Radiological findings in symphyseal and adductor-related groin pain in athletes: a critical review of the literature

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ABSTRACT
Long-standing symphyseal and adductor-related groin pain is a common problem for many athletes, and requires a multidisciplinary approach. Radiological evaluation of symptomatic individuals is a cornerstone in the diagnostic workup, and should be based on precise and reliable diagnostic terms and imaging techniques. The authors performed a review of the existing original evidence-based radiological literature involving radiography, ultrasonography and MRI in athletes with long-standing symphyseal and adductor-related groin pain. Our search yielded 17 original articles, of which 12 were dedicated to MRI, four to radiography and one to ultrasonography. Four main radiological findings seem to consistently appear: degenerative changes at the pubic symphyseal joint, pathology at the adductor muscle insertions, pubic bone marrow edema and the secondary cleft sign. However, the existing diagnostic terminology is confusing, and the interpretation of radiological findings would benefit from imaging studies using a more systematic approach.

INTRODUCTION
Long-standing groin pain is a common complaint for athletes involved in a number of sports such as soccer, rugby and ice hockey and causes significant morbidity and loss of sporting activity.1 It remains a complex clinical and radiological problem, as it affects a large anatomical region where many different pathological factors can contribute to the overall symptom pattern.2

The pubic symphysis and the adductor muscles are among the many anatomical structures potentially involved in causing athletic groin pain.3 Early studies4 describe clinical findings related to the adductor muscle group and the pubic symphysis, but do not include specific detailed radiological information on potential pathology. Over the past years, the adductor muscles, their insertion at the pubic bones and the pubic symphysis itself have been investigated with several radiological modalities, mainly conventional pelvic radiography, ultrasonography and MRI, whereas other modalities used extensively in the past (eg, isotope bone scan2) are nowadays obsolete due to more informative results obtained with ultrasonography and MRI.6

The aim of our review was to provide an overview of the existing literature assessing radiological findings in symphyseal and adductor-related long-standing groin pain in athletes with the radiological modalities radiography, ultrasonography and MRI, and thereby present an update on current radiological knowledge in this field. The term ‘long-standing groin pain’ is used in this review to describe non-specific groin pain in athletes with a duration of more than 6 weeks, non-specific meaning that this pain cannot objectively be related to the presence of fractures, hip and lumbar pathology, systemic diseases or neoplasms.

METHODS
Search
A search was made in MEDLINE for all relevant articles published until 1 June 2012 using the following combination of words (‘adductor tendinosis’ OR ‘secondary cleft sign’ OR ‘adductor enthesitis’ OR ‘pubic symphysis’ OR ‘adduction-related’ OR ‘adductor tendinitis’ OR ‘osteitis pubis’ OR ‘pubalgia’ OR ‘groin’ OR ‘adductor strain’ OR ‘tendon injury’) AND (‘validity’ OR ‘sensitivity’ OR ‘specificity’) AND (‘standards’ OR ‘false positive’ OR ‘false negative’ OR ‘reference’ OR ‘reliability’ OR ‘reproducibility’ OR ‘kappa’ OR ‘examination’ OR ‘examine’ OR ‘asses’ OR ‘findings’ OR ‘results’ OR ‘register’ OR ‘interrater’ OR ‘inter rater’ OR ‘test’) AND (‘MRI imaging’ OR ‘MRI’ OR ‘magnetic resonance’ OR ‘roentgen’ OR ‘radiography’ OR ‘X-ray’ OR ‘ultrasonography’ OR ‘ultrasound’ OR ‘sonography’) AND (‘sport’ OR ‘sports’ OR ‘football’ OR ‘soccer’ OR ‘athlete’ OR ‘athletic’ OR ‘athletes’ OR ‘sportsmen’).

Abstracts of all articles listed on the search list were then read to include original studies dedicated to athletic long-standing groin pain emanating from the pubic symphysis and the adductor musculotendinous insertions. Articles were excluded if they were reviews, case reports or cadaver studies, if they were dealing with surgery, surgical results, sports hernias, hip or abdominal pathology or asymptomatic individuals and if they were not written in English or French. Articles were excluded if the main radiological modalities used were CT (as this review does not include traumatic injuries), isotope bone scan (rarely used nowadays) or herniography (used to diagnose hernias). However, if these modalities were merely additional examinations used to complement one of the main modalities of interest (radiography, ultrasonography or MRI), the study was still included. MRI studies where all scans were performed at a field strength below 1.0 Tesla were also excluded to ensure adequate quality of MRI.7

In this initial selection round, studies were included based on the information provided in their abstract. In the second round, included articles were read in full length and excluded if they...
were not reporting radiographic, ultrasonographic or MRI findings in athletes with long-standing groin pain emanating from the pubic symphysis and/or the adductor musculotendinous insertions, or if they were providing insufficient information about their radiological results. Lastly, reference lists of the retrieved papers were hand-searched to identify further relevant studies.

Search results
The MEDLINE search yielded 252 results. Of these, 236 were excluded, leaving 17 articles for inclusion in this review: 4 articles involve radiography as their main radiological modality, 1 involves ultrasound (US) and 12 involve MRI (see online supplementary figure S1). Most of the retrieved studies are based on a combination of clinical, radiological and sometimes surgical data. In the following sections, we extract all relevant radiological results from these studies, which implies less emphasis on clinical and surgical results.

Conventional radiography is the original modality used to assess athletes with symphyseal and adductor-related groin pain. It is still prevalent today as it depicts pelvic bony and articular structures. Patients can be examined in a supine position or standing upright (weight-bearing) to show the presence of symphyseal instability. Ultrasonography provides dynamic real-time images and is particularly adapted for examining superficial soft tissues (tendons and muscles) in the groin area. MRI is useful in imaging parts of the body with little density contrast (such as soft tissues), and provides images with high resolution and contrast by using strong magnetic fields and non-ionising radiation, combined with a large field-of-view.

Retrieved studies were evaluated for our analysis according to the following parameters: study design and participants, presence of control groups, inclusion and exclusion criteria, clinical findings, radiological protocols and evaluation and reliability of radiological findings (tables 1–4).

Ideally, study groups should be as homogeneous as possible in terms of age, sex and sports practiced to ensure that participants are comparable: the frequency of degenerative musculoskeletal changes increases with age,9 there are anatomical variations in the pelvic region between sexes, and different sport types affect the pelvic musculotendinous structures differently depending on the predominant movement patterns. Inclusion and exclusion criteria should be as well defined as possible to ensure that study participants are selected properly and are representative of the pathology of interest. Symptomatic cases should be compared with well-matched asymptomatic controls to evaluate differences in a case-study group. If they are compared with those of an asymptomatic matched control group, as differences between groups could point at possible aetiological symptom-provoking factors. In 10 of 17 studies, a control group was included. There was a total of six MRI case–control studies,10–12 14–16 17–19 of which one had two control groups12 and five had one control group.14–16 17–19–20 Three radiographic studies had one21 23 or two22 control groups. In the US study,23 patients in the case-study group functioned as their own controls, as their symptomatic and asymptomatic sides were compared with each other. Control groups consisted of athletes in four studies,14–16 17–19 of sedentary individuals in one MRI study20 and two radiographic studies21 23 and of both athletes and sedentary individuals in one MRI12 and one radiographic study.23

Clinical findings
A correct documentation of clinical findings is essential when interpreting radiological results subsequently. Both should ideally be held up against each other to avoid misinterpretation of radiological signs that may be incidental findings unrelated to the actual symptoms experienced by the patients.

Clinical examination of study participants varies among retrieved studies. Overall, 14 of 17 studies evaluated participants clinically. Two radiographic studies,21 22 the US study23 and 11 of 12 MRI studies10–12 14–16 17–19 20–24 included a preliminary clinical examination of all case-study participants, whereas 1 MRI14 and 2 radiographic studies25 26 mentioned none. In two MRI studies,11 24 all study participants underwent a reproducible clinical examination focused on the groin and lower abdominal areas.27

Radiological protocols
To ensure homogeneity of research results, radiological evaluation of all study participants should ideally be performed with the same radiological equipment and according to a predefined identical protocol. In 10 of 17 studies, radiological examinations were identical for all participants.10 11 13–17 19 24 26

In one radiographic study,26 pelvic radiographs were obtained in a supine position for all participants, whereas in another study,25 pelvic films were recorded differently for cases and controls. In two radiographic studies,21 22 the position in which pelvic films were taken was not described. Individuals participating in the US study23 were examined on the same machine and at the same transducer frequency. Neither the radiographic nor the ultrasonographic protocols were reproducible.

Among the retrieved MRI studies, radiological protocols included at least one MRI scan per participant per study. In three studies, patients had undergone additional radiographs of...
Not defined Clinical adductor dysfunction

Clinical adductor dysfunction

Clinical adductor dysfunction

Osteitis pubis

Pubalgia

Osteitis pubis

Degenerative changes at symphyseal joint

Degenerative changes at symphyseal joint

Musculotendinous structures of the groin and abdominal wall. Inguinal hernia, hip and SI joints

None

None

None

None

None

Surgery (modified Bassini hernioplasty)

None

Bone marrow edema.
Cases: recruited at end of pre-season after 6 weeks

Cases: Patients referred with suspicion of groin injury, no groin surgery

Controls: Asymptomatic, hip pain and pain from sartorius muscles

Inclusion criteria

Cases: Groin pain>3 months

Controls: Groin pain, no groin symptoms

Exclusion criteria

Cases: Sports hernia at clinical examination before referral

Cases: Acute groin injury, insufficient clinical and surgical details available

Not described

Clinical findings

(1) type of examination
(2) findings

Cases: Groin pain for average of 3 months

Cases: Groin pain for average of 3 months

Diagnosis entity used by authors

Osteitis pubis

Adductor dysfunction

Athletic pubalgia

Osteitis pubis

Osteitis pubis

Radiology protocol

(1) Field strength
(2) Sequences

(1) 1.5T

(2) Coronal T1 & STIR, axial T2

(1) 1.5T

(2) Coronal T1 & STIR, axial T2

(1) 1.5T

(2) Coronal T1 & STIR, axial T2

(1) 1.5T

Additional radiologic examinations

None

None

None

None

Pelvic radiographs

Pelvic radiographs and isotope bone scan

Evaluation of MRI scan

2 Radiologists blinded to side of symptoms. Diagnosis by consensus. Presence of secondary cleft sign Degenerative changes at symphyseal joint

2 Radiologists blinded to clinical details. Diagnosis by consensus BMO (graded 0–2) Degenerative changes at symphyseal joint Musculotendinous structures of the groin & abdominal wall Graded at 1 and 2 reading (0–2)

3 Radiologists blinded to clinical details. Diagnosis by consensus BMO (not graded) Osteitis pubis (BMO with degenerative changes at symphyseal joint) Abnormal resectus abdominis and adductor tendons Presence of secondary cleft sign

2 Radiologists blinded to clinical details. Diagnosis by consensus BMO (graded 0–3) Degenerative changes at symphyseal joint

2 Radiologists blinded to clinical details. Diagnosis by consensus BMO (graded 0–3) Degenerative changes at symphyseal joint Abnormal conjoin tendon Abnormal adductor enthesis

Table 2  MRI case–control studies

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<tbody>
<tr>
<td>Case-study group</td>
<td>100 athletes (soccer)</td>
<td>52 athletes (35 soccer, 13 rugby, 4 athletics), of whom 27 previous surgery</td>
<td>141 patients (127 athletes: 41 American football, 23 soccer, 15 running, 14 hockey, 34 others)</td>
<td>18 athletes (15 soccer, 3 rugby)</td>
<td>89 athletes (Australian football)</td>
<td>16 athletes (13 soccer, 1 cross-country skier, 1 runner, 1 ice-hockey)</td>
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<td>sports type, gender,</td>
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<td>age)</td>
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<tr>
<td>Controls</td>
<td>100 athletes (50 rowers, 50 soccer)</td>
<td>6 athletes (5 soccer, 1 rugby)</td>
<td>Male. Age 17–37</td>
<td>25 (physical activity unknown)</td>
<td>Male. Age 18–39</td>
<td>70 athletes (rowers)</td>
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<td>Sex unknown. Age: 18–28</td>
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<tr>
<td>Inclusion criteria</td>
<td>Cases: Debilitating groin pain and symptoms and signs at pubic symphysis Controls: Asymptomatic, hip pain and pain from sartorius muscles</td>
<td>Cases: Patients referred with diagnoses ‘athletic pubalgia’ and ‘sports hernia’ Controls: Asymptomatic</td>
<td>Cases: Patients referred with suspicion of groin injury Controls: Asymptomatic</td>
<td>Cases: recruited at end of pre-season after 6 weeks intensive training Controls 1: age-matched, min. 6 weeks intensive training Controls 2: no prior history of groin pain, no physical exercise within 6 weeks, age-matched</td>
<td>Cases: osteitis pubis (established by exclusion of other groin disorders, typical clinical history and signs, pelvic radiographs isotope bone scan and MRI) Controls: Asymptomatic</td>
<td></td>
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<tr>
<td>Exclusion criteria</td>
<td>Cases: Sports hernia at clinical examination before referral Controls: groin pain</td>
<td>Cases: Acute groin injury, insufficient clinical and surgical details available</td>
<td>Cases: Inadequate MRI of pubic region. Images older than 120 days from time of physical examination</td>
<td>Not described</td>
<td>Not described</td>
<td>Cases: inguinal hernias, iliopectas and abdominal muscle-related pain, chronic prostatitis. tendinitis of the groin, bursitis or hip disorders</td>
</tr>
<tr>
<td>Clinical findings</td>
<td>(1) Not described (2) Groin pain for average of 3 months</td>
<td>(1 and 2) Not described</td>
<td>(1) Not reproducible but details given (2) 93 positive for rectus abdominis tendon lesion, 15 for adductor compartment lesion, 71 for both, 16 for osteitis pubis (not defined)</td>
<td>None</td>
<td>(1) Not reproducible but details given (2) 52 athletes positive for current groin symptoms and signs (tenderness on palpation of symphysis and superior pubic rami)</td>
<td>(1) Not described (2) All cases have tenderness of pubic symphysis &gt;3 months. 3 cases with adductor-type pain on palpation</td>
</tr>
<tr>
<td>Diagnostic entity used</td>
<td>Osteitis pubis</td>
<td>Adductor dysfunction</td>
<td>Athletic pubalgia</td>
<td>Osteitis pubis</td>
<td>Osteitis pubis</td>
<td>Osteitis pubis</td>
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<td>by authors</td>
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<tr>
<td>Radiology protocol</td>
<td>(1) 1.5T (2) Coronal T1 &amp; STIR, axial T2</td>
<td>(1) 1.5T (2) Coronal: T1 &amp; STIR, axial T2. Oblique axial: T1, T2 FatSat, T1FatSat postgadolinium</td>
<td>(1) Cases: various (117 at 1.5T, 2 at 3.0T, 16 at 0.2–0.3T, 6 at 0.6–0.7T) Controls: 1.5T (2) Protocols not defined</td>
<td>(1) 1.5T (2) Cases: coronal T1 and STIR, axial T2 FatSat Controls: coronal STIR only</td>
<td>(1) 1.5 T and 1.0 T (2) Coronal and axial: T1 and T2 FatSat</td>
<td>(1) 1.0 T (2) Coronal and axial: T1 and STIR</td>
</tr>
<tr>
<td>Additional radiologic</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
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<td>examinations</td>
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<tr>
<td>Evaluation of MRI scan</td>
<td>2 Radiologists blinded to side of symptoms. Diagnosis by consensus. Presence of secondary cleft sign Degenerative changes at symphyseal joint</td>
<td>2 Radiologists blinded to clinical details. Diagnosis by consensus BMO (graded 0–2) Degenerative changes at symphyseal joint Musculotendinous structures of the groin &amp; abdominal wall Graded at 1 and 2 reading (0–2)</td>
<td>3 Radiologists blinded to clinical details. Diagnosis by consensus BMO (not graded) Osteitis pubis (BMO with degenerative changes at symphyseal joint) Abnormal rectus abdominis and adductor tendons Presence of secondary cleft sign</td>
<td>2 Radiologists blinded to clinical details. Diagnosis by consensus BMO (graded 0–3) Degenerative changes at symphyseal joint Abnormal conjoint tendon</td>
<td>2 Radiologists blinded to clinical details. Diagnosis by consensus BMO (graded 0–3) Degenerative changes at symphyseal joint Abnormal conjoint tendon Abnormal adductor enthesis</td>
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Continued
The difference in BMO in the 3 groups (surgical, conservative and control) is not statistically significant, although grade 3 oedema is not found in asymptomatic cases. 62% of those (47 cases and 5 runners) have current group pain and symptoms at clinical exam. Secondary cleft sign identified with 100% sensitivity and specificity on MRI and fluoroscopy. Present in 12 cases. Secondary cleft sign corresponds to side of symptoms. MRI sensitivity 68% and specificity 100% for rect. abdom., 86% and 89% for adductor lesions compared to surgery. Present in 12 cases of adductor lesions.

Table 2 Continued

<table>
<thead>
<tr>
<th>Study</th>
<th>Reproducibility of radiology</th>
<th>Interobserver agreement</th>
<th>Conclusions/results</th>
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</thead>
<tbody>
<tr>
<td>Cunningham et al (2007)</td>
<td>None</td>
<td>None</td>
<td>Secondary cleft sign seen in 48.8%, osteitis pubis in 9% of cases. Both in 43%. Secondary cleft sign and BMO only present in cases but not controls.</td>
</tr>
<tr>
<td>Robinson et al (2004)</td>
<td>None</td>
<td>Physical examination in 141 cases</td>
<td>Positive MRI findings in 138 cases: Secondary cleft sign in 66 cases, BMO in 63 cases. MRI sensitivity 68% and specificity 100% for rect. abdom., 86% and 89% for adductor lesions compared to surgery.</td>
</tr>
<tr>
<td>Brennan et al (2005)</td>
<td>None</td>
<td>None</td>
<td>Surgery in 8 patients not responding to conservative treatment of groin pain</td>
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<tr>
<td>Verrall et al (2001)</td>
<td>None</td>
<td>None</td>
<td>None</td>
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<td>Paajanen et al (2008)</td>
<td>None</td>
<td>None</td>
<td>None</td>
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</table>

BMO, bone marrow oedema.

DISCUSSION

The aim of our review is to provide an overview of the existing scientific evidence on radiological pathological findings in athletes with long-standing symphyseal and adductor-related groin pain. It has proved challenging to extract information from Imaging studies, and radiological findings in athletes have been reviewed in 4 articles. Despite the variety of imaging studies included in the review (MRI, CT, US, and X-ray), no consensus has been reached on the definition and interpretation of radiological findings. The diagnostic criteria for athletic pubalgia are still under debate, and the use of different imaging techniques and reporting standards may contribute to the variability in the results. The reproducibility of radiological findings is limited, and the interobserver agreement is often low. Therefore, further research is needed to develop standardized diagnostic criteria for athletic pubalgia and to improve the reliability of radiological assessments.

Reliability of radiology

Imagery and interobserver agreements are important factors in measuring the probability of confusion with athletic pubalgia. MRI scans were performed on the same machine in all but three studies. MRI scans were not performed on the same machine in all but three studies. MRI scans were not performed on the same machine in all but three studies. MRI scans were not performed on the same machine in all but three studies. MRI scans were not performed on the same machine in all but three studies. MRI scans were not performed on the same machine in all but three studies. MRI scans were not performed on the same machine in all but three studies.
For all patients: Plain pelvic films in supine position and additional positions if necessary

None
Isotope bone scans (number unknown)
4 cases
CT, 2 cases MRI

Plain pelvic AP films (not defined if supine or standing)

Not described

Cases: groin and/or lower back pain (sciatica)

Controls: Asymptomatic

Radiographs (number unknown)

Pain and weakness in groin area during physical activity

Cases

None

(1) Not reproducible
(2) All cases have unilateral pain
(9 adductor-related, 13 hamstring, 5 rectus femoris, 4 gluteal muscle, 2 rectus abdominis)

Cases

None

(1) Not described
(2) All cases have unilateral pain

None

(1) Not described
(2) All cases have unilateral pain

None

(1) Not described
(2) All cases have unilateral pain

None

(1) Not described
(2) All cases have unilateral pain

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(2) All cases have unilateral pain

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(1) Not described
(2) All cases have unilateral pain

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(1) Not described
(2) All cases have unilateral pain

None

(1) Not described
(2) All cases have unilateral pain
Cunningham et al.\textsuperscript{17} define it radiologically as the presence of para-articular bone marrow oedema (BMO), remote from the adductor muscle attachment, Brennan et al.\textsuperscript{14} as symphysial degenerative changes on conventional radiographs and MRI, and as BMO in the medial pubic bones. Zoga et al.\textsuperscript{20} define it on MRI as BMO spanning the symphysis. For others,\textsuperscript{10–19} ‘osteitis pubis’ represents a combination of pubic groin pain, local tenderness on palpation of the symphysis, pain-filmed bilateral hip adduction and the presence of pubic BMO on MRI. ‘Athletic pubalgia’ is a quite unspecific term that describes sports-related pain at the site of the pubic symphysis, and appears in two of the retrieved MRI studies.\textsuperscript{18,20} It is used as a diagnostic term when the physical examination of athletes is indeterminate, and the cause of groin pain is unidentifiable.\textsuperscript{18}

Pubic instability is another ill-defined radiological and clinical term. Standard radiography of the pelvis consists of static inlet and outlet anteroposterior views, but evaluating pathological vertical shift motion between the symphysis joint surfaces requires a dynamic stress examination of the pelvis. This was first achieved by Chamberlain\textsuperscript{28} in 1930 using single-leg-stance (flamingo) views. Despite the methodological shortcomings and a lack of demographic information concerning the study population, normal motion at the pubic symphysis was measured up to 2 mm in this study and others.\textsuperscript{29–31} One recent study, however, reported a physiological joint motion of up to 5 mm.\textsuperscript{31} There is a need for further imaging studies defining and assessing pelvic instability in athletes, and correlating dynamic radiographic findings with clinical symptoms, before pubic instability can be considered a diagnosis.

### Reliability

Few studies assess the reliability and reproducibility of radiological findings in symphysial and adductor-related groin pain. An accurate interpretation of images depends on functional and reliable imaging parameters that allow multiple observers to reproduce the same results time after time and thereby establish a correct diagnosis. Even though numerous radiological parameters are described in the literature, it remains unclear how subjective their interpretation actually is, and further reliability assessments would therefore improve current practice.

### Gold standards

In a radiological setting, a gold standard is the most accurate diagnostic test against which other radiological modalities are evaluated and compared. Ideally, an MRI scan should be held up against another test known to be the best available under reasonable conditions, to evaluate if the interpretation of MRI is correct and in accordance with the gold standard.

Seven MRI studies and the US study attempted to use a ‘gold standard’,\textsuperscript{11,14,17–20,23,24} whereas the radiographic studies used none. In two MRI studies,\textsuperscript{14,17} fluoroscopy-guided contrast injection into the pubic symphysial cleft in a group of symptomatic athletes was used as a gold standard with which to compare MRI scans. The aim was to demonstrate the presence of a primary and/or secondary cleft sign (defined as extension of contrast material either lateral to the midline or inferior to the symphysial joint\textsuperscript{14}) and assess whether it was visible on both imaging modalities. However, at present, there exists no evidence to prove the exact nature of a secondary cleft and what significance it has for long-standing pain. In two other MRI studies,\textsuperscript{11,24} an injection of a local anaesthetic and steroid into the pubic cleft was performed under US guidance in a group of symptomatic athletes in an attempt to alleviate
pain symptoms. In these studies, symptomatic athletes were MRI scanned with intravenous gadolinium, and the authors interpreted the presence of contrast enhancement at the adductor enthesis as enthesitis. However, both studies reported immediate alleviation of pain symptoms upon pubic cleft injection in all participants, whereas only 17 of 24 individuals displayed contrast enhancement at the adductor muscle insertion in the first study, and 13 of 28 individuals in the second study.

Three MRI studies used surgery as a reference to evaluate radiological results. Zoga et al compared MRI findings retrospectively with physical examination findings and surgical results in a group of 141 patients, of whom 102 had undergone surgery. They reported MRI sensitivities and specificities of 68% and 100% compared with surgery for rectus abdominis tendinous injuries, and of 86% and 89%, respectively, for adductor tendon injuries. However, MRI scans were not easily comparable as they differed in terms of scanning protocols, field strengths and anatomical areas covered. Paajanen et al performed non-randomised surgery on 8 of 18 athletes with osteitis pubis who did not respond to conservative therapy. They found that although operated athletes had more symptoms and a longer pain history than patients treated conservatively, they recovered faster than the non-operated patients. Moreover, they reported no statistical difference in the degree of BMO between the groups of operated and non-operated athletes.

In the US study, 10 of 36 patients were treated surgically, and in 9 of these patients, the surgical findings correlated well with the ultrasonographic findings (of which four patients had ruptured adductor tendons). However, as the nature and aetiology of pathological findings in athletes with groin pain are largely unknown, these gold standards cannot be considered to be better tests than MRI scans.

Owing to the methodological shortcomings listed above, we have attempted to classify the results of the retrieved studies according to the actual radiological findings reported by the authors, and not according to diagnostic terms such as ‘osteitis pubis’, ‘athletic pubalgia’ or ‘adductor dysfunction’, as these diagnoses differ between studies. Radiological findings associated with symphyseal and adductor-related groin pain can therefore be classified into four groups: (1) degenerative changes at and around the symphyseal joint, (2) pathological changes at the adductor muscle insertion to the pubic bone, (3) pubic BMO and (4) the presence of a secondary cleft sign (table 4).

Degenerative changes around the symphyseal joint
The symphyseal joint is a fibrocartilaginous joint with a central disc interposed between two hyaline cartilage-covered joint surfaces. Normally, these joint surfaces are smooth and well delineated, the central disc is contained within the joint capsule and there is often a small physiological fluid-filled space inside the disc (called a primary cleft). Degenerative changes in and around this joint consist of joint surface erosions and irregularities, subchondral sclerosis and cysts, joint space widening or narrowing, central disc herniation and bony proliferation (healing) at the superior margins of the joint. All radiographic studies assessed degenerative changes at the symphyseal joint. Their prevalence is variable among studies and depends on whether the study participants are symptomatic or not. In two radiographic studies, almost all symptomatic athletes presented chronic degenerative changes at the pubic symphysis of greater severity and prevalence than the corresponding non-athletic control groups. Moreover, radiographic studies showed symphyseal joint changes in around 70–80% of asymptomatic athletes but much fewer (45–65%) in non-athletic controls, whereas the prevalence of degenerative changes increased with age.

In MRI studies, the prevalence of degenerative symphyseal changes varied from 20% to 33%, 37%, 50%, 63%, 73% and 98% of symptomatic athletes, whereas the prevalence recorded for asymptomatic athletes varied from 0% to 27%, 33% and 50%. Thus, even though degenerative changes at the symphyseal joint can be observed in both symptomatic and asymptomatic individuals, there is some indication that they are more commonly found in athletes with long-standing symphyseal pain than in asymptomatic athletes.

Pathology at the adductor muscle insertions
Adductor-related groin pain is a diagnostic entity that describes pain related to the adductor muscle insertions at the pubic bones. Schilders et al considered adductor-related pain to be present if the clinical examination demonstrated tenderness at the adductor enthesis, and pain on passive adductor stretching and resisted adduction of the thigh. In another study, the authors used the term ‘adductor-related’ as well as the term ‘adductor dysfunction’ for clinical adductor tenderness and pain exacerbated on resisted adduction, which is identical to the diagnostic entity adductor-related groin pain. There exists at present no radiological grading scale to evaluate the severity of pathology at the adductor enthesis site.

Six of the retrieved MRI studies, 16 18–20 24 one radiographic, 22 and the US study 23 reported findings on groin pain originating from the adductor muscle insertions. The prevalence of adductor enthesis pathology at MRI (defined in three studies as contrast enhancement at the site of the adductor enthesis) was variable: 71% in a group of symptomatic professional athletes, and 46% in a group of recreational athletes with adductor-related groin pain. In another study, three of three athletes with positive clinical adductor-type pain showed increased signal intensity at the site of the adductor muscle attachment.

Pubic BMO
BMO is visible on fluid-sensitive MRI sequences as increased signal intensity within the pubic bone marrow. It has been the subject of considerable interest in several studies, as its presence is suspected of being correlated to the severity of long-standing pubic pain. Even though BMO is a commonly evaluated radiological finding, its assessment is not standardised. There exists no reliable and reproducible grading scale. Instead, BMO was graded subjectively according to a Likert scale (0=no changes, 1=mild, 2=moderate, 3=severe) in five studies, and was moreover graded according to its regional extent at the pubic symphysis (less or more than 2 cm) in two studies. One of these studies evaluated the inter-observer variation for the grading of BMO, yielding a k value of 0.85. In four other articles, the presence of BMO was recorded but not graded. Thus, the assessment of the severity of BMO is rather subjective.

BMO is often found in symptomatic athletes: studies have reported its prevalence as varying from 28% to 44%, 50%, 63%, 70%, 70%, 91%, 94% and 100%. However, it is often present in asymptomatic athletes as well: the prevalence in our retrieved studies spanned widely from 6% to 15%, 48%, 61% and 65%.
Two additional MRI studies examining exclusively asymptomatic athletes reported the prevalence of pubic BMO among their study participants to be 23% \(^{14}\) and 57% \(^{15}\) respectively. Interestingly, in the latter study, \(^{15}\) the prevalence of pubic BMO was 50% in a group of sedentary matched asymptomatic controls. Overall, pubic BMO seems to be more prevalent and more severe in symptomatic versus asymptomatic athletes.

**Secondary cleft sign**

The secondary cleft sign is mentioned in three of the retrieved MRI studies. \(^{14} \) \(^{17} \) \(^{20}\) It has been defined by Brennan et al \(^{14}\) as any evidence at the symphyseal cleft injection of extension of contrast material either lateral to the midline or inferior to the joint, by Cunningham et al \(^{17}\) as an abnormal inferior extension of the cleft in symphyseal fibrocartilage, and by Zoga et al \(^{20}\) as a curvilinear area with the signal intensity of fluid extending inferolaterally from the inferior aspect of the symphysis on coronal images. Its prevalence was 52% \(^{20}\), \(^{67}\% \) \(^{14}\) and 88% \(^{17}\), respectively, among athletes with symphyseal groin pain in these studies, and it corresponded to the side of symptoms in all cases. Asymptomatic controls in these studies presented no secondary cleft sign, irrespective of whether they were athletes \(^{14} \) \(^{17}\) or sedentary. \(^{20}\)

Authors interpret the secondary cleft sign as a possible consequence of a microtear or traction force at the site of the adductor attachment to the pubic bone, and thus as an indirect sign of a lesion at the adductor muscle attachment site. However, its significance is still debatable.

**CONCLUSION**

Radiological evaluation of long-standing symphyseal and adductor-related groin pain remains a challenging task. Current evidence is based on relatively few heterogeneous studies of varying methodological quality. Four main radiological findings seem to appear consistently: degenerative changes at the pubic symphyseal joint, pathology at the adductor muscle insertions at the pubic bones, pubic BMO and the secondary cleft sign. The existing diagnostic terminology is confusing, and the interpretation of radiological pathological changes would benefit from imaging studies using a more systematic approach. The methodological quality of such studies would be improved by including homogeneous study groups (in terms of age, sex and sport types), well-matched control groups, reproducible clinical examinations and identical, well-designed radiological protocols.

**What does this paper add?**

- Radiological evaluation of long-standing symphyseal and adductor-related groin pain is based on relatively few heterogeneous studies of varying methodological quality.
- The existing diagnostic terminology is confusing.
- Four main radiological findings appear: degenerative changes at the pubic symphyseal joint, pathology at the adductor muscle insertions at the pubic bones, pubic bone marrow oedema and the secondary cleft sign.
- This topic requires further systematic research.

**Correction notice** This article has been corrected since it was published Online First. An author affiliation for Per Hölmich was missing, which has now been added.

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**REFERENCES**


Figure 1: Search results and selection of relevant articles

- 560 references:
  - 35 Case reports
  - 4 Neuroimaging studies
  - 1 Other study

- 107 articles unrelated to topic:
  - 23 articles related to topic but without radiological assessment

- 6 ultrasound studies on sports hernia or abdominal pathology:
  - 2 MRI studies examining only symptomatic athletes
  - 1 MRI study with all scrotal field strength <3 Tesla

Medline search
including MRI, Radiography, and Ultrasoundography

252 Articles

156 Articles

26 Articles:
- 15 MRI
- 4 Radiography
- 7 Ultrasoundography

17 Articles:
- 12 MRI
- 4 Radiography
- 1 Ultrasoundography