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Case Studies

An interesting case series describing a spate of pelvic avulsion injury in a cohort of elite adolescent footballers

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ABSTRACT

Study design: Case series.
Background: There is conflicting opinion on the incidence of pelvic avulsion injury within the literature, being depicted as both population and mechanism specific. A recent spate of pelvic avulsion fractures highlighted the condition and the need for greater awareness amongst stakeholders involved in the development of academy footballers.
Case description: This case report describes a series of six pelvic avulsion injuries within a category 1 football academy season. It describes the injury mechanism and management process, from initial examination to investigations and treatment discussing this in the context of the existing literature.
Outcomes: All players were managed conservatively, successfully completing a 5-phase rehabilitation programme.
Discussion: The report attempts to highlight any underlying factors that may be associated with the recent spate of pelvic avulsion injuries over the 2016-17 academy season and to ultimately encourage dialogue and implementation of viable preventative strategies within an academy programme.

1. Background

A pelvic apophyseal avulsion fracture is unique to adolescents during the time period between the appearance of ossific nuclei at pelvic tuberosities and their fusion (Schuett, Bomar, & Pennock, 2015). The underlying mechanism is usually a sudden forceful concentric or eccentric contraction of the relevant muscle with its attachment to the apophysis (McKinney, Nelson, & Carrion, 2009; Schuett et al., 2015; Serbest, Tosun, Tiftikçi, Oktas, & Kesgin, 2015; Vandervliet et al., 2007). The tensile force results in a fragment of bone being pulled from the pelvis. In adolescents, the hypertrophic zone of the physis is the 'weak link' of the teno-osseos continuum. It is most susceptible to stress as it lacks either proliferating collagen or calcified tissue (Caine, Difiori, & Maffulli, 2006). The attachment of the tendon enthesis to the apophysis is stronger than the junction between the calcified and uncalcified apophysis. This teno-periosteal junction is strengthened by Sharpey's fibres, which merge with the periosteum as well as the underlying bone and secure the tendon-bone interface (Caine et al., 2006).

An avulsion fracture varies with sports and the particular underlying mechanisms (Rossi & Dragoni, 2001; Vandervliet et al., 2007), with kicking a football accounting for 50% of Anterior Inferior Iliac Spine (AIIS) avulsions in one study (Schuett et al., 2015). The literature describes pelvic apophyseal avulsion injuries in multiple case studies, case series (Reina, Accadbled, & Sales de Gauzy, 2009; Serbest et al., 2015; Yildiz, Yildiz, Ozdemir, Green, & Aydin, 2005) and retrospective cohort studies. An AIIS avulsion fracture is described as a 'rare but classic lesion in adolescent athletes' by Reina et al. (Reina et al., 2009), as a 'rare entity' by Serbest et al. (Serbest et al., 2015) and an 'infrequent fracture' by McKinney et al. (McKinney et al., 2009). Conversely, the larger retrospective cohort studies have deemed AIIS avulsion injury as not uncommon, concomitant with kicking in both elite-level and recreational adolescent soccer players (Rossi & Dragoni, 2001; Schuett et al., 2015).

Between the 2013/14 and 2015/16 seasons, a category 1 status Premier League football academy recorded only two clinically suspected and radiologically confirmed pelvic avulsion fractures. One was an Anterior Superior Iliac Spine (ASIS) and the other an AIIS. In the 2016/17 season there were six radiologically diagnosed pelvic avulsion fractures using the same diagnostic criteria. Five

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Table 1
Fracture location, Age (Years), Mechanism (MOI), Displacement (mm), Injury Duration (Days) and Outcome (Return to Play) for each pelvic avulsion fracture.

Player	Sex	Avusion Injury	Side	Injury Date	Age at Injury	MOI	Displacement (mm)	Injury duration (d)	Outcome
a	M	AIIS	L	15.07.2016	14.7	Sprinting	partial / not sig	74	RTP
b	M	AIIS	R	24.08.2016	13.8	Kicking	9	124	RTP
c	M	AIIS	R	23.11.2016	13.3	Kicking	4	79	RTP
d	M	AIIS	L	04.12.2016	13.7	Kicking	6	126	RTP
e	M	AIIS	R	07.05.2017	12.7	Kicking	none reported	72	RTP
f	M	IT	R	28.04.2017	15.2	Kicking	none reported	147	RTP
Mean					13.9		6.3	104	
SD					0.8		2.1	32.5	

were of the AIIS and one was the Ischial Tuberosity (IT). One of the AIIS avulsion fractures was a contralateral sequential AIIS avulsion in the same player 3 months later, a rare injury which has been reported in only two case reports (Gomez, 1996; Yildiz et al., 2005). The original injury occurred at the end of the previous 2015/16 season.

It was therefore important to describe these injuries in the context of the available literature and to try and inform and educate all stakeholders in the collaborative development of academy players on pelvic avulsion fracture and to see if any viable preventative strategies can be identified and implemented within the academy programme structure.

2. Case presentation

The six players were all male full time members of a category 1 status Premier League football academy and aged between 12 and 15 years at the time of injury. The ischial avulsion injury was sustained by a player who was 15.2 years. The mean age for those who only suffered AIIS avulsions was 13.6 years. The injury characteristics of each player is summarised in the table below (Table 1.).

In nearly every instance the injury was reportedly precipitated by a kicking mechanism with the player reporting a concomitant 'pop' like sensation with severe localised pain and difficulty with ambulation. The player with the sequential AIIS avulsion sustained the second contralateral injury at school, after turning sharply and sprinting in the playground.

The reported kicking velocity and pass distance mechanism was variable within the cohort. The player who sustained the IT avulsion, did so following a high velocity long distance shot. Two players with the AIIS avulsions did so after a seemingly innocuous low velocity short distance side foot pass. The other 3 AIIS avulsion mechanisms were following a corner kick, a cross pitch pass and an 18yd shot on goal. None of the players reported any pre-existing peri-apophyseal pain.

On examination each player exhibited classic signs of localised apophyseal tenderness on palpation, guarding against active contraction and passive stretch of the rectus-femoris or hamstring musculature, an antalgic gait, and adopting an off-loaded position. There was a clinical high index of suspicion for an avulsion injury but other pathology along the continuum such as un-displaced avulsion fracture or severe reactive apophysitis were considered as differential diagnoses.

Each player had their diagnosis confirmed with MRI (Toshiba 3-T superconducting MRI system Vantage Titan™ 3T) (Figs. 1 and 2), utilising the onsite imaging facility.

All players were managed conservatively. No player had an avulsed fragment displacement greater than 20 mm and/or neurological compromise. The largest fragment displacement in this case series was 9 mm in an AIIS avulsion. AIIS avulsion radiographic displacement in males in Schuett et al. (Schuett et al., 2015)

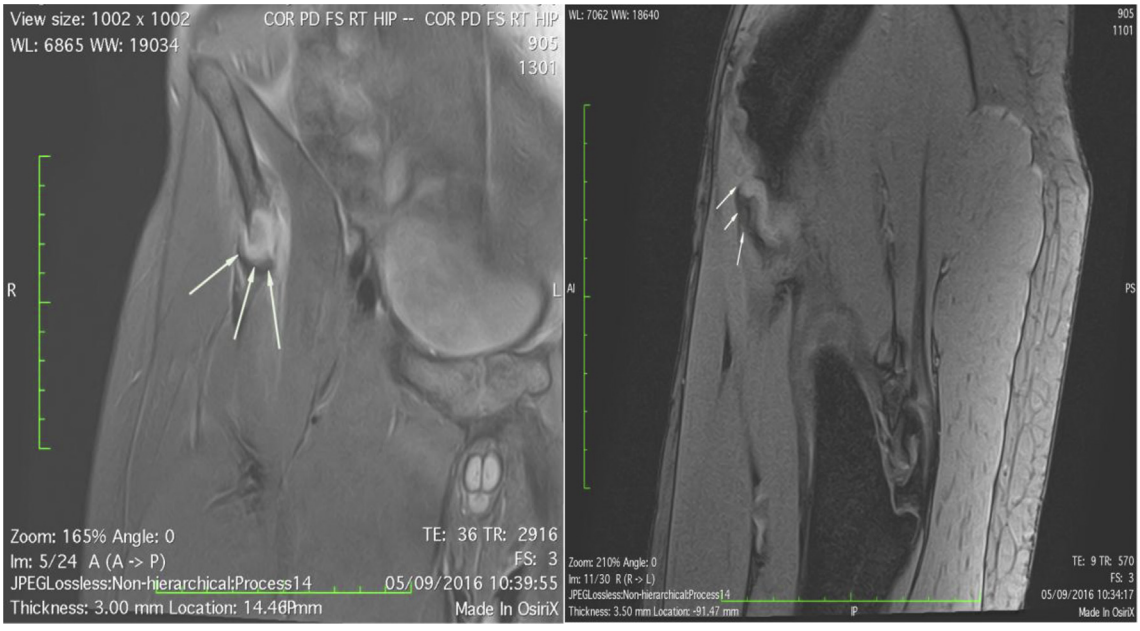

Fig. 1. MRI coronal and sagittal views of right AIIS avulsion fracture (white arrows).

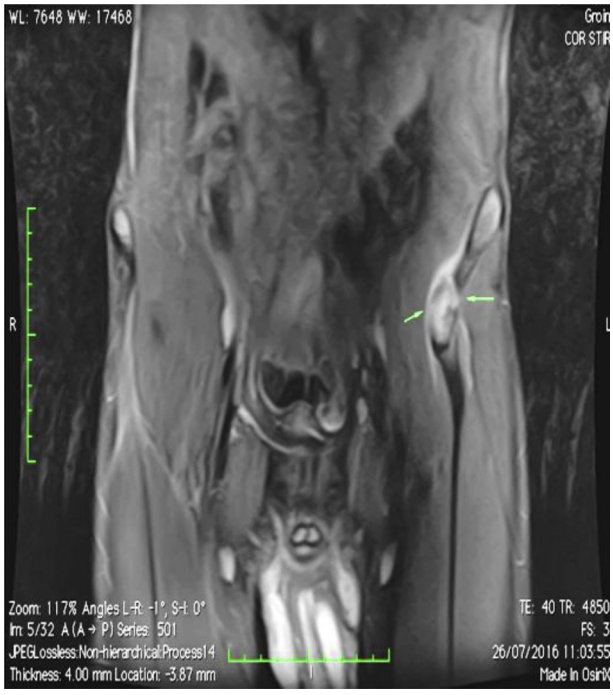

Fig. 2. MRI coronal view of left contra-lateral sequential AIIS avulsion fracture (green arrows). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

averaged 6.6 mm (±4.5). In this case series the average AIIS fragment displacement distance that was reported on MRI was 6.3 mm (±2.1).

Each player followed an acute AIIS avulsion 5-phase rehabilitation protocol (Fig. 3.) developed within the department, based on that by Metzmaker and Pappas (Metzmaker & Pappas, 1985), which underpins the documented guidelines in the literature. This was adapted for the player with the IT avulsion. The rehabilitation protocol was empirically guided by biological tissue healing parameters and set clinical criteria encompassing subjective pain, palpation, range of motion, muscle strength and radiographic appearance.

3. Outcomes

Return to sport post pelvic avulsion fracture should not be earlier than 8 weeks (Metzmaker & Pappas, 1985). In our case series the mean time for return to full training following an AIIS avulsion fracture was 104 days (±32.5) or 14.8 weeks. Two players in our cohort sustained significant long-term sequelae such as that reported in the literature (Schuett et al., 2015). One player incurred persistent AIIS pain for over 3 months after his AIIS avulsion and the other had over 3 months of persistent ischial pain following an IT avulsion. There were no confirmed symptomatic non-unions within our small cohort, though no follow up imaging was undertaken to rule out this feature. In the Schuett et al. (Schuett et al., 2015) study only one of the 4 ischial avulsion non-unions was actually symptomatic.

AIIS Pelvic Avulsion Fracture Rehabilitation Timetable

	Phase 1		Phase 2		Phase 3			Phase 4			Phase 5					
Biological tissue status	Osseous separation				Maturing callus											
			Early callus								Osseous Remodelling					
Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Date																
Player education																
E/C gait re-education / POLICE	•	•														
ROM / isometrics	•	•														
Static Core																
Crook Lying		•	•	•												
4 point			•	•	•	•										
Bridging				•	•	•										
Brace (Plank)				•	•	•										
Side support				•	•	•										
Dynamic Core Control/Mobility																
Mat exercises			•	•	•	•	•	•	•	•	•	•	•	•	•	•
Physio ball				•	•	•	•	•	•	•	•	•	•	•	•	•
Standing					•	•	•	•	•	•	•	•	•	•	•	•
Manual Therapy																
Soft tissue techniques		•	•	•	•	•										
Aerobic																
Cycling (Easy Spinning)					•	•	•	•	•	•	•	•	•	•	•	•
Cross Trainer/Stepper						•	•	•	•	•	•	•				
Rower						•	•	•	•	•	•	•	•	•	•	•
Supine / Sitting UL weights			•	•	•	•	•	•	•	•	•	•	•	•	•	•
Hydrotherapy																
Walking			•	•	•	•										
Deep Water jogging					•	•	•									
Swimming with fins						•	•	•	•	•	•	•	•	•	•	•
Shallow Water Jogging							•	•	•	•						
Shallow Water Running								•	•	•						
FWB weight lifting																
Upper Limb - Push, Pull, OH					•	•	•	•	•	•	•	•	•	•	•	•
Squat, Lunge, Step up, Calf raise etc						•	•	•	•	•	•	•	•	•	•	•
Plyometrics																
Squat, Lunge, Step up								•	•	•	•	•	•	•	•	•
Hopping / bounding									•	•	•	•	•	•	•	•
Sport Specific																
Jogging phase										•	•	•				
Running phase											•	•	•	•	•	•
Sprinting phase													•	•	•	•
Cutting / Turning														•	•	•
Reactive high speed agility														•	•	•

Gentle pain free anterior chain stretching post 3/52

Progression should be criteria-based and guided by biological tissue healing time parameters

Fig. 3. 'X' Academy medical department 5 phase AIIS pelvic avulsion rehabilitation timetable.

Ischial tuberosity avulsions are more prone to non-union with fracture displacement greater than 20 mm[1], but there was no significant retraction reported concerning the only IT avulsion fracture in our series and the largest pelvic avulsion fracture separation overall was 9 mm in an AIIS avulsion. This might explain why there were no non-union complications within our group of players. The player with persisting AIIS pain over 3 months post avulsion had a displacement of 6 mm.

4. Discussion

The mean age at injury in this case series was 13.9 years, which is similar to 13.8 years in Rossi & Dragoni (Rossi & Dragoni, 2001) and 14.5 years in Schuett et al. (Schuett et al., 2015). The AIIS avulsion fractures in our cohort occurred in players aged from 12 to 14 years. The only IT avulsion was in a 15 year old player. This concurs with Schuett et al. (Schuett et al., 2015) who found that age and skeletal maturity were associated with fracture type. Less mature players were inclined to sustain AIIS or hamstring avulsions. In this case series there were no reported avulsion injuries to the ASIS or iliac crest, which typically occur in older players. This is consistent with the Risser stage and triradiate growth plate status, an indirect measure of skeletal maturity by determining the ossification stage of the iliac apophyses (Hacquebord & Leopold, 2012; Vandervliet et al., 2007). In our cohort the oldest academy age group is U16 and therefore a younger cohort than that in the larger retrospective studies by Rossi & Dragoni (Rossi & Dragoni, 2001) and Schuett et al. (Schuett et al., 2015), which had age ranges of 11–35 years and 10–18 years respectively. Schuett et al. (Schuett et al., 2015) reported a 30% incidence of ASIS avulsion in their cohort and Rossi & Dragoni (Rossi & Dragoni, 2001) found a 19% prevalence for the same injury.

Each player was managed conservatively. The criteria for surgical management, widely accepted and adopted in the literature (Rossi & Dragoni, 2001; Schuett et al., 2015), is an avulsed fragment displacement greater than 20 mm, neurological compromise and non-union. Surgery has been reported in only a few published case studies, usually specifically addressing significant Ischial avulsions or AIIS non-unions (Rossi & Dragoni, 2001; Schuett et al., 2015), in light of the propensity to non-union and persistent pain respectively. Individuals with AIIS pelvic avulsion are over 4 times more likely to suffer from future hip pain than other avulsions (Schuett et al., 2015). In one series 22% of patients with AIIS avulsion fractures had continued pain for 3 months or more from their initial injury (Schuett et al., 2015).

In this case series no player reported any apophyseal pain precipitating an avulsion fracture. Nevertheless, several precursors to an avulsion fracture have been proposed in the literature (Porr, Lucaciu, & Birkett, 2011; Reina et al., 2009) including overuse repetitive activity leading to apophysitis. With the variety of kicking mechanisms reported in this player cohort, the loading may be player position specific, with volume, not just velocity of kicking pertinent. Cumulative volume of lower velocity kicking, as well as a high velocity concentric or eccentric muscle contraction, may therefore be a determinant factor in pelvic apophyseal avulsion injury.

In this case series all players had an MRI undertaken to confirm their diagnosis, utilising the on-site imaging facility. X-ray is traditionally the standard modality utilised for diagnosis for a suspected avulsion within the literature (McKinney et al., 2009; Vandervliet et al., 2007). False negatives can also occur with radiography (McKinney et al., 2009), especially delineating a non-displaced avulsion.

MRI is the gold standard investigation to delineate apophyseal pathology as this modality is more sensitive and better characterises underlying bone marrow changes than X-ray (Anderson, Read, & Steinweg, 1998). MRI, unlike X-ray, carries no radiation dose with exposure and although the risks are small with a pelvic x-ray series, it is more pertinent when dealing with the developing skeleton. MRI has also been advocated to evaluate the degree of any tendon retraction, which can influence injury prognosis and management (Vandervliet et al., 2007).

The documented rehabilitation guidelines in the literature for conservative management of acute avulsion fractures are largely based on the 5-phase protocol by Metzmaker and Pappas, first published in the mid-1980s[13]. This was shown to be successful in the conservative management of 27 avulsion fractures, with return to sport not advised before 8 weeks. In one case series of AIIS avulsion fractures after week 10 every patient was reportedly able to 'compete and receive heavy training', with full weight bearing only commenced after 6 weeks (Serbest et al., 2015). In one study return to competitive sport occurred in the 4th month post injury (Yildiz et al., 2005) whilst another study reported a return to full sport in only 6 weeks (Porr et al., 2011). The literature largely encompasses recreational athletes and the only study that involved primarily elite level athletes looked at prevalence and sport distribution of pelvic avulsion injury and did not document return to sport times. The physical demands dictated by an elite football academy will require greater tissue loading capacity and therefore potentially a longer period of rehabilitation when compared to the performance prerequisites for competition at a recreational level. This may explain the disparity in return to sport time between studies, although the heterogeneity not only between studies but also within the same injury itself makes comparison difficult. The retrospective nature of the studies makes follow up challenging and may underestimate the true incidence of either, recurrent pain and re-injury.

AIIS bilateral avulsions occur infrequently and are not widely reported. The Schuett et al. (Schuett et al., 2015) study reported a 5% incidence of bilateral AIIS avulsion injury in their AIIS avulsion fracture cohort of 228 cases. It is unclear whether this was simultaneous or sequential injury. One academy player in this series had

Table 2
Player peak height velocity (PHV) Status.

a				b		
Player	PHV status @ injury	Pre/Post	Months	PHV status @ injury	Pre/Post	Months
a	0	PHV	0	0	PHV	0
b	−0.3	pre	−3.6	−0.3	pre	−3.6
c	−0.5	pre	−6	−0.5	pre	−6
d	−0.2	pre	−2.4	−0.2	pre	−2.4
e	−1.6	pre	−19.2			
f	0.7	post	8.4	0.7	post	8.4
Mean	−0.3	pre	−3.8	−0.06	pre	−0.7
S.D	0.8		9.0	0.5		5.5

a sequential contra-lateral AIIS avulsion, 3 months a part, with the original injury occurring towards the end of the previous 2015/16 season. This injury time frame was similar to a case study involving a long jumper with the same injury (Yildiz et al., 2005).

The underlying causes for this spike in avulsion fracture injury in the 2016-17 season will likely be complex and multi-factorial and it is important to remember that any inferred associations do not denote causality. There was a 23% increase in total game hours in the 2016-17 season between all ages in the academy (U9–U16) compared to the previous season. Total training hours showed a minor 1% increase. Although this was offset by a total squad size increase of 12% in the 2016-17 season such that the per-player training and match hours showed a 6.5% decrease and 10% increase respectively. As total match and training hours per-player actually decreased by 4.1%, there did not seem to be any significant increase in total load to account for the increase in AIIS or IT avulsion fractures. These data are collated from self-reported information inputted by coaching staff and thus open to inaccuracies and recall bias. The uptake of GPS through the academy will allow for more accurate data collection on individual player loading parameters and patterns.

Other changes in the 2016-17 season academy programme were firstly a 1 hour increase in athletic development provision where players in the U12-14 squads were taught fundamental lower limb exercises using body weight only. Secondly, there was the introduction of multi-sport activity comprising of Taekwondo and Gymnastics amongst other activities, each with their unique athletic demands. But the multi-sport training volume was not additional to the academy coaching programme, with an overall reduction (6.5%) in per-player training hours.

A possible influence on injury within this cohort is the player's Peak Height Velocity (PHV) status. It has been suggested that players in or around their PHV are more susceptible to injury (Caine et al., 2006; Van der Sluis et al., 2014). In this injured cohort the player's mean PHV status was −0.3 (±0.8) or 3.8 months pre-PHV (Table 2a). There was one U12 player who was −1.6 or 19.2 months pre-PHV, without this outlier the mean would be −0.06 (±0.5) or 0.7 months pre-PHV (Table 2b), thus these players were very much in and around their PHV. Of course there are players in or around their PHV who do not incur any injury during this period - reflecting the complex multi-variable nature of any injury. Players in and around their PHV may be more susceptible to injury but this in itself does not predict individual physeal injury risk.

Pelvic avulsion injury may be more common in the elite adolescent environment than reported. This case series describes a spate of pelvic avulsion fractures within a season at a category 1 football academy. An increase in training and playing load did not account for the increase in pelvic avulsion injury. Players in and around their PHV may have a susceptibility to avulsion injury but this in itself is not predictive of apophyseal injury. This case series will hopefully increase awareness of this injury within the elite environment and encourage dialogue amongst stakeholders in the academy programme to implement viable preventative strategies.

Conflicts of interest

None declared.

Ethical approval

Not applicable.

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Declarations of interest

None.

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Appendix A. Supplementary data

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