Hip and groin pain in athletes
Morphology, function and injury from a clinical perspective
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CHAPTER 1

General Introduction
Groin pain lists in the top 6 most common athletic injuries\textsuperscript{95,140,148}. It mostly affects those who participate in sports that involve accelerations, decelerations, rapid change of direction and kicking\textsuperscript{202}.

Athletes with hip and groin pain typically consult a large number of different (para) medical specialists like (sports and manual) physiotherapists, (sports) medicine physicians, (orthopaedic or general) surgeons and radiologists\textsuperscript{175}. Consequentially, numerous different approaches regarding diagnostics and treatment have been described. Overcoming differences in terminology and definitions used will help mutual understanding\textsuperscript{250} and is essential for communication of both clinicians and researchers. A team effort, where all specialists involved appreciate one another’s expertise, will help to gain further insight and advance in this field of sports medicine.

### From anatomy to structural diagnosis

The complex anatomy of the hip and groin region is likely one of the reasons making a clear diagnosis is difficult in case of injury\textsuperscript{91}. Musculo-tendinous structures span the anterior groin region: the adductors connect to the rectus abdominis sheath and pubic symphysis via an aponeurosis\textsuperscript{50,196}. The adductor brevis and gracilis tendons fuse, forming a common tendinous junction\textsuperscript{50}. This interrelatedness may impede making a valid structural diagnosis. A structured approach for the anatomical orientation on this region is helpful to the clinician. Falvey et al. presented a clock-wise orientation for this region to locate the adductors, pubic bone, symphysis, rectus abdominis and inguinal ligament\textsuperscript{64} (see Figure 1).

The hip is also an acknowledged and common source for groin pain\textsuperscript{250}. However hip pathology may result in pain in other regions than the groin alone\textsuperscript{41,131}. Thus when groin pain is present clinicians should include hip-related pathology into their differential diagnosis\textsuperscript{250}.

### Classification of groin pain in athletes

One of the diagnostic problems is that imaging findings in the hip and groin region do not correlate well with symptoms experienced by injured athletes\textsuperscript{28}. Degenerative changes of the symphyseal joint, adductor muscle insertion pathology, pubic bone marrow oedema and secondary cleft sign were found the most common findings in athletes with long-standing adductor related groin pain\textsuperscript{28}. It should be noted that in players suffering acute groin injury, MRI is negative in 1 out of 5 cases\textsuperscript{210}.
These findings have led to the adoption of a clinical entities approach describing clinical patterns, that relate the origin of complaints to functional anatomical regions rather than morphological changes or structural damage. This approach has been agreed upon in the Doha Consensus on terminology and definitions in groin pain in athletes. Four clinical entities can be defined. Figure 2A represents the anatomical locations of these defined entities. The clinical examination to determine the clinical entity present is reliable and is presented in Figure 2B. These are as follows:

- **Adductor-related groin pain**: present when there is recognizable pain at the origin of the adductors (Figure 2B.1) and whilst adduction against resistance (Figure 2B.2).
- **Iliopsoas-related groin pain**: Iliopsoas tenderness (Figure 2B.5 and 2B.6). Iliopsoas-related groin pain is more likely if there is pain on resisted hip flexion (figure 2B.4) and/or pain on stretching the hip flexors (Figure 2B.3).
- **Inguinal-related groin pain**: Pain location in the inguinal canal region (figure 2B.8) and tenderness of the inguinal canal (Figure 2B.7). No palpable inguinal hernia is present. Inguinal-related groin pain is more likely if the pain is aggravated with resistance testing of the abdominal muscles (Figure 2B.9) or on Valsalva/cough/sneeze.
• Pubic-related groin pain: Local tenderness at palpation of the pubic symphysis and the immediately adjacent bone (Figure 2B.10).

The hip joint, next to these clinical entities, is also a recognized source for groin pain in this population.\cite{41,131}

The hip joint in athletes

Both the proximal femur and acetabulum contribute to mobility and stability. Form closure and force closure assist in adequate load transfer\cite{182}. The morphology of the hip joint is highly variable. A decreased form closure (i.e. hip dysplasia, a shallow acetabulum) may result in less efficient load transfer.

Figure 2. A Defined clinical entities\cite{32} (source: BJSM, with permission). B Clinical examination of the athlete with groin pain targeting presence of clinical entities\cite{32} (source: Brukner’s and Khan’s Clinical sports Medicine, with permission).
Its presence can be recognized by findings of increased hip range of motion\(^{166}\), and is associated with an increased risk of hip osteoarthritis later in life\(^{97}\). The anatomical shape of the femoral head also varies; this ranges from being spherical, allowing full range of motion with an adequate functioning femoral-acetabular interface to being less spherical, affecting the congruence of the femoral-acetabular interface. Asphericity is usually found at the anterosuperior side of the femoral head, just above the femoral neck junction\(^{8}\) where a bony formation may be present. This is referred to as cam morphology\(^{9}\).

**Cam morphology of the hip**

Asphericity of the femoral head is quantified by measuring the alpha angle according to Nötzli (see Figure 3\(^{169}\)). The alpha angle quantifies the sphericity of the femoral head; the higher the alpha angle the more aspherical the femoral head.

Cam morphology is likely to develop in adolescent years, when the physes are open\(^{2,4,222}\). Extension of the growth plate of the femoral head in the anterolateral direction, where cam morphology usually develops is found\(^{156}\) (see Figure 4).

Cam morphology has been reported to be more prevalent in athletic populations when compared to non-athletic ones. It might therefore result from loads applied to the hip during skeletal growth. Whether or not a load dose response exists in this developmental process is unclear.

**Figure 3.** A Radiological assessment of the hip of a football player. B Radiograph presenting the Lauenstein view of the hip where a bony formation (cam) affecting the sphericity of the femoral head is visible at the white arrow. C A standardized set of bony landmarks is used to quantify the alpha angle\(^{222}\) (source: AJSM, with permission).

Presence of a cam morphology is associated with an increased risk of development of hip osteoarthritis\(^{3,5,7,97}\). At forced flexion and internal rotation a cam may be forced into the acetabulum. Tissue degeneration and chondral delamination may occur, eventually resulting in pain and disability\(^{7}\). Clinical provocation of a painful hip is often performed using flexion in combination with adduction and internal rotation (FADDIR), stressing the anterosuperior hip joint structures. When symptoms and both clinical and radiological signs are present “femoroacetabular impingement syndrome” (FAIS) is the preferred
A review on psychometric properties of clinical hip joint examination shows that most tests have good sensitivity but poor specificity. As a result, these tests can best be used for the exclusion of hip pathology rather than inclusion. A recent review of the literature on the role of imaging in identifying hip pathology showed that most research was done in highly specialised settings. This is problematic as athletes in these tertiary referral settings have a very high pre-test probability of having hip pathology and the studies therefore found that imaging did little to alter the post-test likelihoods of pathology.

The injury spectrum definitions: injury versus (no) symptoms (at all)

In football, 4-19% of all time-loss injuries relate to the hip and groin region. Wide ranges of prevalence may be the result of different study types and their quality as well as heterogeneity of terms, definitions and classification systems used. Injury incidence rates vary from 2.1 to 7.7 injuries per 1000 hours for football training sessions and increase towards 12 to 35 injuries per 1000 hours for football matches.

When an athlete suffers from a groin injury, this may result in long recovery periods, with an average between 15 and 20 days. A time-loss injury, referring to a situation in which an athlete is unable to fully take part in training or match due to injury, may be the result of accumulating problems with an insidious onset or an acute injury and is thus on the severe end of the injury spectrum. Time-loss injury prevalence numbers likely are underestimates of the extent of the groin pain burden in athletes because many athletes will keep on playing while having pain and discomfort in this region. Therefore it is of...
interest to evaluate whether or not “healthy” athletes experience groin symptoms and in the case of the latter, the burden of these symptoms experienced.

Quantifying symptoms
Patient reported outcome measures (PROs) are considered the gold standard to quantify symptoms. A recent review showed that 4 PROs (HAGOS, Hip Outcome Score (HOS), International Hip Outcome Tool (iHOT) 12 and 33) can effectively be used to assess hip and groin problems experienced by young and active individuals. The use of PROs is encouraged to gain detailed information about the clinical course experienced and to effectively compare different treatment strategies.

The Hip and groin Outcome Score (HAGOS), a 37-item questionnaire, was developed by Thorborg et al. and can reliably be used to assess perceived symptoms and disability from complaints in the hip and groin region. A translated and cross-culturally adapted Dutch version was developed according international guidelines in collaboration with the originator and published online (www.koos.nu) but needs validation in the target population in Holland.

The number of hip arthroscopies is on the rise, with an 18-fold increase between 1999 and 2009. A lack of high-quality evidence to support this development has recently been highlighted. The need for stakeholders to assess the potential benefits of any intervention and compare results of treatment strategies across studies requires a PRO that is suitable for this population and objective.

The use of iHOT-33 is advised internationally to quantify symptoms in young and active patients with femoroacetabular impingement (FAI) and describe results of hip arthroscopy in this population. HAGOS can also be used for this objective. No Dutch version of iHOT-33 is available yet.

Translation and validation of PRO’s should be systematic and done according to existing recommended guidelines. This improves the reproducibility of the process applied, the methodological quality of the study and the final product. The Consensus-based Standards for the selection of health Measurement Instruments (COSMIN) criteria should be used for these purposes.

The physical examination paradigm
Athletes presenting with complaints go through an examination or, in cases of self referral to a physical therapist, a diagnostic screening process, aiming to identify the need for additional specialized (secondary) care, based on the presence of so-called “red flags”. When no such suspicion is present the examining clinician focuses on bodily function to address structural and functional failure. Both can be described systematically using the
International Classification of Diseases (ICD)\textsuperscript{166} and International Classification of Function (ICF)\textsuperscript{163} Joint, muscle and tendon function can be assessed by specification of range of motion, coordination, strength and load bearing capacity (see Figure 5)\textsuperscript{199}.

Range of motion can be measured in degrees and presented systematically per joint\textsuperscript{126}, while strength can be tested either statically (isometric) or dynamically, either for one muscle group (across one joint) or for greater portions of the kinetic chain\textsuperscript{199}. Qualitative measures of coordination are performed more often in recent years, using motion capture systems. When assessing movements of multiple body segments in 3D space and studying angles, angular velocity and acceleration or deceleration, large data sets are obtained. It is unclear at this moment, which of the many parameters do or do not matter.

Figure 5. Physiotherapeutic paradigm: Range of motion, coordination, strength, load bearing capacity\textsuperscript{199}. Physiotherapy comprises all these fields of physical function as described in the International Classification of Function (ICF)\textsuperscript{163}.

Before the assessment of injured athletes can deliver new insights, the relevance of movement characteristics has to be determined. Conceptual approaches of human movement like proximal-to-distal movement sequencing, muscle length-strength relationships, neuromuscular patterns and biological workspace need to be considered.

**Groin pain and range of motion**

Clinicians seeing footballers with hip and groin related problems recognize the problems experienced with kicking a ball\textsuperscript{221}. Athletes report pain on kicking and a reduced kicking power. Many clinicians intuitively feel the importance to assess hip range of motion (ROM). Literature on this relationship is heterogeneous in many ways and inconsistent\textsuperscript{137,157,202}. 
It was our clinical experience that there is no clear clinical pattern found in the majority of patients for hip range of motion, either regarding symmetry or reduced ROM in injured players. We felt a systematic review of the literature was needed on how the information present could be structured and how the incongruence found in clinical practice should be interpreted. One of the complicating factors is that cam morphology of the hip is associated with decreased hip internal rotation \(^{15}\). The interplay between the presence of hip and groin symptoms and cam morphology and hip range of motion is unclear. This information may assist in interpreting the findings during physical examination.

We have observed that maximal power kicking is troublesome most of the time when groin pain is present \(^{221}\). We also observed that increasing hip range of motion often seemed to result in improved kicking ability and lower pain levels. We could however not explain why patients might benefit from any increase in hip ROM and the literature did not provide a straightforward answer. Combining information on biomechanics and kicking performance in order to propose a mechanism for hip and groin injury was a way to gain new insights in this field. Relating this to clinical studies of hip and groin function loss may lead to new insights on this not well understood type of injury.

**Coordination: Kicking biomechanics**

Football players must be able to kick a ball with maximal speed over large distances, preferably in an economic way. Extreme muscle work and energy loss should be avoided as it induces fatigue and inaccuracy, consequentially leading to an increased injury risk \(^{105}\). Biomechanical analysis of full-body, high-speed actions like kicking informs how the body generates speed. Different concepts of human movement apply.

The instep kick is divided in the preparation, backswing, leg cocking, acceleration and follow through phase \(^{30}\). The backswing phase of the kick involves a sequential wind up of the athlete’s body; a tension arc is formed \(^{212}\). These coupled movements stretch and load the interconnected anterior abdominal and thigh muscles \(^{221}\). Potential energy is stored within the body and converted into kinetic energy during the downswing.

The kicking leg displays a proximal to distal kinematic motion sequence during the downswing. Segmental speeds are summed serving to generate maximal foot speed at ball impact \(^{106,125,184}\). Figure 6 of a mass spring mechanism schematically represents this energy transfer phenomenon \(^{244}\).
Pre-stretch velocity and range of motion (ROM) correlate to powerful contraction forces that induce segmental acceleration\textsuperscript{24}. Storage of elastic energy and increased segmental motion excursions enhance segmental velocity.

The segmental speed of the lower leg is correlated to ball speed in kicking. This is considered a quality measure of kicking. Previous studies show that speed of the distal segment of the leg is the result of previous explained mechanisms. How central body actions contribute in this speed development is unclear.

**Treatment of adductor-related groin pain**

A recent systematic\textsuperscript{259} review showed that there is some high quality evidence for treatment of adductor related groin pain applying exercise therapy\textsuperscript{96,252}. Adjunct manual therapy seems to speed up the recovery process resulting in a shorter time to return to sports\textsuperscript{252}. These well-conducted studies may however reflect a situation that remains far from the “true clinical setting”. In daily practice, the athlete and clinician aim for an efficient and quick return to sport whenever possible. Pre-defined non-individualized treatment protocols do not suit this approach.

Successful return to play seems (at least partially) to be dependent on the athlete’s “psychological readiness to return to play”\textsuperscript{67}. This likely needs attention and consideration during decision making in the clinic but should also in studies\textsuperscript{12}. No such information in the current hip and groin literature is available yet. Describing the clinical
course of patients after treatment paying attention to these issues may offer directions for clinical care and new research.

**Outline of this thesis**

This thesis aims to further evaluate afore mentioned aspects in this introduction.

Groin pain can result in injury leading to time-lost to play. Assessing time-loss injuries have been the gold standard for many years to perform injury incidence and prevalence studies. Symptoms may exist while time-loss is (yet) not present. Presence and severity of hip and groin symptoms can be assessed using PROs. There is a lack of cross-culturally adapted PROs in the Dutch language that are validated in the target population according existing guidelines. A Dutch version of HAGOS and the findings of the validation study according the COSMIN checklist are presented in **Chapter 2**.

A Dutch version of the iHOT-33, a PRO that is used internationally to assess perceived hip function in young and active individuals with hip related pain and disability and the findings of its validation according the COSMIN checklist are presented in **Chapter 3**.

The discrepancy in the existing literature on the relationship between reduced hip ROM and athletes with groin pain resulted in the question “Why may range of motion be of importance in a football action like kicking, and how does that relate to the existing literature on groin pain”. A review of the literature was conducted to answer this question and is presented in **Chapter 4**.

After conducting this review it became clear that the existing literature is not equivocal whether or not decreased hip ROM is associated with an increased risk for the development of groin pain and if hip ROM differs between athletes with and without groin pain. The available literature leaves us without clarity on how this evidence should be applied by clinicians and researchers. A systematic review of the literature was conducted to adequately interpret the existing literature, describe why inconsistency exists and guide clinicians and researchers in the field on how to handle these findings either in the clinic or in future studies. The findings are presented in **Chapter 5**.

Femoroacetabular impingement syndrome (FAIS) is frequently described as a cause of hip and groin pain in young athletes. Cam morphology, being the most common morphology in FAIS related problems, has previously been related to decreased hip ROM while groin pain itself has also been related to decreased hip ROM. A cross sectional study was performed to study the relationship of hip ROM to either groin pain and/or the presence of cam morphology. As interrelatedness may exist we corrected for interaction effects. The findings of this study can be found in **Chapter 6**.

Cam morphology is thought to develop during adolescence, around the time of closure of the physes. External high impact loading stimuli in flexion and rotation like in football
are thought to trigger this morphological adaptation of bone. We questioned whether a load dose relation may exist for athletic loading in youth and studied this in a cohort of professional footballers. These findings are presented in Chapter 7.

Footballers with groin pain usually experience more symptoms and pain when maximally kicking a ball. The literature on biomechanics of sporting actions shows that a sequential wind-up and wind-off exists to store energy and consequentially release it to produce ball velocity. We questioned whether or not range of motion of body segments is larger in maximal than in sub-maximal kicking in sub elite footballers. These findings explore the hypothesis that adequate ROM is essential for maximal performance. The findings of this study are presented in Chapter 8.

Classical hip ROM examination assesses one joint in isolation, not taking into account the interdependency with adjacent segments within the total kinetic chain. Therefore we developed a test that allows hip ROM assessment while mimicking the wind-up position of the body during kicking. The reliability of this new test was studied and reference values were obtained in non-injured elite and amateur footballers. These were compared with findings in players with long-standing adductor related groin pain. This study is presented in Chapter 9.

An active treatment regimen seems to be effective for adductor related groin pain. There is evidence that adjunct manual therapeutic modalities may speed up the recovery process. The value of manual adjuncts alone is unclear, as these have been studied in combination with exercise therapy and a return to running program for a fixed, pre-defined period. A prospective study was performed to study the clinical course after manual manipulation of the adductors in combination with a self-guided return to sports program. The results of this study are described in Chapter 10.

The findings of the studies in this thesis are discussed in Chapter 11. Chapter 12 contains an English and Dutch summary.