THE ANATOMICAL BASIS OF GROIN PAIN IN ATHLETES

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This thesis is the culmination of a program of research which initially began in 1995. It reflects a major professional interest in the imaging of sports injuries which developed gradually over the 10 year period between 1992 to 2001, based upon previous clinical experience and expertise in the management of musculoskeletal injuries and their anatomical and pathomechanical origins. The central theme of study relates to the use of cross-sectional imaging techniques to investigate the pathoanatomical basis for groin pain in athletes with particular reference to professional soccer players with chronic groin pain.

The current thesis is based around two key postulates. Firstly, that most of the commonly diagnosed causes of groin pain in professional athletes are anatomically and functionally linked and, secondly, that modern cross-sectional imaging can demonstrate both the correct diagnosis and the underlying biomechanical causes.

The program of study consists of three different but linked project themes. The first investigates the scope of the problem, i.e. the differential diagnosis and prevalence of groin pain in professional soccer players. The second investigates the precise “normal” anatomy, i.e. the gross topographical anatomy of the pubic symphysis and parasymphseal regions as actually exists rather than the regional anatomy that appears in classical anatomical texts. The third builds upon the first two projects and, investigates the underlying pathomechanical processes using magnetic resonance imaging.

The study results suggest that a unifying mechanism of injury exists which partly explains the diagnostic and therapeutic difficulties that occur in athletes with groin pain. It also demonstrates that better understanding of the true pubic symphyseal anatomy allows a more accurate diagnosis to be made and that magnetic resonance imaging can demonstrate the relevant underlying pathoanatomy. The thesis adds significantly to the body of scientific knowledge related to this important sports-related, clinical condition.
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GLOSSARY OF TERMS

Computed Tomography; a cross-sectional imaging modality using X-rays to generate a volume data set using an extended grey-scale produced via a process of Fourier transformation analysis.

Cross-sectional imaging; an imaging modality which allows anatomical images to be acquired and displayed in a two or more planes.

Enthesitis; an inflammatory process involving an enthesis i.e. the region of bony insertion of a ligament, tendon, joint capsule or fascia.

Enthesopathy; the generic term for any abnormality involving an enthesis.

Groin; an area of the body which includes the lower abdominal wall, inguinal and pubic symphyseal regions and the external genitalia.

Hernia; the passage of a visceral structure through a normal or abnormal defect in a separate investing structure. In the groin this usually relates to the passage of tunica vaginalis, peritoneal fat, omentum and or bowel through a natural opening from the abdominal cavity into the groin region (e.g. inguinal, femoral or obturator canals) or through a similar but false opening (e.g. a tear in the rectus sheath of transversalis fascia and muscle).

Herniorrhaphy; the surgical repair of a hernial defect either via the overlying skin or via a transperitoneal route using a laparoscopic (fibre optic telescope) technique.

Hip Adductor Muscles; a group of muscles inserting into the pubic bones which producing a hip adduction movement i.e. a movement towards the midline, and consisting of the adductor longus, adductor brevis, gracilis and the anterior portion of adductor magnus muscles.
**Inflammatory Arthritis:** all arthritides whether due to mechanical wear, crystal deposition or abnormal autoimmune response produce inflammation, however, this term is usually reserved for the auto-immune group i.e. rheumatoid arthritis and the “sero-negative” spondyloarthopathies (e.g. ankylosing spondylitis, psoriatic arthritis, reactive arthritis and inflammatory bowel disease-related arthritis).

**Inguinal Region:** the region of the body related to the inguinal ligament i.e. the inguinal ligament itself and its reflections (e.g. the lacuna ligament), the inguinal canal and its internal and external openings (“rings”), the anterior abdominal wall structures which fuse to form the inguinal ligament (tranversalis fascia, the aponeurosis of the transversus muscle, internal and external oblique muscle aponeuroses) and the structures passing through the inguinal canal (e.g. the spermatic cord).

**Magnetic Resonance Imaging:** a cross-sectional imaging modality using radio waves returning from some of the body’s protons (mainly water) to generate a volume data set using an extended grey-scale produced via a process of Fourier transformation analysis. The process requires the body to be lying centrally within a powerful magnetic field (usually in the range of 0.35 to 3.0 Tesla for clinical scanners) to allow manipulation of the spin axes of these excess charge protons.

**Osteoarthritis** (syn. Osteoarthrosis, Degenerative Joint Disease); is the process of articular surface hyaline cartilage wear (osteoarthrosis) and any associated synovial response (osteoarthritis).

**Osteomyelitis:** infection of bone due either to direct inoculation or haematogenous spread of an infective organism. If the area of osteomyelitis is in continuity with a joint it may produce a secondary joint infection and subsequent severe synovitis i.e. a septic arthritis. When occurring in the vertebral body end-plate and the adjacent intervertebral disc it is termed an infective discitis, and when it occurs in the subarticular region of the pubic bodies and the adjacent symphysis it is termed an infective pubic symphysitis.
**Parasymphysial Region;** the area of the body which includes the pubic symphysis, pubic bodies and adjacent soft-tissues.

**Stress Injury to Bone;** a spectrum of bony injury due to repetitive minor injury with consequent microfractures to trabecular bone. In its earliest stage this may be asymptomatic or symptoms may occur due to bone marrow oedema and raised intra-osseous pressure. Overt complete fracture may occur at its end-stage. Within the intervening spectrum there is an attempt at fracture repair as evidenced by periosteal and endosteal new bone formation and an increasing degree of pain with predisposing physical activity.

**Tendonitis;** a primary inflammatory process involving a tendon as opposed to inflammation of surrounding connective tissue condensations (paratendinitis), inflammation of tendon sheath (tenosynovitis) or inflammation forming part of a response to repetitive minor injury and tendon degeneration (tendinosis).

**Tendonopathy;** the generic term for any abnormality involving a tendon including intrasubstance tear and partial tendon rupture.

**Ultrasound Imaging;** a cross-sectional imaging modality using high frequency ultrasound waves (1.5 to 15 Megahertz) to generate an image either as a grey-scale image or as a colour flow image when combined with Doppler-shift analysis.
ACKNOWLEDGEMENTS

I wish to thank the late David Wilson, former Physiotherapist at Huddersfield Town Football Club for initially inspiring in me an interest in the subject of groin pain in athletes.

I wish to thank my colleagues working with me on the gross anatomical sections of this work namely;
Dr. Roger Soames, Senior Lecturer in Anatomy, University of Leeds (now James Cook University, Queensland)
Ms. Lynne Gathercole, Superintendent Radiographer, CT Department, The General Infirmary at Leeds
Mr. Ernest Schilders, Consultant Orthopaedic Surgeon, Bradford Royal Infirmary
Dr. William Stannish, Orthopaedic Surgeon, Halifax
Mr. Hans Marynissian, Consultant Orthopaedic Surgeon, Burnley General Hospital
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I wish to thank Professors Dennis McGonnagle at the University of Leeds for his collaboration over a parallel field of study i.e. imaging of inflammatory arthritis, which allowed the concept of enthesopathy as a cause of groin pain to emerge.

Finally, I wish to thank Professor Bruce Davies, at the University of Glamorgan, for his most useful advice and support during the completion phase of this thesis.
STATEMENT OF ORIGINALITY

None of the included material has been submitted by me for another award at this University or elsewhere.

I have been responsible for the large majority of the intellectual property related to the current submitted thesis. However, due to the multi-disciplinary team nature of certain sections of this work there are parts of the submitted thesis where this intellectual property is not solely mine. Where this has been the case, the collaborating investigators have been duly acknowledged. None of this work is currently being submitted by any one of these collaborators as part of a higher research award and to my knowledge neither do they have any intentions in doing so.

Signed,

Wayne William GIBBON

Dated:
This “Overview” consists of three sections outlining the nature of the research work forming the Thesis and the context in which that research has been performed. The sections are entitled:

**Hypothesis** – outlining the postulates on which the Thesis is based

**Research Summary** – outlining the process of research and the key observations made within the body of work

**Personal History** – outlining the professional context of the research work in keeping with the retrospective “Portfolio” nature of the Thesis. (NB. This latter section is outlined in detail in accordance with the Portfolio Thesis concept i.e. that the thesis assesses the individuals global contribution to professional and research knowledge and not solely the intellectual property of the contained work itself).
HYPOTHESIS

"Chance is a word that does not make sense. Nothing happens without a cause"
Voltaire (1694-1778), French Writer.

Chronic groin pain is a major cause of morbidity in professional and elite athletes. Great diagnostic difficulties exist, however, reflecting the fact that the causes of groin pain are protean (see Table I in Project 1) and also possibly reflecting clinical prejudice. Alternatively, it can be postulated that many of the diagnostic difficulties are due to the fact that the different diagnoses are inter-linked anatomically or biomechanically.

The current thesis is based on two postulates:

• Most of the commonly diagnosed causes of groin pain in professional athletes are anatomically and functionally linked i.e. due to the way the anatomical structures around the groin and pubic region are inter-related both in structure and function the same injury mechanisms can result in injuries to apparently different structures.

• In athletes with groin pain medical imaging may demonstrate both the correct diagnosis, and through careful observation of the imaging anatomy and physical signs, the underlying biomechanical causes which, in certain circumstances, can be used to guide initial therapy.
RESEARCH SUMMARY

"Genius is to see what everybody else has seen and to think what nobody else has thought"
Albert Szent-Gyorgyi (1893-1986), Hungarian biochemist and winner of the 1937 Nobel Prize for Medicine

The current thesis consists of three different but linked projects:

Project 1: Investigation of the scope of the problem – “The Differential Diagnosis and Prevalence of Groin Pain in Professional Soccer Players”.


Investigation of the scope of the problem – “The Differential Diagnosis and Prevalence of Groin Pain in Professional Soccer Players”.

The preliminary phase of this program of research (Project 1) investigates the scope of the problem. This consists of two parts; a systematic literature search and postal survey, to assess the incidence and nature of groin injuries in professional athletes.

The literature search forming the basis of the work was initially performed in 1995, was updated throughout the period of study, and a final search performed at the end of 2004 during the write-up phase of this thesis. The review examines the previously proposed aetiologies for groin pain. It also assess inter-sport and intra-sport variations in the reported incidence of groin injuries.
Review of existing literature suggests that in many respects the pubic symphysis may be considered analogous to the intervertebral discs of the spine. Osteitis pubis, as described in the literature, essentially reflects two distinctly separate conditions i.e. mechanical stress-related premature symphyseal degeneration and a true, non-suppurative, inflammatory "osteitis". The former is a stress phenomenon involving the symphyseal region often with coexisting associated degenerative changes and both the radiographic and magnetic resonance imaging appearances are remarkably similar to those changes seen in intervertebral disc degeneration. Therefore, the condition traditionally considered to be "osteitis pubis" appears to reflecting excessive wear from physical activity and as such is unlikely to be a major cause of groin symptoms in athletes. This "mechanical" osteitis pubis may be related, at least in part, to a limitation of hip movement.

A true inflammatory "osteitis" representing a non-suppurative condition which is clinically (and radiologically) very similar to parasymphyseal osteomyelitis except for it being self-limiting and less destructive may also occur but is much less common. This is an acute inflammatory condition akin to a spinal "mechanical" (non-infective) discitis but occur in the pubic symphyseal region. The magnetic resonance imaging appearances would tend to agree with the concept of trabecular microfracture stress injury as the main underlying pathological process. Both on clinical and imaging examination this condition may be indistinguishable from pubic osteomyelitis.

Occasionally a traumatised parasymphyseal area may act as a focus for blood-borne infection especially in the immunocompromised, (a state which may occur in athletes due to the effects of "over-training"), making differentiation of "true" osteitis pubis from pubic osteomyelitis even more difficult.

Diagnostic confusion could be due to the fact that many of the diagnoses are anatomically and / or biomechanically linked. The literature search highlights a number of important issues which subsequently helps to direct the research process. In particular the different pubic adductor tendon and rectus abdominis insertional problems are all probably descriptions of enthesopathy as the primary cause of chronic groin pain. The large muscle bulk relative to their pubic insertional cross-sectional area (especially those of the anterior
adductor group) means that a large force per unit area is generated at their entheseal attachments, potentially resulting in an entheseal overuse phenomenon. The finding that steroids infiltrated below the pre-pubic soft tissues can produce dramatic symptomatic improvement would seem consistent with the theory that the apparent pubic symphyseal symptoms relate to an adjacent entheseal injury and not the symphyseal degenerative process itself. It also explains the reported correlation between radiological sacroiliac joint abnormality and a past history of groin or lower abdominal pain i.e. if pelvic instability either instigates or exacerbates a parasymphyseal tendon enthesopathy.

A literature review performed with specific reference to the gross anatomical appearances of the public symphyseal region suggested significant errors in the classical anatomical descriptions of the pubic region. Of particular relevance are the errors related to the precise nature and anatomical relations of the conjoint tendon representing the fused infero-medial aponeuroses of internal oblique and transversus abdominis. This is considered an important structure with regards to inguinal hernia surgery. It is also of note from the literature that adductor origin symptoms apparently subsided following hernia repair and that further clinical investigation in athletes with a “Sportsman’s Hernia” who are not cured by herniorrhaphy produces an alternative treatable diagnosis in more than 80% of cases (most of which are cured by addressing the more latterly diagnosed condition). This suggests a link between pubic enthesopathy and inguinal hernia formation in athletes which is consistent with the veterinary literature showing crossed and uncrossed fibres exist in the prepubic tendon of the horse and some other mammals.

Therefore, the literature suggests that a functional and anatomical link exists between the rectus abdominis-inguinal ligament and the common adductor aponeurosis. However, although the above conditions may be interlinked, their differentiation is still necessary from other causes of groin pain in athletes such as parasymphyseal muscle tears and ilio-psoas tendinopathy.

Compilation of the conditions known to be potential causes of groin pain in athletes shows that groin injuries in soccer players constitute a much greater relative burden of disease
regarding overuse compared to acute injuries i.e. most groin problems are overuse phenomena rather than acute injuries.

The results of the postal survey performed to assess the incidence and nature of groin injuries in professional soccer players, and the ways in which they are subsequently imaged forming part of Project 1, shows that on average 23 - 25% of players will sustain a groin injury during any one season of which 25 - 32% will recur during that same season. A mean of 4.1 matches are lost per injury. In both England and the rest of Western Europe adductor origin strains are by far the most commonly diagnosed cause of groin pain i.e. constituting 44 - 46% of groin injuries. However, a remarkably high rate for diagnosing inguinal hernia in Football Association clubs (18.5% of eventual diagnoses made on players with groin pain) is seen when compared to other European clubs (3% of eventual diagnoses).


The cadaveric anatomical dissection study program (Project 2) is an evolutional one spread over a six year period (1996-2001) and carried out at three different university departments of human anatomy. Each of these studies built on the findings of the previous gross anatomical study and in all, 41 formalin-embalmed cadaveric dissection studies were performed and documented using digital photography (ideally these dissections would have been carried out on fresh cadaveric specimens, however, this was not possible for logistical reasons related to specimen availability).

The dissections studies demonstrate a number of important anatomical points with regards to the potential causes of groin pain. The posterior symphyseal margin is only covered by a thin (75% <2mm, 25% 2-4mm) sheet of soft tissue consisting of a condensation of the anterior pelvic peritoneum. A tight adherence of the deep surface of the rectus sheath to the superior pubic bone surface and symphysis exist constituting the superior symphyseal ligament. The anterior rectus sheath, however, extends distal to this ligament.
A close relationship exists between the insertion of the inguinal ligament, rectus abdominis muscle / rectus sheath and the origin of adductor longus. A condensation of the adductor tendon origins extends inferiorly and slightly medially from the anterolateral pubic margin (previously described as the inferior radial ligament) and thus fuses with a pre-pubic inguinal ligament continuation above to form cruciform anterior pubic ligaments. The inguinal ligament inserts onto the pubic tubercle and then extends over the anterior surface of the pubic bone dividing the pubic bone into superior and inferior halves separated by this “X” or “V” shaped inguinal ligament extension. A conjoint rectus abdominis-common adductor origin aponeurosis exhibits tight adherence to the central portion of the anterior pubic surfaces and this anterior pubic ligaments / inguinal ligament extension and to the antero-lateral pubic margin.

In effect the adductor longus and pyramidalis muscles form a continuous line separated only by the inguinal ligament extension over the anterior pubic bones. In sagittal cross-section a triangular condensation of fibrocartilage lies between the muscular adductor brevis pubic origin, the adductor longus and rectus abdominis reflecting their common involvement in the formation of the inguinal ligament origin.

The medial half of each of the bellies of rectus abdominis can continue distally as a ligament running over the anterior symphysis, partially decussating so as to interdigitate distally with the gracilis origin and fascia bilaterally (recto-gracilis ligament). This structure does not appear to have been previously described.

The greatest areas of trabecular bone density is in the subchondral (2.49 to 4.46 –fold increase) and subentheseal (1.62 to 4.46 –fold increase) regions (Table 9 vide infra). This appears to reflect the site of greatest entheseal surface area and the line of applied traction forces. Maximum bone density relates to the lines of pull of rectus abdominis and common adductor attachments suggesting that entheseal forces may predispose to parasymphyseal stress injury.

Within the pubic symphysis itself a degenerative secondary symphyseal fissure can propagate from posterior to anterior separating the fibrous symphyseal disk from the
fibrocartilage overlying the pubic bone ends. A process of posterior symphyseal extrusion can also occur forming the posterior pubic eminence which may ossify via ossicle formation within the extruded fibrous tissue.

Investigation of the pathomechanical process – “The Magnetic Resonance Imaging Appearances in Professional Footballers with Chronic Groin Pain”.

Project 3 of this program of research represents a series of sequential studies building on the experience gained from the previous study but all related to the common theme of using MR imaging to assess the causes of groin pain in professional soccer players. These studies were all carried out in Yorkshire (UK) between 1995 and 2001 using a standard imaging protocol and all relate to analysing the correlation between pubic symphyseal, pubic bone and parasymphyseal soft tissue morphology and symptoms in footballers.

When compared to asymptomatic, non-athletic volunteers significant symphyseal and parasymphyseal degenerative changes are present in both asymptomatic and symptomatic professional soccer players. Symphyseal changes reflect intensity of participation in soccer rather than the cause of symptoms i.e. a strong correlation exist between being a professional soccer player and pubic symphyseal and parasymphyseal changes (p<0.005 – p<0.001) but not with symptoms (not significant at p>0.005). A weaker correlation exists between para-sacroiliac joint changes and changes in the pubic symphyseal region. Central anterior, posterior and superior symphyseal extrusion, increased symphyseal signal and all types of para-symphyseal or para-sacroiliac marrow change although abnormal in non-athletes must be considered to be “normal” in professional soccer players and therefore cannot be assumed to be the cause of a players groin pain.

No significant difference in incidence of changes is seen when symptomatic professional soccer players are compared to symptomatic professional rugby players. Anterior, posterior and superior symphyseal extrusion, increased symphyseal signal, all types of parasymphyseal marrow change and Modic-equivalent type 3 parasacroiliac marrow change
although abnormal in non-athletes must be considered to be “normal” in all professional footballers whether soccer or rugby league.

There is no correlation between age of players and lateralising signs, i.e. shearing / traction injury to the anterior pubic enthesal attachments, pre-hernia complex or marrow oedema. However, a significant association exists between symptoms and adductor origin shear injury, anterolateral pubic marrow oedema and anterolateral symphyseal high signal. In 135 professional soccer players with groin pain 123 had evidence of a rectus abdominis pubic insertion injury, common adductor origin injury or both. An enthesal injury was also, however, seen at these sites on 22 of the asymptomatic contralateral sides in these 84 unilaterally symptomatic footballers. Magnetic resonance imaging demonstrated a combined rectus abdominis – common extensor origin injury in 25 (71%), isolated rectus abdominis enthesal injury in 3 (9%), isolated common adductor origin injury in 2 (6%) and rectus abdominis – common extensor origin injury combined with “true” osteitis pubis in one player (3%). Magnetic resonance imaging was able to demonstrate a rectus abdominis – common extensor origin shear injury in the symptomatic groin of professional soccer players with a Chi-Square-Independence Test value of 200.4368, p <0.0001 and a Cohen's Kappa Coefficient of 0.7823, p <0.0001. Premature pubic symphyseal degenerative or parasymphysial stress changes were seen in all but 2 of the players (1.5%).

When considering asymptomatic players at time of study but having lateralised magnetic resonance imaging abnormality the majority subsequently developed symptoms on that side within 18 months of initial study.

In the studies performed nineteen percent of players were still symptomatic having undergone previous surgical groin repair. In no player was there evidence of a residual / recurrent inguinal hernia i.e. the repairs had been surgically “successful” even though symptoms remained. When considering the groins exhibiting a direct inguinal hernia or “pre-hernia complex” 79% exhibited features of a rectus abdominis shear injury whilst 50% had a rectus abdominis – common extensor origin shear injury.

If players with magnetic resonance imaging evidence of symptomatic enthesopathy are given ultrasound-guided pubic symphyseal injection of steroids 56% will not require
surgery and are able to return to full sporting activity. The presence of an underlying entheseal traction phenomenon and tendinitis would explain why infiltration of the entheses by lignocaine (2%) and triamcinolone (1%) can produce symptomatic cure of unexplained groin pain. It would also explain why patients with a palpable and surgically proven direct inguinal hernia exhibit symptomatic relief by local entheseal injection.

Repetitive axial loading and lateral compression forces are exerted on the pelvis ring joints during sprinting. As there is only a thin connective tissue layer over the back of the symphysis pubis it is not be surprising that these compression forces result in posterior symphyseal extrusion and buttressing osteophyte formation. The resulting loss of joint space may allow further increased movement at the symphysis and sacro-iliac joints reflecting pelvic instability in turn increasing the shearing forces on the anterior pubic soft tissues.

Should the entheseal bone be weaker than the attached tendons then a stress injury may occur to the parasymphyseal bone, this possibly explaining the configuration of parasymphyseal stress fractures. If the pubic attachment of the conjoint rectus abdominis-common adductor aponeurosis is subjected to repeated excessive traction forces it seems reasonable to expect that it may become “sheared off” its osseous attachment. The attachment is a major stabiliser of the pubic symphysis and, therefore, its detachment results in potential pelvic instability to para-sagittal pelvic rotatory forces. The configuration of the pubic symphysis and the loss of symphyseal joint space may exacerbate this pelvic instability. The inguinal ligament is inseparable from the superolateral attachment of the above common aponeurosis and therefore it is likely to be “sheared off” its osseous attachment to the pubis in this same region therefore pre-disposing to the inguinal pre-hernia complex. Involvement of adjacent nerves by tearing, scarring or adjacent soft tissue oedema may further exacerbate symptoms and further cloud the diagnostic picture.

The concept of an anatomical and functional relationship between the rectus abdominis and common adductor origins provides a unifying concept for groin injuries in athletes. It explains why the surgical procedures of herniorrhaphy, rectusplasty and adductor tenotomy have all been shown to produce symptomatic relief and why correcting the muscle

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imbalance between abdominal and adductor musculature has also been shown to be beneficial.

Although the work included in this Thesis now stretches over an 11 year period is has maintained its contemporary relevance. Indeed subsequent publications by other authors fail to appreciate the relevance of the gross anatomy. The work has stimulated research by other authors and their work, which rather than detracting from the Thesis significance, more confirms the results found in this work.

The diagnostic dilemma of groin pain in athletes in general and elite footballers in particular remains problematic and no other research has been able to provide a unifying concept whereby many of the know aetiologies are inter-related.
PERSONAL HISTORY

“We learn from experience that men never learn anything from experience”.
George Bernard Shaw (1856-1950), Irish dramatist.

I have a strong track-record in the field of sports injury imaging. This resulted in my being made a Visiting Professor in Sports Medicine at Leeds Metropolitan University (October 1997 to February 2000), a Visiting Professor in Sport and Health Sciences at Sheffield Hallam University (March 1999 to March 2001) and Inaugural President of The International Congress For Imaging In Sport (ICIS) in June 1997 (subsequently adopted by the Sports Medicine Subgroup of The European Society for Skeletal Radiology). I have been a member of Editorial Board of The British Journal of Sports Medicine for more than 5 years (1998-2004).

Most unusually, professional soccer players (from Cardiff City FC and Barry Town FC) and international rugby union players (from Cardiff TFC and Argentina “Pumas”) were referred to myself for imaging whilst a Lecturer in Cardiff, i.e. before becoming a “consultant” radiologist. On taking up such a position in Leeds I was referred an increasing number of players over my first 2-3 years as a consultant radiologist. Subsequently, on a regular basis I was personally referred players from 38 different professional soccer clubs. In addition I saw injured players from 10 professional rugby league and union clubs, plus the touring Australian national rugby league team on 3 separate UK tours. I was also asked to see players from 2 county cricket clubs and a number of players from the South African and West Indian international cricket “Test” touring sides. Accordingly, between 1996 and 2001 I saw on average 2-3 professional athletes every day whilst working as a skeletal radiologist in Leeds. I also provided an ultrasound screening service for tendinopathy at the UK Athletics National Squad bi-annual screening weekends 1999-2000. Subsequent to this, I provided imaging services, using a portable ultrasound system, at the British Olympic Association “holding-camp” at the Ramada Resort, Carrara on the Gold Coast, Queensland, Australia before they de-camped to Sydney for the 2000 Olympic Games.
Due to the high numbers of athletes being referred to me for investigation I started to develop a significant degree of expertise in the imaging of both acute and chronic sports-related injuries. In 1995 I was asked to present some of my concepts on the imaging of sport injuries at two different conferences for sports surgeons and sports physicians - "Imaging Of Soft-Tissue Injuries" at the 7th Joint Conference on Sports Injury organised by The Football Association / The Royal College of Surgeons of Edinburgh (Lillishall) and "Imaging Of Sports Injuries" at a Symposium on Sports Medicine organised by the British Orthopaedic Sports Trauma Association subgroup of The Royal College of Surgeons of England, (London). Also in that year I was asked to give lectures on sports injuries to important radiological audiences when presenting "MRI Of Sports Injuries" at the 8th Somerset MRI Course in Torquay and "Sports Injuries To The Lower Limb" at The Royal College of Radiologists Symposium: “Current Advances in Imaging of Trauma” in London. The following year I was asked to be both session organiser and lecturer at a symposium on the "Imaging of Sports Injuries" at the British Skeletal Radiology Society Refresher Course in Edinburgh. Also in 1996 I was asked for the first time to lecture internationally on a sports medicine subject when asked to speak on "Diagnostic Ultrasound in Sports Injuries" at the Symposium Sonographicum of the Netherlands Radiology Society at Utrecht. Later that year I went on a mini lecture tour to the USA providing lectures on "Imaging Of Sports Injuries" to the Departments of Radiology at Stanford University Medical Centre, Palo Alto, CA, Henry Ford Hospital, Detroit, MI, Bowman-Grey Hospital, Winston-Salem, NC and University of Southern Alabama Medical Centre, AL.

In addition to adults with sport injuries I was starting to develop expertise in the imaging of child athletes. Accordingly, I was asked by The British Paediatric Radiology Society to lecture on the "Imaging of Sports Injuries in Children" at their conference in Edinburgh in April 1997. The concepts I was developing with regards to mechanisms of overuse injuries resulted in my being invited to lecture the same year on "Tendon Injuries in Man" at a symposium on "The Imaging of Athletic Injuries in Racehorses" arranged by The Royal Veterinary College in London there being parallels between overuse injuries across animal species.

The range of imaging modalities in which I was developing sports imaging expertise was exemplified in the year 1998 when I gave lectures on three different modalities i.e.
"Ultrasound Diagnosis Of Sports Injuries" (British Medical Ultrasound Society Annual Congress, Harrogate), "Nuclear Medicine In Sports Medicine" (Royal Marsden Hospital Nuclear Medicine Course, London) and "MRI Appearances of Sports Knee Injuries" (British Society for Skeletal Radiology Refresher Course, Harrogate). In 1997 I co-published a review article on "Ultrasound in the Diagnosis of Sports Injuries" [1] and the following year I was asked to write an editorial on this same theme for the British Journal of Sports Medicine where I advocated its use by sports physicians and physiotherapists [2]. Subsequent to this, I trained the sports medicine and physiotherapy staff at Manchester United, Liverpool and Blackburn Rovers Football Clubs to use a portable Sonosite™ ultrasound system en site at their training grounds.


My first published article on a sports medicine related subject was not actually in a medical journal but a letter to The Times, published in 1991 [3], advocating the use of MRI rather than CT in the screening of head injuries in professional boxers. This was written in the
wake of the Michael Watson tragedy. A case report on a young athlete with capitate stress fracture was my first sports injury article published in a medical journal [4]. The majority of sports related articles I subsequently published have in some way been related to the imaging and biomechanics of injury. The exceptions are a leader article on the methodology of postgraduate medical education [5] and a light-hearted article on eponymous medical conditions, both published in the British Journal of Sports Medicine [6].

The anatomical data for this thesis was accumulated via three cadaveric studies (the latter two in conjunction with Dr. Ernest Schilders). The MRI study population was one that I developed over 8 years as a Skeletal Radiologist in Leeds with the vast majority referred privately to me up until March 2001 when I emigrated to Australia. The use of prospective rather than retrospective data provides greater information with regards to the correlation between imaging and clinical findings. This is particularly true in terms of patient cohort homogeneity, as a relevant history can be taken directly from the patient, and if necessary, clinical examination performed in the MRI suite. Unfortunately, the itinerant and often transient nature of professional soccer players’ careers makes follow-up studies extremely difficult and even in prospective studies long-term follow-up can be difficult, limiting the accuracy of longitudinal data. Between 1997 and 2000 I started to recognise on MRI studies that the location of pubic changes in soccer players was mainly anterolateral rather than parasymphysial [7, 8] suggesting the site of injury to be the enthesal insertion of the adductor tendons or rectus abdominis [9, 10]. The imaging appearances of this enthesopathy were remarkably similar to the enthesal and sub-entheseal oedema I had contemporaneously shown on MRI studies in patients with rheumatoid-factor negative arthritis [11]. Indeed it was the MR observations made in patients with inflammatory enthesitis [12] that was the stimulus for my inclusion of intravenous Gadolinium-enhancement with spectral fat-suppression into the standard Leeds MR Groin Study Protocol which I introduced in 1996. Over 350 athletes were subsequently examined using this protocol. The initial anatomical [13] and functional studies suggested that the rectus abdominis insertion – adductor longus origin – gracilis origin form a functional unit linked by their attachment to the anterior pubic bones.
In October 1995, I presented for the first time to a large audience regarding the imaging of hip and groin related pathology when I gave a lecture entitled "MRI of the Bony Pelvis" at the 8th Somerset MRI Course in Torquay. The following year at the American Roentgen Ray Society Annual Meeting in San Diego, CA, USA I presented the early data which forms part of the MRI section of this thesis [14]. In this paper I postulated as to how MRI could show a link between pelvic instability and conjoined pubic adductor / rectus abdominis insertional disruption. My first major presentation on groin pain in soccer players was in April 1997 when I gave a lecture entitled "MRI of groin pain in athletes" at the Combined Meeting of Irish and British Skeletal Radiology Societies at Galway, Republic of Ireland. In November of the same year I presented further scientific data on this subject at a major international meeting when I gave the paper “Groin pain in footballers: MR imaging appearances” with co-author M Crowe at the 83rd Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL, USA [7]. In this paper I demonstrated the typical MRI symphyseal changes seen in professional footballers and how the changes traditionally thought to reflect “osteitis pubis” are activity-related and do not correspond with pain. I also, at that time, showed that there was a positive association between pelvic tendon shearing injury and pain and that Modic-equivalent changes may occur analogous to those changes seen in the spine adjacent to intervertebral discs.

I gave my first presentation on sports-related groin pain to a soccer-specific audience when I gave a lecture entitled "MRI of Chronic Groin Injuries in Professional Soccer Players" to the Football Association / The Royal College of Surgeons of Edinburgh, 10th Joint Conference on Sports Injury at Lillishall in July 1998. That same year my paper “Groin Pain in Soccer Players - MRI Appearances" was awarded "Best Paper" at the British Association for Sport and Medicine Annual Congress at Peebles, Scotland [15]. My first lectures relating to ultrasound-guided treatment of hip and groin pain were "US-Guided Injection of the Hip" at the European League Against Rheumatism Musculoskeletal Ultrasound Instruction Course, Scheveningen, NL in May 1998 and “The Groin and Hips” at the inaugural British Musculoskeletal Ultrasound Course, Oxford in February, 1999. In the same year I presented a series of lectures at major conferences on the imaging of groin injuries - “Groin Injuries” at the 2nd International Congress on Imaging in Sports Medicine, Salzburg, Austria (June), "Groin Injuries in Sport" at the Sports Medicine MRI Symposium.
In 1997, I published a "Pictorial Essay" [9] on the MR imaging appearances of diseases of the pubis and pubic symphysis which demonstrated for the first time in the medical literature a number of important features and concepts including:

- how posterior symphyseal extrusion can occur in adolescents
- Modic-equivalent changes in the pubis and sacroiliac joint region
- Rectus Abdominis (RA) - Common Adductor Origin (CAO) soft tissue shear injury
- pelvic "locking" due to lateral pelvic compression forces
- the natural history of pubic symphyseal bridging following osteomyelitis
- how obturator externa muscle tears can cause chronic groin pain in athletes.

Much of the initial data and concepts discussed in this thesis were further touched upon in an article in The Lancet in 1999 [10] including how the RA-CAO changes seen on MRI and the relationship to the inguinal ligament was compatible with Holmich's "functional link" [16]. In November 2000, with my co-author E. Schilders, I presented a Scientific Exhibit: "Anatomy Of The Pubic Symphysis Region: Gross Anatomy and Imaging Correlation" at the 86th Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL, USA [13]. This was my first major presentation specifically related to the groin dissection studies presented in this thesis. I first published an article related to the postal survey included in this thesis in 1999 [17]. I was also co-author of an article, again in The Lancet, in 2000 showing how applied forces to the pelvic and hip regions can affect trabecular bone density [18].

In 1999 I was co-author of a leader article on the “Sportsman’s Groin” in the British Journal Surgery in which it was postulated that imaging may show the changes of enthesopathy related to “hernia” formation in athletes [19]. The enthesopathy concepts followed on in part from a paper for which I was similarly co-author, which was given on inflammatory diseases in November 1997 at the American Rheumatology Association 61st National Scientific Meeting, Washington, DC, USA Nov, 1997 [20]. I was asked by The Football Association to provide a follow-up lecture in July 2000 - "Imaging of Athletic Injuries to
the Groin” at the 12th Joint Conference on Sports Injuries, The Football Association / Royal College of Surgeons of Edinburgh, Lillishall. In October, 2001 I gave my first lecture on this subject in Australia when I gave a presentation entitled “Groin Injuries in Athletes” to The Royal Australian and New Zealand College of Radiologists 52nd Annual Scientific Meeting in Melbourne.

After obtaining my basic medical qualification (Bachelor of Medicine, Bachelor of Surgery, MB.BS.) at St. Thomas' Hospital Medical School, University of London in June 1981 I spent 6 years in surgical positions at House Surgeon and Registrar level including approximately 3 years as an Orthopaedic Registrar in major UK Teaching Hospitals. In May 1985 I was made a Fellow of the Royal College of Surgeons of Edinburgh (F.R.C.S.). Subsequent to this surgical training period I became a Fellow of the Royal College of Radiologists (F.R.C.R.) in April 1990 and took up a series of academic radiology positions. These included Clinical Lecturer in Medical Imaging, University of Manchester and Registrar in Radiology, North West England Radiology Training Scheme (1st October, 1987 to 30th June, 1990); Lecturer in Radiology, University of Wales School of Medicine, Cardiff, UK (1st September, 1992 to 30th June, 1993); Clinical Senior Lecturer, University of Leeds, UK (1st July, 1993 to 20th March, 2001); and Professor and Discipline Head of Medical Imaging, University of Queensland, Australia (23rd March, 2001 to date). This combined clinical orthopaedic surgery and academic radiology background has given me a fairly unique perspective on skeletal trauma. I always try to use imaging to demonstrate not just the abnormality, but the cause of that abnormality i.e. I try to explain the underlying biomechanics of that injury.

Between 1998 and 2000 I published three articles on the mechanism of Achilles tendon injury and how they reflect microtendinosis accumulation proportionate to the forces applied [21-23]. These followed on from a paper given at the 83rd Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago IL, USA in November 1997, where I showed how ultrasound could demonstrate the prevalence of subclinical lower limb tendon degeneration in professional soccer players [24]. In 1999 I was co-author of an article showing how MRI can help demonstrate the biomechanical faults in child athletes resulting in calcaneal apophysitis (Sever’s Disease), chronic distal radial physeal
plate injury (Gymnasts' wrist) and metatarsal head osteochondritis (Freiberg’s Disease) [25]. It also showed how reverse angle MRI images of the spine can help demonstrate spondylolyses. A further article that I wrote in 1998 showed how MR imaging could be used to demonstrate the enthesal nature and pathomechanics of bone injury in “shin splints” [26]. In 2000 I co-authored a paper at the American Roentgen Ray Society Annual Meeting, in Washington DC, USA describing posterolateral ankle impingement and the underlying mechanism of injury [27]. I was the lead author in all of the above papers and I believe they adequately show my interest and expertise in the use of cross-sectional medical imaging to explain the mechanism of sports-related injuries.

In August 2005 I was notified by the University of Queensland that I was to be awarded a Higher Doctorate (MD) based on my thesis entitled “Imaging in Inflammatory Arthritis – A multi-Disciplinary Team Approach”.

Accordingly, I believe that this “biomechanistic” perspective combined with my exposure to large numbers of athletic overuse injuries and my other clinical interest of “inflammatory enthesopathies” has given me a unique insight into the pathomechanics of overuse injuries in general and chronic groin injuries in particular. This is the intellectual basis for this current thesis.
INTRODUCTION
The preliminary phase of this program of research investigates the scope of the problem, i.e. how common is groin pain and what are the recognised causes in athletes in general and professional soccer players in particular? The current thesis is based on reference material generated through a systematic electronic literature review the strategy and result for which are included in Appendix 1. This literature search forms a major part of the work contained in this thesis. The search was initially first performed in December 1995, and was then subsequently updated throughout the period of study, until a final search was performed in November 2004 as part of the final write-up phase of this thesis.

STUDY SEQUENCE

Differential Diagnosis
1. Systematic literature review regarding the previously proposed aetiologies for groin pain.
2. Compilation of conditions known to be potential causes of groin pain in athletes i.e. a differential diagnosis list was generated (Table 1) and the nature of these individual medical conditions was examined with particular reference to their MR imaging appearances

Injury Prevalence
3. Literature review to assess of inter-sport and intra-sport variations in the reported incidence of groin injuries
4. Postal survey to assess the incidence and nature of groin injuries in professional soccer players and the ways in which they are subsequently imaged
Differential Diagnosis

“A man can seldom – very, very seldom – fight a winning fight against his training; the odds are too heavy”

Mark Twain (1835-1910), US writer.

It would seem possible that many of the recognised causes of groin pain in athletes are inter-linked and adequate treatment requires the addressing of more than one of these component clinical conditions [16].

The problem of groin pain in athletes is not a new one. Pierson [28] was probably the first to describe chronic stress injury to the symphysis pubis or “osteitis pubis” in 1929. He termed the condition osteochondritis of the symphysis pubis which indeed better reflects the articular nature of the injury. Spinelli described osteitis pubis in athletes as early as 1932 [29]. This condition has also been termed dynamic osteopathy [30] and tenosteochondrosis of the pubis, reflecting the dynamic nature of the condition and the inter-relationship of bone, joint and tendon aetiological components [31]. Subchondral trabecular fracture as a cause for groin pain in athletes was reported by Williams in 1978 [32]. Pubic symphyseal osteomyelitis was first described in an athlete in 1953 [33] and the differentiation between inflammatory or “true” osteitis pubis and low grade pubic osteomyelitis has remained a diagnostic problem in athletes ever since.

Probably the first description of adductor muscle injuries in athletes was in ten-pin bowlers in 1959 [34]. Wiley was the first investigator in the English literature to associate traumatic osteitis pubis with abnormalities of the gracilis tendon origin in 1983 [35]. This single case report described the significant histopathological findings seen in the excised tissue at the gracilis enthesis. These included a mixture of viable and non-viable bone fragments, extensive fibrosis and an absence of infection, suggesting a chronic traction phenomenon at the osseotendinous junction inferior margin of the symphysis pubis. Although this was the first record of the condition in the English literature, it had been described 20 years earlier in the German literature [36]. Wiley in this report also commented on the fact that avulsion of the gracilis tendon origin is associated with concurrent avulsion of the ligamentous support of the inferior region of the symphysis and avulsion of bony fragments at the edge
of the pubis. This infers a relationship between the stability of the symphysis and tendinous avulsion. Pelvic adductor syndrome as a cause of groin pain in footballers was first postulated in 1967 [37], rectus abdominis tendinopathy in 1987 [38] and adductor longus tendinopathy in 1992 [39].

In 1954 Carnevale [40] described a condition, he termed inguinocrural pain in footballers, which was probably an early description of the “sportsman’s hernia” i.e. an imminent, but non-palpable, direct inguinal hernia. This has subsequently been thought to be a common cause of unexplained chronic groin pain in athletes especially in the UK. Ashby, in 1994, found inflammation of the inguinal ligament at its pubic insertion to be a cause of obscure chronic groin pain [41]. This and the above pubic adductor tendon and rectus abdominis insertional problems are all probable descriptions of enthesopathy as a primary cause of chronic groin pain.

Physician bias may also affect the eventual clinical diagnosis. Ekberg et al [42] compared the diagnoses made by 5 specialists (general surgeon, orthopaedic surgeon, urologist, nuclear medicine physician and radiologist), in 21 athletes complaining of unexplained chronic groin pain. These investigators found that in 90% of cases more than one diagnosis was made and in 14% of cases the specialists made four or more different diagnoses for each patient. The authors concluded that “the final diagnosis (and treatment) often reflects the specialty of the doctor and as a result alternative causes of groin pain are overlooked”. It could be implied from these results that the diagnosis made in athletes with groin pain reflects clinical prejudice [43]. Such a premise is almost certainly, at least partially, correct as Ekberg et al [42] themselves show by their belief that ilio-psoas tendinitis is a common condition in elite athletes, even though such a condition was not diagnosed at all in the 323 cases of groin pain contained in the 6 different series by other authors that they themselves reviewed.
Table 1: The Differential Diagnosis of Groin Pain

1. **Muscle tear**
   - a) Adductor group - adductor longus
     - adductor brevis
     - gracilis
   - b) Rectus femoris
   - c) Rectus abdominis
   - d) Oblique / tranversalis (inferior portions)
   - d) Hamstring group
   - e) Sartorius
   - f) Ilio-psoas

2. **Tendonitis or tear**
   - a) Adductor origin - adductor longus
     - adductor brevis
     - gracilis
   - b) Rectus femoris
   - c) Ilio-psoas

3. **Bone or apophysis avulsion**
   - a) Adductor origin
   - b) Anterior inferior iliac spine / apophysis
   - c) Ischial apophysis
   - d) Anterior superior iliac spine / apophysis
   - e) Lesser trochanter / apophysis

4. **Bursitis**
   - a) Ilio-pectineal
   - b) Ilio-psoas

5. **Pubic symphysitis / osteitis pubis**

6. **Pubic osteomyelitis**

7. **Stress fracture**
   - a) Inferior pubic ramus
   - b) Parasymphysial
   - c) Femoral neck
### Table 1: The Differential Diagnosis of Groin Pain (Continued)

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<tr>
<th><strong>8. Entrapment neuropathy</strong></th>
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<tbody>
<tr>
<td>a) Ilio-inguinal nerve neuralgia</td>
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<tr>
<td>b) Obturator neuralgia</td>
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<td>c) Genito-femoral causalgia</td>
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<th><strong>9. Hip pathology</strong></th>
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<tr>
<td>a) Osteoarthrosis</td>
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<td>b) Slipped capital femoral epiphysis</td>
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<th><strong>10. Inguinal lymphadenitis</strong></th>
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<th><strong>11. Hernia</strong></th>
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<tr>
<td>a) Direct inguinal</td>
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<td>b) Indirect inguinal</td>
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<td>c) Femoral</td>
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<tr>
<td>d) Obturator</td>
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<td>e) Spigelian</td>
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<th><strong>12. Genito-urinary</strong></th>
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<td>a) Orchitis</td>
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<td>b) Prostititis</td>
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<td>c) Scrotal trauma / haematocele</td>
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<td>d) Low renal calculus</td>
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<th><strong>13. Haematoma</strong></th>
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<tr>
<td>a) Direct blow</td>
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<tr>
<td>b) Tear of inferior epigastric artery (Rectus sheath)</td>
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<th><strong>14. Referred pain</strong></th>
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<tbody>
<tr>
<td>a) Spine - spondylolysis</td>
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<tr>
<td>Sheuermann’s disease</td>
</tr>
<tr>
<td>high lumbar disc prolapse</td>
</tr>
<tr>
<td>b) Sacro-iliac joint - instability</td>
</tr>
<tr>
<td>sacro-iliitis</td>
</tr>
<tr>
<td>osteoarthritis</td>
</tr>
<tr>
<td>c) Acute abdominal / pelvic viscus inflammation</td>
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<th><strong>15. Idiopathic</strong></th>
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In one study reviewing the case-notes of 189 athletes with chronic groin pain, 27% were found to have multiple pathologies [44]. One possible explanation for the diagnostic confusion could be that there may indeed be more than one diagnosis in many athletes. However, this confusion could also be due to the fact that many of the diagnoses are indeed, as postulated, anatomically and / or biomechanically linked.

Osteitis pubis, as described in the literature, essentially reflects two distinctly separate conditions:-

1. Symphyseal Stress Injury / Symphyseal Degeneration / Mechanical Osteitis Pubis: a stress phenomenon involving the symphyseal region often with coexisting associated degenerative changes.
2. Inflammatory “True” Osteitis Pubis: a true inflammatory “osteitis” representing a non-suppurative condition which is clinically (and radiologically) very similar to parasymphysyeal osteomyelitis except for it being self-limiting and less destructive.

Symphyseal Stress Injury

Lettin, in a communication to the Innominate Society, suggested that osteitis pubis is caused by subchondral trabecular fractures that are akin to other forms of stress fractures and not due to infarction as had been previously thought [32].

In spinal intervertebral disc degeneration there is loss of disc height, vertebral body end-plate sclerosis and marginal osteophyte formation on conventional radiographs and disc desiccation with end-plate fatty infiltration or sclerosis (Modic types 2 and 3 changes) on MR imaging [45]. A mechanical discitis may also occur with fluid signal within the central nuclear cleft, oedema within the end-plates (Modic type 1 change) and adjacent perivertebral soft tissue oedema. In severe case, differentiation of a mechanical discitis from an infective discitis may be extremely difficult requiring biopsy for microbiological assessment. Personal experience of MR imaging of athletes with groin pain suggested that the pubic symphysis may be considered analogous to the intervertebral discs of the spine, only lying in a sagittal rather than a horizontal plane (recognising this concept formed in part the original stimulus for embarking on the current body of work).
On both conventional radiography and MR imaging the appearances of pubic symphyseal degeneration and pubic “symphysitis” are remarkably similar to those changes seen in intervertebral disc degeneration and mechanical discitis. MR imaging, in particular, is able to demonstrate pubic bone marrow changes analogous to the Modic types 1-3 changes seen in the spine (Figs. 1-3). These spinal changes can be centred around the disc and the vertebral end plates or at the site of entheseal attachment i.e. the anterior and posterior longitudinal ligaments. In the symphyseal region these changes may be seen to be related to the subchondral plate or at the insertion of the inguinal ligament, rectus abdominis and anterior adductor tendons, again showing the analogous nature of these anatomical sites and their corresponding chronic injury processes.

Therefore, the condition traditionally considered to be “osteitis pubis” appears to be structurally and pathophysiologically akin to intervertebral disc degeneration reflecting excessive wear from physical activity and as such is unlikely to be a major cause of groin symptoms in athletes.

MR imaging is able to show “mechanical” changes of parasymphyseal subchondral sclerosis, posterior-superior pubic symphyseal extrusion with buttressing osteophyte formation, subchondral cyst formation (and para-sacroiliac joint sclerosis) i.e. MR-equivalent changes to those thought to represent “osteitis pubis” on conventional radiographs (Fig. 4).

An acute inflammatory condition akin to a spinal “mechanical” (non-infective) discitis can occur in the pubic symphyseal region with fluid within the pubic symphysis and symphyseal cleft and oedema in the sub-chondral bone as well as below the attached anterior tendons and the bladder base. This condition is a “true osteitis pubis” or “symphysitis” and like spinal discitis may be the cause of quite severe symptoms (Fig. 5).
Figure 1: Modic Type 1-equivalent Changes

*T2-weighted fat-suppressed transverse section images though the mid-pubic symphysis in two different professional soccer players showing two different distributions of bone marrow oedema(*). In both cases these changes are more marked on the left side. A) Subarticular – adjacent to the symphysis pubis, B) subentheseal – at the site of insertion of the anterior pubic soft tissue, and C) T1-weighted sagittal image through the lower lumbar spine showing typical Modic type 1 end-plate changes adjacent to the L3/4 intervertebral disk.
Figure 2: Modic Type 2-equivalent Changes

*T1*-weighted non-fat-suppressed transverse section images though the mid-pubic symphysis in two professional soccer players showing two different distributions of bone marrow fatty infiltration(*). In both cases these changes are again more marked on the left side. A) Subarticular – adjacent to the symphysis pubis, B) subenthesal – at the site of insertion of the anterior pubic soft tissue, and C) T1-weighted sagittal image through the lower lumbar spine showing typical Modic type 2 end-plate changes adjacent to the L5/S1 intervertebral disk.
Figure 3: Modic Type 3-equivalent Changes

*T1*-weighted non-fat-suppressed transverse section image though the mid-pubic symphysis in a professional soccer player showing two different distributions of subcortical / subchondral bone sclerosis bilaterally i.e. these changes are present both in a sub-articular position posteriorly adjacent to the symphysis pubis and also in a sub-enthesal position at the site of insertion of the anterior pubic soft tissue.
Figure 4: Symphyseal Degenerative Changes – “Osteitis Pubis”

a) Frontal pelvic radiograph showing superior marginal osteophyte formation, subchondral cysts and subarticular sclerosis, B) axial CT scan demonstrating posterior marginal osteophyte formation, subchondral cysts and subarticular sclerosis (box), C) T1-weighted axial MR image showing marked posterior symphyseal extrusion in 16 year old “apprentice” soccer player (arrow), and D) coronal T1-weighted image showing apparent superior symphyseal extrusion indenting the bladder base (arrowheads).
Figure 5: “True” Osteitis Pubis

Coronal STIR image showing fluid within the symphysis pubis, bilateral parasymphseal bone marrow oedema and oedema in the adjacent soft tissues at the bladder base and adductor muscles bilaterally. The patient was a professional soccer player with severe symphyseal pain and bilateral groin pain. The condition was completely resolved with rest and non-steroidal oral anti-inflammatory agents.

It is interesting that an injection of local steroid into the symphyseal region has been shown to produce dramatic effect in patients with osteitis pubis, which appears to be degenerative rather than primarily inflammatory in origin [46]. If apparent pubic symphyseal symptoms are actually related to an adjacent enthesal injury and not the symphyseal degenerative process itself, then perhaps it would not be surprising to find that steroids infiltrated below the pre-pubic soft tissues should produce dramatic results (as is the case in patients with an inflammatory arthritis-related enthesitis). In distance runners an association appears to exist between strenuous conditioning of the rectus abdominis and adductor muscles and the production of this condition [46]. In a different study, eight intercollegiate athletes with refractory osteitis pubis, (who on analysis of the article would appear to have symphyseal stress changes), all had significant symptomatic benefit from subsequent injection of corticosteroid into their symphysis pubis [47].
"True" Osteitis Pubis

Athletes with "true" osteitis pubis have bilateral severe adductor pain, exacerbated by symphyseal compression. It has been suggested that the chronic behaviour of osteitis pubis may be promoted by poor vascular supply that often exists to the periosteal and subperiosteal regions of the pubic bones [48]. MR imaging shows profound bilateral parasymphyseal bone marrow oedema, with oedema at both adductor origins, fluid within the symphyseal cleft and often oedema around the bladder base. The raised intra-osseous pressure related to this bone marrow oedema may in part be instrumental in the production of the severe pain. Injection of steroids into the symphyseal cleft often produces dramatic benefit in such patients presumably by reducing the effects of the regional oedema. Greater care, however, must be taken to avoid steroid injections if there is anything to suggest an infective cause as this is likely to be seriously exacerbated by local corticosteroid effects.

The differentiation between pubic osteomyelitis and "True" Osteitis Pubis is important, as the majority of cases of pubic osteomyelitis require surgical debridement and curettage for adequate control of the infective process. The clinical course of osteomyelitis is usually progressive in contrast to the osteitis pubis which is self limiting and generally produces less bone destruction. The eventual clinical course of osteomyelitis of the pubis is, therefore, sufficiently different from that of osteitis pubis to justify considering it as a separate entity. The spectra of these conditions, however, tend to overlap, and it is in this overlapping area that diagnostic difficulties arise [49]. Occasionally a traumatised parasymphyseal area may act as a focus for blood-borne infection especially in the immunocompromised, (a state which may occur in athletes due to the effects of "over-training"), making differentiation from pubic osteomyelitis even more difficult.

Pubic Osteomyelitis

Osteomyelitis of the pubic symphyseal region is rare, accounting for less than 1% of all cases of osteomyelitis produced by haematogenous spread [50]. Unfortunately athletes are not immune to pubic osteomyelitis and indeed as stated above, the combination of their tendency to immunosuppression and minor trauma to the region may even increase the risk. Probably the first recorded case of post traumatic pubic symphyseal osteomyelitis in an athlete was an 18 year old reported by Adams and Chandler in 1953 [33]. In this case the
athlete slowly developed symphyseal pain, over a twelve month period, following an injury whilst running at a high school indoor track event. When conventional radiography has been performed in athletes with pubic symphyseal osteomyelitis there has usually been symmetrical bone destruction of the pubic symphysis with apparent widening of the symphyseal region [51, 52]. Even on MR imaging it can be extremely difficult to distinguish between pubic osteomyelitis and non-infective osteitis pubis particularly in their early stages before discrete abscess formation occurs (Fig. 6).

Bacteriologically proven staphylococcus aureus osteomyelitis of the symphysis pubis can be completely asymptomatic [53]. Needle biopsy may be inadequate and even open biopsy is not always able to isolate organisms which are often sparse within the infected subchondral bone in patients with parasymphyseal osteomyelitis. Indeed, in patients with known infection who undergo such curettage, a causative organism is only isolated in approximately 50% of cases, emphasising the difficulty in making the definitive diagnosis of pubic osteomyelitis, particularly in its early stages. That-being-said, it may be the only certain way of distinguishing between early osteomyelitis and osteitis pubis as initially both on clinical examination and imaging investigations, they may appear to be identical [54].
Figure 6: Pubic Osteomyelitis

A) Coronal and B) transverse axial STIR images through the pubic regions showing a discrete abscess cavity within the right obturator internus muscle (arrows), with fluid within the symphysis and oedema within the parasymphyseal bone marrow and adjacent soft tissues. The patient was a professional footballer with pubic symphysitis and a pelvic abscess following an episode of acute prostatitis which subsequently resolved following intravenous antibiotic therapy.
Stress Fractures
Excessive cyclical loading of the parasymphyseal region may lead to a stress injury. Parasymphyseal stress fractures, however, are rare in athletes being more common as insufficiency rather than overuse fractures. With regards to “True” Osteitis Pubis the MR imaging appearances would tend to agree with the concept of trabecular microfracture stress injury as the main underlying pathological process [47]. There would appear to be a correlation between MR imaging Modic type I change and increased uptake on Technetium 99m MDP isotope bone scan studies in such cases (Fig. 7).

Hip Joint Dysfunction.
Restriction of hip rotation may increase the shear stresses applied to the ipsilateral hemipelvis in the anteroposterior plane [32]. It has also been suggested that “Mechanical” Osteitis Pubis may be a stress phenomenon related at least in part, to a limitation of hip movement [32]. In patients with a degenerative symphyritis there is loss of hip internal rotation and to a lesser extent external rotation, possibly relating to a very minor degree of prior slipped capital femoral epiphysis during adolescence. There appears to be an increased tilt deformity in 83% of athletes with osteitis pubis as compared to 25% of athletes overall. It has also been noted that there is an increased incidence of symphyseal stress phenomena following hip arthrodesis [55]. These observations would tend to support the concept that minor limitation of hip movement, due to adolescent injury to the proximal femoral physeal plate, can predispose to later pubic symphyseal problems.

There may also be accelerated hip joint degeneration in the older soccer player which may present as groin pain. Symptomatic hip osteoarthritis (OA) will usually exhibit increased enhancement with intravenous Gadolinium-DTPA due to an associated synovitis which may benefit, at least temporarily, from ultrasound-guided intra-articular injection of steroids. Labral injuries are probably more common than usually recognised due to diagnostic difficulties. Conventional MRI and ultrasound imaging are relatively insensitive at demonstrating labral tears and although MR-arthrography may be more sensitive, it is still probably inferior to hip arthroscopy in diagnosing these injuries (Fig. 8).
Figure 7: Pubic Stress Injury

A) T2-weighted fat-suppressed transverse image through the mid pubic symphyseal region, and B) T1-weighted coronal images through the sacrum. A) There is a right parasymphyseal stress fracture which has become medially displaced due to lateral compression forces (arrow), and B) there are bilateral lines of decreased signal parallel to the sacro-iliac joints (arrowheads) reflecting the fact that the stress forces are acting on both anterior and posterior sections of the pelvic ring.

Sacro-iliac Joint Dysfunction

It has been previously suggested that symphyseal degenerative changes are often associated with concurrent sacroiliac joint (SIJ) dysfunction [56]. In one radiographic study of professional footballers with symptoms at time of investigation, there was evidence of overt symphyseal instability in one third of players, marginal irregularity in three quarters and reactive sclerosis adjacent to the symphysis in two thirds of players. There were abnormalities in the region of the gracilis origin in a further two thirds and evidence of stress sclerosis in the iliac component of one or both sacroiliac joints in just over half of these professional soccer players. In this study there was good overall correlation between radiological SIJ abnormality and a past history of groin or lower abdominal pain [56].
**Figure 8: Hip Joint Osteoarthritis and Labral Tear**

Two different professional soccer players, both in their mid-twenties and both with groin pain related to hip joint OA. A) Coronal STIR image showing a mildly deformed right femoral head (R) and profound hip joint effusion, and B) coronal T1-weighted image of the left hip showing a rim of femoral head osteophytes. There is also a low signal band between the joint capsule and lateral acetabular margin (arrow) reflecting an associated labral tear.

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**Adductor Tendinopathy**

Balanced micro-injury and subsequent repair normally occurs in tendons in response to applied deforming forces [21-23]. If the generation of tendon micro-tears exceeds the rate of repair then the tensile strength of the tendon may be sufficiently reduced as to result in partial rupture or even adductor tendon origin avulsion. Their large muscle bulk relative to their pubic insertional cross-sectional area means that a large force per unit area is generated at their entheseal attachments, potentially resulting in an entheseal overuse phenomenon. At other anatomical sites where powerful muscles act via long lever-arms through small surface area entheseal attachments, (e.g. common extensor origin at the elbow, plantar aponeurotic origin at the calcaneum), excessive repetitive cyclical activity will result in focal tendon degeneration (tendinosis) or insertional inflammation (enthesitis) (Fig. 9). In this respect adductor origin tendinopathy may be considered to be akin to “tennis elbow”. Also these muscles extend a long way down the thigh before inserting broadly into...
the femoral shaft or, in the case of gracilis, the tibial plateau. Accordingly they have a longer effective lever-arm. The longer lever-arm plus the greater muscle bulk and relatively smaller entheseal surface area in males compared to females may explain, at least in part, the higher incidence of chronic adductor problems in male athletes.

**Figure 9: Bilateral Adductor Longus Tendon Origin Enthesopathy**

*Figure 9: Bilateral Adductor Longus Tendon Origin Enthesopathy* (A) T1-weighted and B) T2-weighted fat-suppressed transverse axial images through the mid-pubic region showing an area of abnormality. This is but not typical fluid signal being high signal on T1- and high signal on T2-weighted consistent with granulation tissue at the junction between the left anterior pubis and the overlying adductor longus (arrows). This is bordering on frank avulsion at its lateral margin. There are lesser adductor longus tendon changes with subtle Modic type 2 changes at the corresponding entheseal insertion on the right.

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“Sportsman’s Hernia”

This condition is not a true hernia and is perhaps more accurately referred to as the inguinal “pre-hernia” complex (Fig. 10). In one study of 65 consecutive professional footballers undergoing surgery for groin pain due to a “pre-hernia”, 25 players (39%) also had pain in the adductor origin region [57]. There was a return to full sporting activity 10 weeks after surgery in 97% of these professional footballers, regardless of the fact that any associated
adductor injury was not specifically addressed by the surgery. Presumably, therefore, the adductor origin symptoms subsided following hernia repair.

Conversely, the reported symptomatic cure rates for herniorrhaphy in sportsman’s hernia range between 63% and 94%, compared to greater than 99% for many studies of herniorrhaphy for conventional inguinal herniae [58] i.e. the poorer success rate in athletes may reflect failure to attend to any associated adductor problem. Further clinical investigation in athletes who are not cured by herniorrhaphy produced an alternative treatable diagnosis in more than 80% of cases, most of which are cured by addressing the more latterly diagnosed condition [43].

**Parasymphysial muscle tears**
Any of the muscles in the groin region may be torn in athletes although clinically it is well recognised that the adductor muscles are particularly vulnerable in soccer players [59]. Chronic tears may produce a diffuse muscle swelling with symptoms due to mass effect. These tears may markedly enhance with intravenous Gadolinium-DTPA. On MR imaging these combined features mean that such tears are liable to be confused as being due to more ominous pathology (Fig. 11). It is interesting that once such an adductor muscle tear occurs (or if the tendinous origin is completely avulsed) then chronic symptoms may disappear due to defunctioning of the causative overload process.

**Ilio-psoas tendinopathy**
This usually reflects a tenosynovitis (Fig. 12) rather than tendinitis and not uncommonly there is associated “snapping” of the iliopsoas tendon over the anterior capsule / acetabular margin of the underlying hip (Fig. 13). Alternatively such an overuse phenomenon may reflect the iliopsoas muscle functioning as a hip flexor particularly in kicking sports a process which again could be exacerbated by limitations in hip movement. Symptomatic athletes often benefit from ultrasound-guided steroid infiltration reflecting the inflammatory nature of the tenosynovitis.
Figure 10: Hernia Formation

Transverse axial images through the groin in patients complaining of groin pain. A) and B) Indirect Hernia (H) with an oedematous surrounding tunica vaginalis, C) direct hernia (arrow), and D) pre-hernia complex with bulging / weakness of the anterior abdominal wall at the level of the external inguinal ring (arrowhead).
Figure 11: Acute Muscle Tear (Obturator Externa)

A) Transverse axial T2-weighted and B) Coronal STIR images showing high signal intramuscular haematoma within the right obturator externa muscle (*).
Figure 13: The Anatomical Basis for the “Snapping” Iliopsoas Tendon

Three photographs of a dissected male left groin. The tape is retracting the femoral neurovascular bundle medially. A) The myotendinous region of the ilio-psoas tendon has been exposed, B) a pair of dissection forceps has been passed down a funnel-shaped facial opening through which the tendon passes to reach its insertion into the lesser trochanter of femur, and C) the funnel shaped tunnel has been opened up. The tendon is lying on its posterior wall. This dissection suggests that the snapping can occur at two points – the iliopsoas tendon may “snap” within this tunnel or the whole tunnel containing the tendon “snaps” over the underlying hip.
INJURY PREVELANCE

"Some people think football is a matter of life and death. I don’t like that attitude. I can assure them it’s much more serious than that!"


Introduction

There is a high risk of injury whilst playing soccer especially at the “elite” or professional level, with at any one time 2 out of the 11 first choice players in any club being unable to play due to injury [60]. In professional soccer almost 100% of regular first team players will sustain at least one significant injury per season and the average time out of action per injury is approximately 13 weeks [61]. The proportion of groin injuries varies with the level at which the soccer is being played. The highest percentage occurs at the highest performance level i.e. they represent 35% of all injuries at that level, compared to 14% at an intermediate level and 13% in the youth team [62]. When considering groin injuries in soccer players it is noticeable that they constitute only 3% of acute traumatic injuries as opposed to 55% of overuse injuries, this emphasizing the fact that most groin problems are overuse phenomena rather than acute injuries [63]. Such injuries tend to be associated with a prolonged recovery as 50% of players with groin pain will have symptoms that persist for more than 20 weeks after initial injury [63]. These above figures suggest that groin injury in professional soccer players is extremely costly both in terms of player / team performance and financial loss due to inability to participate in games. Detailed knowledge is therefore required as to the common injury mechanisms in order to develop preventative and therapeutic regimes.

Background

Soccer, in terms of its number of participants, is the world’s most popular team sport both for men and women. The Federation of International Football Associations (FIFA) founded in 1904 involves 186 countries, with a total of approximately 200 million registered soccer players [63]. In Europe soccer is the most popular sport. This is reflected in the fact that in a prospective epidemiological and socioeconomic study of European soccer injuries, the majority of sports injuries treated in the emergency department occurred during soccer matches [64]. In The Netherlands, which has a total population of about 15 million people,
the Royal Dutch Soccer Association (KNPB) has 1 million licensed players, [65]. In this particular country, when considering all sports injuries, outdoor soccer constituted 29.1% of the total number of injuries and indoor soccer a further 7% [66].

Contradictory evidence exists as to the possible relationship between the level at which a player performs and the likelihood and severity of injury. Some authors have found that fewer injuries occur in professionals but when these injuries occur they are more serious than in amateur players [67]. Whereas, others have concluded that, when considering soccer players of different skill levels, injury rates seem to be related more to the number of competitive games played than the actual skill level of players and that there is no difference in the severity of injuries sustained [66]. Competition seems to produce a higher risk of injury than practice, even when corrections are made for exposure time [66]. In one study 79% of injuries were sustained during matches [67]. There appears to be no significant correlation between playing position and susceptibility to injury [68], although it is possible that slightly more injuries occur in midfield players [62].

As opposed to soccer-related injuries in general, when considering groin / thigh injuries, the highest percentage occur at the highest performance levels. In one study, overuse injuries constituted approximately one third of all injuries in footballers of which three quarters were injuries to the groin or thigh musculature [62]. This study further emphasises the fact that most groin problems are overuse phenomena rather than acute injuries.

Athletic injury epidemiology literature is sparse and often fails to incorporate anything but the most basic statistical analysis. Table 2 attempts to summarise the crude incidence data for groin injuries in different sports [69-100]. These results show that groin pain is far from being a solely soccer-related problem. However, most studies do seem to show an incidence of approximately 20-25% for soccer which is higher than all other sports with the possible exception of ice hockey. This high incidence in ice hockey may reflect the fact that during the skating motion hips are held in external rotation. The relatively lower but still significant “martial arts” incidence may reflect training methodology. The similar incidence for soccer, both rugby codes and American and Australian football may at first glance suggest that the phenomenon may be related to kicking. However, as there is such a variation in required
skills both within and between these sports, "kicking" may not be the primary cause per se. The wide variation in their respective training regimes would similarly seem to make this unlikely to be the central cause for groin injuries. These sports do all, however, require rapid changes in direction and it could be that these injuries in some way reflect repetitive "ballistic" hip rotational movements. An alternative explanation may be that these sporting activities produce forces on the pelvis which result in pelvic ring instability. Poor flexibility could also have a causative role as there is a slightly lower incidence of groin pain in gymnasts, and both youth and female soccer players have a lower incidence than adult male soccer players (although differences in the power generated by muscular contraction between these groups could equally explain this effect).
Table 2: Incidence of Groin Injuries - A Comparison of Different Sports

<table>
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<tr>
<th>Sport / Study Authors</th>
<th>Year Published</th>
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<th>Data Collection Period (Mths)</th>
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* Female soccer players  ** Youth soccer players
POSTAL SURVEY

GROIN PAIN IN PROFESSIONAL SOCCER PLAYERS: A COMPARISON BETWEEN ENGLAND AND THE REST OF WESTERN EUROPE.

Abstract

Objective - To assess the incidence and nature of groin injuries in professional soccer players and the ways in which they are subsequently imaged.

Method - Postal surveys were carried out to assess groin injuries during the 1996-97 season of both 92 English Premier and Nationwide League clubs and the premier / first division clubs in 7 Western European countries. A 50% return rate was obtained for the English and 30% return rate for the Western European clubs.

Results - In England and Europe 23 - 25% of players sustained a groin injury during the single season of which 25 - 32% recurred during that same season. These injuries resulted in 22 - 27 player-matches lost per club per season with a mean of 4.1 matches lost per injury. There was also no significant difference in the incidence of groin injuries relative to training schedule. Adductor origin constituted 44 - 46% of groin injuries. A remarkably high rate for diagnosing an inguinal hernia was found in English clubs (18.5%) compared to clubs in the other Union of European Football Associations (EUFA) countries (3%). Imaging provided the primary diagnosis in 59% of groin injuries at UEFA clubs compared to 26% at English clubs.

Conclusion - There is a remarkable similarity between results for the English and Western European clubs. Groin injuries are a significant cause of morbidity in professional soccer players.
Introduction
The aim of the study was to assess the number and nature of groin injuries in professional soccer players and their impact on subsequent matches missed. A secondary aim was to assess the imaging performed for investigation of such injuries.

Subjects and Method
Two postal surveys were carried out to assess groin injuries during the 1996-97 season. The first survey was of the 92 English Premier and Nationwide League clubs. The second survey was of the premier division clubs in 7 European countries, i.e. Netherlands (n=18), Denmark (n=12), France (n=18 clubs), Scotland (n=10), Italy (n=18), Germany (n=18) and Spain (n=20). These 7 countries were chosen as being representative of professional soccer in Western Europe. A standard questionnaire was adopted (Fig. 14). Questionnaires were translated into Spanish, German, Italian and French and sent out to UEFA clubs as appropriate.

There were 46 questionnaires returned by the English clubs representing an exactly 50% return rate which is reasonably good for such a postal questionnaire. The return rate from the European clubs, perhaps not surprisingly, was lower at 30% (Netherlands, n = 10 clubs (55% return rate), Denmark n = 6 (50%), France n = 5 (28%), Scotland n = 5 (50%), Italy n = 3 (17%), Germany n = 3 (17%) and Spain n = 2 (10%).

Results
In both England and Europe there is remarkable consistency in the incidence of groin pain in professional soccer players (Table 3). On average 23 - 25% of players will sustain a groin injury during any one season of which 25 - 32% will recur during that same season. Such injuries result in 22 - 27 player-matches lost per club per season with a mean number of 4.1 matches lost per injury.

When considering English football there was no statistically significant difference between the incidence of groin pain in the Premier League and the Nationwide League. There was also no significant difference in the incidence of groin injuries relative to total hours of training, the average number of hours spent “fitness” training nor the average number of
minutes per week spent performing “sit-up” or other abdominal exercises. In both England and Europe there is an increased incidence of groin injury on the dominant kicking side, relative to the non-dominant kicking side, with most groin pain being, at least initially, unilateral (Table 4).

In both England and the rest of Western Europe adductor origin strain by far the most commonly diagnosed cause of groin pain i.e. constituting 44 - 46% of groin injuries (Table 5). Most diagnoses are of similar incidence in England and Europe except for a remarkably high rate for diagnosing an inguinal hernia in Football Association (FA) clubs (18.5%) compared to UEFA clubs (3%). Stress fractures were also less commonly diagnosed in England than in Europe, although the incidence is still very low and this discrepancy could reflect this low overall incidence and natural statistical fluctuations.

There is a greater reliance on imaging in Europe with imaging providing the primary diagnosis in 59% of groin injuries at UEFA clubs compared to 26% at FA clubs. The most commonly performed imaging investigation was conventional radiography (Table 6). The results also demonstrate the greater use of diagnostic ultrasound in sports medicine in mainland Europe compared to the UK.
1. What is the size of your squad? 48

2. How many of these are: Full Professional? 28
   Semi Professional? -- 20

3. For how many hours per week do squad members train? (please tick)

<table>
<thead>
<tr>
<th>Hours</th>
<th>Less than 5</th>
<th>5-10</th>
<th>11-15</th>
<th>16-20</th>
<th>over 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ticks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. How much of this is: Fitness? 40%
   Ball Skills? 60%

5. Approximately how many minutes per week of the fitness training is based around sit-ups/abdominal exercises?

   2

6. In the last 12 months, approximately how many members of your squad have suffered from groin pain?

   6

7. Could you estimate how many of these players suffered from each of the following:

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Suffered</th>
</tr>
</thead>
<tbody>
<tr>
<td>adductor muscle strain</td>
<td>✓</td>
</tr>
<tr>
<td>rectus abdominus strain</td>
<td>✓</td>
</tr>
<tr>
<td>iliotibial strain</td>
<td></td>
</tr>
<tr>
<td>rectus femoris strain</td>
<td></td>
</tr>
<tr>
<td>internal/external oblique strain</td>
<td>✓</td>
</tr>
<tr>
<td>inguinal hernia</td>
<td>6</td>
</tr>
<tr>
<td>femoral hernia</td>
<td></td>
</tr>
<tr>
<td>osteitis pubis</td>
<td></td>
</tr>
<tr>
<td>stress fracture of femoral neck</td>
<td></td>
</tr>
<tr>
<td>stress fracture of pubic bone</td>
<td></td>
</tr>
<tr>
<td>ilioinguinal neuralgia</td>
<td></td>
</tr>
<tr>
<td>bursitis</td>
<td></td>
</tr>
<tr>
<td>genito-urinary conditions</td>
<td></td>
</tr>
<tr>
<td>gastrointestinal conditions</td>
<td></td>
</tr>
<tr>
<td>other (please specify)</td>
<td></td>
</tr>
</tbody>
</table>

8. Approximately what percentage of those injured had their injury on:

   The dominant kicking side? 3 on non dominant.
   Both sides? 3 bilateral
Figure 14: Sample of Returned Postal Survey Questionnaire (Continued)

9. How many of the players with groin injuries at your club received the following diagnostic techniques?

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical diagnosis only</td>
<td>4</td>
</tr>
<tr>
<td>Plain X-ray</td>
<td></td>
</tr>
<tr>
<td>Ultrasound scan</td>
<td></td>
</tr>
<tr>
<td>Computerised tomography (CT) scan</td>
<td></td>
</tr>
<tr>
<td>Magnetic resonance imaging (MRI) scan</td>
<td>2</td>
</tr>
<tr>
<td>Angiography</td>
<td></td>
</tr>
<tr>
<td>Isotope bone scan</td>
<td></td>
</tr>
</tbody>
</table>

10. What would be the usual treatment at your club for the following conditions? (Please tick)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Passive Conservative¹</th>
<th>Active Conservative²</th>
<th>Surgical³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adductor muscle strain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rectus abdominis strain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iliopsoas strain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rectus femoris strain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal/external oblique strain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inguinal hernia</td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Femoral hernia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Osteitis pubis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stress fracture of femoral neck</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stress fracture of pubic bone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iliopsoinal neuralgia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bursitis</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

11. How many (approximately) of the affected players suffered recurrence of their groin pain subsequent to treatment sufficient to cause them to miss matches?

3

12. In all, how many playing hours of competitive football would you estimate were lost as a result of groin injury over the last 12 months?

2 Parents out for 6 weeks, 4 parents close season

Thank you for taking time to fill in this questionnaire. If you have any further comments, feel free to write them in the space below or overleaf.

We have had more than our fair share of inguinal hernias. I would be interested to hear your findings. We have used two surgeons. One is MacCannan.

2. J. Gilmour

¹Passive conservative treatment - treatment by rest / heat / cold only
²Active conservative treatment - treatment by means of physiotherapy, analgesic injections, diathermy, etc.
³Surgical treatment - e.g. hernia repair, etc.
Table 3: The Incidence and Injury Impact of Groin Injuries in Professional Soccer Players.

<table>
<thead>
<tr>
<th>Results of Postal Survey</th>
<th>FA %</th>
<th>UEFA %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of clubs returning questionnaires</td>
<td>46</td>
<td>34</td>
</tr>
<tr>
<td>% teams returned questionnaires</td>
<td>50%</td>
<td>30%</td>
</tr>
<tr>
<td>Number of professional players</td>
<td>1381</td>
<td>954</td>
</tr>
<tr>
<td>Number of groin injuries</td>
<td>325</td>
<td>222</td>
</tr>
<tr>
<td>Percentage of players with groin injury</td>
<td>25.3%</td>
<td>23.3%</td>
</tr>
<tr>
<td>Number of recurrent groin injuries</td>
<td>106</td>
<td>56</td>
</tr>
<tr>
<td>Percentage of players with recurrent groin injury</td>
<td>32%</td>
<td>25%</td>
</tr>
<tr>
<td>Number of player matches lost</td>
<td>1336</td>
<td>915</td>
</tr>
<tr>
<td>Mean number of player matches lost / club / season</td>
<td>22.2</td>
<td>26.7</td>
</tr>
<tr>
<td>Mean number of matches lost / injury</td>
<td>4.1</td>
<td>4.1</td>
</tr>
</tbody>
</table>

Table 4: Side of Groin Injury Relative to Dominant Kicking Side.

<table>
<thead>
<tr>
<th>Symptomatic side</th>
<th>FA %</th>
<th>UEFA %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dominant alone</td>
<td>64%</td>
<td>56%</td>
</tr>
<tr>
<td>Bilateral</td>
<td>16%</td>
<td>24%</td>
</tr>
<tr>
<td>Non-dominant alone</td>
<td>20%</td>
<td>22%</td>
</tr>
</tbody>
</table>
### Table 5: Diagnosed Cause of Groin Pain in Professional Soccer Players

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>FA % of player diagnoses</th>
<th>UEFA % of player diagnoses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adductor muscle strain</td>
<td>44</td>
<td>46</td>
</tr>
<tr>
<td>Rectus abdominis strain</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Iliopsoas strain</td>
<td>6.5</td>
<td>12</td>
</tr>
<tr>
<td>Proximal rectus femoris strain</td>
<td>7.5</td>
<td>8</td>
</tr>
<tr>
<td>Internal / external oblique strain</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Inguinal hernia</td>
<td>18.5</td>
<td>3</td>
</tr>
<tr>
<td>Femoral hernia</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>Osteitis pubis</td>
<td>5.5</td>
<td>8</td>
</tr>
<tr>
<td>Stress fracture of femoral neck</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Stress fracture of pubic bone</td>
<td>0</td>
<td>1.5</td>
</tr>
<tr>
<td>Ilioinguinal neuralgia</td>
<td>0.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Bursitis</td>
<td>1.5</td>
<td>3</td>
</tr>
<tr>
<td>Genito-urinary condition</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Gastro-intestinal condition</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>Other (please specify)</td>
<td>0.5</td>
<td>0</td>
</tr>
</tbody>
</table>

### Table 6: Imaging Of Groin Injuries

<table>
<thead>
<tr>
<th>Imaging technique</th>
<th>% of Studies Performed at FA Clubs</th>
<th>% of Studies Performed at UEFA Clubs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional radiography</td>
<td>15</td>
<td>43</td>
</tr>
<tr>
<td>Diagnostic ultrasound</td>
<td>7</td>
<td>29</td>
</tr>
<tr>
<td>Computed tomography (CT)</td>
<td>2.5</td>
<td>3</td>
</tr>
<tr>
<td>Magnetic resonance imaging (MRI)</td>
<td>16</td>
<td>21</td>
</tr>
<tr>
<td>Herniography</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Radionuclide (isotope) bone scan</td>
<td>2.5</td>
<td>8</td>
</tr>
</tbody>
</table>
**INITIAL CONCLUSIONS**

1. Groin pain is a major problem in sport and especially so in professional soccer; 23 - 25% of players will sustain a groin injury during any one season of which 25 - 32% will recur during that same season with a mean of 4.1 matches lost per injury.

2. Most groin problems are overuse phenomena rather than acute injuries.

3. The “sportsman’s hernia”, pubic adductor tendon origin and rectus abdominis insertion problems all probably reflect different sites for a similar injury process i.e. an enthesopathy secondary to repetitive minor injury.

4. The large muscle bulk of the hip adductor relative to their pubic insertion cross-sectional area means that a large force per unit area is generated at their enthesal attachments potentially resulting in an enthesal overuse phenomenon.

5. In both England and the rest of Western Europe adductor origin strain is by far the most commonly diagnosed cause of groin pain apparently constituting 44 - 46% of groin injuries. A remarkably high rate for diagnosing an inguinal hernia exists in Football Association clubs (18.5%), when compared to UEFA clubs (3%). The study represented survey returns for injuries sustained by 547 players i.e. a considerable number of players. However, the significance of all of the conclusions extrapolated from survey results must be considered within the context of the limited number of responses i.e. 50%

6. Further clinical investigation in athletes, who are not cured by hernia repair, will produce an alternative treatable diagnosis in more than 80% of cases, most of which are subsequently cured by addressing the more latterly diagnosed condition. Conversely, adductor origin symptoms often subside following hernia repair. Therefore, adductor origin injury and the development of a “pre-hernia complex” appear to have a common cause i.e. they both appear to relate to a strain-type injury.
7. Great diagnostic confusion often exists when diagnosing the precise cause of groin pain in athletes. This diagnostic confusion may be due to the fact that many of the diagnoses are anatomically and/or biomechanically linked.

8. The pubic symphysis may be considered analogous to the intervertebral discs of the spine. Accordingly, on conventional radiography and MR imaging, the appearances of pubic symphyseal degeneration and pubic “symphysitis” are remarkably similar to those changes seen in intervertebral disc degeneration and mechanical discitis.

9. The condition traditionally considered to be “osteitis pubis” appears to be structurally and patho-physiologically akin to intervertebral disc degeneration reflecting excessive wear from physical activity and as such is unlikely to be a major cause of groin symptoms in athletes.

10. The fact that steroids infiltrated below the pre-pubic soft tissues often produce dramatic results in athletes with pain apparently due to a symphyseal degenerative process may be related to the treatment of an adjacent enthesal injury and not the symphyseal problem itself (due to therapeutic steroid agent diffusion away from the infiltration site).

11. In a “True” Osteitis Pubis the MR imaging appearances would tend to suggest that trabecular microfracture stress injury is the main underlying aetiology.

12. Osteitis pubis may be a stress phenomenon related to a limitation of hip movement.

13. There is good overall correlation between radiological SIJ abnormality and a past history of groin or lower abdominal pain suggesting pelvic instability to be associated with groin pain in athletes.

14. Occasionally, a traumatised parasymphyseal area may act as a focus for haematogenous infection especially in the immunocompromised individual, (a state which may occur in athletes due to the effects of “over-training”), making differentiation from pubic osteomyelitis even more difficult.

65
"If men could learn from history, what lessons it might teach us! But passion and party blind our eyes and the light which experience gives is a lantern on the stern, which only shines on the waves behind us!"

_Samuel Taylor Coleridge (1772-1834), English poet._

**INTRODUCTION**

The cadaveric anatomical dissection study program was an evolutional one spread over a six year period (1996-2001) and consisted of separate short, but intensive, periods of cadaveric dissection at three different university departments of human anatomy. The first of these was supplemented by a Computed Tomography (CT) correlation study. In all, 41 formalin-embalmed cadaveric dissection studies were performed and documented using digital photography. Each of these studies built on the findings of the previous gross anatomical study. In all of these studies I conceived the study, supervised the dissection process, and analysed all of the results, both gross anatomical and CT. I also performed a significant proportion of the dissection work itself, although this latter function was shared with my co-workers. Dr. Schilders in particular was of great help in applying surgical techniques to the dissection process. He also helped me in conceptualising the links between my gross findings and the relevant surgical anatomy. The dissections would ideally have been carried out on fresh cadaveric specimens. This was not possible for logistical reasons related to specimen availability. Great care was, therefore, taken to try to evaluate whether true conjoined structures were present and as to the precise nature of the tissue planes at the time of dissection. Accordingly, gentle blunt dissection was used whenever possible in order to free-up any natural tissue planes.
STUDY SEQUENCE

1. Background investigation based on a systematic literature review performed with reference to the gross anatomical appearances of the public symphyseal region

2. Anatomical Dissection Study 1 - performed at the Department Of Anatomy, University Of Leeds, Yorkshire, UK (April-December 1995)


4. Anatomical Dissection Study 2 - performed at the Department Of Anatomy, Dalhousie University, Halifax, Nova Scotia, Canada (August 1999)

5. Anatomical Dissection Study 3 - performed at Department Of Anatomy, University Of Queensland, Brisbane, Australia (June 2001)

BACKGROUND

Pubic Symphysis

The word symphysis is derived from the Greek term for a "growing together". It is a pelvic joint and like all other pelvic joints has to carry the weight of the upper part of the body whilst also having to allow pelvic distension during labour [101]. In humans the pubic symphysis usually begins as a synchondrosis and later develops into a hemiarthrosis and may finally develop into a true diarthrodial joint.

The two cartilaginous pelvic halves of the human embryo are at first widely separated, however, by time the foetus reaches a crown-rump length (CRL) of 30mm (10 weeks in utero) the pubic bones are closely approximated ventrally [102]. The primary ossification centres of the pubic bones usually appear between 18 and 28 weeks in utero, and may be detected radiographically in all full term foetuses [103]. The symphysis is approximately 9-10 mm wide at birth with thick cartilaginous end plates. These end plates in adults reach a thickness of 200-400 microns. Secondary ossification centres appear in early adolescence and these may be multiple and irregular in distribution. The symphysis has achieved its overall adult size by mid adolescence [104].
At birth there is an uninterrupted connection between the pubic bones, which anteriorly and inferiorly consists of vascularised ligamentous connective tissue, whilst posteriorly and superiorly are formed of true fibrocartilage. During the second year of life a median cleft appears within this cartilage portion, which coincides with an increase in shear stresses. These increased forces at the symphysis pubis are due to the adoption of an erect posture during walking with consequent increase in body weight passing through this articulation. These clefts are termed physiological or primary clefts and are seen in approximately 75-80% of individuals less than 16 years of age [105]. The osteocartilaginous covering of the pubic articular surfaces is initially smooth and slightly concave, but progression of ossification leads to well defined interdigitation of cartilage between the osseous region, producing a series of 8-12 transverse ridges. These ridges slowly flatten out during late adolescence and become smooth by approximately 23-25 years of age. This adaptation probably helps to preserve the vulnerable growth cartilage against applied shearing forces [105].

Secondary traumatic clefts may occur eccentrically within the hyaline cartilage covering the articular surfaces of the pubic bone ends forming the symphysis. Such secondary clefts are more common in adult females (34%) compared to adult males (21%), suggesting them to be degenerative clefts related to birth trauma [105]. Similar cartilage injury occurring elsewhere in the body is recognised as being a precursor to osteoarthritis. In adults, complete clefts may occur within the fibrocartilage and extend along its entire anterior to posterior extent. A significant proportion of these latter fissures go on to develop a synovial lining i.e. effectively forming a diarthrodial joint.

In childhood and adolescence, a retropubic eminence i.e. a visible and palpable ridge over the posterior aspect of the pubic symphysis is absent [105]. Such an eminence develops in postpartum women, particularly in multiparous females, and macroscopically averages 4 mm in anteroposterior and 8 mm in transverse plane. In males the retropubic eminence has been noted to develop later and is smaller with a maximum anteroposterior diameter of 2 mm and transverse diameter of 4 mm, and is not usually demonstrated below 36 years of age. This eminence consists of a mixture of the posterior transverse ligament and extruded symphyseal cartilage, occasionally containing local nodules of degenerating or even...
proliferating cartilage. The bony lipping at the posterior margins of the symphyseal facets develops later and represents buttressing osteophytes around a posteriorly extruded symphyseal fibrocartilage secondary to increased horizontal compressive forces related to symphyseal instability [106]. The size of the retropubic eminence has been reported to be directly proportional to the size of the symphyseal cleft and subsequent attrition and extrusion of the symphyseal disc fibrocartilage [105]. In females ligamentous hyperplasia posteriorly may be a significant factor in formation of the retropubic eminence. In multi-racial samples of male pubic bones significant differences are found across racial groups. Advanced pubic symphyseal patterns are seen in Afro-Caribbeans and Latin-Americans at a younger age than White Caucasians i.e. the former have more accelerated degenerative changes in the pubic symphysis [107].

Sutro [108] commented on the presence of degenerative changes within the anterior symphyseal ligament with resulting clefts and cysts. Such an occurrence could explain at least in part anterior symphyseal migration following repetitive minor injury. He also described herniation of fibrous or hyaline cartilage into the subchondral bony end-plates, subchondral sclerosis and irregular symphyseal clefts as part of a pubic symphyseal degenerative process.

The symphyseal blood supply is derived from multiple branches from the obturator, inferior epigastric, medial femoral circumflex, and internal pudendal arteries, as well as other branches from arteries close to the symphyseal area [104].

The suprapubic ligament attaches to the crest of the tubercles of the pubic bone, whilst the thin posterior pubic ligament fuses with the intrapelvic abdominal wall fascia. Interestingly, these authors also describe how the fibres of the anterior pubic ligament blend with the rectus abdominis fascia [104]. These ligaments, however probably contribute little to the overall stability of the symphysis pubis, this being mainly dependent on the thick inferior pubic ligament (arcuate ligament).
Inguinal Region

The anatomy of the inguinal region is enigmatic and confusing. Among the many structures involved in hernial repair are the iliopubic tract, the transversus abdominis aponeurosis and the transversalis fascia, the transversalis crura and sling, and the inguinal canal. There is still, however, much disagreement among surgeons and anatomists about the existence, structure, and function of these anatomic entities.

In a study of 135 fresh male cadavers carried out during autopsy examinations, Condon [109] found a significant number of errors in the “classical” description of groin anatomy. These differences may be ascribed to the fact that since the latter third of the 19th century cadaveric anatomical dissections have been performed on embalmed specimens. Embalming has the effect of apparently thickening such structures as the transversus aponeurosis and the deeper transversalis fascia. Also, embalming the proteins in connective tissue has the unfortunate effects of binding adjacent structures to each other and of distorting their anatomic relationships. Review of literature from prior to the mid-19th century, however, shows that the description of groin anatomy from that time was usually accurate.

Condon’s study showed that in only 3% of groins does a conjoint tendon representing the fused infero-medial aponeuroses of internal oblique and transversus abdominis, actually insert into the pubic tubercle and adjacent pubic crest as is classically described [109]. His study showed that in 97% of cases, these tendinous aponeuroses are separate structures with 74% inserting independently into the rectus sheath at least 5mm above the pubic tubercle (as previously classically described). Similarly Casten [110] found separate internal oblique and transversus aponeuroses rather than the classical conjoint tendon in greater than 90% of 854 groins undergoing operative hernia repair, with these structures again inserting into the rectus sheath rather than the pubic tubercle. Condon also noted that a reflected inguinal ligament consisting of oblique superomedially reflected fibres passed between the medial end of the inguinal ligament and the anterior rectus sheath in 70% of specimens. A similarly orientated ligament attaching to the posterior rectus abdominis muscle surface (Henle’s ligament) was present in 45% of specimens. Both Condon and Casten agreed that these latter reflected ligaments were
important in reinforcing the medial portion of the inguinal canal close to its pubic attachment.

The flat muscles of the anterior abdominal wall pass down well in front of the pectineal ligament of Astley Cooper on the summit of the superior pubic ramus, thus providing space for the spermatic cord and the great vessels of the lower limb to leave the abdomen. The abdominal wall layers turn back more inferiorly to close the gap on the medial side of the external iliac vein. The external oblique aponeurosis is reflected to form a strong inguinal ligament, and the attached fascia lata turns back as the lacunar ligament to meet and fuse with the pectineus muscle fascia 1-1.5 cm below Cooper's ligament. This leaves a deep trough, between Cooper's ligament posteriorly and the posterior inguinal wall anteriorly, which houses the transversely placed femoral canal [111]. Anatomical and histological findings suggest, however, that the ligament of Cooper represents a thickening of the pectineal fascia rather than a thickening from the periosteum as previously supposed [112]. Senile ultrastructural changes in collagen microfibrils may lead to supportive and mechanical insufficiency of the fascia transversalis resulting in herniation [113].

The functional anatomy of the inguinal canal is modified by regional osseous, muscular and ligamentary variations. The pubic tubercle is not in a constant position in relation to the interspinous diameter. The more inferior the pubic tubercle is located, the more often morphological alterations are to be found in obliquus externus, obliquus internus, transversus and cremaster muscles as well as the fascia transversalis [114]. The thickness of tissue around the deep inguinal ring (peritoneum, transversalis fascia and intervening connective tissue) varies at different sites, being maximal lateral to the testicular vessels (2.2 +/- 0.4 mm) and least over the efferent ducts (0.2 +/- 0.1 mm) [115]. Comparison of anatomic variations in both sexes shows that the distance between the pubic tubercle and the internal ring is larger, and that the rectus muscle is significantly wider in females. The diameter of the internal ring itself is larger in males, however, although significant variability exists. These anatomic variations may explain the sex differences in hernia formation [116] i.e. the much greater male incidence for inguinal hernia (and prehernia complex) formation.
**Adductor Origins**

The ventral arc of the pubis is a ridge of bone for muscular and ligamentous attachments. The tendons of gracilis and adductor brevis, which are themselves fused for a variable extent, arise from this ridge of bone, and the fibres of the ventral pubic ligament which is attached to its medial border [117]. The proximal insertion of the gracilis muscle is a strong tendinous lamina arising from the anterior aspect of the pubis and from the ischiopubic ramus [118]. The arterial supply of the gracilis muscle appears to be very rich, consisting of various pedicles entering the muscle by its lateral side. The main neurovascular bundle issues from the profunda vessels of the thigh, coming either from the adductor artery (73%), the medial circumflex artery (19%) or both networks (8%) [119]. The musculotendinous junction is usually clearly demarcated [116]. Both this junction and the osseous insertion of adductor longus tendinous fibres are predominantly found on the anterior surface, while the posterior surface consists mainly of muscle tissue. The medial boundaries are the longest part of the tendon bilaterally in women, while the lateral aspect of the left muscle is greater in men. Tendinous fibres are predominantly found on the anterior surface, whilst the posterior surface consists mainly of muscle tissue. However, cadaveric dissection studies have shown are several types of anomalies may be present, which could partially explain why localising the site of injury can be so difficult.

Analysis of the fibres in the prepubic tendon of the horse and some other mammals have shown that it is composed of the crossed and uncrossed tendons insertions of the pectineus muscles, the pelvic tendons of the rectus and oblique abdominis muscles, and the tendons of origin of the cranial portion of the gracilis muscles [120].

It has been previously noted [108] that the anterior fibres of the symphyseal ligament decussate with short fibres firmly binding its “corners” to the pubic bones. The decussation of fibres would appear to be consistent with the interlacing distal ends of the rectus sheath. Sutro’s suggestion that only the corners are tightly fixed by short ligamentous fibres [108] is consistent with osseotendinous junctions of the common adductor origin and rectus sheath-inguinal ligament attachment via Sharpey-Shaffer fibres at the four corners of the lateral pubic margins. Indeed Todd [121] had also noted that irregular “retrogressive epiphyses” were present at the superior and inferior ventral corners of the pubic bones. These
presumably actually reflect apophyses for tendon attachment. The prominent decussation means that if the adductors, rectus abdominis, inguinal ligaments etc. on one side of the body undergo traction forces then the anterior pubic regions are rotated forward bilaterally, thus minimising the shearing effect on the symphysis pubis. This again would be consistent with a functional and anatomical link between the rectus abdominis-inguinal ligament and the common adductor aponeurosis akin to the Achilles tendon – calcaneal apophysis – plantar aponeurosis acting as an anatomical and functional link during the heel-raise phase of gait.

The Sacroiliac Joints
Sacroiliac joint instability would seem to have been recognised for many centuries. A copper wire ligature has been demonstrated between the sacrum and right ilium in an exhumed adult female skeleton, dating back to approximately 1600 to 1700 A.D. [122].

The largest and most consistent movement of the sacral promontory occurs when an individual moves from a recumbent to a standing position [123]. The shorter articular surfaces of the iliac side may partly explain why degenerative changes tend to be more prominent on the iliac side [123]. The sacrum and ilium are held in a position by a capsular ligament and a number of more dorsal accessory ligaments [124]. In adults these ligaments are arranged in two distinct cranial and caudal groups resisting the oblique shearing force produced at the lumbosacral junction by vertical axial loading due to the weight of the trunk in the erect posture [124]. The tendency is for the weight of the body to rotate the sacrum towards a more horizontal position, and accordingly to tilt the pelvis in a sagittal plane, rotating the pelvic inlet to a more anteriorly facing position. It would not, therefore, be surprising, should symphyseal instability exist, that the hemipelvis would rotate on the abnormal side into a more superior position potentially resulting in sacroiliac joint disruption and hemipelvic rotatory instability. Such movements, however, are small. Roentgen stereophotogrammetric analysis has shown that when the pelvis rotates around its transverse axis, movement at the sacroiliac joints is on average of 2.5° with a mean translation of 0.7 mm and with no significant difference occurring between symptomatic and asymptomatic joints [125]. The sacroiliac joints are, therefore, constructed in such a way as to have a largely static function, i.e. elastic transmission of body weight to the legs,
rather than a dynamic function, i.e. movement [126]. The sacroiliac joints of bipeds are under a 50-70% greater strain than those of quadrupeds [127] and this may be further increased by single-leg stance as occurs with pivoting to change direction at speed and during a kicking action.

The buffering capacity of the sacroiliac joints decreases with age [128]. There is evidence of definite degenerative change within the cartilage on the iliac side of the sacroiliac joint in all adults older than 30 years of age. Dilmann [126] noted on conventional radiographs that in approximately 30% of patients with hyperostosis triangularis ilii there is evidence of capsule or ligamentous disruption and associated degenerative changes, this becoming 58% of patients when tomographic studies of the sacroiliac joints are performed. It would appear that functional insufficiency of the sacroiliac joints predisposes to hyperostosis triangularis ilii, (a physiological triangular zone of hyperostosis located at the anterior corner of the sacroiliac joints), which is usually more prominent on the iliac side. This area narrows superiorly whilst still retaining its triangular shape, i.e. in three dimensions it appears to be shaped like a pyramid with triangular sides. Increasing the applied stressing forces results in an expansion of this triangular area of 'physiological' hyperostosis i.e. a normal physiological response to the forces applied. The hyperostosis triangularis ilii consists of areas of transformation of cancellous into compact bone, with mosaic structures occurring as a sign of increased bone turnover [126]. The sclerosis is also partly related to degenerative change in the articular cartilage resulting in subchondral sclerosis. The adjacent bone marrow can be haematopoietic. Alternatively, fatty or fibrous replacement may occur as has been noted both in the subchondral marrow of the sacroiliac joints as well as adjacent to the symphysis pubis [126].

Permanent asymmetrical transfer of body weight (e.g. a fixed rotatory scoliosis) may lead to a unilateral stressing phenomenon and resulting degenerative change within a single sacroiliac joint. Interestingly, many authors feel that the hyperostosis triangularis ilii regresses spontaneously following conservative or surgical treatment of pelvic instability and a number of follow up studies support this conclusion [129-131]. It is also noticeable that such hyperostosis can occur in inflammatory conditions predisposing to sacroiliitis, such as the seronegative spondyloarthropathies. This appears to be independent of the
sacroiliitis changes, which in the main tend to be on the sacral side of the joint. These findings again suggest that the phenomenon of hyperostosis ilii reflects instability which in this case is due to inflammatory arthritis-related ligamentous damage. Exercise related stress reaction to the sacroiliac joint is an unusual cause of low back pain in athletes and is probably self-limiting. Such changes are more readily evident on bone scintigraphy than conventional radiographs, but may reflect an acute variant of the hyperostosis triangularis ilii [132].
ANATOMICAL DISSECTION STUDY 1

Location
Department of Anatomy, University of Leeds, Yorkshire, UK.

Study Period
April-December 1995.

Co-Worker
Dr. Roger Soames, Senior Lecturer in Anatomy, University of Leeds who helped arrange access to the cadavers for dissection.

Aims
1. To assess the precise anatomical relationship between the soft tissues surrounding the pubic bones and the pubic symphysis particularly the tendon and ligament attachments of the perisymphyseal region.
2. To examine transverse sectional anatomy with particular reference to the soft tissues surrounding the pubic bones and the pubic symphysis.

Materials and Method
Initially 20 cadaveric specimens were examined. All were formalin fixed cadavers that had died when greater than 65 years of age (age range at death 65-79 years). However, due to their poor condition 4 specimens were excluded from the study leaving 16 specimens (11 male and 5 female) which were dissected and analysed macroscopically.

Dissection
The region of interest was harvested from a formalin-fixed cadaver by sawing bilaterally through the superior and inferior pubic rami approximately 2cm lateral to the pubic bodies. The soft tissues were then divided along a vertical line parallel to these osteotomies and then transversely through the anterior abdominal wall and proximal adductor regions approximately 5cm cephalad and caudal respectively to the pubic bodies. Each specimen therefore consisted of the anterior pubic bone and pubic symphysis, medial inguinal...
ligaments, rectus sheath, transversalis fascia and associated muscles of the lower anterior abdominal wall, adductor muscle origins and the soft tissues anterior and immediately posterior to the pubic symphysis. The skin and subcutaneous fat was then removed (Fig. 15).

The soft tissue planes were then carefully dissected, photographed and documented using a set proforma (Table 7). The recordings were made using a semi-quantitative scale.

Where a structure may or may not be present it was assessed using a 5-point-scale i.e.

0 = definitely not present,
1 = probably not present,
2 = equivocal,
3 = probably present,
4 = definitely present.

Where a structure was initially expected to be inevitably present it was quantified using a 4-point-scale with 0 being the lowest and 3 the highest point of the scale i.e.

0 = not present,
1 = small,
2 = intermediate,
3 = large.

The latter scale, used to evaluate the size / extent of the anatomical structure in a semi-quantitative manner, is in effect a subset of point-4 of the former scale. The scales could, therefore, have been combined by subgrouping point 4 into 4.1, 4.2 and 4.3 or, alternatively, 4a, 4b and 4c (it was felt, however, that the latter scale would cause greater confusion).
Figure 15: The Layered Dissection Method for Assessing Tissue Planes over the Anterior Pubis.

A. A midline sagittal incision is made in the anterior layer of the rectus sheath.

B. The two halves of the anterior rectus sheath are reflected laterally exposing the distal insertion of the rectus abdominis muscle. A sagittal incision is made into the anterior layer of the rectus muscle.

C. The two halves of the anterior rectus abdominis muscle are reflected laterally exposing the anterior pubic bone surfaces and their anterior marginal attachments.
Table 7: Scoring Proforma for Documenting the Gross Anatomical Appearances of the Right Pubic Region.

<table>
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<tr>
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<tr>
<td>a) Deep surface of anterior rectus sheath</td>
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<td></td>
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<tr>
<td>b) Superior bone surface of symphysis</td>
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<tr>
<td>c) Combined</td>
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<tr>
<td>Anterior rectus extension below SSL</td>
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<tr>
<td>Conjoint adductor longus / gracilis aponeurosis</td>
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<tr>
<td>Inferior radial ligament (IRL) thickness</td>
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<td>Inguinal ligament - IRL continuation</td>
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<td></td>
</tr>
<tr>
<td>a) Ipsilateral continuation</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>b) Contralateral continuation</td>
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<td></td>
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<td>a) Super laterally</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>b) Infero-laterally</td>
<td></td>
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</tbody>
</table>

* due to the nature of the semiquantitative scale there are no units associated with the thickness “measurement”

NB. A similar proforma was also completed for the left side for each specimen.
Results

These are summarised in Table 8. The relevant points are:

1. The posterior symphyseal margin is covered by a thin (75% <2mm, 25% 2-4mm) sheet of soft tissue consisting of a condensation of the anterior pelvic peritoneum (Fig. 16).

Figure 16: The Posterior Aspect of The Pubic Bodies And Symphysis.

The sagittally incised posterior rectus sheath (arrows) inserts more anteriorly than the superior pubic ridge reflecting the insertion of this sheath into the anterosuperior pubis to form the superior symphyseal line.

2. There was a tight adherence of the deep surface of the rectus sheath to the superior pubic bone surface and symphysis in all specimens, this apparently constituting the superior symphyseal ligament (SSL). In separating these structures a soft tissue ridge was left on the deep surface of the rectus sheath and / or the superior bone surface of symphysis and pubic crest. In the majority of cases the SSL appears to be a well defined, substantial structure.

3. There was probable or definite extension of the anterior rectus sheath below the SSL in 12 of the 16 (75%) specimens with a modal value for the scores of 4. In no specimen was there definitely no extension.
4. There was a probable or definite conjoint adductor longus / gracilis aponeurosis at 65% of the pubic origins. Conversely, there was probably or definitely no conjoint aponeurosis at only 6% of the pubic origins and in no specimens was there a separate pubic origin for the anterior adductor muscles.

5. A condensation of the adductor tendon origins extending inferiorly and slightly medially from the anterolateral pubic margin inferiorly has been previously described as the inferior radial ligament (IRL) (Fig. 17). In the present study it was present in all cases. It was a substantive structure in 56% of groins.

6. In the majority (50%) of specimens this IRL united proximally with the inguinal ligament at the pubic tubercles. Conversely in only 25% (8 groins) was there definitely neither ipsilateral nor contralateral continuation. In 25% there was probably or definitely an ipsilateral extension and in a further 25% of the cases a contralateral (cruciform) extension.

7. An apparent tissue plane was found immediately superficial to the IRL -inguinal ligament continuation or “cruciate” anterior pubic ligaments (APL). This consisted of a sheet of soft tissue formed above by the anterior rectus sheath extension distal to the SSL and below by the common adductor origins. The rectus abdominis-common adductor origin aponeurosis (RA-CAO) demonstrated tight adherence to the central portion of the anterior pubic surfaces and the APL. In no cadaver was there definitely no such an adherence, however, there was probably not one in 50% of specimens.

8. There was demonstrable adherence of the RA-CAO to the antero-lateral public margin in all specimens. There was a probable or definite adherence superiorly in 88% and inferiorly in 69% and in no specimen was there probably or definitely no such adherence at either of these sites.
Figure 17: The Alignment of the Inferior Radial Ligament

A. The IRL inferiorly forms a crescentric continuation with the ipsilateral anterolateral pubic border superiorly (dotted curved line). The separated tight bony adherence is again seen as matching bone irregularity and bone remnant (arrows). This attachment is in direct line with this crescent.

B. The IRL inferiorly forms a cruciform continuation with the contralateral anterolateral pubic border superiorly (dotted straight line). The separated tight bony adherence is again seen as matching bone irregularity and bone remnant (arrows). This attachment is in direct line with the limbs of this cross.
### Table 8: Results of Anatomical Dissection Study 1
(Using the same semi-quantitative scales as described for Table 7)

<table>
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<tr>
<th>Combined Right &amp; Left</th>
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<td>Superior symphyseal ligament (SSL)</td>
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</tr>
<tr>
<td>a) Deep surface of anterior rectus sheath</td>
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<td>8</td>
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<td>0</td>
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<tr>
<td>b) Superior bone surface of symphysis</td>
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<td>Conjoint adductor longus/gracilis aponeurosis</td>
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</table>

* 8 groins had neither ipsilateral nor contralateral continuation
ANATOMICAL DISSECTION STUDY 1: SUPPLEMENTARY CROSS-SECTIONAL STUDY

Location
The Department of Radiology, The General Infirmary at Leeds, Yorkshire, UK

Study Period
April 1996

Co-Worker
Ms. Lynne Gathercole, Superintendent Radiographer, CT Department, The General Infirmary at Leeds who performed the CT studies on these specimens prior to my subsequent workstation-based analysis.

Aim
To examine the trabecular pattern of the parasymphyseal region to see if the distribution reflects the orientation of soft tissue attachments (i.e. the traction and compression forces applied at these entheses).

Materials and Methods
Six cadaveric specimens were examined and 5x3mm transverse CT sections were obtained (Philips SR, Eindhoven, NL). The Hounsfield Unit values were obtained for 9 regions of interest reflecting the pubic bones of the parasymphyseal regions. An average was taken for the 2 sides. The site and distribution of osteophytes was noted and compared with macroscopic appearances following subsequent section.

Sectioning
The six cadaveric specimens that underwent CT were initially sectioned transversely through the level of the mid pubis. They were then trimmed at the junction of pubic bodies and rami. The configuration of the pubic symphysis was then examined and correlated with the nearest corresponding CT section. The remaining specimens were sectioned sagittally through the mid symphysis to evaluate the thickness of surrounding soft tissue attachments.
The reduced specimens were then photographed using a digital camera with macro lens system.

On transverse axial CT sections the pubic bones were arbitrarily divided into 9 regions (Table 9A). The mean regional Hounsfield Unit value for each region was measured. The mean Hounsfield Unit value for each of the 9 regions for each section of each of the two pubic bodies was then aggregated (Table 9B). The regions were then ranked in order of magnitude with 1 being the greatest value of mean Hounsfield Units (Table 9C). The regions were then calculated relative to the lowest ranked region i.e. region 9, so that a Relative Hounsfield Unit could be calculated for each region (Table 9D).

**Results**

Comparison of the different sections shows macroscopically how the degenerative secondary symphyseal fissure propagates from posterior to anterior separating the fibrous symphyseal disk from the fibrocartilage overlying the pubic bone ends (Fig. 19). It also shows how the process of posterior symphyseal extrusion progresses to form the posterior pubic eminence by ossicle formation within the extruded fibrous tissue.

The ossicle forming in Fig 19 C is central in position whilst that in Fig 20 C is laterally placed i.e. a true buttressing osteophyte at the margin of the posteriorly extruded symphysis pubis. A more centrally placed osteophyte is also noted on CT scanning in Fig 20 E when compared to the laterally placed “claw” osteophyte in Fig 20 F.

The greatest areas of trabecular bone density are in the subchondral (2.49 to 4.46 fold increase) and subenthesal (1.62 to 4.46 fold increase) regions (Fig. 21 and Table 9). The former presumably reflects the transverse compression forces across the pubic symphysis resulting in anterior, or more commonly, posterior symphyseal extrusion. The triangular area of higher trabecular density anterolaterally in the superior portion of the pubis corresponded to the site of entheses of the IL, AL and RA (Fig. 22). The same appearances in the inferior portion of the pubic bodies corresponded with the origin of the gracilis tendons and gracilis fascia.
Figure 18: Sectioning Technique

A) A specimen photograph of the posterior aspect of pubis showing the pubic eminence (arrows), B) a photograph following transverse sectioning of the pubic bones showing the matching pubic eminence on the two section halves (arrows), C) inferior surface of upper half of sectioned specimen with area marked showing lines of further sectioning (dotted square), and D) macrophotograph of sectioned area from C showing in greater detail the tissues forming the pubic eminence. There is posterior extrusion of the symphysis (arrowheads) and a small asymmetrically placed ossicle (arrow) being formed within the fibrous tissue overlying the posterior pubic margin.
Figure 19: Progression of Central Symphyseal Fissure Formation

Transverse sections have been taken from three different cadaveric specimens showing various degrees of fissure formation. A) Fissure developing in the posterior third of the pubic symphysis. B) Increasing posterior symphyseal extrusion and the fissure is propagating anteriorly. C) A fissure along the whole length of the fibrocartilaginous surface of the right pubic body with Y-shaped posterior extension. A small ossicle (arrow) is developing within this “Y”.

Figure 20: Progression of Posterior Symphyseal Extrusion and Posterior Symphyseal Osteophyte Formation

A-C) Transverse sections have been taken from three different cadaveric specimens and show increasing changes. A) A bulge is seen at the posterior symphyseal margin reflecting early posterior extrusion. B) Increasing posterior symphyseal extrusion is seen with asymmetric extension to the left and there is a suggestion of early changes of ossification. C) Progressive posterior symphyseal extrusion with an ossicle within the laterally extruding fibrocartilaginous disc on the left. D-F) Transverse axial CT scan images of three different cadavers again showing progressive development of buttress osteophyte formation adjacent to the posteriorly extruded pubic symphysis. In this series these changes are again asymmetrical more prominent on the left.
The triangular configuration of the areas of increased trabecular bone density appeared to reflect the site of greatest enthesal surface area and the line of applied traction forces. Maximum bone density reflected the site of RA-CAO attachment and was along its lines of pull according to Wolff’s Law. Lateral compression forces would produce the increased trabecular density in the medial sub-articular section of the pubic bone and are greater than the traction forces producing the increased trabecular density over the anterolateral or sub-enthesal part of the pubic bodies (Table 9 and Fig. 23A & B). The adductor longus tendon apparently exerts a greater force on the pubic bodies than gracilis, and both of these are greater in magnitude than the forces applied by adductor brevis (the central 60% in Fig. 36C). This boundary between the dense and less dense trabecular bone regions may result in a “fault-line”, i.e. these enthesal forces may predispose to parasymphyseal stress injury.

Figure 21: Parasymphyseal Trabecular Bone Pattern (Macroscopic Appearance)

*Transverse axial CT image demonstrating a triangular area of increased trabecular bone density either side of the pubic symphysis. The oblique lateral border with “normal” trabecular density appears to be in line with the attached insertion of the inferior radial ligament formed by combination of adductor longus and gracilis tendons (arrows).*
Figure 22: Symphyseal and Parasymphyseal Degenerative Phenomena

Transverse axial CT image demonstrating degenerative changes in the anterior pubic bones of five different cadaveric specimens. A) and B) demonstrate two different types of subarticular cyst formation with the cyst being deeper and with a more sclerotic margin in B suggesting a greater bone reaction bordering on bone erosion. C) Midline anterior and posterior symphyseal extrusion, D) rectus abdominis insertional “traction” spur and posterior symphyseal “buttressing” spur, and E) extensive new bone formation at adductor ( gracilis) entheseal insertion.
Table 9: Parasymphyseal Trabecular Bone Pattern (Relative Bone Density)

A) Nominal Parasymphyseal Regions*

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B) Average Hounsfield Units per Region

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C) Relative value of Hounsfield Units

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D) Ranking per Region

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<td>9</td>
</tr>
<tr>
<td>(Posterior)</td>
<td>3</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

* for descriptive and analytical purpose the pubic bones are divided into nine geographical areas with amalgamation of the left and right sides e.g. region 1 represents the anteromedial part of both pubic bones immediately adjacent to the symphysis pubis; region 9 represents the posterolateral parts of the pubic bones i.e. the regions furthest away from the symphysis pubis and, therefore, closest to the pubic rami.
A) Anterior to Posterior Variance - Pubic trabecular bone density is greater anteriorly than posteriorly

![Regional Variation in Bone Density](image)

B) Medial to Lateral Variance Pubic trabecular bone density is greater medially than laterally

![Regional Variation in Bone Density](image)
C) Superior to Inferior Variance - Pubic trabecular bone density is greatest in its most superior 20% and then in its most inferior 20% i.e. the areas where adductor longus and gracilis tendons attach respectively.
ANATOMICAL DISSECTION STUDY 2

Location
Department of Anatomy, Dalhousie University, Halifax, Nova Scotia, Canada.

Study Period
August 1999

Co-Workers
Dr. Ernest Schilders, Consultant Orthopaedic Surgeon, Bradford Royal Infirmary who helped with the anatomical dissections and surgical context. Dr. William Stannish, Orthopaedic Surgeon, Halifax who helped arrange access to the cadavers for dissection.

Aims
1. To examine further the soft tissue structures inserting into the anterior pubic and parasymphyseal regions.
2. To obtain a better understanding of the surgical anatomy of the pubic parasymphyseal soft tissue structures by layer dissection.

Materials and Methods
Fifteen formalin-fixed cadaveric specimens (10 male, 5 female: age range at death 62-80 yrs), were dissected, examined macroscopically and the appearances recorded as digital photographic images. The cadavers were fixed by trans-femoral artery perfusion of a mixture of formalin, glycerine, ethyl alcohol, phenol crystals and salicylic acid. The dissection findings were recorded photographically using a digital camera (C-900 Zoom, Olympus Optical Co. Ltd., Tokyo, Japan). Thirty proximal lower limbs and 15 lower anterior abdominal walls were dissected by a combination of blunt- and sharp-dissection recording the gross anatomical appearances of each soft tissue layer exposed. The structures attached to the anterior and superior side of the pubic bones were recorded with their corresponding relationships. Similarly examined were the pubic insertions of the inguinal ligament, gracilis origin and adductor longus origin as well as its proximal musculotendinous junction. Any sex differences were noted in order to find a possible
explanation for the significant difference between men and women with regards to the incidence of sports related groin pain.

**Results**

The current study suggests a number of inaccuracies in the anatomical literature with regards to the gross anatomy of the anterior pubic soft tissues. Anatomical Study 2 demonstrates that a close relationship exists between the insertion of the inguinal ligament, rectus abdominis muscle / rectus sheath and the origin of adductor longus. These relationships are not as is classically described. This study also shows that in certain individuals a ligament may run over the anterior symphysis interdigitating inferiorly with the gracilis origin and fascia lata (recto-gracilis ligament). The inguinal ligament inserts onto the pubic tubercle and then extends over the anterior surface of the pubic bone dividing the pubic bone into superior and inferior halves separated by this “V” shaped inguinal ligament extension (Fig. 24).

In males the fibres of the inguinal ligament do not appear to reach the midline i.e. they do not cover the anterior symphysis pubis, whereas in females the fibres do reach the midline and join with fibres from the contra-lateral side. In the current study 2 male specimens showed how the medial half of each of the bellies of rectus abdominis can continue distally as a ligament running over the anterior symphysis, partially decussating so as to interdigitate distally with the gracilis origin and fascia bilaterally. We termed this ligamentous structure the recto-gracilis ligament. In the remaining male, and all of the female specimens, the medial half of each rectus abdominis also continued as a ligament but this inserted only onto the anterosuperior part of the pubic bones i.e. there was no direct continuity with the gracilis or gracilis fascia. In men the ligament was thicker and apparently divided into two separate structures.

The anterior rectus sheath inserted on to the anterior-superior edge of the pubic bone and joined the fascia of the common adductors to form an aponeurosis, which covered the anterior surface of the pubic bone. This aponeurosis was firmly anchored on the lateral and superior parts of the pubis but less so on the anterior surface (Fig. 25). The lateral half of the rectus abdominis and pyramidalis muscles inserted onto the lateral
half of the anterosuperior part of the pubis and anterior pubic extension of the inguinal ligament bilaterally (Fig. 26). The insertion could be either muscular or tendinous but did not actually cross the fibres of the inguinal ligament distally.

Figure 24: The Anterior Pubic Extension of the Inguinal Ligament.

A. The external oblique aponeurosis has been incised transversely and extended medially into the anterior rectus sheath in a male patient. A pair of forceps (1) is reflecting the inferior border of this extension inferiorly and lies in the region of the right pubic tubercle.

B. The external oblique aponeurosis and rectus sheath has been excised whilst the forceps from (A) continues to lie at the pubic tubercle. A pair of scissor tips (2) marks the corresponding left pubic tubercle. A second pair of forceps (3) is lying at the apex of the pyramidalis muscle.

This dissection illustrates how the inguinal ligament does not terminate at the pubic tubercle but continues as a V-shaped structure over the anterior pubic bodies (arrowheads). Pyramidalis inserts into its superior border whilst the adductor muscles (*) insert into this inguinal ligament extension at its inferior margin.
Figure 25: Pre-pubic Aponeurosis

The anterior rectus sheath has been reflected superiorly. The aponeurosis of the rectus abdominis muscle (RA) is interdigitating with the fascia overlying and aponeuroses of the adductor origins (A). The termination of the inguinal canal lies in between (arrows).

The adductor longus originated from the anterior surface of the pubic bone and corresponding inguinal ligament anterior extension (Fig. 24). The musculotendinous junction was different in men and women and our findings were similar to those previously described. The musculotendinous junction was a clearly demarcated oblique line on the anterior surface of the muscle with the medial border longer than the lateral border. The posterior part was muscular at its origin. In females the musculotendinous junction was V-shaped but the medial side was still longer than the lateral side. The origin of the adductor longus was more rounded in males and flattened in females.

The gracilis is a very flat muscle and originates from both the inferior pubis and ischial rami as a similarly flat aponeurosis. At the anteroinferior edge of the pubis the aponeurosis fused with the fascia lata and in some cases may form part of a “rectogracilis ligament” (vide infra). The adductor brevis originated from the inferior ramus below the adductor longus and gracilis. Its origin is essentially muscular.
Figure 26: Common Alignment of Pyramidalis and Adductor Longus

A scalpel handle is elevating the pyramidalis muscles away from the underlying rectus abdominis muscle. Once elevated there appears to be a common alignment (broken line)
ANATOMICAL DISSECTION STUDY 3

Location
Department of Anatomy, University of Queensland, Brisbane, Australia

Study Period
June 2001

Co-Workers
Dr. Ernest Schilders, Consultant Orthopaedic Surgeon, Bradford Royal Infirmary again helped with the anatomical dissections and surgical context but on this occasion was joined by Dr. Hans Marynissan, Consultant Orthopaedic Surgeon, Burnley General Hospital who also helped with the dissection process. Dr. Vaughan Kippers helped arrange access to the cadavers for dissection.

Aim
To assess in detail the pubic entheseal origins of the adductor tendons particularly with regards to the gross sagittal sectional anatomy.

Materials and Method
11 fixed and 1 non-fixed specimen (6 males, 6 females; age at death 57–81 years).

Results
A number of the gross anatomical appearances observed were contrary to those described in classical anatomical texts. This third study helps confirm the variations noted in Study 2.

1. The IL inserts onto the pubic tubercle but then extends over the anterior surface of the pubic bones. This IL extension (ILE) is usually a “V” shape. This can be complete “V” or incomplete in the midline when crossing the anterior border of the symphysis. It can also merge with its contralateral counterpart and IRL to form an “X” rather than “V” shaped configuration.

2. The lateral half of the RA can be muscular or tendinous and inserts onto the anterosuperior pubis and corresponding ILE (Fig. 27).
Figure 27: Rectus Abdominis Insertion

Para-midline sagittal sections through the pubic body of a male cadaver.

A. The distinctive soft tissues layers of the lower anterior abdominal wall as its inserts into the pubis (P) can be clearly identified. 1. anterior rectus sheath; 2. pyramidalis muscle; 3. rectus abdominis aponeurosis; 4. rectus abdominis muscle; 5. posterior rectus sheath.

B. The inferior soft-tissue attaching to the anterior pubis (P) are demonstrated showing 6. adductor longus aponeurosis and facia overlying the adductor origins; 7. origin of adductor longus; 8. origin of adductor brevis; 9. pre-pubic inguinal ligament extension.

3. The AL origin occurs at the anteroinferior surface of the pubis and corresponding ILE (Fig. 28).

4. In sagittal cross-section a triangular condensation of fibrocartilage lies between the muscular adductor brevis pubic origin, the AL and RA representing their common ILE origin (Fig. 29).

5. The AL and pyramidalis muscles form a continuous line separated only by the ILE.
6. In 3 cadavers a variant existed deep to the pyramidalis whereby “ligamentous” slips of RA continued distally over the anterior symphysis, partially decussating to interdigitate with the gracilis origin and gracilis fascia bilaterally (Fig. 30). Some of these were more rudimentary than other.

7. The lower RS, pyramidalis (± RA) and AL (± adductor brevis, gracilis) aponeuroses form a fused connective tissue sheet bound firmly to the anterior pubic bones laterally but only to a variable extent centrally (and not at all in 50%).

Figure 28: Adductor Origins
The adductor longus (L), adductor brevis (B) and gracilis (G) pubic origins insert into the inguinal ligament (I) pre-pubic extension and interdigitates with the pre-pubic extension of the anterior rectus sheath / rectus abdominis aponeurosis (R).
Figure 29: Triangular Pre-Pubic Fibrocartilaginous Condensations
Sagittal sections through six different pubic bodies in all of these specimens different variations in form are seen but with the common theme that some form of triangular cross-section fibrocartilaginous condensation appears to exist (*).

Figure 30: The Recto-Gracilis Ligament Variations
Two further cadavers with evidence of a recto-gracilis ligament. A) A well developed pair of ligaments in a male patient similar to those seen in Fig. 12. B) A pair of poorly developed and rudimentary recto-gracilis ligaments in a female cadaver with a probe showing the cleavage plane with the underlying rectus abdominis muscle.
INITIAL CONCLUSIONS

There are a significant number of errors in the classical description of the soft tissue attachments to the pubic bodies (Fig. 31).

1. In only 3% of groins does a conjoint tendon representing the fused infero-medial aponeuroses of internal oblique and transversus abdominis, actually insert into the pubic tubercle and adjacent pubic crest as is classically described. In 97% of cases, these tendinous aponeuroses are separate structures with 74% inserting separately into the rectus sheath at least 5mm above the pubic tubercle. Therefore, an injury to the rectus abdominis insertion will potentially weaken the posterior wall of the inguinal canal at the level of the external inguinal ring i.e. predispose to a “sportsman’s hernia or visa versa with the direct inguinal hernia predisposing to the rectus abdominis insertion injury.

2. The posterior symphyseal margin is only covered by a thin (<2mm) sheet of soft tissue consisting of a condensation of the anterior pelvic peritoneum.
   - The tight adherence of the deep surface of the rectus sheath to the superior pubic bone surface and symphysis constitutes a superior symphyseal ligament (SSL).
   - The rectus abdominis-common adductor origin aponeurosis tightly adheres to the central portion of the anterior pubic surfaces and the APL and also to the antero-lateral public margin.
   - A condensation of the adductor tendon origins extends inferiorly and slightly medially from the anterolateral pubic margin of the inferior radial ligament (IRL) and fuses with the strong inferior pubic arch ligament.

These findings mean that direction of least resistance for pubic symphyseal extrusion is posteriorly. Posterior symphyseal extrusion progresses to form the posterior pubic eminence by ossicle formation within the extruded fibrous tissue.

3. A functional and anatomical link between the rectus abdominis, inguinal ligament and the common adductor aponeurosis (Fig. 32).
• The IL inserts onto the pubic tubercle as classically described, however, it then extends over the anterior surface of the pubic bones as a "V" or "X" shaped extension i.e. the ILE.
• The lateral half of the RA can be muscular or tendinous and inserts onto the anterosuperior pubis and corresponding ILE.
• The adductor longus originated from the anterior surface of the pubic bone and corresponding ILE.
• The AL tendon and pyramidalis muscles form a continuous line separated only by the ILE.

Injury to one link of this functional chain may affect one of the other links resulting in clinical diagnostic confusion.

4. In sagittal cross-section a triangular condensation of fibrocartilage lies between the muscular adductor brevis pubic origin, the AL and RA representing their common ILE origin (Fig. 33). Separation of these structures from the underlying bone could result in both an enthesal avulsion injury and potentially a pre-hernia complex.

5. The lower RS, pyramidalis (± RA) and AL (± adductor brevis, gracilis) aponeuroses form a fused connective tissue sheet bound firmly to the anterior pubic bones laterally but only to a variable extent centrally (Fig. 34). Again, separation of these structures from the underlying bone could result in both an enthesal avulsion injury and potentially a pre-hernia complex.

6. The medial half of each of the bellies of rectus abdominis can continue distally as a ligament running over the anterior symphysis, partially decussating so as to interdigitate distally with the gracilis origin and fascia bilaterally (recto-gracilis ligament). This again may cause difficulty in localising symptoms and exacerbate any clinical diagnostic confusion.

7. Excessive forces at enthesal sites predispose to a subsequent parasymphysial stress injury to bone.
Figure 31
Illustration of the Frontal View of the Pubic Symphyseal Region – Classical Description

LEGEND
1. Rectus Sheath
2. Adductor Longus Tendon & Muscle
3. Gracilis Tendon & Muscle
4. Pubic Body
5. Pubic Symphysis
6. Arc of External Inguinal Ring
7. Conjoined Tendon
8. Spermatic Cord
9. Inguinal Canal
10. Gracilis Fascia
Figure 32
Illustration of the Frontal View of the Pubic Symphyseal Region – Actual Anatomy
The rectus abdominis and adductors lie anterior to the pubis. Therefore, when they are sheared off their pubic bony anchors by their excessive repetitive traction forces, from both above (RA) and below (CEO), they tend to be lifted forward away from the bone.
Figure 34A
Illustration of the Axial Section Through the Upper Pubic Bodies

Figure 34B
Illustration of the Axial Section Through the Upper Pubic Bodies With Separation Of the Superolateral Soft-Tissues Due to Shearing Forces (or Raised Intra-Abdominal Pressure).

The result of the shearing injury, and the anterior positioning of rectus abdominis, gracilis and adductor longus muscles relative to the pubic bones, is that the separated osseotendinous junctions are lifted forward (arrow) with consequent defunctioning of the external inguinal ring and formation of a "pre-hernia" complex.
INTRODUCTION
This program of research represents a series of sequential studies building on the experience gained from the previous study but all related to the common theme of using MR imaging to assess the causes of groin pain in professional soccer players. These studies were all carried out in Yorkshire (UK) between 1995 and 2001 using a standard imaging protocol (Table 11).

STUDY SEQUENCE
1. Correlation between pubic symphyseal, pubic bone and parasymphyseal soft tissue morphology and symptoms in soccer players
2. Correlation between pubic symphyseal, pubic bone and parasymphyseal soft tissue morphology and age in professional soccer players
3. Comparison of pubic symphyseal and pubic bone changes between professional soccer and professional rugby league players
4. Large retrospective cross-sectional study correlating pubic symphyseal, pubic bone and parasymphyseal soft tissue morphology and symptoms in professional soccer players
5. Extrapolation of study 1 as a large prospective study

6. Extrapolation of study 4 as a large prospective study

7. Correlation between pubic symphyseal, pubic bone and parasymphyseal soft tissue morphology and symptoms in professional soccer players who have undergone previous surgical groin repair

Table 11: MR Imaging Sequences

<table>
<thead>
<tr>
<th>Imaging Sequence</th>
<th>Imaging Plane (RF Coil Type - Patient Position)</th>
<th>TR</th>
<th>TE</th>
<th>TI</th>
<th>Field of View (mm)</th>
<th>Slice Thickness/Gap (mm)</th>
<th>Acquisition Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2-UTSE</td>
<td>Transverse - to body (Whole Body-Prone)</td>
<td>2544</td>
<td>100</td>
<td>220</td>
<td>220 / 1.1</td>
<td>9.0 / 0.9</td>
<td>2.07</td>
</tr>
<tr>
<td>STIR TSE</td>
<td>Coronal - to body (Whole Body-Prone)</td>
<td>1500</td>
<td>17</td>
<td>160</td>
<td>400 / 0.8</td>
<td>7.0 / 0.7</td>
<td>3.18</td>
</tr>
<tr>
<td>T1-TSE</td>
<td>Coronal - to sacrum (Spine-Supine)</td>
<td>445</td>
<td>14</td>
<td>320</td>
<td>320 / 1.3</td>
<td>4.0 / 0.4</td>
<td>2.54</td>
</tr>
<tr>
<td>T2-TSE SPIR</td>
<td>Transverse - to pelvic brim (Spine-Prone)</td>
<td>2269</td>
<td>120</td>
<td>220</td>
<td>220 / 1.4</td>
<td>6.0 / 0.6</td>
<td>2.20</td>
</tr>
<tr>
<td>T1-SE</td>
<td>Transverse - to pelvic brim (Spine-Prone)</td>
<td>570</td>
<td>14</td>
<td>220</td>
<td>220 / 1.4</td>
<td>6.0 / 0.6</td>
<td>5.29</td>
</tr>
<tr>
<td>T1- TSE SPIR*</td>
<td>Transverse - to pelvic brim (Spine-Prone)</td>
<td>484</td>
<td>16</td>
<td>220</td>
<td>220 / 1.4</td>
<td>6.0 / 0.6</td>
<td>8.14</td>
</tr>
</tbody>
</table>

* Post-intravenous injection of 10 mls of Dimeglumine Gadopentate (Magnavist, Schering, Germany) containing 469mg / ml.
Legend

TR   recovery time
TE   echo time
TI   inversion time
SE   spin echo
TSE  turbo spin echo
UTSE ultrafast turbo spin echo
STIR short “tau” inversion recovery
SPIR spectral inversion recovery
MRI STUDY 1:
CORRELATION BETWEEN PUBIC SYMPHYSEAL, PUBIC BONE AND PARASYMPHYSEAL SOFT TISSUE MORPHOLOGY AND SYMPTOMS IN SOCCER PLAYERS

Aims
1. To examine the morphology of the pubic symphysis, adjacent pubic bodies and the soft tissue structures inserting into them.
2. To correlate the MR imaging appearances of these structures with groin pain in amateur and professional soccer players.

Co-Workers
Dr. Martin Crowe (MC), Dr. Neil Jenkins (NJ) and Dr. Simon M Freeman (SMF) - all of whom were, at the time of study, Radiology Fellows at The General Infirmary at Leeds.

Subjects and Method
The control cohort was recruited from asymptomatic, non-athletic male volunteers within the Department of Radiology. Thirteen volunteers were found with a mean age of 30 years (range 26-35 years). The asymptomatic professional soccer players (n=11) were volunteers from a single English first division football club. The age of the players reflected difficulty in recruiting players with no previous history of groin pain. They had a mean age of 21 years (range 17-37 years) with a modal age of 18 years i.e. slightly younger than the symptomatic groups. The amateur symptomatic study cohort consisted of 11 keen amateur players (12 symptomatic groins) with a mean age of 30 years (range 18-41 years). The professional symptomatic group consisted of 47 consecutive professional soccer players (66 symptomatic groins) referred by 6 different professional clubs for investigation of groin pain over a 24 month period. These players had a mean age of 28 years (range 18-35 years).

All MR imaging studies were performed using a 1.5 Tesla unit (Philips Medical Systems, Best, NL). A standard imaging protocol was used throughout (Table 1). All studies were
analysed “blind” by 2 experienced radiologists (WWG, MC). Each MR imaging feature was evaluated using a 5-point scale.

0     Definitely no abnormality present
1     Probably no abnormality present
2     Equivocal as to whether an abnormality present
3     Abnormality probably present
4     Definitely an abnormality present

In cases where subsequent analysis demonstrated divergence of opinion a consensus result was achieved combining these results with those of 2 additional radiologists (NJ, SMF). Finally the consensus results were correlated with the subject data. Changes in the parasymphyseal bone marrow similar to those seen adjacent to vertebral end-plates in disc injury / degeneration were documented i.e. type 1 - marrow oedema, type 2 - fatty replacement, type 3 - bone sclerosis. Any anterior, posterior and / or superior symphyseal extrusion was also recorded as well as the presence and site of increased symphyseal fluid signal. A pre-hernia complex on MR imaging was defined as the presence on the axial scans of a small direct or indirect inguinal hernia or a focal bulging of the transversalis fascia at the level of the external ring and / or a tear in the anterior abdominal wall adjacent to that ring on coronal sequences. Any tears in the adductor muscle group, obturator externa, quadratus femoris etc. were also noted as well as any shearing injury to the conjoint rectus abdominis-common adductor aponeurotic insertions.

Cohen Kappa Coefficient values, for each observer relative to consensus result, were then calculated for 5 of the major MR imaging features from a random sample of 50 subjects (selected from across all cohorts).

Results

When compared to asymptomatic, non-athletic volunteers significant symphyseal and parasymphyseal degenerative changes are present in both asymptomatic and symptomatic professional soccer players (Tables 12 and 13).
Table 12: Correlation between Study Groups and Non-Lateralising Signs
[2-tail Wilcoxon Rank Sum / Mann-Whitney U-Test]

<table>
<thead>
<tr>
<th>Study Group</th>
<th>1+2</th>
<th>1+3</th>
<th>1+4</th>
<th>2+4</th>
<th>3+4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior Symphyseal Extrusion - Central</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Posterior Symphyseal Extrusion</td>
<td>p&lt;0.005</td>
<td>NS</td>
<td>p&lt;0.001</td>
<td>p&lt;0.05</td>
<td>p&lt;0.005</td>
</tr>
<tr>
<td>Superior Symphyseal Extrusion</td>
<td>p&lt;0.05</td>
<td>NS</td>
<td>p&lt;0.01</td>
<td>NS</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>Increased Symphyseal Signal - Central</td>
<td>p&lt;0.01</td>
<td>NS</td>
<td>p&lt;0.005</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Para-Symphyseal Bone Marrow Oedema</td>
<td>p&lt;0.005</td>
<td>NS</td>
<td>p&lt;0.001</td>
<td>NS</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>Para-Symphyseal Subchondral Cyst</td>
<td>NS</td>
<td>NS</td>
<td>p&lt;0.01</td>
<td>p&lt;0.05</td>
<td>p&lt;0.005</td>
</tr>
<tr>
<td>Bilateral Sacro-Iliac Joint Stress Phenomenon</td>
<td>p&lt;0.005</td>
<td>NS</td>
<td>p&lt;0.005</td>
<td>NS</td>
<td>p&lt;0.005</td>
</tr>
</tbody>
</table>

1. Non-athletic asymptomatic controls (n=13)
2. Asymptomatic professional soccer players (n=11)
3. Symptomatic amateur soccer players (n=11)
4. Symptomatic professional soccer players (n=47)

NB. Table 12 shows that there is no correlation between symptoms and the presence of appearances consistent with pubic degeneration on MR imaging but a strong correlation between such appearances and the playing of professional football.
Table 13: Correlation between Study Groups and Bone Marrow Changes
[2-tail Wilcoxon Rank Sum / Mann-Whitney U-Test]

<table>
<thead>
<tr>
<th>Study Group</th>
<th>1 and 2</th>
<th>1 and 3</th>
<th>1 and 4</th>
<th>2 and 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1 Parasymphseal Marrow Change</td>
<td>p&lt;0.05</td>
<td>NS</td>
<td>p&lt;0.05</td>
<td>NS</td>
</tr>
<tr>
<td>Type 1-3 Parasymphyseal Marrow Change</td>
<td>p&lt;0.01</td>
<td>NS</td>
<td>p&lt;0.001</td>
<td>NS</td>
</tr>
<tr>
<td>Type 3 Parasacroiliac Marrow Change</td>
<td>p&lt;0.001</td>
<td>NS</td>
<td>p&lt;0.001</td>
<td>NS</td>
</tr>
<tr>
<td>Type 1-3 Parasacroiliac Marrow Change</td>
<td>p&lt;0.005</td>
<td>NS</td>
<td>p&lt;0.005</td>
<td>NS</td>
</tr>
</tbody>
</table>

1. Non-athletic asymptomatic controls (n=13)
2. Asymptomatic professional soccer players (n=11)
3. Symptomatic amateur soccer players (n=11)
4. Symptomatic professional soccer players (n=47)

There was however, a significant increase in posterior symphyseal extrusion and parasymphyseal subchondral cyst formation possibly related to the older mean age of the symptomatic players presumably reflecting severity of symphyseal degeneration and inflammatory component. **Central anterior, posterior and superior symphyseal extrusion, increased symphyseal signal and all types of para-symphyseal or parasacroiliac marrow change although abnormal in non-athletes must be considered to be “normal” in professional soccer players and therefore cannot be assumed to be the cause of a player’s groin pain.** When considering “lateralising features” compared to the side of symptoms in professional soccer players there was a **significant association between symptoms and adductor origin shear injury, anterolateral pubic marrow oedema and anterolateral symphyseal high signal** (Table 14).
Table 14: Correlation between Symptomatic Side and Lateralisng Signs  
[Pearson Correlation Matrix]  

<table>
<thead>
<tr>
<th>Sign</th>
<th>SS</th>
<th>ASE</th>
<th>PSE</th>
<th>SSE</th>
<th>RAISI</th>
<th>CAISI</th>
<th>ASIS</th>
<th>ABME</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>p&lt;0.05</td>
<td>p&lt;0.05</td>
<td></td>
</tr>
<tr>
<td>ASE</td>
<td>NS</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>P&lt;0.01</td>
</tr>
<tr>
<td>PSE</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>p&lt;0.01</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>SSE</td>
<td>NS</td>
<td>NS</td>
<td>p&lt;0.01</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>PBME</td>
<td>NS</td>
<td>p&lt;0.01</td>
<td>p&lt;0.01</td>
<td>p&lt;0.01</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>PSC</td>
<td>NS</td>
<td>NS</td>
<td>p&lt;0.05</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>PHC</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>p&lt;0.05</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>RAISI</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>p&lt;0.01</td>
<td>p&lt;0.01</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>CAOSI</td>
<td>p&lt;0.01</td>
<td>p&lt;0.01</td>
<td>p&lt;0.05</td>
<td>NS</td>
<td>p&lt;0.01</td>
<td>*</td>
<td>p&lt;0.01</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>ASIS</td>
<td>p&lt;0.05</td>
<td>NS</td>
<td>NS</td>
<td>p&lt;0.01</td>
<td>p&lt;0.01</td>
<td>p&lt;0.01</td>
<td>*</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>ABME</td>
<td>p&lt;0.05</td>
<td>p&lt;0.01</td>
<td>NS</td>
<td>NS</td>
<td>p&lt;0.01</td>
<td>p&lt;0.01</td>
<td>p&lt;0.01</td>
<td>*</td>
</tr>
<tr>
<td>ASJSP</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

Symptomatic Side (SS)  
Anterolateral Symphyseal Extrusion (ASE)  
Posterior Symphyseal Extrusion (PSE)  
Superior Symphyseal Extrusion (SSE)  
Para-Symphyseal Bone Marrow Oedema (PBME)  
Para-Symphyseal Subchondral Cyst (PSC)  
Pre-Hernia Complex (PHC)  
Rectus Abdominis Insertion Shear Injury (RAISI)  
Common Adductor Origin Shear Injury (CAOSI)  
Anterolateral Symphysis Increased Signal (ASIS)  
Anterolateral Bone Marrow Oedema (ABME)  
Antero-Superior Sacro-Iliac Joint Stress Phenomenon (ASJSP)
If either an adductor origin or rectus abdominis aponeurotic pubic attachment shear injury was present there was a high probability of associated ipsilateral groin pain in the region (p<0.001). There was however no significant association with rectus abdominis shear injury alone but this is likely to reflect the small number of positive results (compared to adductor shear injury). There was also no statistically significant association between symptomatic side and unilateral increased signal in the anterolateral symphysis pubis, ipsilateral parasacroiliac marrow change nor anterolateral Modic-equivalent type 1 pubic marrow change. This latter absent correlation with anterolateral type 1 pubic marrow change is perhaps surprising as it would be expected at the site of soft tissue traction injury but this may simply reflect injury chronicity.

Interestingly of the 5 players asymptomatic at time of study but having lateralised MR imaging abnormality 3 have subsequently developed symptoms on that side within 18 months of initial study. Not surprisingly the 5 cases of acute muscle tears in the pelvic region all corresponded with the side of symptoms (3 adductor longus / brevis, 1 obturator externa and 1 quadratus femoris tear) although not reaching statistical significance using the Mann-Whitney test due to low positivity. Table 15 demonstrates the validity of using the assessed MR imaging features for the subsequent cross-sectional studies (for complete results of analysis using a range of nonparametric studies for 2x2 contingency tables – see Appendix 2). The Kappa values for observer 1, the more experienced of the two observers who carried out the bulk of subsequent analyses ranged from 0.8333 to 0.9533 showing a high degree of correlation with “gold standard” consensus results. The Kappa values for observer 2 were lower ranging from 0.5455 to 0.9083. The greatest discordance in terms of the latter observer was in the assessment of “Anterior Symphyseal Extrusion” which was also the lowest Kappa value for observer 1. In terms of “Posterior Symphyseal Extrusion”, “High Symphyseal Signal” and “Parasymphysisal RA +/- or CAO Enthesopathy” there were high Kappa values for both observers (range 0.8095 to 0.9533). Greatest concordance between observers occurred when assessing “High Symphyseal Signal” and “Posterior Symphyseal Extrusion”. These results suggest that assessment results produced by observer 1 should have a good correlation with those expected by the consensus result. Consequently, single observer results were used for subsequent studies.
Table 15: Cohen's Kappa Coefficient for Key MR Imaging Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Observer 1 (WG)</th>
<th>Observer 2 (MC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior Symphyseal Extrusion</td>
<td>0.8333</td>
<td>0.5455</td>
</tr>
<tr>
<td>Posterior Symphyseal Extrusion</td>
<td>0.9533</td>
<td>0.9083</td>
</tr>
<tr>
<td>High Symphyseal Signal</td>
<td>0.9151</td>
<td>0.8739</td>
</tr>
<tr>
<td>Parasymphysial RA +/-or CAO Enthesopathy</td>
<td>0.901</td>
<td>0.8095</td>
</tr>
<tr>
<td>Parasymphysial Bone Marrow Oedema</td>
<td>0.9436</td>
<td>0.7076</td>
</tr>
</tbody>
</table>
MRI STUDY 2:  
CORRELATION BETWEEN PUBIC SYMPHYSEAL, PUBIC BONE AND PARASYMPHYSEAL SOFT TISSUE MORPHOLOGY AND AGE IN PROFESSIONAL SOCCER PLAYERS

Aim
To assess whether the changes seen in the pubic symphysis, adjacent pubic bodies and the soft tissue structures inserting into them are age-related (i.e. whether they are “physiological” related to ageing rather than “pathological” related to symptoms).

Subjects and Method
The study group consisted of sixty-six consecutive professional soccer players with groin pain attending for MR imaging. There were 11 players between 16-20 years of age at presentation, 18 players between 21-25 years, 29 players between 26-30 years and 8 players over 30 years old.

Results
There was a strong association between player age >25 years and their having parasympyseal bone erosion / subchondral cyst formation and both posterior and anterior symphyseal extrusion at an even earlier age (Table 16).

There was no correlation between age of players and the presence of signs at non-midline anatomical site i.e. shearing / traction injury to the anterior pubic enthesal attachments, pre-hernia complex or marrow oedema on either left or right side (Table 17).

These was no significant correlation between symphyseal morphology and increased signal nor potential causes of anterior symphyseal / parasympyseal pain i.e. anterior symphyseal extrusion, adductor tendon enthesal injury nor pre-hernia complex formation (Table 18).
Table 16: Changes with age in professional footballers: Compression Injury
[2-tail Wilcoxon Rank Sum / Mann-Whitney U-Test]

<table>
<thead>
<tr>
<th>Comparison Groups</th>
<th>1 and 2</th>
<th>1 and 3</th>
<th>1 and 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior Symphyseal Extrusion</td>
<td>p=0.0452</td>
<td>p=0.1266</td>
<td>p=0.2477</td>
</tr>
<tr>
<td>Posterior Symphyseal Extrusion</td>
<td>p=0.0418</td>
<td>p=0.0533*</td>
<td>p=0.1372</td>
</tr>
<tr>
<td>Superior Symphyseal Extrusion</td>
<td>p=0.2244</td>
<td>p=0.8395</td>
<td>p=0.4090</td>
</tr>
<tr>
<td>Increased Symphyseal Signal</td>
<td>p=0.5545</td>
<td>p=0.5935</td>
<td>p=0.3637</td>
</tr>
<tr>
<td>Parasymphseal Marrow Change</td>
<td>p=0.8182</td>
<td>p=0.2175</td>
<td>p=0.3637</td>
</tr>
<tr>
<td>Parasymphseal Erosion / Cyst</td>
<td>p=0.1310</td>
<td>p=0.0011</td>
<td>p=0.0575*</td>
</tr>
<tr>
<td>Right Parasacrococcygeal Marrow Change</td>
<td>p=0.8182</td>
<td>p=0.0630</td>
<td>p=0.7726</td>
</tr>
<tr>
<td>Left Parasacrococcygeal Marrow Change</td>
<td>p=0.2786</td>
<td>p=0.4287</td>
<td>p=0.5089</td>
</tr>
</tbody>
</table>

* borderline significance

Age Group Number
1 16-20 11
2 21-25 18
3 26-30 29
4 30+ 8

Table 17: Changes with age in professional footballers: Enthesal Injury**

<table>
<thead>
<tr>
<th>Comparison Groups</th>
<th>1 and 2</th>
<th>1 and 3</th>
<th>1 and 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right RA and / or AO Shear Injury</td>
<td>p=0.6936</td>
<td>p=0.5076</td>
<td>p=0.3423</td>
</tr>
<tr>
<td>Left RA and / or AO Shear Injury</td>
<td>p=0.1396</td>
<td>p=0.3027</td>
<td>p=0.2312</td>
</tr>
<tr>
<td>Right Anterolateral Pubic Marrow Change</td>
<td>p=0.4905</td>
<td>p=0.3479</td>
<td>p=0.1604</td>
</tr>
<tr>
<td>Left Anterolateral Pubic Marrow Change</td>
<td>p=0.1783</td>
<td>p=0.6587</td>
<td>p=0.6203</td>
</tr>
<tr>
<td>Right Pre-hernia Complex</td>
<td>p=0.5327</td>
<td>p=0.4616</td>
<td>p=0.8365</td>
</tr>
<tr>
<td>Left Pre-hernia Complex</td>
<td>p=0.7427</td>
<td>p=0.7404</td>
<td>p=0.5633</td>
</tr>
</tbody>
</table>

** Statistical method and age-groups same as for table 15.
Table 18: Shearing Injury Relative to Symphyseal Morphology
[2-tail Wilcoxon Rank Sum / Mann-Whitney U-Test]

<table>
<thead>
<tr>
<th>Comparison Symphyseal Types</th>
<th>1 and 2</th>
<th>1 and 3</th>
<th>1 and 4</th>
<th>1 and 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Anterior Symphyseal Extrusion</td>
<td>p=0.7321</td>
<td>p=0.9168</td>
<td>p=0.1349</td>
<td></td>
</tr>
<tr>
<td>Left Anterior Symphyseal Extrusion</td>
<td>p=0.7879</td>
<td>p=0.5121</td>
<td></td>
<td>p=0.0092</td>
</tr>
<tr>
<td>Right Increased Symphyseal Signal</td>
<td>p=0.6598</td>
<td>p=0.6690</td>
<td>p=0.1939</td>
<td></td>
</tr>
<tr>
<td>Left Increased Symphyseal Signal</td>
<td>p=0.7321</td>
<td>p=0.3667</td>
<td></td>
<td>p=0.4066</td>
</tr>
<tr>
<td>Right RA and / or AO Shear Injury</td>
<td>p=0.3527</td>
<td>p=0.1597</td>
<td>p=0.1016</td>
<td></td>
</tr>
<tr>
<td>Left RA and / or AO Shear Injury</td>
<td>p=0.6422</td>
<td>p=0.1654</td>
<td></td>
<td>p=0.1880</td>
</tr>
<tr>
<td>Right Ant-lateral Pubic Marrow Change</td>
<td>p=0.2606</td>
<td>p=0.6690</td>
<td>p=0.0843</td>
<td></td>
</tr>
<tr>
<td>Left Ant-lateral Pubic Marrow Change</td>
<td>p=0.5906</td>
<td>p=0.7611</td>
<td></td>
<td>p=0.1786</td>
</tr>
<tr>
<td>Right Pre-hernia Complex</td>
<td>p=0.6076</td>
<td>p=0.1309</td>
<td>p=0.0592</td>
<td></td>
</tr>
<tr>
<td>Left Pre-hernia Complex</td>
<td>p=0.7692</td>
<td>p=0.7683</td>
<td></td>
<td>p=0.6266</td>
</tr>
</tbody>
</table>

### Symphyseal Type (n) (x) Range

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>(x)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>33</td>
<td>29.6</td>
<td>22 - 47</td>
</tr>
<tr>
<td>Type 2</td>
<td>4</td>
<td>20.5</td>
<td>17 - 29</td>
</tr>
<tr>
<td>Type 3</td>
<td>19</td>
<td>24.0</td>
<td>17 - 34</td>
</tr>
<tr>
<td>Type 4</td>
<td>7</td>
<td>27.4</td>
<td>18 - 35</td>
</tr>
<tr>
<td>Type 5</td>
<td>3</td>
<td>27.3</td>
<td>22 - 30</td>
</tr>
</tbody>
</table>

Configurations of the Symphysis Pubis

Type 1

Type 2

Type 3

Type 4

NB Type 5 is mirror image of Type 4, Type 2 is “normal” in young adolescents
MRI STUDY 3:
COMPARISON OF PUBIC SYMPHYSEAL AND PUBIC BONE CHANGES BETWEEN PROFESSIONAL SOCCER AND PROFESSIONAL RUGBY LEAGUE PLAYERS

Aim
To assess whether the changes seen in the pubic symphysis, adjacent pubic bodies and the soft tissue structures inserting into them, are specific to professional soccer players or are similar to changes seen in other types of professional “footballers”.

Subjects and Method
The control group was recruited from asymptomatic, non-athletic male volunteers within the department of radiology. Thirteen volunteers were found with a mean age of 30 years (range 26-35 years). The asymptomatic professional soccer players (n=12) were volunteers from a single first division football club. The age of the players reflected difficulty in recruiting players with no previous history of groin pain. They had a mean age of 21 years (range 17-37 years) with a modal age of 18 years i.e. slightly younger than the symptomatic groups. The symptomatic group consisted of 25 consecutive professional soccer players referred by 4 different professional clubs for investigation of groin pain over a 12 month period. These players had a mean age of 27 years (range 18-35 years) reflecting the age of professional footballers in England. In addition an age matched group of symptomatic professional rugby league players were scanned (n=16, mean age 29 years, range 23-33 years) to assess whether the changes seen in symptomatic soccer players were unique to soccer or were also seen in similar high body-contact sports.

The same protocol was used as for Study 1. All studies were again analysed “blind” by 2 experienced radiologists (WWG, MC). Each MR imaging feature was evaluated using a 5-point scale. In cases where subsequent analysis demonstrated divergence of opinion, a consensus result was achieved combining these results with those of 2 additional experienced radiologists (NJ, SMF). Finally the consensus results were correlated with the subject data.
NB. Ideally, this study should also have included a cohort of asymptomatic rugby league players. However, this was not possible due to logistical reasons, it not being possible to obtain a group of volunteers in the way it was possible for professional soccer where overall player numbers and clinical contacts were greater.

**Results**

When compared to asymptomatic, non-athletic volunteers using the Mann-Whitney test significant symphyseal and parasymphyseal changes were present in both professional soccer and rugby players (Table 19). There was however, no significant difference between these asymptomatic professional soccer players and symptomatic professional rugby players. There was also no significant difference in incidence of changes when symptomatic professional soccer players were compared to symptomatic professional rugby players.

*Anterior, posterior and superior symphyseal extrusion, increased symphyseal signal, all types of parasymphyseal marrow change and Modic-equivalent type 3 parasacroiliac marrow change although abnormal in non-athletes must be considered to be “normal” in professional footballers whether soccer or rugby league.*

This study again shows that there is no correlation between symptoms and the presence of appearances consistent with pubic degeneration on MR imaging but a strong correlation between such appearances and the playing of professional football whether association footfall or rugby league.
Table 19: Changes Related to Professional Sporting Activity – Comparison between Soccer and Rugby League Footballers

[2-tail Wilcoxon Rank Sum / Mann-Whitney U-Test]

<table>
<thead>
<tr>
<th>Comparison Groups</th>
<th>1 and 2</th>
<th>1 and 3</th>
<th>1 and 4</th>
<th>2 and 3</th>
<th>2 and 4</th>
<th>3 and 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior Symphyseal Extrusion</td>
<td>p=0.0415</td>
<td>p=0.0278</td>
<td>p=0.0201</td>
<td>p=0.1314</td>
<td>p=0.1145</td>
<td>p=0.8411</td>
</tr>
<tr>
<td>Posterior Symphyseal Extrusion</td>
<td>p=0.0023</td>
<td>p&lt;0.0001</td>
<td>p=0.0004</td>
<td>p=0.0478</td>
<td>p=0.1314</td>
<td>p=0.5565</td>
</tr>
<tr>
<td>Superior Symphyseal Extrusion</td>
<td>p=0.0387</td>
<td>p=0.0017</td>
<td>p=0.0460</td>
<td>p=0.1944</td>
<td>p=0.8892</td>
<td>p=0.1949</td>
</tr>
<tr>
<td>Increased Symphyseal Signal</td>
<td>p=0.0039</td>
<td>p=0.0023</td>
<td>p=0.0014</td>
<td>p=0.6380</td>
<td>p=0.4862</td>
<td>p=0.2732</td>
</tr>
<tr>
<td>Type 1 Parasympyseal Marrow Change</td>
<td>p=0.0414</td>
<td>p=0.0210</td>
<td>p=0.0334</td>
<td>p=0.6037</td>
<td>p=0.6761</td>
<td>p=0.5565</td>
</tr>
<tr>
<td>Type 1-3 Parasymp. Marrow Change</td>
<td>p=0.0098</td>
<td>p=0.0003</td>
<td>p=0.0004</td>
<td>p=0.8839</td>
<td>p=0.4300</td>
<td>p=0.3427</td>
</tr>
<tr>
<td>Subchondral Erosion or Cyst</td>
<td>p=0.6635</td>
<td>p=0.0393</td>
<td>p=0.0201</td>
<td>p=0.0947</td>
<td>p=0.0601</td>
<td>p=0.9680</td>
</tr>
<tr>
<td>Type 3 Par sacroiliac Marrow Change</td>
<td>p=0.0006</td>
<td>p=0.0008</td>
<td>p=0.0393</td>
<td>p=0.6614</td>
<td>p=0.1637</td>
<td>p=0.0800</td>
</tr>
<tr>
<td>Type 1-3 Par sacroiliac Marrow Change</td>
<td>p=0.0011</td>
<td>p=0.0040</td>
<td>p=0.0913</td>
<td>p=0.7456</td>
<td>p=0.1501</td>
<td>p=0.1059</td>
</tr>
</tbody>
</table>

Group 1  Asymptomatic non-athletic volunteers  n = 13
Group 2  Asymptomatic professional soccer players  n = 12
Group 3  Symptomatic professional soccer players  n = 25
Group 4  Symptomatic professional rugby players  n = 16
MRI STUDY 4:
A LARGE RETROSPECTIVE CROSS-SECTIONAL STUDY CORRELATING PUBIC SYMPHYSEAL, PUBIC BONE AND PARASYMPHYSEAL SOFT TISSUE MORPHOLOGY AND SYMPTOMS IN PROFESSIONAL SOCCER PLAYERS

Aims
To perform a retrospective study of a large cohort of professional soccer players to see whether a correlation exists between the morphology of the pubic symphysis, adjacent pubic bodies and the soft tissue structures inserting into them and symptoms.

Subjects and Method
A retrospective study was performed of 135 consecutive Professional Footballers with chronic groin pain (greater than 4 weeks duration) examined over a 24 month period. (Initially, there were 143 professional soccer players referred to our department but 8 players with a sub-acute muscle tear as cause of their groin pain were excluded from the study). The MR imaging appearances were compared with 30 asymptomatic professional soccer players.

All MR imaging studies were performed using the same imaging protocol. The players were referred from 22 English and Scottish League Clubs. The average age of the players was 26.8 years (range 17-39 years). There were 84 with unilateral symptomatic groins (right 42, left 42) and 51 players in whom both groins were symptomatic.

Twenty-six symptomatic players had evidence of previous surgical groin repair of which 9 players had bilateral repairs (i.e. a total of 35 repairs were seen of which 23 were right sided and 12 left sided repairs).

Results
In the 135 professional soccer players with groin pain 123 had evidence of a rectus abdominis pubic insertion injury, common adductor origin injury or both (Table 20). Such changes were seen in 65 of the 66 players with bilateral symptoms and 73 of the symptomatic groins of the 84 players with unilateral symptoms. A complete avulsion of the
common adductor origin was present in 10 (6%) of these shearing injuries. An entheseal injury was also, however, seen at these sites on 22 of the asymptomatic contralateral sides in these 84 unilaterally symptomatic footballers. In 8 of the 60 asymptomatic players there was evidence of RA-CAO injury.

In the 12 players where no such injury was found, an alternative diagnosis was found in 6 players (1 with bilateral and 5 with unilateral symptoms). An L4/5 lumber disc herniation was found in 3 players. In 2 further players the coronal imaging of the sacro-iliac joints demonstrated an L5 lysis or L4 ununited stress fracture of their pars inter-articularis but both of these players also had a common adductor origin ± rectus abdominis shear injury to explain their groin pain.

Another symptomatic player without RA-CAO changes had MR evidence of an indirect inguinal hernia to explain their groin pain. In addition a direct inguinal hernia or “pre-hernia complex” evidenced by conjoint tendon tear, bulging transversalis fascia at the level of the external inguinal ring was present unilaterally in 12 (8%) symptomatic players and bilaterally in one further player. All of these had evidence of RA-CAO changes on MR examination. When considering the 12 groins exhibiting a direct inguinal hernia or “pre-hernia complex” 11 (79%) exhibited features of a rectus abdominis shear injury whilst 7 (50%) had a CAO shear injury. An indirect inguinal hernia was present in 2 players, one of whom was a symptomatic player without RA-CAO changes.

Hip osteoarthritis (OA) with synovitis was found on the symptomatic side in another 2 players without RA-CAO injury. Hip joint OA with synovitis was also found in 5 more players, 3 on the asymptomatic side and on the symptomatic side where a pubic entheseal abnormality was noted to concurrently exist. The mean age of these players with hip OA was only 28 years with the youngest being 25 years of age. One of the players in addition to the synovitis had evidence of an acetabular labral tear and labral cyst formation. A true osteitis pubis is unusual and in the current study was only seen in 4 (3%) players. All of these patients had associated CAO-RAI shear injury. None of the players currently being
reviewed were found to have a pubic osteomyelitis. In 6 players no cause for groin pain was identified.

Premature pubic symphyseal degenerative or parasympphyseal stress changes were seen in all but 2 of the players (1.5%). Posterior symphyseal extrusion was seen in 123 players (86%), parasympphyseal marrow changes in 119 (83%) and subchondral cyst formation in 66 (46%) players.

Twenty-six of these 135 players (19%) were still symptomatic having undergone previous surgical groin repair. This represented 35 repairs (right 23, left 12). In these players MR imaging demonstrated a combined RA-CA origin injury in 25 (71%), isolated RA entheseal injury in 3 (9%), isolated CA origin injury in 2 (6%) and RA-CA origin injury combined with “true” osteitis pubis in one player (3%). Two of the players who had MR imaging evidence of a CAO injury demonstrated complete tendon avulsions. A residual / recurrent indirect hernia was seen in only 5 symptomatic groins (14%). No abnormality was detected apart from post-surgical change in 4 soccer players (11%). These otherwise normal groins constituted 67% of all of the symptomatic groins and no convincing cause for ongoing symptoms was identified.

MR imaging was able to demonstrate a RA-CAO shear injury in the symptomatic groin of professional soccer players with a Chi-Square-Independence Test value of 200.4368, \( p < 0.0001 \) and a Cohen’s Kappa Coefficient of 0.7823, \( p < 0.0001 \) (Table 21).
Table 20: The Incidence of RA-CAO Injury in Professional Soccer Players with Groin Pain (n = 270 groins)

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Right</th>
<th>Left</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isolated CAO shear injury</td>
<td>34</td>
<td>37</td>
<td>71</td>
</tr>
<tr>
<td>Isolated RA shear injury</td>
<td>17</td>
<td>22</td>
<td>39</td>
</tr>
<tr>
<td>Combined CAO-RA shear injury</td>
<td>47</td>
<td>38</td>
<td>85</td>
</tr>
<tr>
<td>Total</td>
<td>98</td>
<td>97</td>
<td>195*</td>
</tr>
</tbody>
</table>

*Of which 21 were asymptomatic

Table 21: MR Imaging Demonstration of a RA-CAO Injury as a Predictor of Groin Pain in Professional Soccer Players

(n=165 including 135 symptomatic and 30 asymptomatic players, 195 abnormal groins)

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>RA-CAO unit injury</th>
<th>No RA-CAO unit injury</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptomatic groin</td>
<td>173</td>
<td>13</td>
<td>186</td>
</tr>
<tr>
<td>Asymptomatic groin</td>
<td>30</td>
<td>114</td>
<td>144</td>
</tr>
<tr>
<td>Total</td>
<td>203</td>
<td>127</td>
<td>330</td>
</tr>
</tbody>
</table>

Chi-Square-Independence: 200.4368  p < 0.0001  
Cohen’s Kappa Coefficient: 0.7823  p < 0.0001
MRI STUDY 5:  
EXTRAPOLATION OF MRI STUDY 1 AS A LARGE PROSPECTIVE STUDY

Aim
To perform a large prospective study of soccer players in order to correlate the morphology of the pubic symphysis, adjacent pubic bodies and the soft tissue structures inserting into them with symptoms of groin pain.

Subjects and Method
MRI examinations were performed on 143 male professional soccer players (mean age 27 years, range 16-38 years) who presented over a 24 month period complaining of chronic groin pain. The results were compared with 3 different control groups: 15 asymptomatic, non-athletic male volunteers (mean age 30 years, range 26-35 years), 15 asymptomatic professional soccer players (mean age 21.0 years, range 17-37 years) and 15 symptomatic, low level amateur soccer players (mean age 28.2 years, range 18-41 years).

Results
There was a strong correlation between being a professional soccer player and pubic symphyseal and parasymphyseal changes (p<0.005 – p<0.001) but not with symptoms (not significant at p>0.005) (Table 22). Some of these changes such as posterosuperior symphyseal extrusion and para-symphyseal subchondral cyst formation were, however, slightly more marked in symptomatic compared to asymptomatic professional players (p<0.05). Parasymphyseal and para-sacroiliac joint “stress” changes were not significant at p>0.05.

When considering the correlation between control study groups and CAO and / or RA shear injury such an injury was present in 123 of 143 (86%) symptomatic professional soccer players and 4 of 15 (27%) asymptomatic professional players. At 3 years follow-up all 4 had subsequently developed groin symptoms sufficient to merit surgery. Conversely there was no evidence of CAO or RA injury in either the 15 symptomatic amateur soccer players or the 15 non-athletic asymptomatic controls.
Table 22: Correlation between control study groups and non-lateralising signs
(2-Tail Mann-Whitney Test)

<table>
<thead>
<tr>
<th></th>
<th>1+2</th>
<th>1+3</th>
<th>1+4</th>
<th>2+4</th>
<th>3+4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterosuperior Symphyseal Extrusion</td>
<td>p&lt;0.005</td>
<td>NS</td>
<td>p&lt;0.001</td>
<td>p&lt;0.05</td>
<td>p&lt;0.005</td>
</tr>
<tr>
<td>Para-Symphysis Bone Marrow Oedema</td>
<td>p&lt;0.005</td>
<td>NS</td>
<td>p&lt;0.001</td>
<td>NS</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>Para-Symphysisal Subchondral Cyst</td>
<td>NS</td>
<td>NS</td>
<td>p&lt;0.01</td>
<td>p&lt;0.05</td>
<td>p&lt;0.005</td>
</tr>
<tr>
<td>Bilateral Sacro-Iliac Joint Stress Phenomenon</td>
<td>p&lt;0.005</td>
<td>NS</td>
<td>p&lt;0.005</td>
<td>NS</td>
<td>p&lt;0.005</td>
</tr>
</tbody>
</table>

1. Non-athletic asymptomatic controls (n=15)
2. Asymptomatic professional soccer players (n=15)
3. Symptomatic amateur soccer players (n=15)
4. Symptomatic professional soccer players (n=143)
MRI STUDY 6:
EXTRAPOLATION OF MRI STUDY 4 AS A LARGE PROSPECTIVE STUDY

Aims
1. To perform a prospective study of the correlation between rectus abdominis and common adductor origin changes and whether they are functionally interlinked in symptom generation.
2. To correlate parasacroiliac joint changes and groin symptoms.
3. To assess the diagnostic accuracy of MR imaging in professional soccer with groin pain.

Subjects and Methods
The control cohort was recruited from asymptomatic, non-athletic male volunteers within the department of radiology. Eighteen volunteers were found with a mean age of 30.5 years (range 24-39 years, modal age 29.5 years). The asymptomatic professional soccer players (n=11) were volunteers from a single English first division football club. The age of the players reflected difficulty in recruiting players with no previous history of groin pain. They had a mean age of 19 years (range 17-27 years) with a modal age of 18 years i.e. slightly younger than the symptomatic groups (for logistical reasons part of this cohort included players from MR Study 1 as they had been enrolled retrospectively at time of examination of suspected non-groin related pathology). The amateur symptomatic study cohort consisted of 31 keen amateur players with a mean age of 30 years (range 16-39 years, modal age 31 years). The professional symptomatic group consisted of 174 consecutive professional soccer players referred by 22 different professional clubs for investigation of groin pain over a 36 month period. These players had a mean age of 26.5 years (range 17-39 years, modal age 27 years).

All studies were performed on a 1.5 Tesla MRI system using the standard departmental imaging sequence proforma for pelvic disease which included the routine administration of intravenous Gadolinium-DTPA as a contrast agent. In the context of the study “asymptomatic” refers to subjects undergoing clinical MRI studies of the pelvis for symptomatic conditions not related to the groin, parasymphysseal pain or any other
recognised cause for such. The remaining patient cohorts were patients prospectively referred to the same Medical Imaging Department for MR imaging assessment of their chronic groin pain. These cohorts built upon those in Study 5 but were modified depending on whether the region was seen in sufficient standardisation and detail and for definitive scoring purposes. Entry criteria for the asymptomatic non-athletic volunteer controls and asymptomatic professional soccer players included them not having any previous groin pain lasting for more than 7 days. Entry criteria for the symptomatic amateur and professional soccer players included an absence of groin pain lasting for more than 6 weeks. Patients with a history of previous groin surgery were also excluded from the study (see Study 7). Therefore, the players included in the study were not strictly consecutive in terms of referral but were consecutive in terms of patients with matching entry criteria and who had MR studies suitable for full analysis. All MRI studies were evaluated by the same investigator (WG) without any knowledge of clinical findings at time of assessment. Imaging features were evaluated by the same “blind” investigator on 2 separate occasions >6 months apart and a consensus value recorded.

MR imaging criteria for assessment of symphyseal degeneration included: anterior or posterior symphyseal extrusion, subchondral cyst formation, subarticular marrow changes (equivalent to Modic type 1-3 changes seen in vertebral bodies). Criteria for assessment of entheseal injury included: subentheseal marrow oedema or hyperaemia, granulation tissue or fluid dissection between a tendon insertion and underlying pubis (reflecting acute or chronic entheseal separation), peritendinous oedema or hyperaemia. Criteria were assessed using the same 5-point scale as in Study 1. In terms of scoring, a positive result was recorded if a feature was unequivocally present i.e. only a score of 3 and 4 were taken as a positive result. However, if any feature was noted as being positive in any particular area i.e. pubic symphysis, parasympyseal bone, para-sacroiliac joints, rectus abdominis insertion, common adductor origin, hips joints or inguinal region then it was taken as being a positive result overall for that bony region / pathological process.
Results

With regards to the pubic region:
- there was a strong correlation between pubic symphyseal / parasymphyseal changes and being a professional soccer player (Table 23)
- there was no correlation between changes in these regions and groin symptoms when comparing amateur and professional soccer players
- symphyseal changes reflected intensity of participation in soccer rather than the cause of symptoms.

With regards to the pubic entheseal insertions of RA and CAO:
- a strong correlation existed between the presence of CAO or RA changes and the side of symptoms (Table 24 and Table 25)
- a pathogenic link existed between these two structures (Table 26).

With regards to the sacro-iliac joints:
- a strong correlation existed between para-sacroiliac joint changes and changes in the contralateral para-sacroiliac joint region (Table 27 and Table 28)
- a weaker correlation existed between para-sacroiliac joint changes and changes in the pubic symphyseal region
- no correlation existed between para-sacroiliac joint changes and age (there was also no correlation between symphyseal changes and age).

With regards to MR imaging as an imaging tool this appeared to be an accurate way of diagnosing the cause of groin pain in professional soccer players (Table 29).
Table 23: Symphyseal / Parasymphyseal Changes in Soccer Players
(2-tailed Mann Whitney U-test)

The correlation reflects whether any demonstrable changes are present at symphyseal or parasymphyseal sites to suggest a structural abnormality secondary to sports-related injury relative to the level at which soccer has been played.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>x</td>
<td>p=0.0104</td>
<td></td>
<td>p&lt;0.0001</td>
</tr>
<tr>
<td>2</td>
<td>p=0.0104</td>
<td>x</td>
<td>p=0.0109</td>
<td>p=0.0121</td>
</tr>
<tr>
<td>3</td>
<td>p=0.7244</td>
<td>p=0.0109</td>
<td>x</td>
<td>p&lt;0.0001</td>
</tr>
<tr>
<td>4</td>
<td>p&lt;0.0001</td>
<td>p=0.0121</td>
<td>p&lt;0.0001</td>
<td>x</td>
</tr>
</tbody>
</table>

1. non-athletic asymptomatic controls
2. asymptomatic professional soccer players
3. symptomatic amateur soccer players
4. symptomatic professional soccer players

Table 24: Severity of Changes Present at the RA and CAO Pubic Entheses.
(n-= number of groins)

The grading reflects a 4-point scale where:

Mild changes = an abnormality is only just demonstrable but definitely present
Moderate changes = changes are clearly identifiable
Severe changes = florid changes are present ± partial or complete enthesal avulsion

<table>
<thead>
<tr>
<th></th>
<th>Right CAO (n)</th>
<th>Right RA (n)</th>
<th>Left CAO (n)</th>
<th>Left RA (n)</th>
<th>Symphysis (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No abnormality</td>
<td>104</td>
<td>134</td>
<td>117</td>
<td>166</td>
<td>60</td>
</tr>
<tr>
<td>Mild Changes</td>
<td>39</td>
<td>45</td>
<td>40</td>
<td>33</td>
<td>46</td>
</tr>
<tr>
<td>Moderate Changes</td>
<td>70</td>
<td>47</td>
<td>61</td>
<td>32</td>
<td>118</td>
</tr>
<tr>
<td>Severe Changes / Avulsion</td>
<td>21</td>
<td>8</td>
<td>16</td>
<td>3</td>
<td>10</td>
</tr>
</tbody>
</table>
Table 25: Symptomatic Side Versus Lateralising Changes

(2-tailed Mann Whitney U-test)

Lateralisignsconstitutechangesattheenthesesormusclesononeormoreside(includingtear),pubicbonechangesawayfromtheimmediateparasymphysialregionordefinesymphysialcleftextensiontoone sideorboth.

<table>
<thead>
<tr>
<th>Symptomatic Side</th>
<th>Right CAO</th>
<th>Right RA</th>
<th>Left CAO</th>
<th>Left RA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>p&lt;0.0001*</td>
<td>p=0.0004*</td>
<td>p=0.3061</td>
<td>p=0.6771</td>
</tr>
<tr>
<td>Left</td>
<td>p=0.0247</td>
<td>p=0.2635</td>
<td>p&lt;0.0001*</td>
<td>p=0.0048*</td>
</tr>
<tr>
<td>Bilateral</td>
<td>p=0.0002*</td>
<td>p&lt;0.0001*</td>
<td>p&lt;0.0001*</td>
<td>p=0.0003*</td>
</tr>
</tbody>
</table>

* significant at p<0.005

Table 26: Co-correlation with CAO - RA changes

(Spearman Rank Correlation Coefficient - Spearman Rho)

Cross-correlation of the lateralising changes described in Table 25 relative to ipsilateral and contralateral rectus abdominis and common adductor tendon pubic entheses (including the adjacent pubic bones).

<table>
<thead>
<tr>
<th></th>
<th>Right CAO</th>
<th>Right RA</th>
<th>Left CAO</th>
<th>Left RA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right CAO</td>
<td>x</td>
<td>p=0.5093</td>
<td>p=0.2857</td>
<td>p=0.1294</td>
</tr>
<tr>
<td>Right RA</td>
<td>p=0.5093</td>
<td>x</td>
<td>p=0.1363</td>
<td>p=0.4404</td>
</tr>
<tr>
<td>Left CAO</td>
<td>p=0.2857</td>
<td>p=0.1363</td>
<td>x</td>
<td>p=0.4509</td>
</tr>
<tr>
<td>Left RA</td>
<td>p=0.1294</td>
<td>p=0.4404</td>
<td>p=0.4509</td>
<td>x</td>
</tr>
</tbody>
</table>

Where:

+1 perfect direct relationship
-1 perfect inverse relationship
0 no relationship
Table 27: Para-Sacroiliac Joint Changes Relative to Sport
(2-tailed Mann Whitney U-test)

The correlation reflects whether any demonstrable changes are present at the sacroiliac joints or parasacroiliac sites to suggest a structural abnormality secondary to sports-related injury relative to the level at which soccer has been played.

### Right sided changes

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>x</td>
<td>p=0.003</td>
<td>p=0.4937</td>
<td>p&lt;0.0001</td>
</tr>
<tr>
<td>2</td>
<td>p=0.003</td>
<td>x</td>
<td>p=0.004</td>
<td>p=0.9329</td>
</tr>
<tr>
<td>3</td>
<td>p=0.4937</td>
<td>p=0.004</td>
<td>x</td>
<td>p&lt;0.0001</td>
</tr>
<tr>
<td>4</td>
<td>p&lt;0.0001</td>
<td>p=0.9329</td>
<td>p&lt;0.0001</td>
<td>x</td>
</tr>
</tbody>
</table>

### Left sided changes

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>x</td>
<td>p=0.0104</td>
<td>p=0.9174</td>
<td>p=0.0008</td>
</tr>
<tr>
<td>2</td>
<td>p=0.0104</td>
<td>x</td>
<td>p=0.0027</td>
<td>p=0.362</td>
</tr>
<tr>
<td>3</td>
<td>p=0.9174</td>
<td>p=0.0027</td>
<td>x</td>
<td>p&lt;0.0001</td>
</tr>
<tr>
<td>4</td>
<td>p=0.0008</td>
<td>p=0.362</td>
<td>p&lt;0.0001</td>
<td>x</td>
</tr>
</tbody>
</table>

1. non-athletic asymptomatic controls
2. asymptomatic professional soccer players
3. symptomatic amateur soccer players
4. symptomatic professional soccer players
Table 28: Correlation with Para-Sacroiliac Joint Changes
(Spearman Rank Correlation Coefficient - Spearman Rho)

The correlation reflects whether *any* demonstrable changes are present at symphyseal or parasymphyseal sites (and sacroiliac joint regions) to suggest a structural abnormality secondary to sports-related injury relative to changes being demonstrable at one or other sacroiliac joints.

<table>
<thead>
<tr>
<th>Site of Changes for Correlation</th>
<th>Right Para-Sacroiliac Joint Changes</th>
<th>Left Para-Sacroiliac Joint Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.1639</td>
<td>-0.1198</td>
</tr>
<tr>
<td>Symphysis Pubis</td>
<td>0.4240</td>
<td>0.3911</td>
</tr>
<tr>
<td>Right CAO</td>
<td>0.2595</td>
<td>0.2505</td>
</tr>
<tr>
<td>Right RA</td>
<td>0.2993</td>
<td>0.2874</td>
</tr>
<tr>
<td>Left CAO</td>
<td>0.3538</td>
<td>0.3525</td>
</tr>
<tr>
<td>Left RA</td>
<td>0.2226</td>
<td>0.2323</td>
</tr>
<tr>
<td>Contralateral SI Joint</td>
<td>0.8138</td>
<td>0.8138</td>
</tr>
</tbody>
</table>

+1 perfect direct relationship
-1 perfect inverse relationship
0 no relationship
Table 29: Accuracy of MR Imaging in Diagnosing the Cause of Groin Pain in Soccer Players - Overall Test Results

<table>
<thead>
<tr>
<th></th>
<th>Uncorrected (n)</th>
<th>Corrected (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>True +ve</td>
<td>223</td>
<td>228</td>
</tr>
<tr>
<td>True -ve</td>
<td>127</td>
<td>130</td>
</tr>
<tr>
<td>False +ve</td>
<td>54</td>
<td>49</td>
</tr>
<tr>
<td>False -ve</td>
<td>68</td>
<td>65</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Uncorrected (%)</th>
<th>Corrected (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>77%</td>
<td>78%</td>
</tr>
<tr>
<td>Specificity</td>
<td>70%</td>
<td>73%</td>
</tr>
<tr>
<td>Positive Predictive Value</td>
<td>81%</td>
<td>82%</td>
</tr>
<tr>
<td>Negative Predictive Value</td>
<td>65%</td>
<td>67%</td>
</tr>
<tr>
<td>Accuracy</td>
<td>74%</td>
<td>76%</td>
</tr>
</tbody>
</table>

“Corrected” reflects:
3 subjects with normal para-symphyseal regions but hip OA seen on the ipsilateral side, and
5 professional soccer players who were asymptomatic at time of study and who
subsequently became symptomatic.
MRI STUDY 7:
CORRELATION BETWEEN PUBIC SYMPHYSEAL, PUBIC BONE AND PARASYMPHYSEAL SOFT TISSUE MORPHOLOGY AND SYMPTOMS IN PROFESSIONAL SOCCER PLAYERS WHO HAVE UNDERGONE PREVIOUS SURGICAL GROIN REPAIR

Aim
To assess whether MR imaging can show abnormal changes at the rectus abdominis and common adductor origins in professional soccer players which correlate with persistent symptoms following surgical groin repair.

Subjects and Method
Thirty six professional soccer players (age range 19-36yrs, mean 25yrs) from 16 clubs were examined over a 36 month period. In all, 54 of the groins had undergone previous repair of which 49 (14 unilateral right, 9 unilateral left, 13 bilateral symptomatic repairs) were still symptomatic 3-9 months following surgery (mean 4.5 months). Five players with previous bilateral repairs had asymptomatic repairs on one side and a symptomatic repair on the contralateral side. All surgical groin repairs were performed for a “sportsman’s hernia”. There had been 32 laparoscopic and 24 “open” repairs previously carried out on these 36 players.

The players were examined on a 1.5 Tesla system and a standard MR imaging protocol was used throughout. The protocol included small field-of-view fat suppressed T2-weighted and fat suppressed T1-weighted post intravenous Gadolinium-DTPA sequences performed parallel to the “true” pelvis specifically centred on the inguinal regions.

Abnormalities at the pubic enthesal insertions of RA and CAO were assessed using a 4-point scale.

0 Normal appearances
1 Mild changes of enthesal injury
2 Moderately severe changes of enthesal injury
3 Severe changes of enthesal injury or enthesal avulsion
All studies were assessed by the same observer (WG) “blind” as to which groins were still symptomatic. Ten asymptomatic groins following repair in non-athletes were included in the study list to avoid bias where only one side was operated upon previously.

**Results**

Abnormal changes were present at both the ipsilateral RA and CAO in 30 symptomatic groins, isolated changes at the CAO in 8 and isolated changes at the RA insertion in a further 3 groins (Table 30). No cause for pain was found in the peripubic symphyseal region in 3 groins. Further imaging in these 3 players, however, showed there was hip joint synovitis secondary to early osteoarthrosis present on the same side as 2 symptomatic groins and lower lumbar spondylolysis was found in another symptomatic player. **In no player was there evidence of a residual / recurrent inguinal hernia i.e. the repairs had been surgically “successful” even though symptoms remained.**

**Table 30: MR Imaging Appearances in the Symptomatic Groins Following Surgical Repair**

(n= number of groins)

<table>
<thead>
<tr>
<th></th>
<th>Right CAO</th>
<th>Right RA</th>
<th>Left CAO</th>
<th>Left RA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal appearances</td>
<td>3</td>
<td>8</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Mild changes</td>
<td>6</td>
<td>7</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Moderate changes</td>
<td>14</td>
<td>9</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Severe Changes / Avulsion</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>
MRI STUDY 8
PILOT THERAPEUTIC STUDY OF ULTRASOUND - GUIDED PERCUTANEOUS PUBIC SYMPHYSEAL STEROID INJECTION IN PROFESSIONAL SOCCER PLAYERS FOLLOWING PATIENT SELECTION USING MR IMAGING CRITERIA

Aim
To show how symphyseal steroid injection improves symptoms in professional soccer players who have MR imaging and clinical evidence of chronic injury at their common adductor pubic origins.

Subjects and Method
Twenty-five consecutive players in whom ultrasound (US)-guided symphyseal steroid injection was performed were included in the study. MR imaging in all cases had shown evidence of RA + / or CAO enthesopathy. All of the players had been already listed for adductor tenotomy, herniorraphy or other surgical reconstruction procedure to the groin region. The mean age of the players was 25 years (range 18 – 32 years). The mean follow-up was 11 months (range 6 – 22 months). Injections were performed using a 22G, 10cm spinal needle performed by a superior approach (Fig. 44). A small (26mm) footprint 5-10 MHz variable frequency transducer was used for needle guidance. Injections were performed using an aseptic technique and local anaesthesia (Lignocaine HCL 2%, 10-15mls). Triamcinolone (40mg in 1ml) was injected directly into the central cleft of the symphysis pubis (present in all cases). The intention was to leave the injected fluid pooled in the false space produced by the antero-lateral propagation of the degenerative symphyseal cleft. This was to allow the deposited fluid to remain at the site of enthesal injury rather than run the risk of intratendinous injection.

Results
There were no initial complications of the procedure. 14 of the 25 players (56%) did not require surgery and were able to return to full sporting activity at time of follow-up. Two players who were initially asymptomatic had subsequent sudden avulsions at their adductor origins at 8 and 10 weeks respectively. However, on subsidence of initial acute
symptoms all chronic symptoms remained cured in both of these players suggesting an effective “auto-tenotomy” had occurred.

Figure 44: Technique for Ultrasound-Guided Pubic Symphyseal Steroid Injection
A) MR imaging was initially performed to ensure correct diagnosis, B) under aseptic condition and local anaesthesia using a 5-10MHz linear-array ultrasound transducer for guidance a 22G spinal needle is inserted into the symphyseal clef., C) Microbubbles in the Triamcinolone (40mg in 1 ml) are clearly seen as reverberation artefact, D) diagram of needle placement, E) transverse ultrasound image in similar plane to MR image in A shows a hypoechoic band of granulation tissue within an area of osseotendinous separation of left common adductor origin (*), F) same as E but with echogenic needle tip now visible to left side of pubic symphysis (arrow), and G) longitudinal view of same needle (arrowheads).
INITIAL CONCLUSIONS

1. Central anterior, posterior and superior symphyseal extrusion, increased symphyseal signal and all types of para-symphyseal or para-sacroiliac marrow change although abnormal in non-athletes must be considered to be "normal" in professional soccer (and rugby) players. Therefore, a mechanical osteitis pubis reflects excessive physical activity and cannot be assumed to be the cause of groin pain per se.

2. A "true" osteitis pubis is an unusual cause of groin pain in professional soccer players.

3. On MR imaging there is evidence of a rectus abdominis pubic insertion injury, common adductor origin injury or both in 91% of professional soccer players with groin pain and a significant association exists between symptoms and these appearances. Although, an entheseseal injury was also seen at these sites in 26% of the asymptomatic contralateral sides in footballers with unilateral symptoms, almost all of these groins will develop symptoms within 3 years.

4. When considering groins exhibiting a direct inguinal hernia or "pre-hernia complex" 79% also exhibit features of a rectus abdominis shear injury whilst another 50% exhibit a CAO shear injury. Conversely, in the present study, there was no evidence of a residual / recurrent inguinal hernia in symptomatic players following hernia repair, i.e. the repairs had been surgically "successful" even though symptoms remained. Therefore, if a "sportsman’s hernia" is associated with groin pain it does not appear to be the sole contributing factor.

5. Ultrasound-guided pubic symphyseal corticosteroid infiltration avoids surgery and full sporting activity in 56% of symptomatic players.
DISCUSSION

The Scope of the Problem

Groin injuries are the commonest cause of chronic (persistent or non-acute) injury in a wide range of sports, especially football. Depending on which published data is chosen they constitute up to 27% of injuries in soccer [100], 12% in American Football [72], 11.3% in rugby [83] and 6.6% in Australian-rules football [73]. In a study of players participating at various competition levels in a Danish soccer club, the combined injuries sustained resulted in a loss of 17% of all game hours during the season [64]. There is a much greater incidence of injuries in indoor as compared to outdoor soccer (6-fold increase) but this is mainly due to an increase in acute trauma rather than chronic injury [133]. It is interesting that in one study of adolescent soccer players, low levels of perceived risk and estimation of ability were associated with a significant increase in risk of injury, with odds ratios ranging from 3.77-7.92 [134].

In soccer players, groin injuries tend to be associated with a prolonged recovery as 50% of players with groin pain will have symptoms that persist for more than 20 weeks after initial injury [60]. Therefore, as they constitute 55% of overuse injuries the impact on a team’s performance is great. There have been contradictory reports concerning the injury rates in top level compared to lower level soccer players [135]. Some authors have found more injuries in higher ranking teams [136, 96], while others have found no difference in the rates of injury between players of different divisions [62]. Indeed one study found fewer injuries in professional players than amateurs [68]. This discrepancy is probably the consequence of the different methods of obtaining data, rather than a true reflection of the relationship. In the postal survey carried out as part of this thesis there was no difference between Premier and Nationwide League teams.

The results of Project 1 further emphasises the importance of groin injuries in professional soccer players. The incidence of groin injuries in professional soccer players is high
throughout Europe with significant financial consequences. In general there are little differences between England and the rest of Western Europe apart from the fact that in England inguinal hernia problems are probably overdiagnosed and less diagnostic imaging is performed. Approximately 25% of players sustain a groin injury per season with each causing an average of 4 matches to be missed. Therefore, on average each player will effectively miss at least one match per season, i.e. approximately 2% of a club's annual wage bill is lost due to groin injury. When players are earning large salaries then the financial impact of such injuries is great even without taking into account associated medical and rehabilitation costs and losses due to poorer on-field performance. In 42% of injured players there was an injury of the same type and location during the preceding year and in 59% of these "re-injuries" the players had not completely recovered from the previous injury [136]. The present survey has shown a 25% - 32% recurrence rate for groin injuries sustained within the same season. The fact that there appears to be an increased incidence of groin injury on the dominant kicking side may reflect the greater forces being produced in this area in adults. Although often thought to be related to "sit-up" and other abdominal exercises there was no support for this concept in the current study. The only possible link between groin injury and training would appear to be a possible weak statistical association between groin pain and a weekly "fitness" training period in excess of 10 hours per week (p<0.05). If this is correct it could reflect an increased susceptibility to injury with fatigue. The relatively high rate with which inguinal hernias are diagnosed in England is interesting (Table 4). It is possible that this condition is markedly underdiagnosed in Europe. This would perhaps be slightly surprising when there is a lower threshold for diagnostic imaging. Conversely, this condition may be markedly overdiagnosed in England when compared with the rest of Western Europe. There is a greater reliance on imaging in Europe compared with England. There is indeed a greater use of all imaging methods in Europe. However, diagnostic ultrasound in particular is much more frequently used in the investigation of groin pain.

**Pubic Symphysis / Effect of Applied Forces**

If we forget the lessons of the past we are bound to repeat the same mistakes in the future. Traditionally the understanding of gross human anatomy has been considered a cornerstone of medical practice. No longer does this seem to be the case. Many medical practitioners
assume anatomical texts to be factually correct and that there is little new to discover; no potential for significant research quantum; no associated professional kudos in gross anatomical research. But is this a mistaken premise? At autopsy, a significant number of errors have been shown to exist in the “classical” description of groin anatomy [109]. Such discrepancies often reflect the effects of embalming with its apparent thickening of certain structures and distortion of their anatomical relationships. The dissection studies carried out as part of this thesis similarly showed variations in the anatomy of the pre-pubic region when compared with 14 anatomical textbooks reviewed as part of this thesis [137-150].

A number of points can be concluded from Project 2, Study 1. There is an intimate relationship between the anterior adductor tendon origins, inguinal ligament insertions and the inferior extension of the rectus sheath. There is only a minimal soft tissue layer posteriorly i.e. there is minimal soft tissue support to the posterior aspect of the symphysis pubis to prevent posterior symphyseal extrusion. It has been described previously how the forces at the symphysis pubis are compressive particularly when changing from a recumbent to an erect posture [106]. Compressed soft-tissues will move along a path of least resistance. The posterior symphyseal margin is only covered by a very thin restraining layer of soft-tissue compared to all other boundaries (which consist of either thick layers of soft-tissue or bone) which presumably explains the tendency for posterior symphyseal migration demonstrable both on gross anatomical and MR imaging studies.

It is usually thought that the rectus sheath terminates at the superior pubic margin. However, these results suggest that the rectus sheath extends distal to the superior symphyseal ligament (SSL) with there being definitely such an extension in the majority of cases. A conjoint adductor longus / gracilis aponeurosis apparently provides them with a common pubic attachment. In at least 50% of cases this interdigitates with the inguinal ligament at the pubic tubercle. An interdigitating sheet of soft tissue formed from the anterior rectus sheath extension below the SSL and the common adductor origins (RA-CAO) demonstrated adherence to the central portion of the anterior pubic surfaces in 50% of specimens, whereas adherence to the antero-lateral pubic margin was seen bilaterally in all cadavers. In contradistinction an adherence of the RA-CAO to the antero-lateral pubic margin was present in all groins examined and in no specimen was there probably or
definitely **no** such adherence present at either the superolateral or inferolateral margin of the anterior pubis. **Therefore, a shear or avulsion injury to the conjoint common adductor origin - rectus abdominis aponeurosis where it attaches to the anterolateral pubic margin potentially will also shear-off the inguinal ligament at the pubic tubercle.**

On MR imaging the typical features of fibrocartilaginous disc degeneration anywhere in the body is increased disc signal, central fissuring, subchondral sclerosis, marginal osteophyte formation, disc extrusion, subarticular cyst formation and adjacent bone marrow oedema or fatty replacement (Fig. 35).

The prominence of anterior and posterior symphyseal extrusion is likely to reflect the repeated high-impact lateral compression forces being applied. The iliac pubic bones represent a long lever arm with the sacroiliac joints as fulcrum. The medial compression forces at these sacroiliac joints are greatest anterior to the point of ligamentous attachment. As the stronger ligaments are posteriorly placed [125] then logic would seem to state that any compression force is likely to be greatest at the anterior margin of the joint. Also, as the sacrum is relatively fixed compared to the pubic bones during bipedal gait, any subsequent stress-related changes would be expected to be more on the pelvic, rather than sacral, side of the sacroiliac joints. Therefore, any bone changes due to these compressive forces at the sacro-iliac joints should be greatest at the anterior sacroiliac joint margin of the ilium. If this concept is correct then in accordance with Wolff’s Law [131] there should be an increase in trabeculae in a triangular configuration at the anterior border of the ilium adjacent to the sacroiliac joints. In MR imaging terms this would appear as a triangular area of “signal void” (i.e. no signal is obtained on either T1- or T2-weighted MR imaging sequences so that the area appears “black” on all images). These are the typical appearances of hyperostosis triangulare ili seen in professional soccer players. This would seem to explain significant increase in such appearances in professional soccer players compared to non-athletes and amateur players (P<0.005) recorded in MRI Study 1. Therefore, these lateral pelvic compression forces appear to be much higher in professional footballers generally but do not appear to directly reflect symptomatology.
Imaging can demonstrate the effects of these lateral pelvic compression forces in another way. The incidence of traumatic separation of the symphysis pubis during labour and delivery is between 1:600 and 1:3400 according to obstetric literature [151]. Occasionally following symphyseal separation an overlapping dislocation of the symphysis pubis may occur with “locking” [152, 153]. This results in an end-to-side rather than end-to-end articulation between the pubic bodies in the symphysis region (Fig. 36). Such a configuration reflects a medial displacement of one hemi-pelvis relative to the other and requires both disruption of the pubic symphysis and at least one sacro-iliac joint. This seems to confirm the existence of these lateral compression forces.

**Figure 35: Typical Transverse Section MR Image Through the Lower Pubic Symphysis in a Symptomatic Professional Soccer Player.**

There are features of symphyseal degeneration – posterior symphyseal extrusion with buttressing osteophytes, subchondral sclerosis and fatty marrow replacement. There is also intermediate signal granulation tissue separating the left gracilis tendon from its pubic bone origin (arrow).

Any changes at the sacroiliac joints are likely to be greatly magnified at the symphysis pubis due to the moments of force generated via the long pelvic bone “lever”. This could explain the pubic trabecular bone configuration seen in the supplementary study for Project
2. Study 1 where the denser trabecular pattern is greatest in the subarticular region and forms a triangular configuration broadest anteriorly. Lateral compression forces applied to the pubic symphyseal fibrocartilaginous disc should produce loss of disc height / joint space and circumferential bulging of its periphery (Fig. 1). However, such bulging will only take place where the surrounding soft tissues permit the disc to do so. Project 1, Study 1 shows that in the pubic region there is only minimal soft tissue support at the posterior margin of the pubic symphysis. Therefore, there is little to oppose posterior symphyseal bulging and progressive posterior extrusion explaining the posterior symphyseal eminence noted with aging. In order to obtain biomechanical neutrality when such a process occurs anywhere in the body a rim of buttressing osteophytes is formed in an attempt to support the otherwise unsupported fibrocartilage and as the first stages of bone remodelling.

**Figure 36: Post-Partum Symphyseal Rupture with “Locking”**

*Transverse section MR image through the mid-pubic symphysis in a symptomatic professional soccer player. The pubic bones articulate “end-to-side” rather than the usual “end-to-end” configuration. Following symphyseal rupture during childbirth the lateral pubic compression forces have caused the left hemipelvis to migrate medially (arrows).*
The sectional study in Anatomical Study 1 would seem to show that such osteophytes begin as small ossicles within the periphery of the fibrocartilage. Presumably if they are adjacent to bone, where there is sufficient electrical potential difference for osteoblastic stimulation and where adequate blood supply is locally present, then these ossicles will coalesce with the underlying pubic bones to form marginal or buttressing osteophytes. In males the retropubic eminence has been noted to develop later than females and is smaller, with it not being demonstrated below 36 years of age in non-athletic males. The size of the retropubic eminence has been reported to be directly proportional to the size of the symphyseal cleft and subsequent attrition and extrusion of the symphyseal disc fibrocartilage. The results in Project 3, Study 1 show that in this respect male soccer players are not “normal”.

Anterior symphyseal extrusion is limited by the thickness and adherence pattern of the pre-pubic soft tissues. It can be seen from the dissection studies in Project 2 that these are not as classically described. The main area of adherence is to the anterolateral pubic margin. It is along this margin that the gracilis, adductor longus, rectus abdominis and rectus sheath attach tightly binding the anterior soft tissues to the pubic bodies. In some individuals there is also an area of midline adherence. If no such an adherence exists then any anterior extrusion may occur in the median plane the same as posteriorly. If midline adherence does exist then extension will occur between these lateral and midline areas of adherence. Either way such an extrusion is not as readily achieved as posteriorly where soft tissue restraint is largely deficient. The difficulty in achieving such an anterior extrusion would seem to explain why there were no significant differences seen between subgroups in MR Study 1.

The results of Anatomical Dissection Study 1 show that the soft tissues are tightly attached to the superior pubic margin, i.e. the superior symphyseal ligament. On MR imaging such extrusion was apparently present in professional soccer players. At first glance, therefore, it is difficult to see how superior symphyseal extrusion can occur. It is also difficult to see how “flamingo views” can demonstrate such a movement at this point. The answer, however, can probably be explained in terms of the actual plane being assessed. The pelvis is tilted approximately 45 degrees to the horizontal. Therefore, when observed from the front, the apparent superior border of the pubis is in fact the posterosuperior border half way between the midline of the posterior border and the true superior pubic margin. Like the
entire posterior symphyseal region there is only minimal soft tissue covering at this point. The fact that the statistical significance of superior symphyseal migration in MR Study 1 was much weaker than for posterior extrusion (p<0.05-0.01 compared to p<0.005) presumably reflects this aggregation and that in reality true superior extrusion does not actually take place. It also shows that “flamingo” views may in part be demonstrating a translational rather than shearing deformity. Any inferior symphyseal migration is limited by the thick soft tissues of the inferior pubic ligament.

Rotational moment arms of the medial hamstrings and adductors vary with femoral geometry and limb position [154]. Restriction of hip internal rotation due to minor childhood slipped capital femoral epiphysis or a naturally externally rotated gait means that the anterior adductor muscles (gracilis, adductor brevis and adductor longus) effectively become hip flexors. Interestingly, an externally rotated gait is common in professional soccer players and may be advantageous due to an improved ability to turn quickly on the playing field. However, high muscle contraction forces are produced during the kicking movement by the anterior adductors acting as hip flexors. The small anterior adductor group insertional surface area means that high strain forces are produced at their entheses potentially resulting in an overuse phenomenon. This limitation of hip joint movement has been previously implicated as a factor in traumatic osteitis pubis [32, 155]. In a retrospective review of 59 patients with a clinical diagnosis of sports-related osteitis pubis radiographic analysis showed an increased femoral head ratio in 7% of cases suggesting adolescent or childhood epiphysiolysis to be a possible underlying aetiological factor [155].

That hip problems can affect the biomechanical forces across the pelvic ring is evidenced by the fact that para-symphyseal insufficiency fractures may have associated hip osteoarthritis (OA) and approximately 30% have associated rheumatoid arthritis [156]. Conversely stress fracture of the hip has been reported after sacral fusion in an adult with scoliosis [157]. This association with hip pathology is made particularly important by the fact that injuries to the hip itself are not-uncommon in athletes [158] and anterior acetabular labral tear with adjacent chondral damage is now becoming increasingly recognised as a cause of groin pain in footballers with the wider use of hip arthroscopy [159, 160].
The Rectus Abdominis-Common Adductor Origin Functional Unit

The Anatomical and MR imaging studies in Projects 2 & 3 show that the rectus abdominis muscle and rectus sheath in man, as in other members of the ape family [161], does not terminate at the superior pubic ligament but extends anteriorly to cover the anterior aspect of the pubic bones and the pubic symphysis. Inferiorly it interdigitates with the common adductor tendon origins of gracilis, adductor brevis and adductor longus to form a functional and structural unit (RA-CAO unit) (Fig. 37).

Figure 37: Rectus Abdominis-Common Adductor Origin Functional Unit

A) A fresh female cadaveric specimen showing a pair of forceps retracting the superior portions of the external inguinal rings. The medial portions of these rings are inseparable from the anterior rectus sheath whilst infero-laterally the lateral borders of these inguinal rings fuse with the inguinal ligaments (arrowheads). B) A formalin-fixed female cadaveric specimen showing the median raphé (curved arrow) of the rectus sheath passing through the midline of the rectus abdominis musculature separating the two halves of pyramidalis muscle (P). These latter muscles appear to be in continuity with the adductor longus insertions (L) separated by the inguinal ligaments (arrowheads). These dissections show how the inguinal ligaments, rectus sheath, rectus abdominis / pyramidalis muscle and adductor longus muscles are anatomically interlinked.
There is very little anatomical data available, however, from the only anatomy text that could be found on the subject, the gorilla’s rectus abdominis muscle appears to insert onto the anterolateral pubic margin immediately medial to the longer gracilis origin [161]. It does so more distally than is usually described in humans. It is possible that man’s more erect posture has resulted in developmental proximal migration of the RA insertion with its vestige remaining as pyramidalis muscle and with the anterior rectus sheath interdigitating with the more distal adductor tendon aponeuroses and gracilis fascia. The tendons of gracilis and adductor brevis are themselves fused to a variable extent as they arise from the same ridge of bone (ventral arc of the pubis) and the fibres of the ventral pubic ligament which are attached to its medial border [117]. All three of the dissection studies from Project 2 show that in all cases the anterior rectus sheath and rectus muscle do not terminate at the superior pubic margin but continue distally to insert into the anterior pubis across these former structure’s entire width. They also show that the inguinal ligament does not terminate at the pubic tubercle but extends obliquely over the anterior surfaces of the pubic bones forming an incomplete V-shaped configuration. The “V” is incomplete as the ligament terminates just short of the anterior surface of the pubic symphysis. Here they fuse with the presymphyseal connective tissue in the majority of cases adhering tightly to the anterior portion of the symphyseal fibrocartilage. It is this layer which apparently limits the anterior symphyseal migration.

A degenerative symphyseal cleft may be seen on cadaveric sectioning as shown in Supplementary Cross-Sectional Study 1. This cleft is seen frequently in adult females compared to adult males and a significant proportion of these latter fissures go on to develop a synovial lining i.e. effectively thus forming a diarthrodial joint. On MR imaging, this cleft is usually of fluid signal although a vacuum phenomenon may occur. The cleft lies between the pubic symphysis and the articular fibrocartilage overlying the pubic bones. The cadaveric section study shows how this cleft apparently propagates from posterior to anterior. The MR imaging studies show that this area of increased symphyseal signal may extend asymmetrically beyond the anterior symphyseal border separating it from the overlying soft tissue. When it occurs this “dissection” is usually unilateral but can be bilateral (Fig. 38 and Fig. 39). Occasionally this cleavage plane extends so far laterally that
in effect it becomes either a partial or complete avulsion of the soft tissues attached to the antero-lateral pubic margin.

An inferior radial ligament consisting of an adductor tendon condensation extending inferiorly from the inferior end of the antero-lateral pubic margin inferiorly and slightly medially has been previously described in standard anatomical texts. It was present in all cases in Dissection Study 1. In the majority of dissections this could be seen to be in continuity with the inguinal ligament extension over the anterior pubic bone surface either with the ipsilateral side forming an arcuate arrangement or with the contralateral side as a cruciform configuration. Also, in the vast majority of specimens in Dissection Study 1, there was an apparent conjoined adductor longus and gracilis tendon origin, i.e. a common extensor origin (Fig. 37). This was confirmed in Dissection Studies 2 and 3. In all three studies there was a continuous layer of soft tissue consisting of the interdigitating fibres of the rectus sheath and this common extensor origin. This was superficial to the anterior surface of pubic bodies and adherent to their antero-lateral border in all cases and to the pubic symphysis in the majority. Between these two areas there was a discrete cleavage plane. This cleavage plane was similarly seen in the MR imaging study (Figs. 38 and 39).
Figure 37: Left Adductor Longus Origin Enthesal Injury

A) T1-weighted transverse section through the mid pubis at the level of the adductor longus entheseal origin. There is a band of intermediate signal (curved arrow) between the left anterior pubis and the adductor longus tendon. B) Comparable fat suppressed T2-weighted transverse section through the mid pubis at the level of the adductor longus entheseal origin. There is again a band of high signal (curved arrow) between the left anterior pubis and the adductor longus tendon. The signal characteristics of this abnormal band at the left adductor longus enthesis is of oedematous granulation tissue compatible with a chronic injury at this site.

It can be seen from the above anatomical studies that there appears to be a conjoined rectus abdominis / rectus sheath – common adductor origin aponeurosis attached to the anterior pubic bodies at their antero-lateral margin and the inguinal ligament at its insertion into the pubic tubercle and also its pre-pubic extension. It is possible that this is analogous to the pre-pubic tendon seen in other mammals which can be similarly avulsed from its bony pubic origin [162].
Figure 38: Rectus Abdominis Insertion Entheseal Injury.

A) Contrast-enhanced fat suppressed T1-weighted transverse section through the upper pubis at the level of the rectus abdominis insertion showing enhancing granulation tissue at the entheses (arrowheads). B) A similar sequence in another patient at slightly lower level showing extensive enhancement at both rectus abdominis / adductor longus entheses (arrows). A) Appearances are those of granulation tissue consistent with early unilateral (A) and severe bilateral (B) chronic entheseal injury which in the latter is bordering on true entheseal avulsion.

Pubic Stress Injury

The physical laws governing a bone adaptive response to mechanical stresses are poorly understood but have become known as Wolff’s Law [163]. This law basically states that bone formation will increase in areas of compression and decrease in areas of tension. The primary bone trabeculae remodel and orientate themselves along stress lines and eventually form the secondary trabeculae. These latter trabeculae act as internal struts or tie beams to support a bone’s integrity against deforming forces. These high forces at the adductor origins are reflected in the prominent primary trabeculae in the parasymphysseal pubic bones. Such a phenomenon reflects trabecular micro-fracture and repair along the line of deforming forces which in this case is the line of pull of the adductor tendons in accordance with Wolff’s Law. This process provides a degree of protection against the applied forces. Such a phenomenon results in intra-osseous marrow oedema at the site of entheseal attachments.
If the rate of trabecular injury exceeds the speed with which the body can repair these microfractures then a macrofracture will occur, i.e. a stress fracture. In the osteoporotic skeleton such stress fractures may occur with relatively low or normal level of cyclical loading (parasymphyseal insufficiency fracture) [164, 165]. In the skeleton of a young athlete where there is excessive cyclical loading of normal or even “super-normal” bone overuse fractures may result [166].

At an earlier stage, before actual stress fracture formation, the marrow oedema produced by the reparative response could presumably cause some degree of discomfort due to the associated raised intra-osseous pressure. The triangular configuration of the area of increased trabecular bone density reflects the site of greatest entheseal surface area and the line of applied traction forces. Observation of trabecular bone patterns on radiographic and CT studies show that primary trabeculae hypertrophy in the line of applied compression forces and secondary trabeculae also increase in line with applies tendon traction forces. These changes presumably reflect the fact that cyclical microfracture and repair occur to the greatest extent at the sites of greatest applied force (in accordance with Wolff’s Law). The pattern of the trabeculae seen in the CT section of the Supplementary Study 1 demonstrates the direction of the greatest forces applied to the pubic bones. The greatest areas of trabecular bone density were the subchondral and subentheseal regions. The former reflects the transverse compression forces across the pubic symphysis resulting in anterior, or more commonly, posterior symphyseal extrusion. The triangular area of higher trabecular density anterolaterally in the superior portion of the pubis corresponded to the site of entheses of the inguinal ligament (IL), adductor longus (AL) and rectus abdominis (RA). The phenomenon of parasymphyseal stress changes has been previously termed osteitis condensans pubis [167]. Such a description is not unreasonable, reflecting it being analogous to the anterior parasacroiliac changes seen. The same appearances in the inferior portion of the pubic bodies corresponded with the origin of the gracilis tendons and gracilis fascia.
Figure 39: Subenthesal Pubic Bone Marrow Change

Transverse section images through the upper pubic bodies at the level of the rectus abdominis / inguinal ligament insertions. A) T1-weighted sequence. High signal fatty infiltration can be seen in the right pubic body (arrow) below the broad area of soft tissue insertion. Lesser changes are present on the left. The appearances are consistent with Modic type 2 change. B) to D) T2-weighted fat suppressed images showing variations in the anatomical site of marrow oedema i.e. Modic type 1 change (arrowheads). In B it is slightly more medially placed at the enthesal origins than in C reflecting the former being at the rectus abdominis insertion and the latter at the inguinal ligament attachment. In D the oedema is more extensive and also has a prominent subarticular component.
The anterior pubis, inferior ischial ramus and iliac crest have been previously shown to be the anatomical sites of the innominate bones with the lowest average calcium-equivalent densities particularly the area of the pubic tubercles and crest using dual-energy quantitative computed tomography [168].

These recorded figures relate to subjects 72-87 years of age and are consistent with the sites of insufficiency fractures of the pelvis. The CT study supplementary to Project 2 confirms there is a boundary between the dense and less dense trabecular bone regions which could result in a “fault-line” i.e. these enthesal forces may predispose to parasymphysial stress injury.

**Enthesal Injury**

This same balance of micro-injury and repair also occurs in tendons again in response to applied deforming forces [23]. It can be seen that if the pubic symphyseal cleft propagates anterolaterally then this common aponeurosis may be sheared off its pubic attachment. However, a traction injury mechanism is also possible. Repetitive minor injury to a tendon may result in microtears. These may in turn accumulate at the site of excessive mechanical loading, sufficiently weakening the tendon’s tensile strength so that it results in a spectrum of tendinosis which in its severest form reflects intrasubstance tear or even tendon avulsion [22]. If the generation of tendon micro-tears exceeds the rate of repair then the tensile strength of the tendon may be sufficiently decreased as to result in partial rupture or even tendon avulsion [21].

In myotendinous units anywhere in the body there is a tendency for them to fail acutely at their musculotendinous junctions and chronically at their osseotendinous junctions resulting in an enthesopathy. Occasionally tendons may apparently spontaneously rupture. There is, however, sufficient evidence to suggest that in humans at least there is insufficient force generated to create a breaking strain i.e. a force sufficient to produce a truly spontaneous rupture. Such ruptures probably occur as a spontaneous event in a sub-clinically degenerate tendon. A repetitive traction injury to adductor origins, as is common in sports such as soccer, will potentially result in an avulsion of the CAO from the underlying pubic bone. MR imaging in such individuals exhibits sub-entheseal bone marrow oedema at an early
stage and enthesal and perienthesal oedema and intravenous-contrast-enhancing granulation tissue at a later stage (Fig. 40).

Tendons themselves do not have much in the way of pain fibres. In cases where there is chronic enthesal injury, pain may be due either to a more acute inflammatory process in the paratenon or, where it exists, tendon sheath. The only tendon in the groin region to have such a sheath is the iliopsoas tendon and this certainly can become inflamed. All of the other tendons have a paratenon. Pain can also be due to subenthesal marrow oedema resulting in raised intra-osseous pressure. Finally, it can occur at the site of tendon insertion into bone i.e. at the Sharpey-Shaffer fibres analogous to the site of inflammation in patients with spondyloarthopathies such as ankylosing spondylitis. The treatment for recalcitrant chronic enthesal tendinopathies of mechanical origin at other site such as the plantar aponeurosis (fascia) and common extensor origin of the elbow, is tenotomy. Spontaneous rupture is in effect an “auto-tenotomy”. This is the reason why acute tendon rupture in athletes with chronic groin pain may result in long-term symptomatic relief after initial symptoms related to haematoma formation have subsided (assuming there is sufficient tendon retraction of the adductor tendons to avoid the tendon reuniting). This explains the “successful” results seen in the two players with tendon rupture following steroid infiltration in MR Imaging Study 8.

Whether due to shearing injury from below or traction injury from above the overall effect is separation of the RA-CAO anatomical and functional unit from the underlying pubic bone (Fig. 41). The fact that the pyramidalis and adductor longus tendons appear to form a single muscle unit interrupted only by the inguinal ligament pre-pubic extension supports the fact that they work in unison (Project 3, Study 2). This linkage could result in a high shearing force across the pre-pubic soft tissues due to their forced contraction and an enthesal shearing injury with repetitive use. Such an overuse injury is possible during the action of kicking or rapid turning and trunk rotation as regularly occurs in soccer (Fig. 42).
Figure 40: Left Adductor Longus Origin Avulsion

The left tendon origin (arrow) is exhibiting a grossly abnormal signal and has been incompletely separated from the underlying pubis.
Figures 41: Acute-on-chronic Left Gracilis Origin Avulsion

A) STIR coronal and B) T2-weighted transverse sections through the pubic region performed on a professional soccer player complaining of chronic left groin pain. C) coronal, and D) T2-weighted transverse sections through the pubic region performed on the same player 48 hours later having come off the field after 20 minutes of play with sudden severe left groin pain. The small focus of subentheseal high signal in A (arrow) can be seen to be the site of weakness resulting in the subsequent “acute” gracilis tendon avulsion seen in C and D.

Figure 42: “Typical” Parasymphyseal Changes of a Professional Soccer Player.
A),C),E) are T1-weighted images through the upper, middle and lower thirds of the same pubic region and B),D),F) are the respective corresponding fat suppressed T2-weighted transverse sections. These images show symphyseal and subchondral degeneration, bilateral enthesal granulation tissue at rectus abdominis, adductor longus and gracilis insertions right>left, and possible gracilis avulsion developing on the right and pubic stress injury developing on the left.

If such a functional link exists between the rectus abdominis insertion, pubic apophysis and conjoint adductor origin this may explain the apparent injury to the apophyses seen either unilaterally or bilaterally in young athletes with subsequent apophyseal developmental retardation. Minor repetitive trauma to the developing apophyses may explain the high incidence of Type 3 and 4 symphyses in both asymptomatic and symptomatic professional footballers. The high proportion of Type 2 symphyses in the asymptomatic footballers probably reflects the young modal age of this group and the fact that the apophyses do not normally fuse with the main pubic bones until late adolescence or early adulthood (Fig. 43). This would also support the concept that a shearing mechanism exists in adults.
Figure 43: Pubic Growth Retardation Secondary to Chronic Soccer-Related Adolescent Injury

The T1-weighted transverse sections both show features of symphyseal degeneration with posterior osteophyte formation subchondral sclerosis and cyst formation and loss of joint space. In addition there is failure of normal fusion of the right pubic apophysis to the pubic body (arrow).

Pelvic Instability

There would seem to be an association between groin pain and pelvic instability [169, 170]. An alternative explanation, therefore, could be a RA-CAO shearing injury due to hemipelvic instability. If the pubic symphysis becomes unstable due to the laxity, produced by symphyseal degeneration and loss of joint space, then a potential shearing motion may occur at the symphysis pubis. This would certainly fit with the changes seen on “flamingo” stress radiographs although as stated above, their validity is questionable. It would also be in keeping with the configuration of sacral stress lines seen in insufficiency fractures. The long lever arm means that any movement at the sacroiliac joint fulcrum will be markedly amplified at the pubis. This could again result in a shearing motion at the pubic insertion of the RA-CAO unit. Conversely it is possible that the “shearing off” of the pre-pubic soft tissues due to forced RA and / or CAO muscle contraction or chronic entheseal degeneration may produce the hemi-pelvic instability.
There are other factors to suggest such an association between symphyseal "laxity" and pelvic instability exists. In patients with septic arthritis of the symphysis pubis there may be demonstrable associated sacral stress fractures similar to those seen with insufficiency fractures of the pubic rami presumably reflecting resultant pelvic laxity. Wedge resection of the symphysis pubis for the treatment of recalcitrant osteitis pubis produces reasonable initial results. However, at an average of ninety-two months postoperatively, 30% of such patients require bilateral sacro-iliac arthrodesis for instability-related pain. This again shows an apparent association between pubic symphyseal laxity and pelvic ring instability. Similarly, symptoms of osteitis pubis may disappear following application of a Hoffman external fixator to stabilise the pubic symphysis [171]. These symptoms often return when the fixation device is subsequently removed. This is in keeping with the pelvic ring theory which is the basis of all modern classifications for pelvic fractures and their management. This theory arises from the fact that it is rare for single site acute fractures to occur in the region of the pelvis with fractures (or combinations of fractures and dislocations) almost inevitably being "front and back" or bilateral. In one study involving 70 patients with apparent "solitary" fractures of the anterior pelvic ring based on conventional radiographs, on subsequent CT examination approximately 50% had additional incomplete fractures of the anterior part of sacrum and a further 2 patients had partial disruptions of the sacroiliac joints [172]. In another study involving athletes with radiographic evidence of either symphyseal stress changes or avulsion of cortical bone at the site of insertion of the gracilis tendon, sacro-iliac abnormalities were demonstrated in 55% of athletes. A sacral stress fracture was also noted in another athlete [173] (Fig. 44).

An anatomical linkage between lower abdominal wall and thigh structures may help to clarify the nature of some of the clinical symptomatic patterns seen in athletes with groin pain. The majority of acute adductor strains are incomplete muscle tendon tears and accordingly athletes complain of pain and tenderness just adjacent to the musculotendinous junction (of adductor longus or gracilis). In athletes with prolonged lower abdominal and groin pain, increased pain during Valsalva manoeuvres and tenderness along the posterior inguinal wall and external canal, an insidious sports hernia is the most likely diagnosis [174]. However another clinical condition exists termed the "Chronic symphysis syndrome" which represents a combination of abdominal, groin, and adductor pain [175]. In this
condition rectusplasty combined with adductor tenotomy is required for symptomatic relief. The RA-CAO unit concept helps to explain these three conditions and how they can be interlinked. The exact symptom complex present will reflect which “link” in the chain is weakest. This concept can also be extended to the immature skeleton where failure is usually at the physis of the anterior pubic apophyses, i.e. any injury reflects a chronic Salter-Harris type 1 injury or an acute-on-chronic avulsion [176]. It is possible that a muscle imbalance problem, however, may be a more general one affecting this region. In one study in high-performance athletes with severe lower-abdominal or inguinal pain 88% had adductor pain that accompanied the lower abdominal or inguinal pain. These authors describe a distinct syndrome of lower abdominal / adductor pain in male athletes which appears correctable by a procedure designed to strengthen the anterior pelvic floor [177].

The 19th century Prussian technique of embalming anatomical specimens was not commonly performed in France until well into the 20th century. The presence of vertical ligamentous fasciculation of the distal rectus sheath (RS) at the anterolateral pubic margin was recorded in a French anatomical text published in 1902 [178] but does not seem to be recognised in more recent large English language texts. It is possible that these ligaments correspond to those shown in Fig. 45. The fact that these link supra- and infra-pubic structures and also decussate to insert on contralateral as well as ipsilateral sides may partially explain the difficulty in localising the anatomical site for groin pain clinically [42].

There are two principal theories for groin hernia formation: the saccular theory and that of myofascial weakness. Factors may be present that increase the "natural weakness" of the groin: anatomical variations affecting the inguinal triangle; biological disorders affecting inguinal structures (aponeurotic and fascial senescence, collagen diseases and musculo-tendino-aponeurotic dystrophy) [179]. The classical triad of intra-operative findings in cases of pre-hernia complex or “sportsman’s hernia” are a tear of the external oblique aponeurosis with dilatation of the superficial inguinal ring, a tear of the conjoined tendon and a dehiscence between the inguinal ligament and the torn conjoined tendon with this latter component being the “major injury” [57]. There is a question, however, as to whether these changes are secondary to parasymphysseal tendon injury rather than simply reflecting the effects of raised intra-abdominal pressure.
Figure 44: Subentheseal Pubic Bone Stress Injury

A) Fat-suppressed T2-weighted sagittal image through the left pubic body, B) corresponding contrast-enhanced fat-suppressed sagittal and, C) transverse section through the mid pubis. There is a line of signal void parallel to the site of insertion of the rectus abdominis and adductor pubic origins (arrows) with surrounding bone and soft tissue oedema consistent with stress injury to bone.
Figure 45: The Recto-Gracilis Ligament

A and B. Two male cadaver dissections showing the thin bilateral extensions of the rectus abdominis. A) A pair of dissection forceps is lying between these ligaments and the pubic symphyseal region. B) A window has been cut through the more superficial pyramidalis muscle to expose the underlying ligaments. It can be seen that at the proximal end there appears to be a rudimentary muscular component (arrows). At the distal end these ligaments partially decussate to fuse with both ipsilateral and contralateral gracilis fasciae (arrowheads).

It is particularly interesting therefore that contrary to the classical anatomical and surgical texts the conjoint tendon of the transversalis and internal oblique muscles does not usually insert into the pubic tubercle in most individuals. Indeed most people do not even have a conjoined tendon at all. In the majority of patients these tendons forming the posterior wall of the external inguinal ring insert separately into the rectus sheath. Condon showed that in 97% of fresh rather than formalin-fixed cadavers these tendinous aponeuroses are separate structures and that in 74% they insert separately into the rectus sheath and not the pubic tubercle [109]. These misconceptions arise from the technique of embalming resulting in apparent fusion and contraction of soft tissue layers. The correct anatomy is noted in texts written prior to the widespread introduction of embalming in anatomy departments [178]. Similarly, separate internal oblique and transversus aponeuroses rather than the classical
conjoint tendon has been reported in more than 90% of groins undergoing operative hernia repair with these separate structures again inserting into the rectus sheath rather than the pubic tubercle [107]. The current thesis combined with the work of Condon [109] and Casten [110] would tend to suggest that a traction or shearing injury to the inferior rectus sheath at its superolateral pubic margin / pubic tubercle attachment is also likely to result in weakening of both the anterior, medial and posterior borders of the inguinal canal at its medial pubic attachment thus resulting in a potential direct hernia.

It has also been noted that a reflected medial portion of the IL passed between the ligament and the anterior RS in 70% of specimens [109]. In its early stages of development “pre-hernia complex” healing will occur with rest, suggesting there to be an inflammatory component to its pathogenesis [57]. Indeed IL inflammation at its pubic insertion, RA and AL enthesopathy have all been found to be causes of chronic obscure groin pain [41]. In patients with a palpable and surgically proven direct inguinal hernia symptoms can be relieved, at least temporarily, by local entheseal steroid injection in approximately 7% of patients this again suggesting a possible link between pubic osseous-tendon injury and direct inguinal hernia formation [41].

Whether a shearing or traction injury, the separation of the RA-CAO from the anterior pubis will also separate the inguinal ligament from the pubic tubercle. This can occur from below by superior propagation of a gracilis and / or adductor longus tear. Alternatively, it can occur from above by inferior propagation of a rectus abdominis / anterior rectus sheath injury. The fact that the medial border of the external ring is attached to the RS means that such an avulsion may predispose to the inguinal pre-hernia complex, possibly related to straining (i.e. a possible additional link with inguinal hernia formation may exist). Presumably the observation that adductor origin symptoms appear to subside following hernia repair could reflect the reattachment of these avulsed soft tissues even though the adductor problem per se is not specifically addressed.

Therefore, a repetitive injury to the inferior RS at its superolateral pubic margin / pubic tubercle attachment may result in weakening of both the anterior, medial and posterior borders of the inguinal canal resulting in a potential direct hernia. If there is an anatomical
link between the adductors, RA and IL it could explain why gracilis tendinopathy [35], AL tendinopathy [39], incipient direct inguinal hernia [180], IL enthesopathy [41], rectus abdominis tendinopathy [38, 181] and pubic bone stress injury [156] (and even ilioinguinal [182] and obturator entrapment neuropathy [183] have all been postulated as causes of chronic groin pain in athletes.

An overuse enthesopathy may account for both the aetiology and symptoms associated with a “sportsman’s hernia”. Although the “patient’s tenderness diminishes with increasing rest as the inflammation and oedema at the injury site subsides”, Gilmore [57] concluded that: “in severe cases healing will not occur because the main injury is the inguinal ligament-conjoined tendon dehiscence”. The above statement suggests that in the early stages of hernia formation there is a tendonitis (or tendinosis) component.

The results of Project 3 suggest that similar to tendons elsewhere it is possible that in the pubic region repetitive tendon injury results in tendon degeneration (tendinosis). A similar finding has been suggested by other investigators. Inflammation of the inguinal ligament at its pubic insertion has been found to be the cause of chronic obscure groin pain in 61% of patients (62% of groins) [41]. In this latter study a further 10% of patients had rectus abdominis enthesopathy of whom one patient interestingly also had adductor longus enthesopathy and a second patient had concomitant rectus abdominis and inguinal ligament enthesopathy. In this latter study the diagnosis was made by relief of symptoms following infiltration of the entheses by lignocaine (2%) and triamcinolone (1%). At 3-15 months follow-up there was improvement in 88% of groins. The same author also states that in 9 of 136 patients (6.6%), with palpable and surgically proven direct inguinal hernia, symptoms were relieved by local entheseal injection. This again suggests a possible link between pubic osseous-tendon injury and direct inguinal herniae.

The laterality of MR imaging changes, particularly the conjoint rectus abdominis-common adductor shear injury and to lesser extent evidence of a hernia or “pre-hernia” complex, appear to have a strong correlation with symptoms and may be demonstrable subclinically, i.e. before symptoms occurs. The stronger correlation with conjoint adductor-rectus abdominis shear injury than “pre-hernia” complex implies that the former may predispose to
the latter or at least that they have a common injury mechanism. MR imaging demonstration of RA-CAO shear injury is an extremely good predictor of groin pain in professional soccer players having a Cohen's Kappa Coefficient of 0.7823, (p < .0001). This result coupled with the fact that a RA and / or CAO shear injury was only identified in professional soccer players suggests that an injury to the RA-CAO unit is related to sporting activity and is the cause of groin pain in the majority of professional soccer players. The fact that 138 (80.2%) of the symptomatic groins had a CAO shear injury suggest that the predominant injury is probably at adductor end of the RA-CAO unit. However, there was a remarkably even split between sides suggesting the RA-CAO changes to be independent of the kicking side which usually exhibits a right leg dominance.

Laparoscopic repair appears as effective as conventional repair for sporting injuries and permits earlier return to sporting activity. In MR imaging Study 7 of the players with ongoing groin symptoms, 56% of groins exhibited a combined RA-CAO abnormality on the ipsilateral side, 14% had an isolated CAO injury and 5% an isolated RA injury. This would tend to suggest that in these players a RA-CAO was the original cause for the inguinal canal abnormality and that the repair had not adequately addressed this problem.

A causative relationship would explain why 39% of professional footballers undergoing surgery for groin pain due to a “pre-hernia”, also have pain in their adductor origin region [57]. It would also explain why, when considering the players who remain symptomatic following herniorrhaphy for chronic groin pain, 75% have evidence of a combined RA and / or CAO shear injury. When reviewing the results of 323 surgical repairs in 295 athletes reported in 6 separate studies, Friedberg and Kissmeyer-Nielsen [143] found that the symptomatic cure rates for herniorrhaphy in sportsman’s herniae range between 63% and 94% compared to greater than 99% for conventional inguinal herniae. This suggests that groin repair alone may be insufficient to completely relieve symptoms without correction of the CAO component of the RA-CAO unit dysfunction.

In lumbar spine intervertebral disc degeneration there is loss of disc height, vertebral end-plate sclerosis and marginal osteophyte formation on conventional radiographs and disc desiccation and end-plate fatty infiltration or sclerosis (Modic types 2 and 3) on MR
A mechanical discitis may also occur with fluid signal within the disc, oedema within the end-plates (Modic type 1) and adjacent soft tissue oedema [45]. In severe cases differentiation from an infective discitis may be extremely difficult requiring biopsy for microbiological assessment. The pubic symphysis may be considered to be an analogue of the intervertebral discs of the spine and on conventional radiography and MR imaging may have remarkably similar changes to those seen in intervertebral disc degeneration and mechanical discitis. Intervertebral disc degeneration is akin to the condition traditionally considered to be “osteitis pubis” and reflects physical activity and is rarely the cause of major symptoms. Such changes are seen alike in symptomatic and asymptomatic athletes both in the lower lumbar spine and symphysis pubis and are not statistically significant [184]. An acute inflammatory condition akin to a mechanical discitis can occur in the pubic symphyseal region. This is a “true osteitis pubis” or “symphysitis” and may be the cause of quite severe symptoms which may benefit dramatically from symphyseal steroid injection [47]. However, the traumatised area may occasionally act as a focus for haematogenous infection especially in the immunocompromised (which athletes often are due to the effects of “over-training”) making differentiation from pubic osteomyelitis extremely difficult [185]. In one review of 100 cases of pubic osteomyelitis, 19% were associated with sport, particularly soccer, this being only slightly less than the 24% following female incontinence surgery, where there is a high risk of local sepsis, and greater than the 15% of cases related to intravenous drug use [186].

Although, a true osteitis pubis does occur [48, 187] the clinical and MR imaging appearances may be essentially the same as seen in a pubis osteomyelitis [9, 188]. Clinically there is severe but self-limiting lower abdominal wall and bilateral adductor pain with tenderness maximal over the pubis symphysis both by anterior palpation and per-rectal examination. MR imaging demonstration of profound oedema and contrast-enhancement within the symphysis pubis, parasymphyseal pubic bones, RA and CAO tendons and adjacent musculature as well as in the bladder base / retropubic region is consistent with a diagnosis of “true” osteitis pubis. Three players in the current series presented in this way. All three also had evidence of a RA-CAO shear injury and settled dramatically with ultrasound-guided corticosteroid infiltration of the symphyseal cleft [47]. A rapid response to intravenous corticosteroids has also been noted in “post-operative” osteitis pubis [189].
similar response to oral non-steroidal anti-inflammatory agent (Oxyphenbutazone) has also been noted [190]. Also of note is that heparinisation of patients with osteitis pubis may produce a dramatic improvement in approximately 30% of cases raising the possibility that venous infarction may be part of the underlying pathological process (although the reason for this improvement remains unclear) [191]. This seems to be the case regardless of the fact that osteitis pubis is more likely to be due to a vasomotor response than avascular necrosis i.e. more akin to transient regional osteoporosis [192, 193]. The intravenous contrast enhancement seen within the bone marrow of the pubis in a number of Project 2 studies is compatible with the increased tissue perfusion seen when MR imaging reveals callus, fracture line or muscle oedema surrounding the bone stress reaction.

In the present study posteroinferior symphyseal extrusion, parasympyseal marrow changes (marrow oedema, fatty replacement or sclerosis) and subchondral cyst formation were considered to reflect symphyseal degeneration. The corresponding radiographic appearances of subchondral sclerosis, cyst formation or erosion and loss of symphyseal joint space ± buttressing osteophytes are often taken as representing osteitis pubis [194]. Similarly these changes would be expected to produce intense parasympyseal uptake of radionuclide on Tc99m MDP isotope bone scans which is taken by many as reflecting an osteitis pubis in athletes [194, 195]. The current study, however, shows that the incidence of most of these features is significantly increased in asymptomatic (P<0.005) as well as symptomatic (p<0.001) professional soccer players when compared to non-athletic asymptomatic volunteers but not increased in symptomatic amateur players. Bilateral sacro-iliac joint stress phenomenon appears to be associated with playing professional sport (p<0.005) and its concurrence with the above symphyseal changes is likely to reflect underlying instability of the pelvic ring. The MR imaging results suggest that the radiographic and nuclear medicine features, often resulting in a diagnosis of osteitis pubis, may simply reflect pelvis stress changes common to many professional sportsmen. The exception is subchondral cyst formation which does appear to correspond with symptoms and could reflect a more advanced degenerative state and / or pelvic instability as is the case in many other joints. In MR Study 4, 133 of the 135 symptomatic professional soccer players (98.5%) exhibited one or more feature of symphyseal degeneration even though the mean age of the study group
was only 26.8 years. Professional soccer would seem to produce premature and often severe pubic symphyseal joint degeneration which is related to the level of sport played.

In MR Imaging Study 2 there was a strong association between player age and the finding of parasymphseal subchondral cyst formation and posterior / anterior symphyseal extrusion. There was, however, no significant correlation between symphyseal morphology and increased signal nor potential causes of groin pain. This has been similarly demonstrated in a study comparing pelvic radiographs using a 4-point grading system [196]. In this latter radiographic study, male athletes with long-standing groin pain had more frequent and more severe symphyseal bone changes than sex and age-matched controls (p>0.001). Also in asymptomatic individuals these radiographic abnormalities were seen with increased frequency with age in both men and women. MRI Study 1 shows that these appearances are all present in soccer players at a very young age compared to non-athletic controls. Therefore, the current work seems to show that such features do not correspond with a player’s groin symptoms. They appear to represent an accelerated “normal” aging process. These changes are the same as those seen in elderly females due to post-traumatic symphyseal generation resulting from repeated childbirth.

More recently an Australian article has been written on the use of MR imaging in AFL footballers showing that 77% demonstrated increased signal intensity within the pubic bone marrow (p<0.01) when compared to umpires [197]. There was also an association between a past history of groin pain and the presence of other residual abnormalities (p<0.01). They conclude that an “association appears to exist between the clinical features of osteitis pubis and the MRI findings of pubic bone marrow oedema and a stress injury to the pubic bone is the most likely explanation for these findings”, i.e. stress injury to bone may be the underlying cause of osteitis pubis. However, high signal does not inevitably equate to oedema, it being a physical sign and not per se a pathological process i.e. other processes apart from oedema can produce high signal. The precise anatomical site of any changes are important and it is unclear from this article as to whether this “oedema” was subchondral or subenthesal. The non-articular site of this marrow oedema, however, has been noted by other observers. In a study of young soccer players with long-standing groin pain Ekberg et al [198] noted that there was “a characteristic pattern of marrow oedema localised in the
superior pubic ramus at a distance from the symphysis”. Interestingly they also noted that these young symptomatic athletes had “a broadened and irregular symphysis” consistent with the findings in Project 2, Study 2. The findings from the present work suggest that all of these pubic body changes are in some form “stress” related with the medial sub-articular ones reflecting the compression forces and the antero-lateral subentheseal changes reflecting soft tissue “stress injury” to the underlying bone.

The fact that symphyseal changes such as parasymphysial marrow signal change, increased symphyseal fluid and subarticular cysts or erosions have an equal incidence in both asymptomatic and symptomatic footballers, suggest such changes not to be the cause of symptoms. Some of these parasymphysial marrow changes have been noted before in athletes but have been attributed to “symphysitis” [198]. Such a primary inflammatory condition we believe to be rare. The occurrence of such changes, however, may be seen to be significantly raised in soccer players compared to non-athletic volunteers. This fact coupled with the similarity to changes seen in vertebral disc disease suggests such changes to be degenerative in origin. It is not unreasonable to suggest that if the pelvis is subjected to repetitive lateral compression forces symphyseal degenerative changes will be accelerated. In addition symphyseal extrusion would also be expected to be secondary to symphyseal compression and the current significant increase of such extrusion in asymptomatic and symptomatic professional footballers supports such a premise. The radiographic demonstration of the “vacuum phenomenon” within articular structures is usually considered to reflect instability. This vacuum phenomenon was first noted by Fick in 1910 [199] when stretching a cadaver’s fingers while viewed under a fluorescent screen. Rather than a vacuum phenomenon, fluid may be seen filling the secondary midsymphyseal cleft as can be seen in many of the current MR imaging studies. It is possible that this too reflects pelvic instability and certainly para-sacroiliac joint changes, when present, suggests such a phenomenon.

Thickening of the fascial plane overlying the anterior division of the obturator nerve, and deep to the adductor longus and pectineus muscles can result in entrapment of this nerve [99]. The close proximity of the adductor longus tendon at this point means that an adductor tendinopathy and associated scarring of the intervening facia may result in obturator nerve
entrapment and, therefore, produce "neurogenic" medial groin pain. This close anatomical relationship was well demonstrated in Dissection Study 2. The characteristic clinical pattern in athletes is that they complain of medial thigh pain commencing in the region of the adductor muscle origin and radiating distally along the medial thigh with sporting activity. Needle electromyography demonstrates denervation of the anterior adductor muscles and surgical decompression produces symptomatic relief [200]. Injury to neurovascular bundles containing terminal branches of the iliohypogastric nerve as it passes through a tear in the external oblique aponeurosis has also been noted at the time of surgical exploration in 25 male athletes presenting with groin pain [201]. All had improved function following repair of the aponeurotic tear and nerve decompression. Such tears can be expected to occur in some athletes as part of the proposed RA-CAO combinational injury. A similar injury has been described as the "hockey groin syndrome," which relates to the tearing of the external oblique aponeurosis and entrapment of the ilioinguinal nerve [99, 202]. Dissection studies have demonstrated four distinct distributions of the ilioinguinal nerve [202]. Normally there is a dominance of the genitofemoral nerve in the sensory supply to the scrotal / labial and the ventromedial thigh region. However, in type C and D the ilioinguinal nerve has sensory branches to the mons pubis and inguinal crease together with an anterior, proximal part of the root of the penis or labia majora. The nerve was found to share a branch with the iliohypogastric nerve. This would explain the similar results for studies where iliohypogastric and iliohypogastric nerves have both been implicated and also why there may be apparent perineal symptoms related to chronic groin injuries. In addition to the cutaneous branches from the ilioinguinal nerve, cutaneous branches originating from the genital branches of the genitofemoral nerve have been found in the inguinal region in 35% of subjects [203]. In a further 13% the genital branch and the ilioinguinal nerve unite in the inguinal canal. In 11% the genital branch pierces the inguinal ligament to enter the inguinal canal and in 5% the genital branch pierced the border between the ligament and the aponeurosis of the obliquus externus muscle to be distributed to the inguinal region.

The symphysis itself is innervated by numerous branches from the pudendal and genitofemoral nerves. Therefore, entrapment by the ligament may be a reasonable candidate for the cause of chronic groin pain. This entrapment could presumably occur with entheseal
swelling due to repetitive minor injury or swelling, deformity and scarring related to soft tissue separation in the inguinal / pubic region injury.

In groin pain of neural origin the exact nerve involved can be narrowed down clinically by realising that symptoms can be referred to regions other than the groin [204]:

- iliohypogastric nerve also provides sensory fibres to the pelvic viscera
- lateral femoral cutaneous nerve also provides sensory fibres to the knee
- genitofemoral nerve also provides sensory fibres to the testicle.

Although there has been much recent interest in possible neurogenic causes for groin pain it is also interesting to note that in 1984 [205] bilateral obturator neuralgia was described secondary to osteitis of the pubis. If due to "true" osteitis this could reflect the associated marked peripubic soft tissue inflammation / oedema (Fig. 46). Although, the larger nerves of the body are well seen on MR imaging, unfortunately, the ones of relevance here are too small for current system resolution. Indeed, at the present time this is probably the greatest limitation of MR imaging in terms of diagnosing the possible causes of groin pain.

In an independent retrospective study, largely using the data from 52 athletes from Project 3, the abnormal anterior pubis and enthesis enhancement again was seen to significantly correlate with the clinical side for both radiologists (both p=0.008). Also abnormal anterior pubis and adductor longus enthesis oedema was significant for one radiologist (p=0.009) whilst all other features showed no significant correlation (p>0.05) [206]. The independent nature of this evaluation would seem to validate the data from the Project 3 studies. In Project 3, Study 6 it has been shown that MR imaging has a corrected overall sensitivity of 78%, specificity of 73% and accuracy of 76%. These are reasonable figures particularly taking in to account its ability to demonstrate asymptomatic or sub-clinical "disease". This was evidenced by the 5 professional soccer players who were asymptomatic at the time of the study but who subsequently became symptomatic. Therefore, the fact that long-term follow-up on such an itinerant group of subjects is difficult, means that the true "corrected" figures are likely to be better still. None-the less, MR imaging is likely to under-demonstrate hernias and pre-hernia weakness of the posterior wall of the inguinal canal which are better demonstrated on dynamic imaging modalities such as ultrasound [207, 208] and
herniography [209]. MR herniography can also be performed in order to use the individual advantages of the respective modalities i.e. if the herniogram is normal, MRI may reveal other causes of groin pain and may also better visualise related structures in the groin [210]. Herniography itself, however, not without its limitations both diagnostically and practically. In one study of herniography in football players with obscure groin pain there was a 6% incidence of examinations complications related to sigmoid colon puncture [211]. Although all of these were successfully managed conservatively it makes this a much more “invasive” and risky procedure than MR imaging alone. MR imaging also has the advantage of being able to more globally assess the groin region in soccer players and is able to demonstrate associated hip arthropathies, ilio-psoas tendinopathy [212] and deep muscle and tendon pathology, such quadratus femoris tendinitis, which cannot be readily seen in sufficient resolution using ultrasound [213]. This is particularly the case when the clinical “pubalgia” may be multifactorial.

Figure 46: Relationship Between Obturator Nerve and Adductor Longus Origin.
Dissection of the right groin in a fresh cadaveric specimen with the right adductor tendon retracted laterally by a pair of forceps to show the obturator nerve (arrows). The tip of a pair of scissors is lying between the nerve and the underlying pectineus and adductor brevis muscles.
Treatment
Many surgeons when performing a nylon darn for reconstitution of the normal apposition of conjoined tendon and inguinal ligament will usually anchor the medial end of their repair by suturing through the periosteum of the pubic tubercle. Such an act would thus reattach any shearing injury of the rectus abdominis-common adductor aponeurosis. Alternately, considering the beneficial results on endoscopic hernia repair with insertion of reinforcement tantalum mesh, induced fibrosis may produce the effective reattachment of "sheared off tissues [214].

Symphyseal injection of local anaesthetic and steroids (1 ml 1% lignocaine, 1 ml 0.25% bupivacaine, and 4 mg dexamethasone) has been previously shown to have reasonable results in treating intercollegiate athletes in whom prolonged physiotherapy has failed to resolve their symphyseal pain [47]. In this particular study 88% returned to full athletic activity. Symphyseal cleft injection in the diagnosis and treatment of osteitis pubis in athletes is potentially improved in terms of accuracy by imaging-guidance [215]. The pubic symphyseal region is well demonstrated on ultrasound examination [216] and facilitates accurate needle placement (MR Imaging Study 8). In the study performed as part of this thesis, surgery was avoided and the professional soccer players were able to return to full sporting activity in 56% of players. Regardless of the fact that intratendinous injection was confidently avoided due to ultrasound-guidance two players still went on to spontaneous rupture - with beneficial effects (see above). This presumably reflects the fact that the steroids, in reducing the inflammatory response with symptomatic gain, also retarded the healing process increasing the chance of “silent” rupture due to ongoing micro-tear propagation and accumulation as occurs in tendons elsewhere.

A Unifying Concept for Groin Pain in Athletes
The concept of an anatomical and functional relationship between the RA and CAO provides a unifying concept for groin injuries in athletes. It explains why the surgical procedures of herniorrhaphy [217], rectusplasty [38] and adductor tenotomy [39] have all been shown to produce symptomatic relief. The presence of an underlying enthesal traction phenomenon and tendinitis would explain why infiltration of the entheses by lignocaine (2%) and triamcinolone (1%) produces symptomatic cure of unexplained groin pain in 25%
and symptomatic reduction in 30% of groins [41]. It would also explain why 6.6% of patients with a palpable and surgically proven direct inguinal hernia exhibit symptomatic relief by local enthesal injection [41]. Should the enthesal bone be weaker than the attached tendons then a stress injury may occur to the parasympyseal bone, this possibly explaining the configuration of parasympyseal stress fractures [218]. The presence of an underlying RA-CAO unit dysfunction would also explain why correcting the muscle imbalance between abdominal and adductor musculature has been shown to be beneficial [16]. If the pubic attachment of the conjoint rectus abdominis-common adductor aponeurosis is subjected to repeated excessive traction forces it seems reasonable to expect that it may become “sheared off” its osseous attachment. The attachment is a major stabiliser of the pubic symphysis and, therefore, its detachment results in potential pelvic instability to para-sagittal pelvic rotatory forces. The configuration of the pubic symphysis and the loss of symphyseal joint space may exacerbate this pelvic instability. The inguinal ligament is inseparable from the superolateral attachment of the above common aponeurosis and therefore it is likely to be “sheared off” its osseous attachment to the pubis in this same region therefore pre-disposing to the inguinal pre-hernia complex.

The MRI findings suggest that in footballers, changes within the symphysis pubis and adjacent subchondral bone [219], often mistakenly termed “osteoitis pubis”, are simply an accelerated degenerative phenomenon and have no correlation with symptoms, i.e. they reflect the pelvic stress forces existing in professional players, by virtue of their sport, rather than a cause of symptoms. However, based on the prior gross anatomical studies, MRI is able to demonstrate enthesal changes which do appear to be associated with symptoms. These enthesal changes are similar to those seen in primary inflammatory arthritis [220, 221]. The bone marrow oedema and corresponding raised intraosseous pressure may in part be the cause of diffuse pubic pain seen in these footballers and if excessive would be compatible with the MRI appearances seen in a true “osteitis pubis” i.e. a severe but self-limiting inflammatory process akin to a “sterile” pubic osteomyelitis.

Allowing for elastic recoil there is a marked repetitive change in axial loading of the posterior pelvis during sprinting with resulting significant sagittal torsion force on the pelvis and shear force across the sacro-iliac joints [106]. Also when the lumbar spine is flexed,
lateral compression forces are exerted on the pelvis [106]. There is only a thin connective tissue layer over the back of the symphysis pubis and it would not be surprising for these compression forces to result in posterior symphyseal extrusion and buttressing osteophyte formation. The overall effect is a decrease in the width of the disc space with time. This loss of joint space may then allow further increased movement at the symphysis which in-turn would result in increased movement and parallel stress changes at the sacro-iliac joints reflecting pelvic instability. This movement would increase the shearing forces on the anterior pubic soft tissues. If the adductors and rectus sheath are then sheared-off the pubis, this would further exacerbate the effects of the pelvic torsional forces. Involvement of adjacent nerves by tearing, scarring or adjacent soft tissue oedema may exacerbate symptoms and further cloud the diagnostic picture.

Understanding the anatomy of the anterior pubic soft tissues allows correlation with MRI imaging pathoanatomical appearances and therefore a better understanding of the pathomechanism of groin pain in footballers on which to base subsequent treatment.

**CONTEMPORARY RELEVANCE OF THESIS**

At the completion of the current thesis write-up a final electronic literature review was carried out using the same strategy as outlined in the Appendix 1. A comprehensive prospective study of injuries in professional soccer players performed by the English Football Association has again shown the major problem of groin injuries in soccer players [222]. There have been a number of recent review articles regarding hip pathology as a potential cause of groin pain in athletes and on the role of imaging, particularly MR imaging, in delineating the nature of these hip problems [223 - 226]. Indeed one such recent review article was able to cite 231 references [227]. There have also been a number of, mainly case reports, which have made the potential list of differential diagnoses for groin pain in athletes even longer. Myositis ossificans in the iliopsoas muscle is a rare cause of chronic groin pain in soccer players [228]. "Thigh splints," also known as the adductor insertion avulsion syndrome, is a painful condition affecting the proximal to mid femur at the insertion of the adductor muscles of the thigh. A recent article has shown a spectrum of MR imaging abnormalities involving this portion of the femur in a group of patients
presenting with hip, groin, or thigh pain [229]. A case report has been published of a male soccer player suffering from chronic groin pain due to seminal vesiculitis confirmed on MR Imaging [230]. Tendinopathy of the tensor fascia lata has been recently recognised as a cause of anterior groin pain in athletes [231]. Iliopsoas bursitis is similarly an unusual cause of hip pain and the condition may be due to athletic activity [232]. All of these should now be included in Table 1.

Many of the recent articles within this field of study have already been included in the thesis text. Albers et al [229] have shown how pubalgia is a complex process which is frequently multifactorial and that MRI findings can alter the surgical approach. Verral et al [197] have shown how there appears to be an association between the clinical features of osteitis pubis and the MRI findings of pubic bone marrow oedema. They have noted similar degenerative features visualised by MRI in athletes to those outlined in Project 3, such as subchondral cyst formation, that were associated with a past history of groin pain. However, they have not linked these changes to the enthesal anatomy. These authors suggest that a stress injury to the pubic bone is the most likely explanation for these MRI findings and may be the cause of the clinical entity of osteitis pubis. The result of my own work agrees with the fact that there is a stress component but that this is only part of the story. These authors fail to consider the fact that there is a high prevalence of many described changes in asymptomatic athletes. This fact is an important conclusion of the present thesis. Barille et al have similarly linked bone marrow oedema on MR imaging with pain, without considering the natural prevalence of this process [233]. They have, however, stated that inguinal hernias are easily demonstrated by MRI, which allows the direct visualisation of the hernial sac within the inguinal canal which is important as the underestimation of hernia pathology may be considered a weakness of my presented work. Subsequent to my lecture in March 2000, researchers at the Cappagh National Orthopaedic Hospital, in Dublin in 2002 showed that symphyseal cleft injection is a useful technique for the diagnosis and treatment of osteitis pubis in athletes and may facilitate early resumption of competitive duties [215]. This supports the findings in MRI Study 8.

A review article which "presents an overview of the key anatomic structures of the groin region as seen on gross anatomy and the appearance of these structures on ultrasound and
magnetic resonance imaging” has been recently published (2002) [234]. It made some points on how “the role of ultrasound and MRI after surgical inguinal hernia repair is addressed’. However, it concentrated on classical hernia formation as opposed to injuries in athletes and standard doctrine and did not cover the anatomical features outlined in the current thesis. This was also the case in two other review articles by this author in 1998 and 2000 [235, 236] and in another imaging anatomy-based article by Shadbolt in 2001 [237]. Van den Berg in a further article showed how “dynamic MRI” can be used in patients with suspected groin hernia [238]. This study, however, discussed only the appearances in patients with existing palpable hernias and not the “pre-hernia complex” situation. Since starting my research program there has been a good article written on the anatomy of the adductor origins but this has concentrated more on their musculotendinous rather than their osseotendinous junctions [119].

In terms of MR imaging, one article on groin imaging stated that “the primary diagnostic tool for diagnosing hernias is herniography” [210]. However, these authors did go on to concede that “if the herniogram is normal, MRI may reveal other causes of groin pain and may also better visualise related structures in the groin”. The only article published covering the enthesopathic nature of groin pain in athletes was by my successors in Leeds using my patient population, scanning protocol and diagnostic features and principles I had developed prior to my emigrating to Australia in 2001.
FINAL CONCLUSIONS

1. Groin injuries in professional soccer players (and other (footballers") are usually chronic rather than acute injuries, are extremely common (and costly) and appear to be related to repetitive ballistic hip rotation movements.

2. The gross anatomy of the parasympyseal soft-tissues as classically described is often incorrect. The thesis demonstrates that:
   a) the gracilis tendon, adductor longus tendon and gracilis fascia are united at their proximal entheseal origin into the anterior surface of the pubic bodies to form an effective Common Extensor Origin
   b) the inguinal ligaments do not terminate at the pubic tubercles but continue medially and distally to passes to form a V-shaped insertion onto the anterior surfaces of the pubic bodies
   c) the rectus abdominis muscles and anterior rectus sheath do not terminate at the superior border of the pubic bones and actually continues more distally over the anterior surface of the pubic bodies to insert into the inguinal ligament extension
   d) the adductor longus and pyramidalis muscles appear to be virtual continuations of each other and with the anterior rectus sheath and rectus abdominis muscle appear to form a single functionally linked anatomically unit separated only by an extension of the inguinal ligament
   e) a recto-gracilis ligament may exist which may be the cause of diagnostic confusion as it both crosses the inguinal ligament and crosses sides through its decussation
   f) the medial end of the inguinal canal and the external inguinal ring are intimately related to the anterior rectus sheath

Therefore, due to this anatomical link the RA-CAO unit can potentially be sheared-off the superolateral corner of the pubic bodies and in doing so will decompensate the external inguinal ring resulting in an apparent direct inguinal hernia.
3. Anatomical structures (and direction of applied forces) dictate the direction of symphyseal extrusion in pubic symphyseal degeneration.

4. MR imaging is able to shows that:
   a) injury can involve whole or part of this RA-CAO linkage
   b) the pubic symphyseal region can be considered analogous to the spine / intervertebral discs both in terms of the anatomy and any associated injury and disease processes
   c) the features typically ascribed to “Osteits Pubis” are due to a premature degenerative phenomenon and are not themselves major cause of groin pain in athletes
   d) imaging can demonstrated subclinical entheseal injury
   e) imaging can help differentiate a range of aetiological conditions producing groin pain in athletes
   f) “true” osteitis pubis is an unusual condition (and can be very difficult to differentiate from pubic osteomyelitis).

5. The Sportsman’s Hernia is probably over diagnosed in the UK. What is more the injury mechanism is widely misunderstood due to failure to recognise its association with a RA-CEO injury.

6. Ultrasound-guided symphyseal cleft corticosteroid injection can significantly help reduce symptoms in certain professional soccer players i.e. the ones where an inflammatory process predominates due to enthesitis or “true” osteitis pubis.
REFERENCES


34. Hoon JR. Adductor Muscle Injuries in Bowlers. JAMA 1959; 171: 2087-2089


65. UEFA Bulletin. UEFA, Bern, Switzerland, 1988


136. Peterson L and Renstrom L. Soccer injuries - frequency and type. Lakartidningen 1980; 77: 3621-3623


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APPENDIX 1:
Strategy For Systematic Literature Review

Ovid MEDLINE(R)
1966 to November Week 3 2004
* (references since Jan 1996 i.e. approximate start of thesis study program).

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[mp = title, original title, abstract, name of substance, mesh subject heading]
APPENDIX 2:
Statistical Analysis

1. In the Postal Survey reported in Project 1 the low questionnaire return rate for the English Premier and Nationwide League clubs (50%) and European clubs (30%) meant that any detailed statistical analysis would be invalid. Accordingly only Simple Descriptive Statistics were utilised for the analysis i.e. raw percentages and simple mean values were used for analytical purposes.

2. Similarly the low subject numbers in the anatomical studies performed in Project 2 and the lack of benchmark figures again meant that Simple Descriptive Statistics were used for analytical purposes.

3. In most studies in Project 3 Non-Parametric Statistics were used due to the relatively low cohort numbers. This was mainly using a 2-tail Wilcoxon Rank Sum / Mann-Whitney U-Test.

4. A Pearson Correlation Matrix where multiple correlations were required

5. Cohen's Kappa Coefficient was used for comparing Observer Error. This was derived from a computer generated bank of statistics (vide infra) using the .

6. A Chi-Square-Independence Test and a Cohen's Kappa Coefficient were utilised for MRI Study 4 and Spearman Rank Correlation Coefficient - Spearman Rho used for co-correlation in MRI Study 6 where the data sets were larger than in the other MRI studies.

7. Sensitivity, Specificity, Positive Predictive Value, Negative Predictive Value and Accuracy were also used to calculate Test Performance for MRI in MRI Study 6
Statistical Analysis Of Observer Error

**Anterior Symphyseal Extrusion**

**Observer 1**

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<th>Significance</th>
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**Observer 2**

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<td>Cohen's Kappa Coefficient</td>
<td>0.5455 $p=0.0006$</td>
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**Posterior Symphyseal Extrusion**

**Observer 1**
- Degrees of Freedom: 1
- Chi-Square-Independence: 45.5357, p<.0001
- Yates Corrected Chi-Square: 41.1808, p<.0001
- McNemar Paired Chi-Square: 0, p=1
- Phi Coefficient: 0.9543
- Cramer's V: 0.9543
- Contingency Coefficient: 0.6904
- Cohen's Kappa Coefficient: 0.9533, p<.0001

**Observer 2**
- Degrees of Freedom: 1
- Chi-Square-Independence: 41.5966, p<.0001
- Yates Corrected Chi-Square: 37.5011, p<.0001
- McNemar Paired Chi-Square: 0.5, p=0.4795
- Phi Coefficient: 0.9121
- Cramer's V: 0.9121
- Contingency Coefficient: 0.6739
- Cohen's Kappa Coefficient: 0.9083, p<.0001
High Symphyseal Signal (Symphyseal Fluid)

Observer 1

Degrees of Freedom: 1
Chi-Square-Independence: 41.8713 \( p < .0001 \)
Yates Corrected Chi-Square: 38.0773 \( p < .0001 \)
Mcnemar Paired Chi-Square: 0.5 \( p = 0.4795 \)
Phi Coefficient: 0.9151
Cramer's V: 0.9151
Contingency Coefficient: 0.6751
Cohen's Kappa Coefficient: 0.9151 \( p < .0001 \)

Observer 2

Degrees of Freedom: 1
Chi-Square-Independence: 38.2569 \( p < .0001 \)
Yates Corrected Chi-Square: 34.6668 \( p < .0001 \)
Mcnemar Paired Chi-Square: 0 \( p = 1 \)
Phi Coefficient: 0.8747
Cramer's V: 0.8747
Contingency Coefficient: 0.6584
Cohen's Kappa Coefficient: 0.8739 \( p < .0001 \)
Parasymphysial RA +/- CAO Enthesopathy

Observer 1

Degrees of Freedom: 1
Chi-Square-Independence: 40.991 p<.0001
Yates Corrected Chi-Square: 36.6102 p<.0001
Mcnemar Paired Chi-Square: 0.5 p=0.4795
Phi Coefficient: 0.9054
Cramer's V: 0.9054
Contingency Coefficient: 0.6712
Cohen's Kappa Coefficient: 0.901 p<.0001

Observer 2

Degrees of Freedom: 1
Chi-Square-Independence: 32.7664 p<.0001
Yates Corrected Chi-Square: 29.0249 p<.0001
Mcnemar Paired Chi-Square: 0.25 p=0.6171
Phi Coefficient: 0.8095
Cramer's V: 0.8095
Contingency Coefficient: 0.6292
Cohen's Kappa Coefficient: 0.8095 p<.0001
Parasymphyseal Bone Marrow Oedema (Modic Type 3 Change)

Observer 1

Degrees of Freedom: 1
Chi-Square-Independence: 44.6581 p<.0001
Yates Corrected Chi-Square: 39.476 p<.0001
McNemar Paired Chi-Square: 0 p=1
Phi Coefficient: 0.9451
Cramer's V: 0.9451
Contingency Coefficient: 0.6869
Cohen's Kappa Coefficient: 0.9436 p<.0001

Observer 2

Degrees of Freedom: 1
Chi-Square-Independence: 27.3756 p<.0001
Yates Corrected Chi-Square: 23.7347 p<.0001
McNemar Paired Chi-Square: 4.1667 0.0412
Phi Coefficient: 0.7399
Cramer's V: 0.7399
Contingency Coefficient: 0.5948
Cohen's Kappa Coefficient: 0.7076 p<.0001