

The American Journal of Sports Medicine

<http://ajs.sagepub.com/>

Diagnosis of Acute Groin Injuries: A Prospective Study of 110 Athletes

Andreas Serner, Johannes L. Tol, Nabil Jomaah, Adam Weir, Rodney Whiteley, Kristian Thorborg, Matthew Robinson
and Per Hölmich

Am J Sports Med published online May 14, 2015

DOI: 10.1177/0363546515585123

The online version of this article can be found at:

<http://ajs.sagepub.com/content/early/2015/05/13/0363546515585123>

Published by:



<http://www.sagepublications.com>

On behalf of:

American Orthopaedic Society for Sports Medicine



Additional services and information for *The American Journal of Sports Medicine* can be found at:

Published online May 14, 2015 in advance of the print journal.

P<P

Email Alerts: <http://ajs.sagepub.com/cgi/alerts>

Subscriptions: <http://ajs.sagepub.com/subscriptions>

Reprints: <http://www.sagepub.com/journalsReprints.nav>

Permissions: <http://www.sagepub.com/journalsPermissions.nav>

>> [OnlineFirst Version of Record](#) - May 14, 2015

[What is This?](#)

Diagnosis of Acute Groin Injuries

A Prospective Study of 110 Athletes

Andreas Serner,^{*†‡} PT, MSc, Johannes L. Tol,[†] MD, PhD, Nabil Jomaah,[†] MD, Adam Weir,[†] MBBS, PhD, Rodney Whiteley,[†] PT, PhD, Kristian Thorborg,[‡] PT, PhD, M Sportsphysio, Matthew Robinson,[†] MD, PGDip SEM, and Per Hölmich,^{†‡} MD, DMSc

Investigation performed at Aspetar Orthopaedic and Sports Medicine Hospital, Doha, Qatar

Background: Acute groin injuries are common in high-intensity sports, but there are insufficient data on injury characteristics such as injury mechanisms and clinical and radiological findings.

Purpose: To describe these characteristics in a cohort of athletes.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: A total of 110 male athletes (mean age, 25.6 ± 4.7 years) with sports-related acute groin pain were prospectively included within 7 days of injury from August 2012 to April 2014. Standardized history taking, a clinical examination, magnetic resonance imaging (MRI), and/or ultrasound (US) were performed.

Results: The most frequent injury mechanism in soccer was kicking (40%), and change of direction was most frequent in other sports (31%). Clinically, adductor injuries accounted for 66% of all injuries and primarily involved the adductor longus on imaging (91% US, 93% MRI). The iliopsoas and proximal rectus femoris were also frequently injured according to all examination modalities (15%-25%). Acute injury findings were negative in 22% of the MRI and 25% of the US examinations. Of the clinically diagnosed adductor injuries, 3% (US) and 6% (MRI) showed a radiological injury in a different location compared with 35% to 46% for clinically diagnosed iliopsoas and proximal rectus femoris injuries.

Conclusion: Adductor injuries account for the majority of acute groin injuries. Iliopsoas and proximal rectus femoris injuries are also common. More than 1 in 5 injuries showed no imaging signs of an acute injury. Clinically diagnosed adductor injuries were often confirmed on imaging, whereas iliopsoas and rectus femoris injuries showed a different radiological injury location in more than one-third of the cases. The discrepancy between clinical and radiological findings should be considered when diagnosing acute groin injuries.

Keywords: acute groin injuries; adductor; iliopsoas; rectus femoris; muscle strain; injury mechanism; diagnosis; clinical examination; MRI; ultrasound

Groin injuries are common in high-intensity team sports⁴⁴ and account for 8% to 18% of all injuries in soccer,^{2,17,22-24,50,67,69} with a reported incidence of 0.4 to 1.3 groin injuries per 1000 hours of exposure.^{13,17,18,22,24,37,69} The majority of available literature on groin injuries

focuses on long-standing groin pain. Consequently, information on acute groin injuries is limited to case studies and data from general epidemiological studies. These studies often lack a differentiation between acute and long-standing groin injuries^{23,24,26,50,68,69} and frequently do not specify the structures involved.^{2,13,18,22-24,29,30,68}

Although groin injuries are common, the associated injury mechanisms remain undocumented. Information on injury mechanisms provides important knowledge for prevention and rehabilitation programs^{31,32,54} and has shown potential in predicting the time to return to play in acute hamstring injuries.^{3,4} In general, high running loads, change of direction, and kicking are considered potential acute groin injury mechanisms; however, this has yet to be confirmed.

Acute groin injuries are usually diagnosed into categories using a clinical examination. A recent prospective epidemiological study describing clinically diagnosed groin

*Address correspondence to Andreas Serner, PT, MSc, Sports Groin Pain Center, Aspetar Orthopaedic and Sports Medicine Hospital, Sports City Street, PO Box 29222, Doha, Qatar (email: andreasserner@hotmail.com).

†Aspetar Orthopaedic and Sports Medicine Hospital, Doha, Qatar.

‡Sports Orthopaedic Research Center—Copenhagen (SORC-C), Department of Orthopedic Surgery, Copenhagen University Hospital, Amager-Hvidovre, Denmark.

The authors declared that they have no conflicts of interest in the authorship and publication of this contribution.

injuries in football showed that 39% of the groin injuries were acute.³⁷ Adductor injuries were most frequent, with iliopsoas and abdominal injuries also being common. The only prospective study on the diagnosis of acute groin injuries using both clinical examinations and imaging¹⁷ stated that the majority of injuries were clinically diagnosed as muscle/tendon injuries. Only 1 of the 13 clinical injuries could be confirmed using ultrasound (US) likely because of a delay of 1 to 6 months between the onset of symptoms and the US examination. No studies have documented the clinical and radiological findings in a larger cohort with all examinations performed shortly after injury. The aim of this prospective study was to describe injury mechanisms and report clinical and radiological findings in a cohort of athletes with acute groin injuries.

METHODS

Participants

Athletes were included prospectively from August 2012 to April 2014 from an outpatient department at a specialized sports medicine hospital in Doha, Qatar, through a daily walk-in clinic service for the assessment of acute sports injuries. Athletes are referred to this hospital via their club or federation medical staff, in cooperation with a national sports medicine program involving all sporting clubs and federations from the entire country. Inclusion criteria were as follows: male athletes from 18 to 40 years old who participated in competitive individual or team sports and who presented at the hospital's walk-in clinic within 7 days of an acute onset of sports-related groin pain. Athletes were not considered for inclusion if they could not recall a sudden onset of pain (eg, if a more gradual pain onset or exacerbation of previous pain during a game/training was described). Additionally, standard contraindications for magnetic resonance imaging (MRI), such as claustrophobia, were considered. Informed consent was acquired from all athletes at inclusion. Ethical approval was obtained from the Shafallah Medical Genetics Center Institutional Review Board (IRB project no. 2012-013).

Injury History

A standardized injury history was recorded by a sports medicine physician on a study-specific data collection form. Data were collected on the type of sport, injury time (training/match), injury mechanism, leg dominance (defined as the preferred kicking leg regardless of the type of sport), and previous groin injuries. The injury mechanisms were categorized as "kicking," "change of direction," "stretch situations," "sprinting/running," "jumping," and "other" (not further specified). "Kicking" included any form of passes, crosses, shots on goal, and combat kicks. It was also noted whether the injury occurred in the kicking leg or the supporting leg. "Stretch situations" included any situations where the player was reaching with 1 leg (eg, reaching for a ball or sliding on the surface [grass/floor]). Injuries noted as "sprinting/running" were registered when the athlete

was moving straight forward either in acceleration, full sprint, or deceleration. If a sideways movement during running or sprinting was made, it was registered as a "change of direction." Injuries during jumping included both takeoff and landing. All other situations were categorized together, along with instances where there was a definite sudden onset of pain but the athlete could not recall the specific inciting situation.

Clinical Examination

The clinical examination was performed by a sports medicine physician and consisted of hip adduction squeeze tests in 0° and 45° of hip flexion, resisted hip flexion in 0° and 90° of hip flexion, resisted straight and oblique abdominal flexion, hip adductor stretch, the modified Thomas test, the FABER (flexion, abduction, external rotation) test, hip internal rotation range of motion restriction in 90° of hip flexion, the anterior hip impingement test (FADIR [flexion, adduction, internal rotation]), log roll, and palpation of all structures in the groin region including an inguinal canal examination if lower abdominal pain was present. The location of the injury was based on a minimum of 1 positive finding on palpation, stretching, or muscle resistance testing. As there is currently no agreement on a specific algorithm for the diagnosis of acute groin injuries, the clinical diagnosis was based on the individual sports medicine physician's own experience and clinical reasoning. The injury location was categorized as adductor (without differentiating between the different adductor muscles), iliopsoas, abdominal, proximal rectus femoris, and/or proximal sartorius injuries. If more than 1 clinical injury location was present, the injury was registered for each location and as "multiple locations." It was also possible for the sports medicine physician to note a different diagnosis to include other possible causes of acute groin pain, such as hip injuries. To minimize differences in examination techniques between the different sports medicine physicians, instructions were provided on several occasions, and a standardized examination form was completed for every examination.

Radiological Assessment

The radiological examination included US and MRI. Additionally, radiographs were taken to assess for fractures (including avulsion fractures) and other signs of an acute injury. The US examination was performed with a linear array VF 10-5 and a curved array CH6-2 transducer (ACUSON Antares system; Siemens) using a sequential procedure in which all muscles in the groin region on the affected side were assessed. MRI was performed on a 1.5-T magnet system (Magnetom Espree; Siemens) using a body matrix coil and 8 standardized sequences (see the Appendix, available in the online version of this article at <http://ajsm.sagepub.com/supplemental>) based on those used in the Copenhagen Standardised MRI protocol for the pubic and adductor region.⁶ The radiological findings were all assessed by musculoskeletal radiologists. For this study, injuries were categorized dichotomously as positive or negative. Positive findings included radiological

TABLE 1
Injury Mechanisms for 110 Athletes
With Acute Groin Injuries^a

| Injury Mechanism | Total (N = 110) | Football Codes (n = 84) | Other Sports (n = 26) |
|---------------------|--------------------|----------------------------|--------------------------|
| Kicking | 36 (33) | 34 (40) | 2 (8) |
| Change of direction | 22 (20) | 14 (17) | 8 (31) |
| Stretch situations | 19 (17) | 14 (17) | 5 (19) |
| Sprinting/running | 16 (15) | 11 (13) | 5 (19) |
| Jumping | 8 (7) | 5 (6) | 3 (12) |
| Other | 9 (8) | 6 (7) | 3 (12) |

^aData are presented as n (%).

signs of edema, with or without architectural disruption, as well as signs of complete tears or avulsions. A negative finding was reported when none of the aforementioned radiological signs were present. Additional signs of long-standing injuries/overuse, such as adductor tendinopathy, osteoarthritis, or femoroacetabular impingement, were not included in the study. Positive findings in the iliopsoas were classified as injuries to the iliacus, injuries to the psoas, or both. Injuries within the adductor muscle group were likewise classified as injuries to the adductor longus, adductor magnus, adductor brevis, pectineus, gracilis, and obturator externus. One or more positive findings within a muscle group were categorized as 1 injury within the respective injury location.

Statistical Analysis

Statistical analysis was performed with SPSS software (v 21; IBM Corp). The study was primarily based on descriptive statistics. A χ^2 test for independence was performed for distributional comparisons of injury mechanisms and injury locations, with a level of significance at $P \leq .05$.

RESULTS

In the study period, 121 consecutive athletes with an acute groin injury were considered for inclusion. Upon further questioning, 7 players reported a more gradual onset and were excluded, and 3 players did not wish to participate in the study. Of the 111 included participants, 1 player did not attend the imaging appointments and was excluded from the analysis. The study analysis was based on 110 athletes (mean age, 25.6 ± 4.7 years; range, 18-36 years). Players from football codes accounted for 76% (n = 84), with 57% (n = 63) from soccer, 17% (n = 19) from futsal, 1% (n = 1) from beach soccer, and 1% (n = 1) from Australian rules football. Additionally, 10% (n = 11) were basketball players, 8% (n = 9) were handball players, and 5% (n = 6) were athletes from other sports (2 volleyball, 1 taekwondo, 1 decathlon, 1 goalball, and 1 shot put).

Injury History

Injuries occurred during both training (45%) and matches (55%). The overall distribution of the injury mechanisms,

TABLE 2
Location of Acute Groin Injuries on Clinical,
MRI, and US Examinations^a

| | Clinical | MRI | US |
|------------------------------------|----------|---------|---------|
| Total examinations, n | 110 | 105 | 95 |
| Negative imaging result, n (%) | N/A | 23 (22) | 24 (25) |
| Injury location ^b | | | |
| Adductor | 73 (66) | 54 (66) | 45 (63) |
| Adductor longus | — | 50 (93) | 41 (91) |
| Adductor magnus | — | 1 (2) | 1 (2) |
| Adductor brevis | — | 9 (17) | 7 (16) |
| Pectineus | — | 10 (19) | 5 (11) |
| Gracilis | — | 1 (2) | 2 (5) |
| Iliopsoas | 28 (25) | 14 (17) | 13 (18) |
| Iliacus only | — | 7 (50) | 10 (77) |
| Psoas only | — | 1 (7) | 3 (23) |
| Iliacus and psoas | — | 6 (43) | — |
| Rectus femoris | 25 (23) | 12 (15) | 13 (18) |
| Abdominal | 11 (10) | 5 (6) | 4 (6) |
| Sartorius | 7 (6) | 3 (4) | 1 (1) |
| Multiple locations | 32 (29) | 7 (9) | 6 (8) |
| Adductor and iliopsoas | 12 (11) | — | 1 (1) |
| Iliopsoas and rectus femoris | 5 (5) | 1 (1) | 1 (1) |
| Rectus femoris and sartorius | 4 (4) | — | 1 (1) |
| Adductor and abdominal | 3 (3) | 5 (6) | 3 (4) |
| Adductor, abdominal, and iliopsoas | 2 (2) | — | — |
| Adductor and rectus femoris | 2 (2) | — | — |
| Iliopsoas and abdominal | 2 (2) | — | — |
| Iliopsoas and sartorius | 2 (2) | — | — |
| Adductor and sartorius | — | 1 (1) | — |

^aMRI, magnetic resonance imaging; N/A, not applicable; US, ultrasound.

^bInjury locations are noted as n (%) of positive examination findings for the respective examination modality. If imaging showed signs of an injury at >1 location, the injury was counted once in each location and as multiple injury locations with the combination described below. The sum of injuries is therefore higher than the total number of examinations. A specific muscle injury distribution within the adductor and iliopsoas muscles is presented as the percentage of total positive radiological findings within the muscle group.

including a comparison of athletes from football codes with those from other sports, is presented in Table 1. Sixty-one percent (n = 67) of the injuries occurred in the dominant leg, 38% (n = 42) occurred in the nondominant leg, and 1 athlete (1%) had bilateral symptoms. Of the kicking injuries, 81% (n = 29) occurred in the kicking leg and 11% (n = 4) in the supporting leg; there was missing information from 8% (n = 3). In 17% (n = 6) of the kicking injuries, the nondominant leg was the kicking leg. For all other injury mechanisms, 55% (n = 41) occurred in the dominant leg, 43% (n = 32) occurred in the nondominant leg, and 1% (n = 1) was bilateral. A previous groin injury with absence from play was reported by 48% (n = 53) of the players.

Injury Distribution

All athletes (N = 110) were examined clinically, and 90 athletes underwent both MRI and US examinations; 15

underwent MRI only, and 5 underwent US only. Eighteen different sports medicine physicians performed the clinical examinations, 6 different radiologists performed the US examinations, and 9 different radiologists assessed the MRI scans. The distribution of the injury locations is shown in Table 2. A comparison of the overall distribution of injury locations between the 3 examination modalities showed no significant difference ($P = .803$). In 2 cases, possible labral tears were reported (1 bilateral and 1 unilateral). In both cases, the physicians felt that these labral tears were incidental findings when they reviewed the athletes again at 1 and 3 days, respectively, after imaging. Radiographs were obtained from 86 of the athletes, with no signs of acute skeletal injuries detected.

Clinical Diagnosis and Radiological Findings

A post hoc comparison between the clinical diagnosis and radiological findings is provided in Table 3.

DISCUSSION

In this prospective study of 110 athletes with acute groin injuries, we found that kicking was the most frequent injury mechanism in football and change of direction the most frequent mechanism in other sports. The adductor longus accounted for the majority of acute groin injuries. One-fourth of the injuries were negative on imaging. Clinically diagnosed adductor injuries had findings in a different location on imaging (without injury in the adductors) in around 1 of 20 cases. In clinically diagnosed rectus femoris and iliopsoas injuries, a different injury location was found in around 2 of 5 cases.

Injury Mechanism

In the football codes, kicking was shown to be the most frequent cause of injury. The kicking leg was injured in 81% of kicking injuries, and the adductor longus was the most frequently injured muscle. This supports the hypothesis that the adductor longus is at highest risk of an acute injury when the muscle reaches its highest muscle activity and maximal rate of stretch in the swing phase of the kicking leg.¹⁰ Change of direction has mainly been investigated in relation to anterior cruciate ligament injuries^{33,41,63} and performance.^{8,71} Although it is a frequent injury mechanism for acute groin injuries, as confirmed in the present study, information on the contributing factors during change of direction in acute groin injuries is still lacking. In general, the findings in this study confirm descriptions from previous studies, which usually described groin injuries as occurring in sports with kicking, change of direction, twisting, and turning.^{47,50}

Injury Distribution

Previous studies have also found adductor injuries to be one of the most frequent muscle injury locations.^{14,15,25,37,61,66,70} Iliopsoas injuries are rarely included in these overviews,

and rectus femoris injuries are usually included in “quadriiceps injuries” without specification.^{14,25,66,70} The rectus femoris is often reported as the most frequently injured quadriceps muscle.^{11,61} Our findings suggest that it is clinically relevant to include proximal rectus femoris injury in the differential diagnosis during acute groin injury examinations. A recent large prospective study on all muscle injuries in professional soccer contained data on the groin pertinent to our study.¹⁵ All injuries were clinically diagnosed, and in keeping with this study, those authors also found adductor injuries to be the most common groin injuries, followed by quadriceps, iliopsoas, sartorius, and abdominal muscle strains.

Until now, randomized trials aimed at preventing groin injuries with general strengthening programs have not found significant reductions in the incidence of groin injuries.^{19,36,60} The present study adds to the evidence that adductor injuries are the most common groin injuries. We therefore recommend placing a larger emphasis on a more focused intervention with exercises specifically targeting the adductors.^{40,57}

Multiple injury locations were frequent in the clinical examinations (29%), which is in line with previous findings of 24% to 33%.^{34,37,43} Multiple injury locations were, however, less common in the radiological examinations (<10%). The radiological examinations showed that multiple adductor muscles were involved in some athletes. The adductor longus, adductor brevis, and pectineus are often combined. If a tissue-specific diagnosis is important for rehabilitation and/or prognosis, this previously undescribed information may be of relevance. Biomechanically, it may also have implications in future research exploring the cause of adductor injuries. Injuries to the iliopsoas could be radiologically divided into injuries in the iliacus, the psoas, or both, with injuries involving the iliacus muscle occurring more frequently. The iliacus and psoas have generally been considered to form a common tendon at the distal insertion. Recent studies have shown, however, that separate tendons are present in the majority of cases and that an accessory iliacus tendon can sometimes be present.^{45,48,64} The results of the present study support this structural division, as a distinction was often found in both the US and MRI examinations. The diagnostic reliability and clinical relevance remain unknown.

Negative Imaging Findings

Negative imaging results were reported in around 1 of 4 acute groin injuries. Other studies on acute muscle injuries have reported comparable percentages of negative imaging results; in acute hamstring injuries, this percentage varies between 12% to 45%.^{16,21,26,56,59,65} The only available study examining acute groin injuries¹⁷ found that 12 of 13 (92%) clinically diagnosed acute muscle/tendon groin injuries were negative on US. The difference with our findings might be explained by the fact that in that study, 19 of 25 participants had a gradual onset of symptoms as well as a long duration between the clinical examination and US. In our study, acute onset was the main criterion to be included, and imaging was performed shortly after the

TABLE 3
Clinically Diagnosed Injuries Related to Radiological Findings^a

| Injury Location on Clinical Diagnosis | MRI | | | US | | |
|---------------------------------------|---------------|--------------------|-------------------------|---------------|--------------------|-------------------------|
| | Same Location | Different Location | Negative Imaging Result | Same Location | Different Location | Negative Imaging Result |
| Adductor | 50 (72) | 4 (6) | 15 (22) | 42 (68) | 2 (3) | 18 (29) |
| Iliopsoas | 10 (38) | 9 (35) | 7 (27) | 8 (35) | 9 (39) | 6 (26) |
| Rectus femoris | 10 (42) | 11 (46) | 3 (13) | 10 (45) | 9 (41) | 3 (14) |
| Abdominal | 2 (18) | 3 (27) | 6 (55) | 3 (33) | 2 (22) | 4 (44) |
| Sartorius | — | 4 (67) | 2 (33) | 1 (14) | 5 (71) | 1 (14) |
| Total | 72 (53) | 31 (23) | 33 (24) | 64 (52) | 27 (22) | 32 (26) |

^aData are presented as n (%) of injuries in the clinical location where the respective radiological examination was performed. Injuries are noted as “same location” if both the clinical examination and imaging showed positive findings in the respective location and “different location” if imaging did not show positive findings in the clinically diagnosed location but showed findings in a different location. Percentages do not sum to 100% because of rounding. MRI, magnetic resonance imaging; US, ultrasound.

clinical examination. The reasons for the injuries in our study being negative on imaging are unclear. An acute exacerbation of underlying asymptomatic pathological lesions or insufficient sensitivity of the radiological examinations to detect the presence of smaller injuries might be possible explanations. Negative imaging results were particularly common with abdominal injuries, with approximately half of the clinically diagnosed injuries not showing signs of an acute injury on imaging. An anterior connection between the rectus abdominis, the adductor longus, and in some cases also the adductor brevis fibers into the anterior pubic periosteum and pubic symphysis capsule has been shown anatomically.^{52,53,55,58} Injuries both superior and inferior to the pubic attachments are therefore likely with an anterior kinetic chain load transfer, such as in kicking. The lower number of injuries shown on imaging compared with the clinical findings can be a result of increased pain around this presymphyseal anterior connection (“pubic aponeurosis”/“pubic plate”), making it difficult for the physician to distinguish between the different structures. It could also be a lack of sensitivity of the imaging techniques, which could mean that minor injuries in the inguinal region are not detected.

Clinical and Radiological Discrepancy

Clinically diagnosed adductor injuries were frequently confirmed by imaging, and only in 3% to 6% was an injury found in a different location with no injury in the adductors. There was a higher discrepancy between the clinical examination and imaging results for all other locations. Our results show that there was only about a 50% chance of the injuries being confirmed on imaging when an iliopsoas or rectus femoris injury was diagnosed clinically. Only 1 of 7 clinically diagnosed sartorius injuries was confirmed on imaging. This discrepancy may be because of the anatomic proximity of the muscles, making it hard to differentiate the injured structures clinically in acute presentations, where resistance tests might be less specific and palpation pain present adjacent to the actual injury. The

difficulty in distinguishing exact injury locations is also indicated by the higher number of cases with multiple diagnoses after the clinical examination compared with imaging. There is currently no evidence for a specific combination of tests, such as suggested with long-standing groin pain^{34,39}; imaging might therefore add clinical value to the examination and should be considered in injuries that seem less straightforward or that are not following the suggested prognosis. Minor differences in diagnostic techniques by the different sports medicine physicians might also have an influence, emphasizing the need for further investigation of a standardized clinical examination of acute groin injuries.

The discrepancy between clinical and radiological findings should not only be considered in clinical practice. It should also be kept in mind when reviewing the literature on the epidemiology of groin injuries in which injury classifications are often based on a variable combination of clinical examinations and imaging. A gold standard examination for acute groin injuries is difficult to recommend, as a clinical examination entails the risk of an inaccurate injury location, while radiological examinations risk underreporting with negative cases.

Hip Injuries

Although musculotendinous structures are considered as primary locations of acute groin pain in athletes, hip joint injuries have been reported to account for around 5% of all hip and groin injuries in soccer.⁶⁹ Acetabular labral tears (ALTs) are generally considered a result of repetitive trauma but might also present as acute anterior hip or groin pain, which can occur in relation to athletic movements in which the hip can be forced into hyperrotation and/or hyperextension.^{9,39} It has also been suggested that ALTs might be a result of traction from the distal iliopsoas or proximal rectus femoris insertions^{12,20,38}; however, clear evidence of such a causative relationship has not been provided. In line with the low incidence in our study, a large epidemiological study in football (soccer) noted that only

2 of 628 (0.3%) hip and groin injuries were labral tears.⁶⁹ The fact that the reported incidence is low and that the clinical examination possesses only screening accuracy⁴⁹ makes the clinical detection of ALTs challenging. Furthermore, we used noncontrast MRI, and as even magnetic resonance arthrography cannot detect all ALTs,⁵¹ we cannot exclude the underreporting of ALTs in this study.

Femoroacetabular morphologies (FAMs), such as cam and pincer (extra bone formation on the femoral head-neck junction and acetabular rim, respectively) have been suggested as possible risk factors for both ALTs and soft tissue injuries, and they are therefore often reported as a separate diagnosis. Recent studies suggest that these morphological abnormalities may be related to the activity level and type of sport performed during skeletal maturation, when they are considered to be acquired.^{1,42,46,62} Furthermore, FAMs have been reported to be present in up to 75% of asymptomatic athletes⁴⁶ depending on the definition criteria. Cam and pincer deformities were therefore not considered as possible acute injury diagnoses or evaluated in the present study.

Limitations

To describe the injury mechanisms in this study, only history taking was used. Future research could also include video analyses, where the inciting event can be expanded to include the athlete and opponent behavior as well as biomechanical characteristics, as suggested in a comprehensive model for injury causation.⁵

A strength of this study is that 18 different sports medicine physicians performed the clinical examinations. This provides good generalizability but may also add uncertainty to the reliability of the clinical examinations. The clinical examination of athletes with long-standing groin pain using pain provocation tests has shown good intraobserver and interobserver reliability³⁵ and has been used to categorize groin injuries into clinical entities.³⁴ As the clinical diagnosis of acute groin injuries has not been investigated to the same extent, we modified this method to accept only a minimum of 1 positive finding in palpation, stretching, or resistance testing of the muscles. This might have contributed to the higher number of injuries in the clinical examination and might thereby explain some of the negative imaging results. It might also have contributed to the discrepancy between the clinical findings and imaging results.

Excellent interrater and intrarater reproducibility of MRI scoring has been documented in acute hamstring injuries,²⁸ but it is unknown if these figures can be reproduced in acute groin injuries. The groin region is often considered a complex region to assess with imaging⁷; therefore, caution is advised when interpreting imaging findings. Many injury severity grading systems including imaging scoring have been proposed for acute muscle injuries²⁷; however, an agreement on the optimal scoring system is still lacking. The fact that we, in the present study, limited the diagnoses to positive and negative only should increase the validity of our results and give a representable overview of current practice. There was no statistically

significant difference in the distribution of injuries between the different examination modalities. However, the similarity of the MRI and US findings does not account for the fact that injuries from different modalities could represent different individual athletes, and as discussed, there was often a discrepancy between clinical and radiological findings. The reliability and agreement of the different examination modalities in acute groin injuries therefore warrant further investigation. Not all athletes underwent both US and MRI, which was mainly a result of the availability of the radiological examinations within the required time frame.

CONCLUSION

This prospective, consecutive case series of 110 athletes with acute groin injuries shows that the injuries most frequently occurred during kicking in football codes and change of direction in other sports. Two-thirds of injuries were adductor injuries and primarily involved the adductor longus on imaging. Negative findings of an acute injury on MRI and US were reported in around one-quarter of the clinically diagnosed acute groin injuries. Clinically diagnosed adductor injuries were frequently confirmed on additional imaging, whereas when iliopsoas, rectus femoris, and sartorius injuries were diagnosed clinically, an injury was often found in a different location without an injury at the clinically diagnosed location. The discrepancy between clinical and radiological findings should be considered when diagnosing acute groin injuries.

ACKNOWLEDGMENT

The authors thank all the Aspetar employees involved in this study, especially the sports medicine physicians, radiologists, and radiographers who participated in the numerous examinations; the National Sports Medicine Program doctors and physical therapists for referring the athletes; and the doctors and physical therapists who subsequently treated the injured athletes. The authors also acknowledge the cover assistance of Sirine Boukarroum, Arnlaug Wangensteen, Tone Bere, and Arnhild Bakken.

REFERENCES

1. Agricola R, Heijboer MP, Ginai AZ, et al. A cam deformity is gradually acquired during skeletal maturation in adolescent and young male soccer players: a prospective study with minimum 2-year follow-up. *Am J Sports Med.* 2014;42(4):798-806.
2. Arnason A, Sigurdsson SB, Gudmundsson A, Holme I, Engebretsen L, Bahr R. Risk factors for injuries in football. *Am J Sports Med.* 2004;32(1 Suppl):5S-16S.
3. Asklings C, Saartok T, Thorstensson A. Type of acute hamstring strain affects flexibility, strength, and time to return to pre-injury level. *Br J Sports Med.* 2006;40(1):40-44.
4. Asklings CM, Tengvar M, Thorstensson A. Acute hamstring injuries in Swedish elite football: a prospective randomised controlled clinical trial comparing two rehabilitation protocols. *Br J Sports Med.* 2014;48(7):532-539.

5. Bahr R. Understanding injury mechanisms: a key component of preventing injuries in sport. *Br J Sports Med.* 2005;39(6):324-329.
6. Branci S, Thorborg K, Bech BH, et al. The Copenhagen standardised MRI protocol to assess the pubic symphysis and adductor regions of athletes: outline and intratester and intertester reliability [published online December 8, 2014]. *Br J Sports Med.* doi:10.1136/bjsports-2014-094239.
7. Branci S, Thorborg K, Nielsen MB, Hölmich P. Radiological findings in symphyseal and adductor-related groin pain in athletes: a critical review of the literature. *Br J Sports Med.* 2013;47(10):611-619.
8. Brughelli M, Cronin J, Levin G, Chaouachi A. Understanding change of direction ability in sport: a review of resistance training studies. *Sports Med.* 2008;38(12):1045-1063.
9. Byrd JWT. Labral lesions: an elusive source of hip pain case reports and literature review. *Arthroscopy.* 1996;12(5):603-612.
10. Charnock BL, Lewis CL, Garrett WE Jr, Queen RM. Adductor longus mechanics during the maximal effort soccer kick. *Sports Biomech.* 2009;8(3):223-234.
11. Cross TM. Acute quadriceps muscle strains: magnetic resonance imaging features and prognosis. *Am J Sports Med.* 2004;32(3):710-719.
12. Domb BG, Shindle MK, McArthur B, Voos JE, Magennis EM, Kelly BT. Iliopsoas impingement: a newly identified cause of labral pathology in the hip. *HSS J.* 2011;7(2):145-150.
13. Eirale C, Farooq A, Smiley FA, Tol JL, Chalabi H. Epidemiology of football injuries in Asia: a prospective study in Qatar. *J Sci Med Sport.* 2013;16(2):113-117.
14. Ekstrand J, Gillquist J. The frequency of muscle tightness and injuries in soccer players. *Am J Sports Med.* 1982;10(2):75-78.
15. Ekstrand J, Hägglund M, Waldén M. Epidemiology of muscle injuries in professional football (soccer). *Am J Sports Med.* 2011;39(6):1226-1232.
16. Ekstrand J, Healy JC, Waldén M, Lee JC, English B, Hägglund M. Hamstring muscle injuries in professional football: the correlation of MRI findings with return to play. *Br J Sports Med.* 2012;46(2):112-117.
17. Ekstrand J, Hilding J. The incidence and differential diagnosis of acute groin injuries in male soccer players. *Scand J Med Sci Sports.* 1999;9(2):98-103.
18. Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. Intrinsic risk factors for groin injuries among male soccer players: a prospective cohort study. *Am J Sports Med.* 2010;38(10):2051-2057.
19. Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. Prevention of injuries among male soccer players: a prospective, randomized intervention study targeting players with previous injuries or reduced function. *Am J Sports Med.* 2008;36(6):1052-1060.
20. Foote CJ, Maizlin ZV, Shrouder J, Grant MM, Bedi A, Ayeni OR. The association between avulsions of the reflected head of the rectus femoris and labral tears: a retrospective study. *J Pediatr Orthop.* 2013;33(3):227-231.
21. Gibbs NJ, Cross TM, Cameron M, Houang MT. The accuracy of MRI in predicting recovery and recurrence of acute grade one hamstring muscle strains within the same season in Australian rules football players. *J Sci Med Sport.* 2004;7(2):248-258.
22. Hägglund M, Waldén M, Ekstrand J. Injuries among male and female elite football players. *Scand J Med Sci Sports.* 2009;19(6):819-827.
23. Hägglund M, Waldén M, Ekstrand J. Injury incidence and distribution in elite football: a prospective study of the Danish and the Swedish top divisions. *Scand J Med Sci Sports.* 2005;15(1):21-28.
24. Hägglund M, Waldén M, Ekstrand J. Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. *Br J Sports Med.* 2006;40(9):767-772.
25. Hägglund M, Waldén M, Ekstrand J. Risk factors for lower extremity muscle injury in professional soccer: the UEFA Injury Study. *Am J Sports Med.* 2013;41(2):327-335.
26. Hallén A, Ekstrand J. Return to play following muscle injuries in professional footballers. *J Sports Sci.* 2014;32(13):1229-1236.
27. Hamilton B, Valle X, Rodas G, et al. Classification and grading of muscle injuries: a narrative review. *Br J Sports Med.* 2015;49(5):306.
28. Hamilton B, Whiteley R, Almusa E, Roger B, Geertsema C, Tol JL. Excellent reliability for MRI grading and prognostic parameters in acute hamstring injuries. *Br J Sports Med.* 2014;48(18):1385-1387.
29. Hawkins RD, Fuller CW. A prospective epidemiological study of injuries in four English professional football clubs. *Br J Sports Med.* 1999;33(3):196-203.
30. Hawkins RD, Hulse MA, Wilkinson C, Hodson A, Gibson M. The association football medical research programme: an audit of injuries in professional football. *Br J Sports Med.* 2001;35(1):43-47.
31. Heiderscheid BC, Hoerth DM, Chumanov ES, Swanson SC, Thelen BJ, Thelen DG. Identifying the time of occurrence of a hamstring strain injury during treadmill running: a case study. *Clin Biomech (Bristol, Avon).* 2005;20(10):1072-1078.
32. Heiderscheid BC, Sherry MA, Silder A, Chumanov ES, Thelen DG. Hamstring strain injuries: recommendations for diagnosis, rehabilitation, and injury prevention. *J Orthop Sports Phys Ther.* 2010;40(2):67-81.
33. Hewett TE, Torg JS, Boden BP. Video analysis of trunk and knee motion during non-contact anterior cruciate ligament injury in female athletes: lateral trunk and knee abduction motion are combined components of the injury mechanism. *Br J Sports Med.* 2009;43(6):417-422.
34. Hölmich P. Long-standing groin pain in sportspeople falls into three primary patterns, a "clinical entity" approach: a prospective study of 207 patients. *Br J Sports Med.* 2007;41(4):247-252, discussion 252.
35. Hölmich P, Hölmich LR, Bjerg AM. Clinical examination of athletes with groin pain: an intraobserver and interobserver reliability study. *Br J Sports Med.* 2004;38(4):446-451.
36. Hölmich P, Larsen K, Krosgaard K, Gluud C. Exercise program for prevention of groin pain in football players: a cluster-randomized trial. *Scand J Med Sci Sports.* 2010;20(6):814-821.
37. Hölmich P, Thorborg K, Dehlendorf C, Krosgaard K, Gluud C. Incidence and clinical presentation of groin injuries in sub-elite male soccer. *Br J Sports Med.* 2014;48(16):1245-1250.
38. Hosalkar HS, Pennock AT, Zaps D, Schmitz MR, Bomar JD, Bittersohl B. The hip antero-superior labral tear with avulsion of rectus femoris (HALTAR) lesion: does the SLAP equivalent in the hip exist? *Hip Int.* 2012;22(4):391-396.
39. Ikeda T, Awaya G, Suzuki S, Okada Y, Tada H. Torn acetabular labrum in young patients: arthroscopic diagnosis and management. *J Bone Joint Surg Br.* 1988;70(1):13-16.
40. Jensen J, Hölmich P, Bandholm T, Zebis MK, Andersen LL, Thorborg K. Eccentric strengthening effect of hip-adductor training with elastic bands in soccer players: a randomised controlled trial. *Br J Sports Med.* 2014;48(4):332-338.
41. Kristianslund E, Faul O, Bahr R, Myklebust G, Krosshaug T. Sidestep cutting technique and knee abduction loading: implications for ACL prevention exercises. *Br J Sports Med.* 2014;48(9):779-783.
42. Lahner M, Walter PA, von Schulze Pellengahr C, Hagen M, von Engelhardt LV, Lukas C. Comparative study of the femoroacetabular impingement (FAI) prevalence in male semiprofessional and amateur soccer players. *Arch Orthop Trauma Surg.* 2014;134(8):1135-1141.
43. Lovell G. The diagnosis of chronic groin pain in athletes: a review of 189 cases. *Aust J Sci Med Sport.* 1995;27(3):76-79.
44. Maffey L, Emery C. What are the risk factors for groin strain injury in sport? A systematic review of the literature. *Sports Med.* 2007;37(10):881-894.
45. Philippon MJ, Devitt BM, Campbell KJ, et al. Anatomic variance of the iliopsoas tendon. *Am J Sports Med.* 2014;42(4):807-811.
46. Philippon MJ, Ho CP, Briggs KK, Stull J, LaPrade RF. Prevalence of increased alpha angles as a measure of cam-type femoroacetabular impingement in youth ice hockey players. *Am J Sports Med.* 2013;41(6):1357-1362.
47. Polglase AL, Frydman GM, Farmer KC. Inguinal surgery for debilitating chronic groin pain in athletes. *Med J Aust.* 1991;155(10):674-677.

48. Polster JM, Elgabaly M, Lee H, Klika A, Drake R, Barsoum W. MRI and gross anatomy of the iliopsoas tendon complex. *Skeletal Radiol*. 2007;37(1):55-58.
49. Reiman MP, Goode AP, Cook CE, Hölmich P, Thorborg K. Diagnostic accuracy of clinical tests for the diagnosis of hip femoroacetabular impingement/labral tear: a systematic review with meta-analysis [published online December 16, 2014]. *Br J Sports Med*. doi:10.1136/bjsports-2014-094302.
50. Renström P, Peterson L. Groin injuries in athletes. *Br J Sports Med*. 1980;14(1):30-36.
51. Reurink G, Jansen SPL, Bisselink JM, Vincken PWJ, Weir A, Moen MH. Reliability and validity of diagnosing acetabular labral lesions with magnetic resonance arthrography. *J Bone Joint Surg Am*. 2012;94(18):1643-1648.
52. Robertson BA, Barker PJ, Fahrer M, Schache AG. The anatomy of the pubic region revisited: implications for the pathogenesis and clinical management of chronic groin pain in athletes. *Sports Med*. 2009;39(3):225-234.
53. Robinson P, Salehi F, Grainger A, et al. Cadaveric and MRI study of the musculotendinous contributions to the capsule of the symphysis pubis. *AJR Am J Roentgenol*. 2007;188(5):W440-W445.
54. Schache AG, Wrigley TV, Baker R, Pandy MG. Biomechanical response to hamstring muscle strain injury. *Gait Posture*. 2009;29(2):332-338.
55. Schilders E. Groin injuries in athletes. *Curr Orthop*. 2000;14(6):418-423.
56. Schneider-Kolsky ME, Hoving JL, Warren P, Connell DA. A comparison between clinical assessment and magnetic resonance imaging of acute hamstring injuries. *Am J Sports Med*. 2006;34(6):1008-1015.
57. Serner A, Jakobsen MD, Andersen LL, Hölmich P, Sundstrup E, Thorborg K. EMG evaluation of hip adduction exercises for soccer players: implications for exercise selection in prevention and treatment of groin injuries. *Br J Sports Med*. 2014;48(14):1108-1114.
58. Shortt C, Zoga A, Kavanagh E, Meyers W. Anatomy, pathology, and MRI findings in the sports hernia. *Semin Musculoskelet Radiol*. 2008;12(1):54-61.
59. Slavotinek JP, Verrall GM, Fon GT. Hamstring injury in athletes: using MR imaging measurements to compare extent of muscle injury with amount of time lost from competition. *AJR Am J Roentgenol*. 2002;179(6):1621-1628.
60. Soligard T, Myklebust G, Steffen K, et al. Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. *BMJ*. 2008;337:a2469.
61. Speer KP, Lohnes J, Garrett WE Jr. Radiographic imaging of muscle strain injury. *Am J Sports Med*. 1993;21(1):89-95, discussion 96.
62. Tak I, Weir A, Langhout R, et al. The relationship between the frequency of football practice during skeletal growth and the presence of a cam deformity in adult elite football players. *Br J Sports Med*. 2015;49(9):630-634.
63. Tanikawa H, Matsumoto H, Komiyama I, Kiriya Y, Toyama Y, Nagura T. Comparison of knee mechanics among risky athletic motions for noncontact anterior cruciate ligament injury. *J Appl Biomech*. 2013;29(6):749-755.
64. Tatu L, Parratte B, Vuillier F, Diop M, Monnier G. Descriptive anatomy of the femoral portion of the iliopsoas muscle: anatomical basis of anterior snapping of the hip. *Surg Radiol Anat*. 2002;23(6):371-374.
65. Verrall GM, Slavotinek JP, Barnes PG, Fon GT. Diagnostic and prognostic value of clinical findings in 83 athletes with posterior thigh injury comparison of clinical findings with magnetic resonance imaging documentation of hamstring muscle strain. *Am J Sports Med*. 2003;31(6):969-973.
66. Volpi P, Melegati G, Tornese D, Bandi M. Muscle strains in soccer: a five-year survey of an Italian major league team. *Knee Surg Sports Traumatol Arthrosc*. 2004;12(5):482-485.
67. Waldén M, Häggglund M, Ekstrand J. Injuries in Swedish elite football: a prospective study on injury definitions, risk for injury and injury pattern during 2001. *Scand J Med Sci Sports*. 2005;15(2):118-125.
68. Waldén M, Häggglund M, Ekstrand J. UEFA Champions League study: a prospective study of injuries in professional football during the 2001-2002 season. *Br J Sports Med*. 2005;39(8):542-546.
69. Werner J, Häggglund M, Waldén M, Ekstrand J. UEFA injury study: a prospective study of hip and groin injuries in professional football over seven consecutive seasons. *Br J Sports Med*. 2009;43(13):1036-1040.
70. Witvrouw E, Danneels L, Asselman P, D'Have T, Cambier D. Muscle flexibility as a risk factor for developing muscle injuries in male professional soccer players: a prospective study. *Am J Sports Med*. 2003;31(1):41-46.
71. Young WB, James R, Montgomery I. Is muscle power related to running speed with changes of direction? *J Sports Med Phys Fitness*. 2002;42(3):282-288.

For reprints and permission queries, please visit SAGE's Web site at <http://www.sagepub.com/journalsPermissions.nav>