm	6–50 mm	0.54
Left (medial-lateral)	4–23 mm	4–35 mm	0.76
Left (cranial-caudal)	6–31 mm	4–48 mm	0.51
Pain duration prior to MRI	2–720 days	1–1095 days	0.68
Return to play time	5–210 days	7–365 days	0.31

Because of the small numbers, four patients with cortical fracture/fragment injuries were not analyzed for association

out of concern of delaying fracture healing [16, 17]. An additional concern for patients with unrecognized co-existing fracture is for premature referral for surgical repair of a core muscle injury. If the patient's pain stems from an unhealed fracture, surgical intervention would not be helpful.

Limitations to our study include the retrospective nature and the small sample size. Although our study found no association between the presence of fracture and the extent or pattern of soft tissue injury, a larger sample size may expose certain associated injury patterns not identified in this study. Core muscle injury consists of complex soft tissue injury patterns and multiple comparisons of associated injuries were required. Our statistical analysis was conservative, using multiple comparison correction. This is accepted practice but increases the risk of a type 2 error (false-negative conclusion). An additional limitation was the lack of standardized tracking of patient outcomes. Return to play time and pain duration were often estimated as obtaining accurate medical history was challenging. The medical record occasionally contained incomplete documentation, athletes were often referred to other institutions for surgical intervention, or patients became lost to follow-up. A prospective study with standardized tracking of patient outcomes might reveal associations with return to play and pain duration that are not evident when assessed retrospectively.

In conclusion, fatigue-type stress fracture of the pubic bone is a common occurrence in core muscle injury that should be identified and reported as it may affect treatment choice. Further research may identify risk factors for co-morbid fractures and further clarify treatment and prognostic implications.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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