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Pubic apophysitis in elite Australian Rules football players: MRI findings and the utility of VIBE sequences in evaluating athletes with groin pain

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AIM: To confirm that pubic apophysitis is common in Australian Rules footballers with groin pain.

MATERIALS AND METHODS: Thirteen male Australian Football League (AFL) players with groin pain were assessed with volumetric interpolated breath-hold examination (VIBE) MRI over the 2017, 2018, and 2019 AFL seasons. Images were reviewed for pubic maturation, the presence of pubic apophysitis, and associated bone pathology and correlated with side of groin pain.

RESULTS: Pubic apophysitis was seen in 92% of AFL players with groin pain. Delayed maturation of the pubic apophyses was observed in 85%. Pubic bone erosions and cyst-like changes were common (100% and 46%, respectively), but due to delayed maturation of the apophyses and apophysiolysis. Apophysitis associated with adductor brevis-gracilis was more common than adductor longus-associated apophysitis.

CONCLUSION: Pubic apophysitis associated with delayed maturation of the pubic apophyses is common in AFL players and is potentially a significant cause of groin pain in these athletes. Imaging findings in this group are the same as those conventionally describing osteitis pubis. Pubic apophysitis is best visualised with VIBE magnetic resonance imaging (MRI) and may be a more pathologically correct description of early, adductor load-related pubic bone pathology.

Introduction

Groin pain is a common problem in young athletes who participate in kicking and "cutting" sports such as Australian Rules League (AFL) football and soccer. Potential causes include adductor tendon, pubic symphysis, and inguinal and iliopsoas related pathologies, as described in the Doha agreement of 2015.[1]

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The pubic symphysis is a complex anatomical structure that is a common cause of groin pain. It is a fibrocartilaginous joint comprising the medial surfaces of the pubic bones with a central fibrocartilaginous disc.[2,3] Oval-shaped articular surfaces are covered by hyaline cartilage.[2] Articular cartilage thickness is said to vary between 1–3 mm, depending on age and imaging technique.[2]

The pubic symphysis secondary ossification centres appear around late puberty and are said to fuse at around 20–25 years of age[4]; however, in palaeodemographic studies, full closure of the pubic epiphyses does not occur until approximately the 35th year.[5] In particular, the ventral margin or "rampart" is described as an epiphyseal cap that is usually not fully formed until the "immediate post-epiphyseal phase" at 36–40 years of age.[5] The ventral epiphyses in the anatomical literature correspond to the pubic apophyses in contemporary imaging literature, which recognises the presence of tendinous (apophyseal) and ligamentous (epiphyseal) attachments to the pubic symphysis.[3]

Four pubic ligaments (anterior, posterior, superior, and inferior) resist shear and torsional forces across the joint.[2] Descriptions of the pubic ligaments vary; however, they have been shown to have interpubic disc attachments and also interdigitate with the adductor tendons.[2,3] Their functional significance is controversial, with some dispute regarding their roles in pubic symphysis stability, although the anterior pubic ligament has been identified as playing a significant role in groin injury more recently.[2,6,7]

The interpubic disc merges with the apophysis or periosteum of the pubic bones.[2,3] The interpubic cleft is a slit-like oval within the superior and posterior disc that occupies one half to one third of the disc.[2] Its incidence is contentious having said to be present in most, but not all, individuals and is more common in adult women (97%) than men (88%)[2]; however, in the study by Robinson *et al.* (2009), only four of 10 athletes had an identifiable cleft.[3]

The anatomy of the proximal adductor tendons, as well as their relationship to the pubic symphysis, is complex and variable and includes tendinous and direct muscular attachments to both the pubic bone/apophysis and pubic symphysis capsule.[2,3] In a recent anatomical study, the adductor longus, adductor brevis, and gracilis tendons were found to have a fibrocartilaginous enthesis. The proximal adductor brevis muscle (in males) or tendon (in females) and gracilis tendon were also found to be fused at the adductor origin.[8] In the skeletally immature, it has been observed that adductor longus arises from the superior pubic apophysis (superior ventral rampart) along with the insertion of rectus abdominus and conjoint tendon of the inguinal ligament, whilst adductor brevis and gracilis arise from the inferior pubic apophysis (inferior ventral rampart). This anatomical relationship does not appear to have been noted previously.

Since the study by Robinson *et al.*, advances in MRI techniques have allowed significant improvement in the visualisation of the anatomy of the pubic symphysis and adductor origin, allowing us to re-assess the role of some of the potential pain generators in athletes presenting with groin pain.[3,9] In particular, volumetric interpolated breath-hold examination (VIBE) magnetic resonance imaging (MRI) has been reported to be a viable alternative to computed tomography (CT) in the evaluation of sports-related osseous injuries and may be useful in the assessment of apophyseal pathology in the immature skeleton where non-ionising radiation imaging is preferred.[9] More recently, pubic apophysitis has been identified as a potential cause of symptoms in adolescent soccer players with groin pain.[10] At imaging of the pubic symphysis in elite footballers, where pubic apophysitis is suspected to be common, VIBE sequences were performed on all players with groin pain to evaluate for the presence of delayed closure of the pubic apophyses and pubic apophysitis. The imaging was reviewed of all players from one elite AFL club presenting with groin pain during the 2017, 2018, and 2019 AFL seasons and the findings of 13 athletes in whom evidence of pubic apophysitis and delayed maturation of the pubic apophyses or physiological immaturity of the pubic bones was found are reported.

Materials and Methods

The Fremantle Football Club competes in the AFL national competition and is based in Perth, Western Australia. Over the 2017, 2018, and 2019 AFL seasons, retrospective review of MRI, including VIBE sequences of all players scanned for groin pain was undertaken by the club radiologist, a sports imaging specialist with 13 years of experience, including 11 years with the Fremantle Football Club. Informed consent was obtained from players regarding participation in the study. Ethics board approval was not required.

Demographic and clinical data collected included player age and side of groin pain (left, right or bilateral; Table 1). MRI was performed at the Club's affiliated medical imaging centre with either Siemens Magnetom Aera 1.5 T or Magnetom Skyra 3 T MRI machines. The MRI examination protocol typically included a small field of view (18×18cm) axial and coronal T1 and T2-fat saturated sequences at 3 mm section thickness and 3.3 mm section separation. In addition, a small targeted field of view (8.5×20cm) VIBE MRI with 1 mm contiguous sections acquired axial to the pubic symphysis and reformatted in the axial plane, was performed.

Imaging data included staging of pubic symphysis maturation and assessment for the presence of pubic apophysitis and pubic bone changes, including marrow oedema, subchondral cysts, erosions and sclerosis, to allow comparison with cases described by Sailly *et al.* (Tables 1 and 2) Additionally images were reviewed for the presence of apophysiolysis at the pubic symphysis and the presence of a symphyseal cleft and effusion (Table 1).

Staging of the pubic symphysis maturation was performed from reconstructed VIBE MRI images according to the findings of Sailly *et al.*, including assessment of both superior and inferior pubic apophyses (Fig 1). Routine and VIBE MRI images of the pubic symphysis were reviewed for

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Table 1
Pubic apophysitis: pubic maturation and associated imaging findings.

Player	Age (years)	Side symptoms	Maturation Stage Superior	Maturation Stage Inferior	Superior Apophysitis present	Inferior Apophysitis present	Asymmetry or delay secondary Ossification
1	20.6	B R>L	2	2	B R>L	B R>L	R
2	24.2	B	3b	3b	B R>L	B R>L	D
3	24.1	R	2	1R 2L	B L>R	R	R
4	30.1	B R>L	3aR 2L	3bR 2L	–	–	L
5	21.5	B L>R	2	2	B	B L>R	–
6	19.1	B L>R	2	2	B	B	–
7	22.5	B	3a	2R 3bL	–	B R>L	R
8	23.3	L	3a	3b	L	–	D
9	21.3	L	2	2	B L>R	B L>R	L
10	30.9	L	3a	3bR 2L	–	L	L
11	23.3	B R>L	1	2	B	B R>L	D
12	20.3	L	2	2	L	L	L
13	18.7	B L>R	2R 1L	1	B	B	L

L, left; R, right; B, bilateral; >, worse than; D, delayed maturation.

features of apophysitis, including apophyseal oedema (increased T2 signal and apophyseal swelling) and apophysiolysis. The side of bone pathology (bilateral, left or right) was documented. Marrow oedema was assessed as mild, moderate, or severe depending on the degree of right and left pubic body or inferior ramus marrow T2 signal change relative to the right ischial tuberosity at the same level, using 0.3–0.4 cm^2 regions of interest (ROIs). Increased pubic marrow T2 signal intensity of 1–1.5 times compared to ischial tuberosity marrow signal was classified as mild (+), >1.5–2 times was classified moderate (++) and >2 times was classified as severe (+++; Table 2).

Results

Demographic and clinical data

During the 2017, 2018, and 2019 AFL seasons, 65 players were on the Fremantle Football Club playing list. Eighteen players (28%) had MRI examinations of the groin for acute or chronic groin pain. Three players had acute adductor longus musculotendinous junction strain injuries and were excluded from further analysis. One player, who had iliopsoas bursitis, did not undergo VIBE and was also excluded from further analysis. One player had an acute unilateral rectus abdominus insertion tear and conjoint tendinosis, but had persisting groin pain with follow-up groin MRI and was included in the study; the follow-up MRI was the examination used for review in this study. One de-listed player could not be contacted to provide consent; this player's data were excluded from the study. In total, 13 players aged between 18.7 and 30.9 years (average age = 23.1 years) underwent pubic symphysis MRI including VIBE for pubic region groin pain and were able to provide informed consent. There were four cases of left groin pain, one case of right groin pain, and eight cases of bilateral groin pain (Table 1).

Imaging data

Pubic bone maturation

Compared with the study by Sailly *et al.*, the athletes in this study spanned more advanced stages of pubic bone maturation (18.7–30.9 years). In the present study, 13 athletes with four pubic apophyses (left and right, superior and inferior) or 52 apophyses in total were evaluated. According

Table 2
Pubic apophysitis: pubic bone and symphysis findings.

Player	Side symptoms	Erosions	Apophysiolysis	Cysts	Sclerosis	Pubic marrow oedema (R/L)	Symphyseal cleft
1	B R>L	B	B	B	B	B +++	Y
2	B	B	B	–	B	B ++	N
3	R	B	B	R	B	B +++R/++L	N
4	B R>L	B	–	L	–	N	Y
5	B L>R	B	B	–	B	B +	N
6	B L>R	B	B	–	B	B ++	N
7	B	B	B	R	R	R ++	Y
8	L	B	–	–	–	N	Y
9	L	B	B	B	B	B ++R/+++L	Y
10	L	L	L	–	–	L +	Y
11	B R>L	B	B	B	B	B +++	Y
12	L	B	L	–	B	B +R/++L	N
13	B L>R	B	B	–	B	B +++	N

L, left; R, right; B, bilateral; >, worse than; +, mild; ++, moderate; +++, severe; y, yes; n, no.

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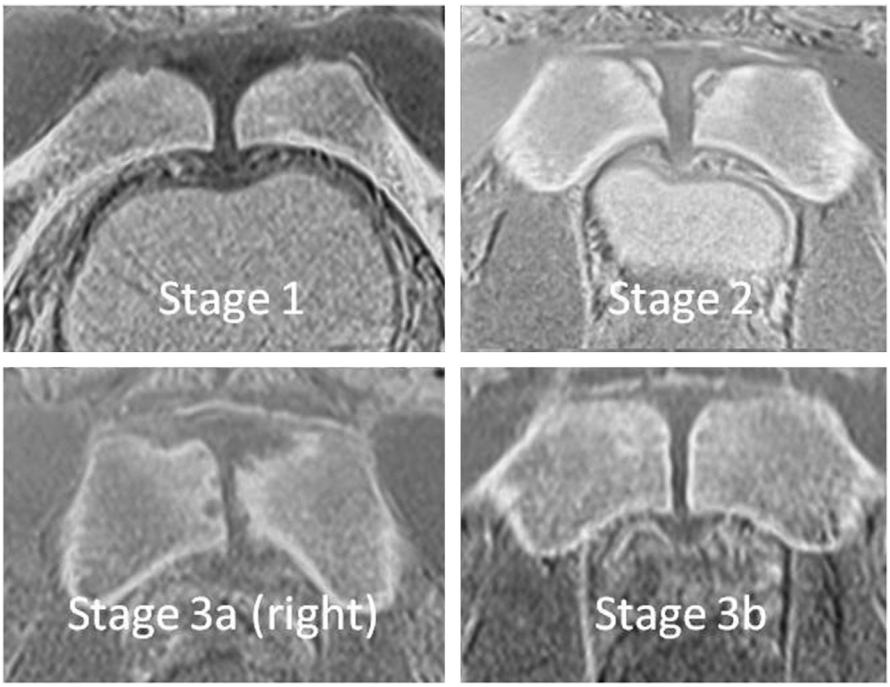

Figure 1 Axial inverted VIBE MRI of the superior pubic symphysis. Staging of superior and inferior pubic symphysis maturation was performed as per the study of Sailly *et al.* Stage 1 shows absence of the secondary ossification centre on the left. Note the right apophysis shows very early ossification (Stage 2). Stage 2 shows development of a secondary ossification centre with delayed maturation and apophysiolysis on the left. Stage 3a shows and incompletely ossified right superior apophysis anteriorly. Left apophysis shows delayed maturation with apophysiolysis giving the appearance of erosions. Stage 3b maturation shows fully formed ventral pubic bones.

to the staging criteria for maturation for the pubic apophysis reported by Sailly *et al.* (Fig 1), only six stage 1 apophyses (open apophyses with absence of secondary ossification centres) in three separate athletes were identified, reflecting the relative maturity of the players included in the study. Stage 2 maturation (secondary ossification centre separate from the metaphysis) was most common, seen in 30 apophyses in 11 athletes. There were 16 "mature" (stage 3a or 3b) apophyses in five athletes. In the present study, stage 3b maturation corresponded to the presence of incomplete apophysis ossification, due to apophyseal immaturity and/or apophysiolysis, giving the appearance of "erosions" in some players (Fig 1). Significant delay in maturation at the pubic apophyses by at least one stage (e.g., Player 3 with stage 2 maturation of the superior pubic apophyses and stage 1 maturation of the right inferior pubic apophysis and Player 11 with stage 1 superior and stage 2 inferior pubic apophyses) or asymmetric delay in development of the pubic apophysis secondary ossification centre was seen in nine of the 13 players. Two of the remaining four athletes (Players 2 and 8) were older than 23 years of age and demonstrated stage 3b apophyses bilaterally, indicating delayed apophysis maturation, as noted by Sailly *et al.* in referring to their comparison group where incomplete pubic apophysis closure was found in four of 21 asymptomatic subjects older than 21 years.[6] The remaining two athletes (Players 5 and 6) aged 19 and 21 years demonstrated stage 2 maturation bilaterally and were considered to be skeletally immature, but probably within normal limits for pubic bone maturation. Eleven of 13 athletes (85%) were therefore thought to have demonstrated evidence of delayed maturation of the pubic apophyses (Table 1).

Pubic apophysitis

Evidence of superior and/or inferior pubic apophysitis was present in 12 of 13 players (92%); one player had bilateral groin pain and no evidence of apophysitis or other groin pathology at imaging. Nine players had evidence of both superior and inferior pubic apophysitis, one player had evidence of superior pubic apophysitis only and two players had evidence of inferior pubic apophysitis only; inferior pubic apophysitis was therefore slightly more common (85%) than superior pubic apophysitis (77%). Superior and/or inferior pubic apophysitis was always present on the side of groin symptoms, and when bilateral groin pain was present apophysitis was observed bilaterally, except in one player where apophysitis was not present at imaging. When unilateral symptoms were present (five players) ipsilateral apophysitis was always present on the symptomatic side. In two of these cases, where unilateral groin pain was present initially, apophysitis was evident bilaterally; however, symptoms became bilateral at follow-up imaging within 2 months in both cases, suggesting the presence of subclinical apophysitis at initial presentation. In five out of eight cases with stage 2 maturation of the superior pubic apophysis, delay in development of the secondary ossification centre was observed on the symptomatic or most symptomatic side, similar to the findings of Sailly *et al.*[6] (Table 1).

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Pubic symphysis and pubic bones

Seven of 13 players (54%) had a visible symphyseal cleft, all with a trace of fluid evident. Only one player developed a small symphyseal effusion on follow-up imaging for ongoing groin pain. Subchondral "erosions" were observed in all players and cysts in six players (46%). Active apophysiolysis was observed in 11 of 13 players (85%) cases. The appearance of erosions was noted to be due to a combination of delayed maturation of the pubic apophyses and apophysiolysis, most frequently being related to apophysiolysis. Marrow oedema was seen in 11 of 13 players (85%); oedema was mild in two players, moderate in three players, severe in three players, mixed (left > right or right > left) moderate and severe in two players and mixed mild and severe in one player. Subchondral sclerosis, indicating chronic pubic bone stress, was present in 10 of 13 players (77%; Table 2).

Discussion

Imaging interpretation of symphyseal injury is made difficult by the varying descriptions and relevance of the anatomical structures involved, the oblique orientation of the pubic symphysis to conventional imaging planes, and complexity and variability of the clinical presentations. Combined with the limited resolution of imaging techniques for pubic symphysis pathology previously, along with Sailly *et al.*, we believe there has been under-recognition of the role of the pubic apophyses in groin pain.[10] Based on their study describing the potential role of superior pubic apophysitis in soccer players with groin pain and the present authors' clinical suspicion that pubic apophysitis is common in Australian Rules footballers, VIBE MRI was performed on AFL players presenting with groin pain to more clearly resolve pubic bone pathology.[10] As with the study by Sailly *et al.*, the present study also found that pubic apophysitis was common and the imaging findings and potential clinical impact of diagnosing pubic apophysitis in a cohort of athletes spanning the later stages of maturation of the pubic symphysis is described.[10]

Imaging findings in pubic apophysitis

CT of the symphysis pubis

In the recent literature, the pubic apophysis has been identified as a potential source of symptoms in patients with groin pain. Sailly *et al.* described in elite academy-level male soccer players the presence of CT imaging features of apophysitis in a young cohort of athletes with groin pain, when compared with asymptomatic young males who had undergone pelvic CT imaging for unrelated reasons. CT imaging findings in these adolescent athletes (age range 13.3–18 years), all with open apophyses, included apophyseal widening, asymmetry, and cyst-like expansions. Of note, in the comparison group, four of 21 asymptomatic individuals older than 21 showed incomplete closure or delayed maturation of the pubic apophysis.[10]

MRI of the pubic symphysis

On T1-and T2-weighted MRI sequences, normal pubic apophyses demonstrate intermediate signal intensity that is isointense to cartilage (Fig 2). Developing secondary ossification centres appear as signal void, similar to subchondral bone (Fig 2). In adolescents and young adults, the apophyses are often similar in signal intensity to the adjacent pubic body due to the presence of red marrow, which may limit resolution of juxta-articular bone pathology.[11] Normal subapophyseal cortical bone appears black on T1- and T2-weighted images (Fig 2). Subchondral "widening" due to incomplete apophyseal maturation is common in young athletes and best appreciated on T1-weighted imaging (Fig 3).

In apophysitis, there is swelling of the apophysis and increased T2 signal relative to normal apophysis (Figs 2–6).[12] The subapophyseal bone appears ill-defined and increased in signal on T1-weighted images and the typical signal void may not be perceptible on T2-weighted images (Fig 2). With delayed *inferior* apophyseal closure in Stage 2 pubic bone maturation, apophysitis may be seen as a broad band of high T2 signal apophysis "sandwiched" between the low-signal superficial secondary ossification centre and subchondral bone (Fig 4).

VIBE MRI of the pubic symphysis and pubic apophysitis

When viewing VIBE sequences, inverted images provide a CT-like appearance to the pubic symphysis, which assists interpretation. On inverted VIBE images of the normal pubic symphysis, hyaline cartilage and articular disc appear as a band of central low signal (Fig 4). In the skeletally immature and those with delayed pubic apophysis maturation, unfused apophyses are of similar hypointensity to hyaline cartilage (Fig 2). Developing secondary ossification centres are more conspicuous on VIBE MRI compared to routine T1-and T2-weighted images (Figs 1 and 2).

As with routine MRI, swelling and increased in signal within the apophysis are also features of apophysitis on inverted VIBE MRI (Figs 2 and 4). A low-signal fibrocartilaginous "enthesis" described in anatomical studies may be more conspicuous superficial to the oedematous apophysis, especially at the inferior pubic apophysis (Fig 5).[8] Apophysiolysis, also seen in other adolescent athletes with overuse, is more clearly visualised on inverted VIBE images and results in apparent widening of the pubic symphysis.[13,14] Apophysiolysis may be seen as ill-defined or well-defined intermediate signal between the low-signal superficial apophysis and ossified subapophyseal bone (Figs 3 and 4). Intermediate signal erosions and cyst-like changes seen in continuity with the apophyses often have signal characteristics of oedematous cartilage on routine sequences and as reported elsewhere, may reflect apophysiolysis and/or displaced cartilage rests (Fig 6).[14] They are not typically in continuity with the symphyseal cleft or of fluid signal, indicating that they are not synovial cysts. Delay in appearance of secondary ossification centres may also be seen and is more readily appreciable on VIBE MRI than routine sequences (Figs 1–3).

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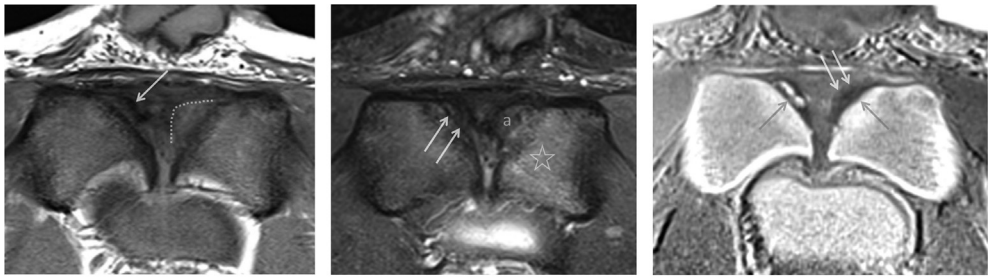

Figure 2 A 20-year-old elite AFL player with left groin pain. (a) Axial T1 MRI showing superior left pubic apophysitis at the adductor longus attachment. The apophysis is swollen (dashed line) and diffusely increased in signal compared to the right. Note the intermediate signal appearance of the normal right apophysis deep to the developing secondary ossification centre (arrow). The left subchondral bone is ill-defined when compared to the right. Note the right pubic marrow signal is iso-intense to the apophysis, due to the presence of red marrow. (b) Axial T2-FS MRI at the same level as Fig 3a, showing moderate left pubic body marrow oedema (star), in addition to the swollen high-T2 signal left pubic apophysis (a) outlined in Fig 1a. Normal intermediate signal right pubic apophysis (arrow) is hypo-intense to the left pubic apophysitis. (c) Axial inverted VIBE MRI more clearly distinguishes the superior pubic apophyses from ossified pubic body bone. There is delayed maturation of the left apophysis (arrows) superiorly, which is more clearly swollen and higher in signal compared to the right, compatible with left pubic apophysitis; a smaller secondary ossification centre was present just below this image. The subapophyseal bone on the left is more subtly ill-defined compared to the right compatible with early apophysiolysis (grey arrows). The developing right secondary ossification centre is clearly resolved. Note the low signal appearance of the normal right ventral apophysis, which is iso-intense to the thin dorsal hyaline cartilage.

Imaging and clinical findings associated with pubic apophysitis

This study corroborates the findings of Sailly *et al.* with regard to the presence of pubic apophysitis in an elite group of football players. As with their CT-based comparison group, VIBE MRI has also demonstrated delayed maturation of the pubic apophyses in the present cohort of older footballers and was a common finding, seen in 85% of players.[10] Apophysitis is common in elite AFL players presenting with groin pain (92%). In the present cohort, apophysitis was observed on the same side as groin pain, except in one case, and may therefore be a clinically significant pain generator. Although Sailly *et al.* largely focussed on adductor longus and the superior pubic apophysis in their younger cohort of soccer players, the present study found that inferior pubic apophysitis associated with the adductor brevis-gracilis origin is slightly more common than superior pubic apophysitis associated with the adductor longus origin. Pathology involving the inferior pubic apophysis and associated tendons may be an under-recognised source of groin pain in AFL footballers. This region is more difficult to evaluate because of its oblique orientation to orthogonal imaging planes and smaller size relative to the superior pubic apophysis. Consequently, it may have been overlooked by previous imaging and clinical studies.

The presence of a fluid signal symphyseal cleft was observed in only 54% of AFL players in the present cohort,

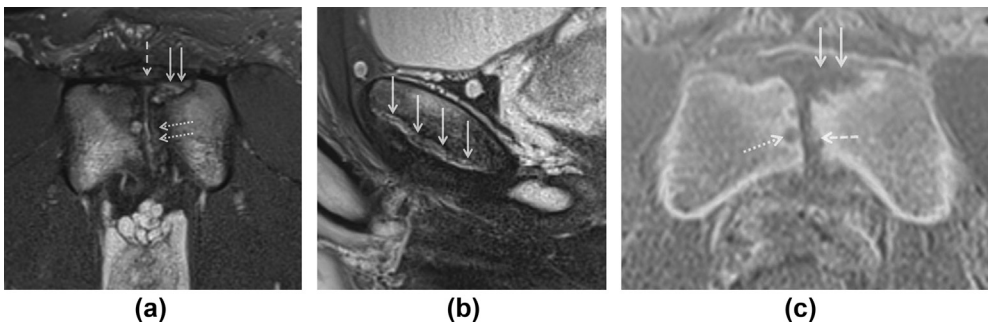

Figure 3 A 24-year-old elite AFL player with bilateral, left greater than right, groin pain. (a) Axial T2-weighted fat-saturated MRI showing a high signal superior left pubic apophysis (arrows) at the medial adductor longus origin, compatible with superior pubic apophysitis. The more dorsal left apophysis (dotted arrows) is "open", resulting in a widened appearance of the symphysis, but is normal in signal. Note the normal anterior pubic ligament (dashed arrow). Small right high-signal cyst-like structure (arrowhead), iso-intense to the left apophysitis, is compatible with either an oedematous displaced cartilage rest or an area of apophysiolysis. (b) Left groin parasagittal T2-weighted fat-saturated MRI showing extensive intermediate signal apophysis due to delayed maturation of the entire ventral rampart on the most symptomatic groin (arrows). (c) Axial VIBE MRI at the same level as Fig 5a showing delayed maturation of the anterior left pubic apophysis as well as the more posterior apophysis (arrows). Apophysiolysis is resolved as ill-defined intermediate–high subchondral signal, appearing as erosions (dashed arrow). Small "cyst"-like structure (dotted arrow), also in Fig 5a, is of similar signal intensity to apophysitis rather than fluid signal, and does not communicate with the thin central symphyseal cleft.

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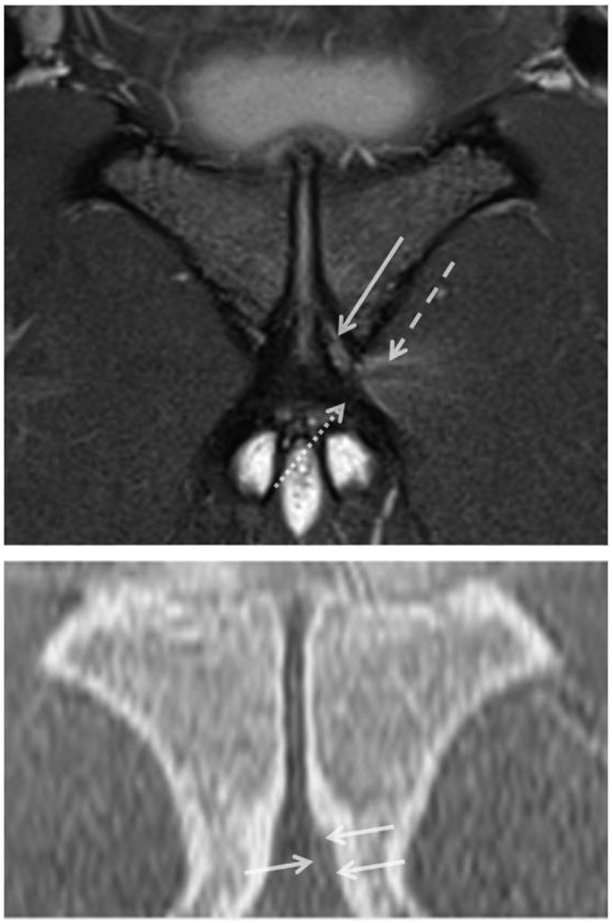

Figure 4 A 30-year-old elite AFL player with left groin pain. Coronal T2-weighted fat-saturated MRI (top image) showing left inferior pubic apophysitis. Intermediate to high T2 signal is seen at the left inferior pubic apophysis associated with the gracilis-adductor brevis attachment (arrow), in continuity with the symphyseal disc. There is mild tendinosis of the gracilis tendon (dotted arrow), with increased signal compared to the right, and oedema at the adductor brevis pubic attachment (dashed arrows). Coronal oblique inverted VIBE MRI at the same level (lower image) demonstrates delayed ossification of the left pubic apophysis and subtly increased apophysis signal (between arrows) relative to symphyseal cartilage, compatible with apophysitis. Noted the thin secondary ossification centre (left arrow), corresponding to a Stage 2 apophysis.

closer to the findings of Robinson *et al.* (40%) than the anatomical literature (around 90% or higher); this may relate to the younger athletic cohorts studied compared to cadaveric studies.[2,3] Only one player developed a symphyseal effusion, present on follow-up imaging for persisting groin pain. Although juxta-articular "erosions" were common and seen bilaterally, these changes were related to apophysiolysis and incomplete pubic apophysis maturation rather than articular disc pathology. This constellation of findings suggests that the joint is not the primary source of symptoms in AFL players with groin pain.

Clinical impact of diagnosing pubic apophysitis

The imaging findings of delayed pubic bone maturation associated with pubic apophysitis (widening and erosions of the pubic symphysis, cyst-like changes, sclerosis and bone marrow oedema) seen in the present cohort of AFL players, are typically described in athletes with osteitis pubis. Misinterpretation of changes related to pubic maturation and apophysitis may have historically resulted in incorrect diagnosis of the type of bone pathology at the pubic symphysis. Although more severe cases where bilateral groin symptoms and imaging findings of florid marrow oedema, apophysiolysis, and symphyseal effusions may reflect a more diffuse pubic bone stress response (osteitis pubis) with or without symphysitis (Fig 6), there may are also be lower grade clinical and radiological presentations where pubic apophysitis is the predominant bone pathology and a more appropriate clinical and radiological diagnosis (Figs 2–4). In these cases, the diagnosis of apophysitis may allow practitioners to focus on load-related management of groin pain, rather than considering unnecessary interventions such as adductor or pubic symphysis surgery. Additionally, screening of the pubic symphysis with VIBE MRI may also allow identification of players at risk of apophysitis, so that appropriate monitoring and injury management programmes may be put in place to prevent injury.

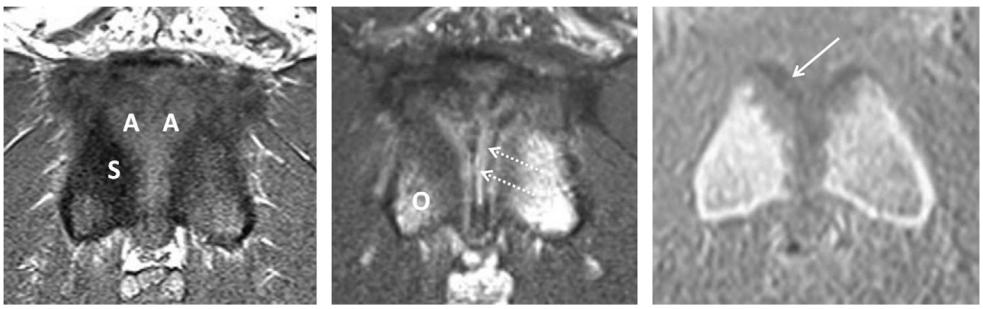

Figure 5 A 20-year-old elite AFL player with bilateral, right > left, groin pain. Axial MRI inferior pubic apophysis montage. T1-weighted, T2-weighted, and VIBE sequences from left to right. T1-weighted image shows widened symphysis due to intermediate signal apophysis (A) as well as sclerosis (S). T2-weighted image showing high-signal apophyses compatible with apophysitis as well as central articular disc (dotted arrow) and severe bilateral marrow oedema (O). VIBE MRI showing asymmetric, delayed right, ossification of the apophysis and a mixture of well- and ill-defined "erosions" due to delayed maturation and apophysiolysis. There is a more swollen right apophysis, compatible with more severe apophysitis. The apophysis is also mildly increased in signal. Note the lower-signal superficial "cap" (arrow), reflecting the fibrocartilaginous composition of the enthesis.

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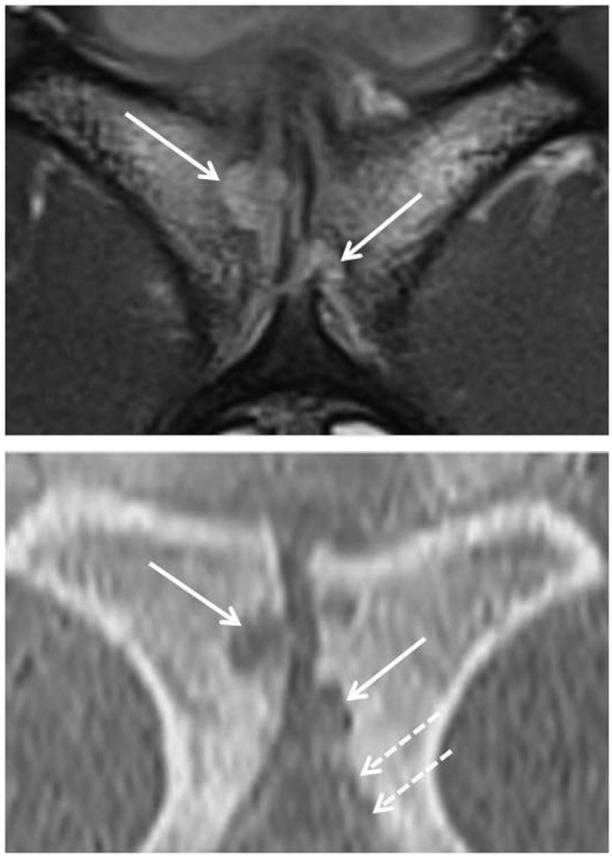

Figure 6 A 21-year-old elite AFL player with left groin pain, who subsequently developed bilateral groin pain. Coronal T2-weighted fat-saturated MRI (top image) showing open apophyses and marrow oedema bilaterally. Left and right "erosions" (arrows) are isointense to and in continuity with the high-signal pubic apophyses, compatible with pubic apophysitis. The player subsequently developed right groin pain. Coronal reformatted VIBE MRI (bottom image) shows more clearly a "cyst"-like erosion on the right and erosion on the left, slightly brighter than apophysis. There is a more ill-defined appearance of the more inferior apophysis and secondary ossification centre on the left (dashed arrow), compatible with apophysiolysis.

Limitations of this study

This study is a retrospective review of a relatively small series of athletes seen over a short (3-year) time frame, performed by one musculoskeletal radiologist. Multiple potential causes of groin pain, in addition to pubic apophysitis were also present at imaging, including adductor tendinopathy, anterior pubic ligament tearing, and pubic bone stress, all of which may contribute to groin pain along with apophysitis and are managed similarly. Therefore, as with the study of Sailly *et al.*, a definitive clinical diagnosis of apophysitis could not be made. Sports-specific and age-related factors may play a significant role in the development of symptoms, and although pubic apophysitis may be common in professional Australian Rules footballers and adolescent soccer players, other diagnoses such as sportsman's hernia may be more significant in older soccer players or other sports such as rugby, American football, or field hockey. The findings of the present study may therefore not be applicable to other sporting codes.

Conclusion

In conclusion, this MRI-based study corroborates the CT findings of Sailly *et al.*, demonstrating imaging features of pubic apophysitis in a cohort of AFL players with groin pain, who are skeletally immature or have delayed maturation of the pubic apophyses. In addition to the findings of Sailly *et al.* at the superior pubic apophysis, inferior pubic apophysitis is more common than superior apophysitis, indicating that the adductor brevis-gracilis origin may have an under-recognised role in the pathophysiology of groin pain. The symphyseal joint is unlikely to be a common source of symptoms in AFL players, given the relatively low presence of symphyseal clefts and effusions in the present cohort. Pubic apophysitis likely accounts for the appearances of "osteitis pubis" in many athletes with groin pain, with apophyseal widening, erosions, and cysts, due to delayed maturation of the pubic apophyses and apophysitis, as seen in the present cohort. Although the term "osteitis pubis" is firmly embedded in the lexicon of clinical practice regarding athletes with groin pain, it may be time to reconsider this diagnosis in favour or a more pathologically and anatomically correct description of early clinical presentations where pubic apophysitis alone is present. Finally, small field of view VIBE MRI may play an important role in the evaluation of athletes with groin pain due to the higher spatial and contrast resolution for pubic bone pathology, in particular by resolving apophysiolysis associated with pubic apophysitis.

Conflict of interests

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Eamon Koh is employed by Envision Medical Imaging.

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