# Hips don't lie...or do they? Patient characteristics, diagnosis and physical impairments in young to middle-aged patients with longstanding hip and groin pain.

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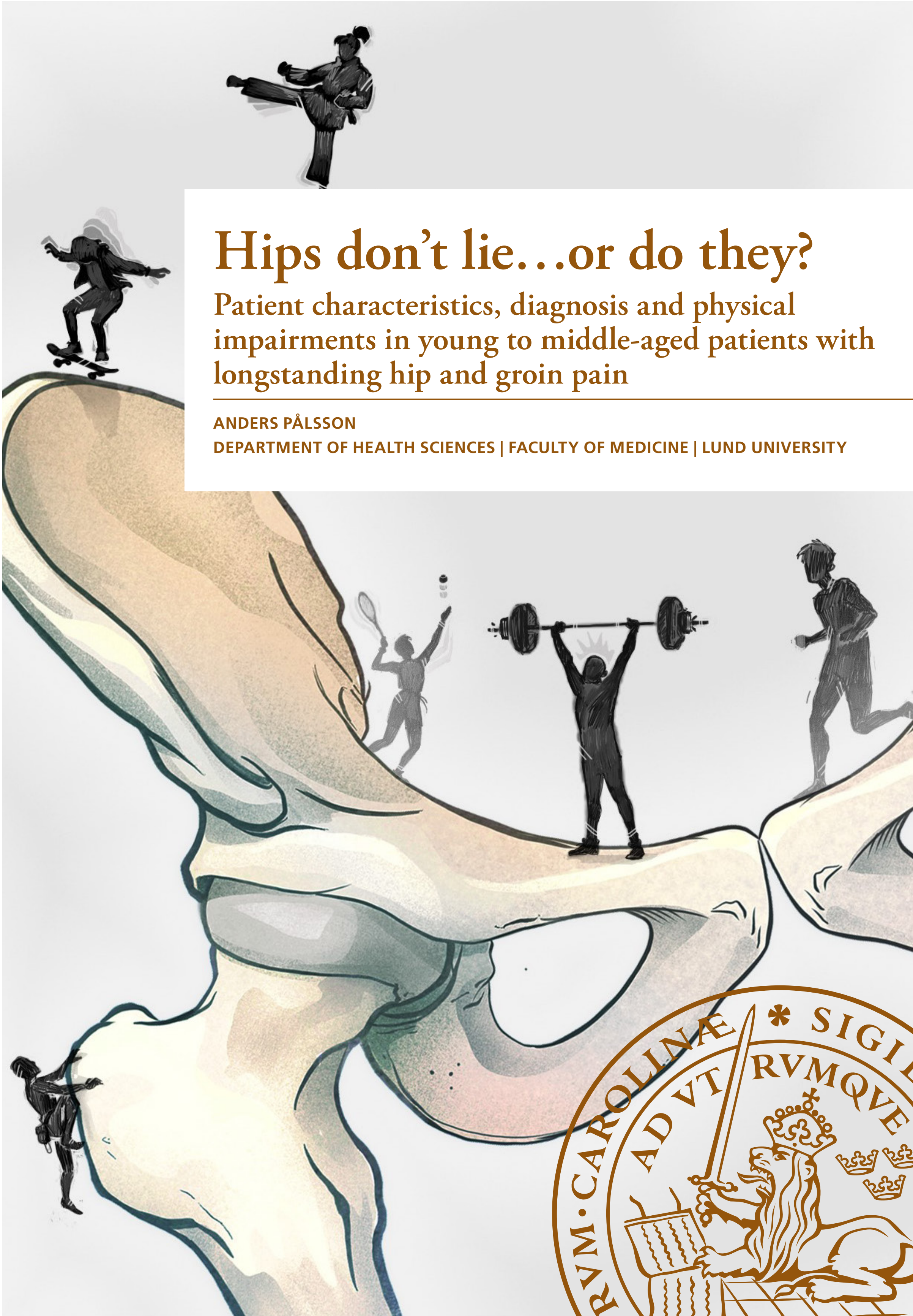

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Anders Pålsson

DOCTORAL DISSERTATION
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**Hips don't lie…or do they?** Patient characteristics, diagnosis and physical impairments in young to middle-aged patients with longstanding hip and groin pain

**Abstract:**
Longstanding hip and groin pain is common in physically active populations and may result in impaired function in daily life and restrictions in sports and physical activities. Diagnostics is challenging in patients with hip and groin pain where both intra-articular and extra-articular structures are potential sources of pain. Pain that originates from intra-articular structures is referred to as hip-related pain, the most common cause of which is femoroacetabular impingement (FAI) syndrome. Patients referred to tertiary care often have hip-related pain and any potential differences in patient-reported and objectively-measured impairment between patients with hip-related pain and non–hip-related groin pain are unknown. Diagnostic criteria for FAI-syndrome have been proposed, however, further investigations on the diagnostic accuracy of the clinical tests used to identify patients with FAI-syndrome are needed.

The overall aim of this thesis was to investigate patient-reported and objectively-measured outcomes in young to middle-aged physically active patients referred to tertiary care due to longstanding hip and groin pain. Specifically, I aimed to describe and compare patient characteristics, patient reported outcomes, and physical impairments between patients with hip-related pain and those with non–hip-related groin pain, as well as to investigate the diagnostic accuracy of the clinical assessment used to identity patients with FAI syndrome.

Two cross-sectional studies were conducted where patient characteristics (sex, age, BMI), patient reported outcomes (pain distribution, activity level, disease-specific symptoms and function, general physical and mental health), and physical impairments (hip range of motion (ROM), muscle function, and performance in functional tasks) were described and compared between patients with hip-related pain and those with non–hip-related groin pain (Papers I and II). Inter-rater agreement and diagnostic accuracy were evaluated by clinical exams, including hip impingement tests and hip ROM tests, both used for identifying patients with FAI-syndrome (Paper III). The association between hip ROM and cam morphology and the diagnostic accuracy of cut-off values for hip ROM to detect cam morphology were calculated (Paper IV).

The hip-related groin pain group had more men, a higher activity level during adolescence, and a higher pre-injury activity level, compared to the non–hip-related groin pain group. No differences between hip-related groin pain and non–hip-related groin pain were observed for age, BMI, pain distribution, disease-specific symptoms and function, or general physical and mental health (Paper I). Patients with hip-related pain showed reduced hip ROM in internal rotation compared to patients with non–hip-related groin pain and controls. No differences in muscle function or performance in functional tasks were observed between patients with hip-related pain and those with non–hip-related groin pain. Both patient groups had worse muscle function and worse performance in functional tasks compared to controls (Paper II). Three impingement tests showed substantial agreement between two raters. All passive hip ROM tests, with the exception of extension, showed moderate inter-rater agreement. The impingement test showed high sensitivity and low specificity, whereas hip ROM tests in internal rotation showed high specificity and low sensitivity (Paper III). A cut-off of 27° in internal rotation showed high sensitivity and specificity for detecting patients with cam morphology (Paper IV).

Based on these findings, early optimal treatment options—especially exercise-based treatment—for all patients despite diagnosis are needed to improve general health and improve hip-related symptoms and function. Exercise-based treatment should target several aspects of muscle function and performance in functional tasks both for patients with hip-related pain and those with non-hip-related groin pain. Treatment to improve hip ROM, in particular internal rotation, may be needed for patients with hip-related pain. A combination of results from hip impingement tests and hip ROM tests may improve diagnostic accuracy in identifying patients with FAI syndrome. Measurement of hip ROM in internal rotation may be used to identify cam morphology in patients with longstanding hip and groin pain.

**Key words:** Hip, groin, hip-related pain, femoroacetabular impingment syndrome, patient-reported outcomes, physical function, diagnosis, inter-rater agreement, diagnostic accuracy, alpha angle, cam morphology, physical examination

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# Table of Contents

# Abstract

Longstanding hip and groin pain is common in physically active populations and may result in impaired function in daily life and restrictions in sports and physical activities. Diagnostics is challenging in patients with hip and groin pain where both intra-articular and extra-articular structures are potential sources of pain. Pain that originates from intra-articular structures is referred to as hip-related pain, the most common cause of which is femoroacetabular impingement (FAI) syndrome. Patients referred to tertiary care often have hip-related pain and any potential differences in patient-reported and objectively-measured impairment between patients with hip-related pain and non–hip-related pain are unknown. Diagnostic criteria for FAI syndrome have been proposed, however, further investigations on the diagnostic accuracy of the clinical tests used to identify patients with FAI syndrome are needed.

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The hip-related groin pain group had more men, a higher activity level during adolescence, and a higher pre-injury activity level, compared to the non–hip-related groin pain group. No differences between hip-related groin pain and non–hip-related groin pain were observed for age, BMI, pain distribution, disease-specific symptoms and function, or general physical and mental health (Paper I). Patients with hip-related pain showed reduced hip ROM in internal rotation compared to patients with non–hip-related groin pain and controls. No differences in muscle function or performance in functional tasks were observed between patients with hip-related pain and those with non–hip-related groin pain. Both patient groups had worse muscle function and worse performance in functional tasks compared to controls (Paper II). Three impingement tests showed substantial agreement between two

raters. All passive hip ROM tests, with the exception of extension, showed moderate inter-rater agreement. The impingement test showed high sensitivity and low specificity, whereas hip ROM tests in internal rotation showed high specificity and low sensitivity (Paper III). A cut-off of 27° in internal rotation showed high sensitivity and specificity for detecting patients with cam morphology (Paper IV).

Based on these findings, early optimal treatment options—especially exercise-based treatment—for all patients despite diagnosis are needed to improve general health and improve hip-related symptoms and function. Exercise-based treatment should target several aspects of muscle function and performance in functional tasks both for patients with hip-related pain and those with non-hip-related groin pain. Treatment to improve hip ROM, in particular internal rotation, may be needed for patients with hip-related pain. A combination of results from hip impingement tests and hip ROM tests may improve diagnostic accuracy in identifying patients with FAI syndrome. Measurement of hip ROM in internal rotation may be used to identify cam morphology in patients with longstanding hip and groin pain.

# Populärvetenskaplig sammanfattning

Långvarig smärta i höft och ljumske är vanligt hos fysiskt aktiva personer och kan leda till nedsatt funktion i det dagliga livet och begränsningar i sport- och motionsutövande. Diagnostik är en utmaning hos patienter med höft- och ljumsksmärta där både strukturer inne i leden och strukturer utanför leden är potentiella källor till smärta. Smärta som härrör från strukturer inne i höftleden kallas höftrelaterad smärta och den vanligaste diagnosen är femoroacetabulärt impingement (FAI) syndrom. Patienter som blir remitterade till specialistvård har ofta höftrelaterad smärta och eventuella skillnader i patientrapporterade besvär och objektivt uppmätta fysiska begränsningar mellan patienter med höftrelaterad smärta och icke-höftrelaterad smärta är okända i denna grupp. Diagnostiska kriterier för FAI-syndrom har föreslagits, men ytterligare undersökning av diagnostisk tillförlitlighet i det kliniska testerna för att identifiera patienter med FAI-syndrom behövs.

Det övergripande syftet med denna avhandling var att undersöka patientrapporterade besvär och objektivt uppmätt fysisk funktion hos unga till medelålders fysiskt aktiva patienter som remitterats till specialistvård på grund av långvarig smärta i höft och ljumske. Specifikt syftade jag till att beskriva och jämföra patientegenskaper, patientrapporterade besvär och fysisk funktion mellan patienter med höftrelaterad smärta och de med icke-höftrelaterad smärta, samt att undersöka den diagnostiska tillförlitligheten i den kliniska undersökningen för att identifiera patienter med FAI-syndrom.

Två tvärsnittsstudier genomfördes där patientegenskaper (kön, ålder, BMI), patientrapporterade besvär och funktion (smärtdistribution, aktivitetsnivå, sjukdomsspecifika symtom och funktion, och allmän fysisk och mental hälsa) och fysisk funktion (rörelseomfång i höftled, muskelfunktion och prestation i funktionella test) beskrevs och jämfördes mellan patienter med höftrelaterad smärta och de med icke-höftrelaterad smärta (Studie I och II). Överensstämmelse mellan två bedömare och diagnostisk tillförlitlighet utvärderades för kliniska test inklusive specifika höftimpingementtest och rörelseomfångstest för att identifiera patienter med FAI-syndrom (Studie III). Även sambandet mellan rörelseomfång och höftmorfologi undersöktes och diagnostisk tillförlitlighet för gränsvärden i rörelseomfång för att identifiera cam-morfologi beräknades (Studie IV).

I gruppen med höftrelaterad smärta var det fler män och de hade en högre aktivitetsnivå under tonåren och en högre aktivitetsnivå före skadan jämfört med gruppen med icke-höftrelaterad smärta. Inga skillnader i ålder, BMI, smärtdistribution, sjukdomsspecifika symtom och funktion, eller allmän fysisk och mental hälsa observerades mellan patienter med höftrelaterad smärta och icke-höftrelaterad smärta (Studie I). Patienter med höftrelaterad smärta visade minskat rörelseomfång i inåtrotation jämfört med patienter med icke-höftrelaterad smärta och friska personer. Inga skillnader i muskelfunktion eller prestation i funktionella test observerades mellan patienter med höftrelaterad smärta och de med icke-höftrelaterad smärta. Båda patientgrupperna hade sämre muskelfunktion och sämre prestation i funktionella tester jämfört med friska personer. (Studie II) Tre höftimpingementtest visade god överensstämmelse mellan två bedömare, medan rörelseomfångstesterna visade måttlig överenstämmelse. Impingementtesterna visade hög känslighet men låg specificitet, medan testerna för rörelseomfång i inåtrotation visade hög specificitet men låg känslighet. (Studie III) Ett gränsvärde i rörelseomfång på 27° i inåtrotation visade hög känslighet och specificitet för att identifiera patienter med cam-morfologi (Studie IV).

Baserat på resultaten i denna avhandling behövs optimala behandlingsalternativ, särskilt träningsbaserad behandling, för alla patienter remitterade till specialistvård oavsett diagnos för att förbättra allmän hälsa och förbättra höftrelaterade symtom och funktion. Den träningsbaserade behandlingen bör rikta in sig på flera aspekter av muskelfunktion både för patienter med höftrelaterad smärta och de med icke-höftrelaterad smärta. Behandling för att förbättra rörelseomfång, särskilt i inåtrotation, kan behövas för patienter med höftrelaterad smärta. Genom att kombinera resultat från höftimpingementtester och rörelseomgångstester kan den diagnostisk tillförlitligheten för att identifiera patienter med FAI-syndrom förbättras. Mätning av rörelseomfång i inåtrotation kan användas för att identifiera cam-morfologi i höftled hos patienter med långvarig smärta i höft och ljumske.

# List of papers

*Paper I*

Pålsson A, Kostogiannis I, Lindvall H, Ageberg E. Hip-related groin pain, patient characteristics and patient-reported outcomes in patients referred to tertiary care due to longstanding hip and groin pain: a cross-sectional study. BMC Musculoskeletal Disorders. 2019;20(1):432. DOI 10.1007/s00167-020-06005-5

*Paper II*

Pålsson A, Kostogiannis I, Ageberg E. Physical impairments in patients with hip-related pain or non-hip-related groin pain compared to healthy controls. In manuscript.

*Paper III*

Pålsson A, Kostogiannis I, Ageberg E. Combining results from hip impingement and range of motion tests can increase diagnostic accuracy in patients with FAI syndrome. Knee Surgery, Sports Traumatology, Arthroscopy. 2020;28(10):3382-3392.

*Paper IV*

Estberger A, Pålsson A, Kostogiannis I, Ageberg E. The association between range of motion and cam morphology in people with longstanding hip and groin pain: a cross-sectional study. In manuscript.

# Thesis at glance

| Aims/s | Main results | Conclusions |
|---|---|---|
| Paper I | | |
| To describe the prevalence of hip-related pain in patients referred to tertiary care and to compare patient characteristics and patient-reported outcomes between patients categorized as having hip-related pain and those categorized as having non-hip-related groin pain. | Thirty-three (47%) patients, (30% women, 70% men, were categorized as having hip-related pain. The hip-related pain group had a higher activity level during adolescence, and a higher pre-injury activity level, compared to the non-hip-related groin pain group. No differences between hip-related pain and non-hip-related groin pain were observed for age, BMI, any HAGOS subscales, any SF-36 subscales or pain distribution. | Only half of the patients referred to tertiary care for long-standing hip and groin pain, who were predominantly men with a high activity level, had hip-related pain. Self-reported pain localization and distribution did not differ between patients with hip-related pain and those with non-hip-related groin pain, and both patient groups had poor perceived general health, and hip-related symptoms and function. |
| Paper II | | |
| To compare physical impairments between patients with hip-related pain and those with non-hip-related groin pain, and to compare both patient groups with healthy controls. | Patients with hip-related pain showed reduced hip ROM in internal rotation compared to patients with non-hip-related groin pain and controls. No differences in muscle function or performance in functional tasks were observed between patients with hip-related pain and those with non-hip-related groin pain. Both patient groups had worse muscle function and worse performance in functional tasks compared to controls. | To optimize treatment outcomes, exercise-based therapy should target several aspects of muscle function both for patients with hip-related pain and those with non-hip-related groin pain while treatment to improve ROM, in particular internal rotation, may be needed for patients with hip-related pain. |
| Paper III | | |
| To evaluate the inter-rater agreement and the diagnostic accuracy of clinical assessment of the hip including hip impingement tests and passive hip ROM, for detecting patients with FAI syndrome. | Anterior impingement test (AIMT), FADIR test and FABER test showed kappa values above 0.6. All passive hip ROM, except extension, had kappa values above 0.4. AIMT and FADIR showed the highest sensitivity, i.e., 80%, with a specificity of 26% and 25%, respectively. Passive hip ROM in internal rotation with neutral hip position had a sensitivity of 29% and a specificity of 94%. | The AIMT, FADIR and FABER tests were reliable between two experienced raters, while results from different raters for hip ROM should be interpreted with caution. The AIMT and FADIR test can only be used to rule out patients with FAI syndrome, while evaluation of ROM in internal rotation with neutral position may be more suitable to rule in patients with FAI syndrome. |
| Paper IV | | |
| To examine the association between passive hip range of motion and the alpha angle in patients with longstanding hip and groin pain, and to examine whether a cut-off value in ROM variables could identify patients with cam morphology. | Decreased ROM in internal rotation with 90° hip flexion, external rotation with 90° hip flexion, and abduction were associated with higher alpha angle. A cut-off of 27° in IRF displayed sensitivity of 81% and specificity of 85% to detect an alpha angle above or below 60°, while a cut-off of 41°in external rotation with 90° hip flexion and of 27° in abduction showed a sensitivity of 72% and specificity of 50% and 60%, respectively. | Reduced ROM in internal rotation with 90° hip flexion, external rotation with 90° hip flexion, and abduction appears to be associated with a greater alpha angle in people with longstanding hip and groin pain. A cut-off of 27° in internal rotation with 90° hip flexion has good sensitivity and specificity to identify people with an alpha angle above or below 60°, and may potentially be used in the clinical setting to identify patients that require further imaging, or that are unlikely to have cam morphology. |

# Definitions

| | |
|---|---|
| Hip-related pain | A condition where intra-articular structures are the primary source of pain. In this thesis hip-related pain refers to, and are limited to, the conditions described in a consensus statement by Reiman et al. (1). |
| Non-hip-related groin pain | In this thesis, non-hip-related groin pain is defined as a condition where the diagnostic criteria for hip-related pain are not fulfilled. |
| FAI-syndrome | A motion-related clinical disorder of the hip with a triad of symptoms, clinical signs and imaging findings and represents symptomatic premature contact between the proximal femur and the acetabulum (2). |
| Physical impairment | Impairment related to body functions such as range of motion, strength or balance. |
| Patient reported outcomes | Measurement of outcomes reported by the patients without interpretation by anyone else (3). |
| Diagnostic accuracy | The ability of a test to detect patient with a certain condition as well as to exclude a patient without a condition. Diagnostic accuracy is often presented as the specificity and sensitivity of a test (4). |
| Inter-rater agreement | The degree of agreement in a clinical test between two or more raters. |

# Abbreviations

| | |
|---|---|
| AIMT | Anterior impingement test |
| BMI | Body mass index |
| DEXRIT | Dynamic external rotatory impingement test |
| DIRIT | Dynamic internal rotatory impingement test |
| FABER | Flexion/abduction/external rotation |
| FADIR | Flexion/adduction/internal rotation |
| FAI | Femoroacetabular impingement |
| LCE | Lateral-centre-edge |
| MRA | Magnetic resonance arthrography |
| MRI | Magnetic Resonance Imaging |
| PRIMT | Posterior rim impingement test |
| ROM | Range of motion |

# Introduction

## Hip and groin pain

Musculoskeletal disorders such as longstanding hip and groin pain are substantial public health problems with strong impacts on health, absence due to illness and work disability (5).

Osteoarthritis is the most common cause of longstanding hip and groin pain in an older population (6). In a young to middle-aged population, hip and groin pain is commonly non-arthritic. Non-arthritic hip and groin pain is most common in physically active populations, both in athletes participating in sports involving forceful hip movement such as cutting manoeuvres, skating, and kicking (7-10), as well as in persons participating in recreational physical activities (11).

Hip and groin pain can have an acute onset which is often related to forceful muscle contractions that occur during abrupt changes of direction or while kicking (12). These acute injuries most commonly affect the musculotendinous structures of the hip, (12) and may lead to a few weeks of absence from sport activities (7, 10, 13). However, in longstanding hip and groin pain the mechanism of injury is rarely apparent and the symptoms have a more insidious onset. Longstanding hip and groin pain may affect several aspects of daily life including limiting activity and quality of life (11, 14-16).

## Epidemiology

The epidemiology of non-arthritic hip and groin pain has mainly been explored within the athletic population, especially in high impact sport activities such as football and ice hockey (10, 17-19). In elite-level football, hip and groin injuries account for 4–19% of all injuries per season and incidence ranges from 0.1 to 2.1 per 1000 hours of exposure (17). The reported incidence of hip and groin injuries in professional ice hockey players is 1.0 per 1000 hours of exposure for men and 0.7 for women (19). However, hip and groin pain may be under-reported due to commonly used time-loss definitions of injury. Wörner et al reported that 50% of the players reported groin pain during one season in a prospective study investigating professional Swedish ice hockey players, (18).

The prevalence of hip and groin pain has been less thoroughly investigated in the non-athletic population. However it is estimated that approximately 10% of the total population will experience hip pain (5).

## Categorization of hip and groin pain

Hip and groin pain may arise from several different structures in the hip and groin area where both extra-articular and intra-articular structures are potential pain generators (20). The most common extra-articular structures associated with pain in the hip and groin area are the musculotendinous structures surrounding the hip joint, especially the hip adductors and the hip flexors (12, 21). Other extra-articular structures such as the pubic symphysis and the inguinal canal may also generate pain (20).

Due to inconsistent terminology of conditions associated with longstanding pain in the hip and groin, a consensus regarding terminology and definitions of groin pain in the athletic population was published in 2015 (20). Four clinical entities were agreed upon; adductor-related, iliopsoas-related, inguinal-related, and pubic-related groin pain (20). In in the same consensus statement, pain originating from intra-articular structures referred to as hip-related groin pain was considered as a possible cause of pain although no clinical entities were agreed upon (20). In 2020, a consensus statement on classifications, definitions and diagnostic criteria for disorders involving intra-articular structures was published (1). In this consensus statement the term "hip-related pain" was agreed upon (1).

## Hip-related pain

Hip-related pain refers to a condition where intra-articular structures of the hip joint is the primary source of pain (1, 2, 22). However, pain originated from intra-articular structures could also include more serious pathologies, not discussed in this thesis, such as osteoarthritis, necrosis of the femoral head, Perthes' disease, slipped capital femoral epiphysis, fractures, or infections (1, 22). In this thesis, the term "hip-related pain" will be limited to the definition used in the recently published consensus statement on classification of hip-related pain in young and middle-aged active adults (1). This statement provides definitions and criteria for the classification of the most common conditions associated to hip-related pain. These are femoroacetabular impingement (FAI) syndrome, acetabular dysplasia and/or hip instability, and other conditions without distinct osseous morphology including labral, chondral and/or ligamentum teres lesions (1).

## FAI syndrome

FAI syndrome is defined as "a motion-related clinical disorder of the hip with a triad of symptoms, clinical signs and imaging findings and represents symptomatic premature contact between the proximal femur and the acetabulum" (2).

The primary symptom is motion-related and/or position-related pain felt in the hip or groin area. Additional symptoms can be stiffness, clicking, locking, catching or give way (2). The clinical signs are reproduction of the patient´s pain by clinical tests designed to provoke the contact between the femur and the acetabulum. The most commonly used test is the Flexion Adduction Internal Rotation (FADIR) test (2, 23). Also, there are often restrictions in hip range of motion (ROM) especially in the impingement position; i.e. internal rotation with 90° hip flexion (2, 24). The imaging findings related to FAI syndrome can be categorized in three different hip morphologies: 1) cam morphology, 2) pincer morphology, and 3) mixed morphology.

Cam-type morphology is a osseous growth often placed at the anterior-superior part of the head-neck junction leading to an aspherical femoral head (25). Cam morphology can be quantified by calculating the alpha angle on a frog-leg lateral radiological projection. The alpha angle is a measurement of the aspherical femoral head, (26) for which a cut off of 60° seems to be the most clinically relevant (27). (Figure 1:A)

Pincer morphology is an over-coverage of the acetabular rim on the femoral head leading to less clearance of hip ROM in the impingement position (25). Pincer morphology can be quantified by measuring the lateral-centre-edge (LCE) angle (26). (Figure 1:B)

Mixed-type morphology refers to when both cam- and pincer-morphology is present (25). (Figure 1:C)

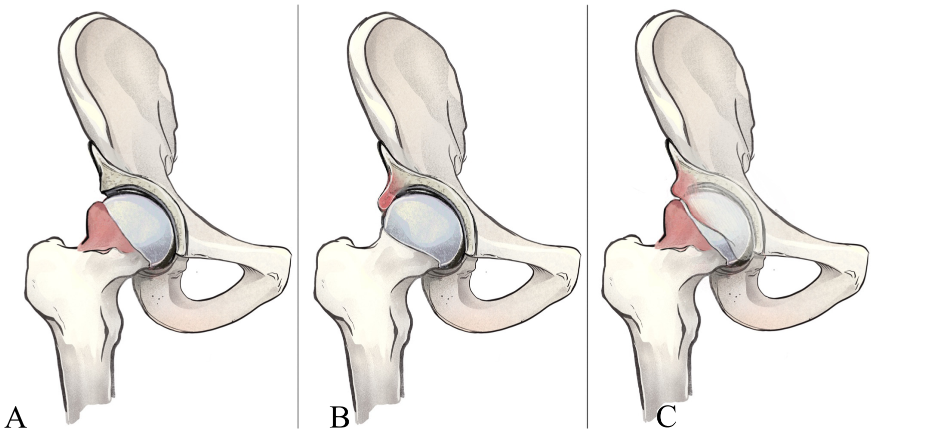


**Figure 1:A-C**
Hip morphologies associated with FAI-syndrome. A: Cam morphology; B: Pincer morphology,; C: Mixed morphology. ©Elina Metso

# Diagnostics of hip-related pain

Several conditions may give raise to referred pain in the hip and groin area. Screening for potential non-musculoskeletal pain such as pain arising from urogenital or gastrointestinal organs, or other musculoskeletal pain that requires different attention as the lumbar spine or the sacro-iliac joints is necessary. Also screening for serious pathology or “red flags” which require immediate or more specific treatment such as infection, tumours, or necrosis of the femoral head is important (22).

To distinguish whether a patient has hip-related pain or not is important since clinical management may differ. A comprehensive strategy is necessary to identify patients with hip-related pain, where the patient´s history, clinical tests, diagnostic imaging and results from diagnostic block injection should be considered (2).

## Patient history

Based on clinical practise, patients with hip-related pain rarely describes an exact moment of onset of pain, but rather a more or less insidious debut with occasional flare-ups of increased pain. The patient often describes pain in the groin area, but the pain might also radiate distally due to the sensory distribution of the femoral and the obturator nerves which innervates the hip joint (28, 29). Accompanying symptoms can be stiffness, clicking, locking, catching or give way (1, 2). Pain localization and distribution in patients with longstanding hip and groin pain is not well investigated. Any potential differences in pain distribution in patients having hip-related pain compared to those without non-hip-related pain, may help clinicians in the clinical screening process of patients with hip and groin pain.

## Clinical tests

*Diagnostic accuracy*

The diagnostic accuracy of a clinical test in often described by providing information of the test’s sensitivity and specificity. Sensitivity is a measure of the percentage of true positive findings in the population with a certain condition. A test with high sensitivity has few false negative outcomes and is therefore suitable in ruling out patients who test negative (4). Specificity is a measure of the percentage of true negative findings in the population without a certain condition. A test with high specificity has few false positive outcomes and is therefore suitable for including patients who test positive (4). In an ideal situation a test possesses both high sensitivity as well as high specificity. However, a combination of a test with high sensitivity with a test with high specificity would increase the diagnostic accuracy.

*Hip impingement tests*

The most common clinical tests for identifying hip-related pain, especially FAI syndrome and labral lesions, are the Flexion Adduction Internal rotation (FADIR), test, the Flexion Abduction External rotation (FABER) test, and the anterior impingement test (AIMT) (30). Other tests for hip-related pain are the Dynamic External Rotatory Impingement Test (DEXRIT), the Dynamic Internal Rotatory Impingement Test (DIRIT), and the Posterior Rim Impingement Test (PRIMT) (30).

Analysis of diagnostic accuracy of FADIR test and FABER test has shown limited diagnostic value since the tests possesses high sensitivity and low specificity and can therefore only be used to rule out patients with hip-related pain when negative (23).

*Hip ROM*

Hip ROM is often clinically evaluated dichotomously as either decreased or not, or painful or not. Affected hip ROM in terms of reduced or painful is considered as a clinical sign in hip-related pain (1, 2). However, evaluation of hip ROM as a diagnostic test has not been investigated and any information of the diagnostic accuracy is lacking.

Further investigation is needed of the diagnostic accuracy in hip impingement tests and hip ROM for identifying patients with FAI syndrome using solid reference standards, based on current best evidence.

## Imaging

Osseous hip morphology such as cam morphology, pincer morphology or acetabular dysplasia can be identified via plain radiography (26). Magnetic Resonance Imaging (MRI) and magnetic resonance arthrography (MRA) can be used to visualize soft tissue injuries such as labral and chondral lesions (31).

However, high prevalence of cam and pincer morphology, as well as labral lesions in non-symptomatic populations have been reported (32). Therefore, there is a high risk of overdiagnosing hip-related pain, especially FAI syndrome and labral lesions, if only diagnostic imaging is considered in the diagnostic process.

## Intra-articular block injection

Clinically, intra-articular block injection can be used both therapeutically and in diagnostics to distinguish between intra-articular and extra-articular pain origins. Byrd et al. (33) reported an accuracy of 90% in identifying intra-articular abnormalities using block injection. However, the diagnostic accuracy for identifying patients with FAI syndrome and/or labral lesions is not yet established (31, 34). Intra-articular block injection may also be used clinically to select potential candidates for hip surgery. However, responding to block injection does not increase the likelihood of having positive short-term functional outcome after surgery (35).

# Consequences of longstanding hip and groin pain

## Objectively measured physical impairments

*ROM*

Restricted hip ROM in patients with longstanding hip and groin pain is associated with decreased performance in functional tasks and is an important aspect for investigation (36). Two current systematic reviews report conflicting results on hip ROM in patients with hip-related pain (24, 37). The conflicting results may be due to different diagnostic criteria for hip-related pain and measurement techniques used in the different studies included in the review and should therefore be interpreted with caution. Reports on hip ROM in patients with hip-related pain based on solid diagnostic criteria is lacking. Also, comparisons of hip ROM between patients with and without hip-related pain have not been made.

*Muscle function and performance in functional tasks*

Poor strength in hip adductors and flexors and altered truck muscle function in patients with longstanding hip and groin pain compared to asymptomatic people were reported in a systematic meta-analysis (14). In a more homogenous patient group of patients with FAI syndrome, more generalized hip muscle weakness was reported, where patients were weaker in all muscle groups compared to asymptomatic controls (24, 37). Also, performance impairments in functional tasks like dynamic balance and altered movement strategies in single-leg squats were reported in patients with hip-related pain (36, 38).

Even though muscle function and performance in functional tasks have been investigated in patients with longstanding hip and groin pain, further insight as to impairments as well as potential differences between patients with hip-related pain and those with non–hip-related pain, is justified.

## Patient reported outcomes regarding impairments, activity limitations, and participation restriction.

Both objectively measured physical impairments and patients' reported outcomes may guide clinicians in providing appropriate treatment as well as in evaluating treatment progress.

Patients with longstanding hip and groin pain report significant pain and symptoms as well as limitations in activity and restricted participation in activities in daily life and sports (11, 14-16). However, further investigation of potential differences in patient-reported outcomes between patients with hip-related pain and those without is needed.

### Early onset of hip osteoarthritis

A link between hip morphology associated with FAI syndrome and hip osteoarthritis has been described by Ganz et al. (39). A maloriented articular surface and premature contact between femur and acetabulum may cause mechanical overloading and shear forces within the joint leading to soft tissue such as lesions of the acetabular labrum and chondral lesions (40). These soft tissue lesions may lead to early onset of hip osteoarthritis. Cam morphology, especially, is associated with development of osteoarthritis, and based on epidemiological data an alpha angle of ≥78° is proposed as a cut-off value marking high risk of early onset osteoarthritis of the hip (27). Cam morphology may be developed during skeletal growth and is believed to be influenced by high impact sports activities (41). However, longitudinal studies investigating cause-effect is warranted.

## Management of longstanding hip and groin pain

In Sweden all patients with any disease or pain are initially managed in primary care. In primary care, the patient is usually referred to a physiotherapist whenever musculoskeletal problem is suspected. If further investigation like diagnostic imaging and/or medical treatment are warranted, or if the patients do not respond physiotherapy-led treatment, the patient is referred to a general practitioner in primary care. Patients are referred to tertiary care if any investigation and/or treatment not provided in primary care prove necessary. Due to this route, patients with hip and groin pain seen in tertiary care are often presented with longstanding symptoms.

Treatment of longstanding hip and groin pain may include patient education, activity modification, exercise-based treatment, manual therapy, analgesics, injection therapy, and in some cases surgery (2, 42, 43). Education involving advise and activity modification has been reported to improve patient reported symptoms and function, but not hip ROM in patients with mild FAI-syndrome (44). Exercise-based treatment for patients with adductor-related groin pain has shown significant and long-lasting improvement in perceived symptoms and function, as well as in return to physical activity (45, 46). In patients with FAI-syndrome, exercise-based treatment alone and together with arthroscopic surgery improves patient reported outcomes (15, 16, 47).

However, which exercise protocol is the most effective is still unknown. Exercise-based treatment should target modifiable physical impairments as well as improve symptoms. Therefore, further insight in the patients physical impairments is crucial in improving exercise-based treatment. Also, further insight in any possible differences in physical impairment between patients with hip-related pain and non–hip-related pain is needed to better tailor treatment plans. The mechanism behind how exercise-based treatment improves pain and other symptoms is unclear, but pain inhibition through mechanoreceptors as well as a reduction in mechanical overloading of the joint through improved movement strategies may play an important part. Manual therapy for longstanding hip and groin pain is not investigated, however, optimizing hip ROM limited by soft tissue such as the joint capsule or by increased muscle tone, may be beneficial.

Due to technical advances and improved surgical techniques, hip pathology such as FAI syndrome with or without labral/chondral lesions can be addressed by hip arthroscopy. The number of arthroscopic procedures in the USA increased 25-fold from 2006 to 2013 (48). The goal of the procedure is to reshape the undesirable osseous morphology of the hip to avoid impingement, and/or address the labral/chondral lesion. This in order to decrease symptoms, improve function as well as possibly reduce the risk of early onset osteoarthritis. However, the effectiveness in improve symptom, increasing activity and participation in the long-term, as well as its effectiveness in preventing the development of hip osteoarthritis is still unknown (49). Even though there is a low prevalence of post-operative complications (1.3%), cases of major complications such as bleeding requiring a transfusion, deep venous thrombosis, and death have been reported (48).

Considering cost-effectiveness and risk, non-surgical treatment such as education, activity modification and high quality physiotherapy-led treatment should be the first choice of treatment in longstanding hip and groin pain.

# Rationale for the thesis

Studies investigating patient-reported outcomes and physical impairment in patients with longstanding hip and groin pain referred to tertiary care mainly include homogenous groups of patients with hip-related pain prior to surgery. Investigation of prevalence of hip-related pain in a more heterogenous group of patients refereed to tertiary care, as well as any differences in patient characteristics, patient-reported outcomes and physical impairment between patients with hip-related pain and those without, is therefore warranted. Insight regarding potential differences in patient-reported outcomes and physical impairments between patient groups would form the basis of optimally-tailored treatment models and appropriate patient evaluation.

The diagnostics involved in longstanding hip and groin pain is challenging, especially when it comes to identifying patients with FAI syndrome. In current literature, inter-rater agreement of clinical tests designed to identify FAI syndrome is lacking. Also, studies of diagnostic accuracy for clinical tests used to identify FAI use reference standards not based on current best evidence and may lack validity. Therefore, evaluation of inter-rater agreement and further investigation of the diagnostic accuracy of clinical tests used in identifying patients with FAI syndrome based on solid reference standards are justified.

Cam-type FAI syndrome is the most prevalent disorder associated with hip-related pain and is also associated with early onset of hip osteoarthritis. Detecting cam morphology early in diagnostic screening may be beneficial in initiating proper treatment plans. Since patients with longstanding hip and groin pain are initially screened by physiotherapists in primary care without access to diagnostic imaging, the diagnostic accuracy of hip ROM tests in detecting cam morphology is of interest.

# Overall aim and goal of the thesis

The overall aim of this thesis was to investigate patient-reported and objectively-measured outcomes in young to middle-aged physically active patients referred to tertiary care due to longstanding hip and groin pain. Specifically, I aimed to describe and compare patient characteristics, patient-reported outcomes, and physical impairments between patients with hip-related pain and those with non–hip-related groin pain, as well as to investigate the diagnostic accuracy of the clinical assessments used to identity patients with hip-related pain.

The goal was to improve the diagnostic investigation and increase the knowledge of patient-reported and objectively-measured outcomes that could contribute to form a foundation for optimally-tailored treatment plans and evaluation of these patients.

## Specific aims

1. Describe the prevalence of hip-related groin pain in patients referred to tertiary care and to compare patient characteristics and patient-reported outcomes between patients categorized as having hip-related pain and those categorized as having non-hip-related groin pain. (Paper I)
2. Compare physical impairments between patients with hip-related pain and those with non-hip-related groin pain, and to compare both patient groups with healthy controls. (Paper II)
3. Evaluate the inter-rater agreement and the diagnostic accuracy of clinical assessment of the hip including hip impingement tests and passive hip ROM, for detecting patients with FAI syndrome. (Paper III)
4. Examine the association between passive hip range of motion and the alpha angle in patients with longstanding hip and groin pain, and to examine whether a cut-off value in ROM variables could identify patients with cam morphology. (Paper IV)

# Methods

## Participants

All patients referred for non-arthritic hip and groin pain (n = 156) to the Department of Orthopedics, Skåne University Hospital, Sweden from October 2014 to January 2017, were recruited consecutively and screened for eligibility according to inclusion and exclusion criteria. Eighty-one participants were included in the cohort (Figure 2).

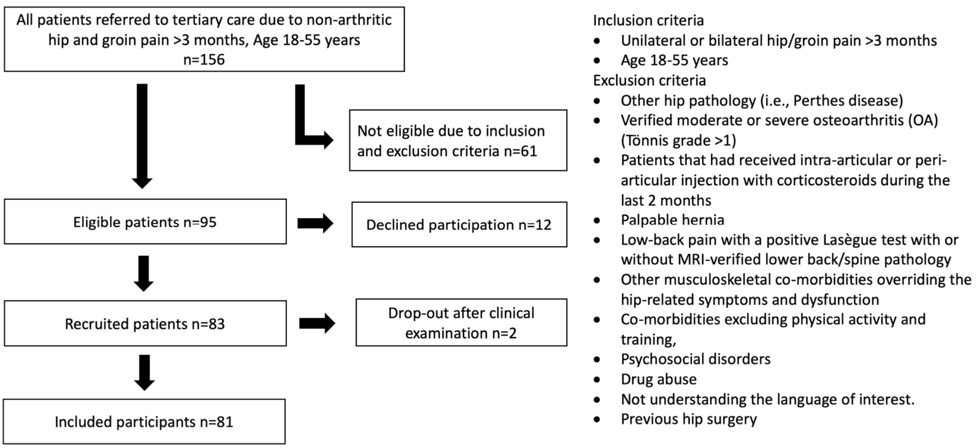


**Figure 2**
Flowchart of the recruitment process.

The included participants were investigated in the order in which they are presented here; 1) clinical assessment, 2) patient-reported outcomes, 3) physical impairment testing, and 4) intra-articular block injection. Radiological investigation was conducted adjacent to referrals to the Department of Orthopedics (Table 1).

**Table 1**
Overview of the investigations conducted in the cohort

| | Patients (n) | Missing data (n) | Reason for missing data |
|---|---|---|---|
| Clinical assessment | 81 | 0 | - |
| Patient-reported outcomes | 72 | 9 | Unknown |
| Physical impairment testing | 81 | 0 | - |
| Intra-articular block injection with follow-up | 70 | 11 | Declined injection (n=7) or missing follow-up (n=4) |
| Radiological investigation | 75 | 6 | Missing Lauenstein projection |

# Clinical assessment

The clinical assessment of the hip included passive hip ROM and hip impingement tests. Two raters assessed the participants, an orthopaedic surgeon (IK) and a physiotherapist (AP). For inter-rater agreement analysis, the first 69 participants were assessed by both raters. The last 12 participants were assessed only by the orthopaedic surgeon.

*Passive hip ROM*

Range and/or patient-reported pain was assessed in passive flexion (Figure 3:A), medial rotation with 90° hip flexion (Figure 3:B), lateral rotation with 90° hip flexion (Figure 3:C), abduction (Figure 3:D), medial rotation in neutral hip position, (Figure 3:E) and extension (Figure 3:F). The tests were categized as 1) decreased range with pain, 2) decreased range without pain, or 3) full range with end-range pain, or 4) full range without pain.

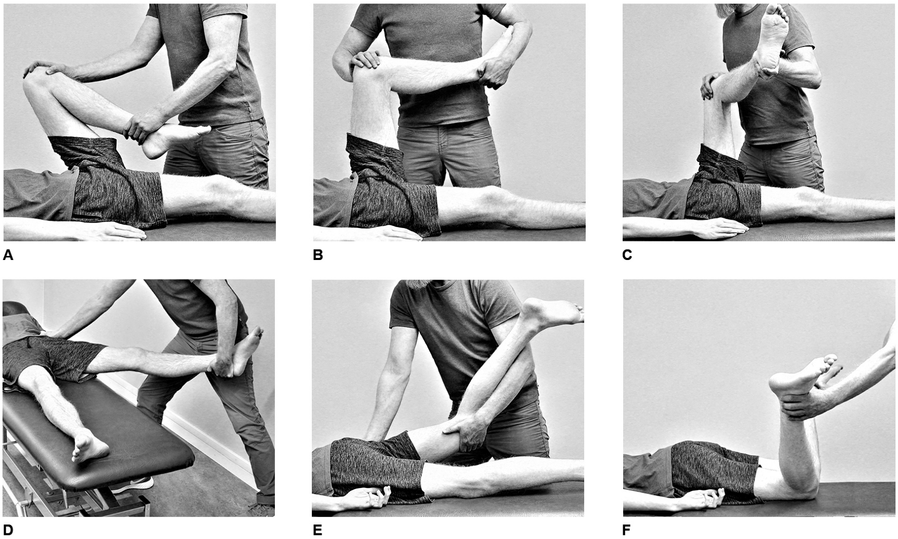

**Figure 3:A-F**
Passive hip ROM.

### *Hip impingement tests*

Six hip impingement tests were included and performed as described by Martin et al. (30). (Table 2) Anterior Impingement Test (AIMT) (Figure 4:A), Flexion/Adduction/Internal Rotation (FADIR) (Figure 4:B), Flexion/Abduction/External Rotation (FABER) (Figure 4:C), Dynamic External Rotatory Impingement Test (DEXRIT) (Figure 4:D), Dynamic Internal Rotatory Impingement Test (DIRIT) (Figure 4:E) and Posterior Rim Impingement Test (PRIMT) (Figure 4:F). The tests were categorized as either negative (no pain), or positive (painful).

**Table 2**
The procedure of the impingement tests.

| Hip impingement tests | Procedure |
|---|---|
| AIMT | The hip was brought into 90° flexion and then into internal rotation and adduction. |
| FADIR | The hip was brought into maximal flexion and then into internal rotation and adduction. |
| FABER | The examined leg was placed with the foot just proximal to the contralateral knee joint, the hip was moved into a combined flexion, abduction and external rotation position. The examiner stabilized the contralateral side of the pelvis to minimize pelvic rotation; |
| DEXRIT | The participant held the contralateral hip in more than 90° flexion. The examiner then brought the hip into approximately 90° flexion and moved the hip through a wide arc of extension, abduction and external rotation. |
| DIRIT | The participant held the contralateral hip in more than 90° flexion. The examiner then brought the hip into approximately 90° of flexion and moved the hip through a wide arc of extension, adduction and internal rotation. |
| PRIMT | With the participant in supine position lying at the edge of the examining table, both hips were brought into flexion, and the patient was instructed to keep the contralateral hip in flexion while the examined hip was brought into extension, abduction and external rotation |

AIMT = Anterior Impingement Test, FADIR = Flexion Adduction Internal Rotation, FABER = Flexion Abduction External Rotation, DEXRIT = Dynamic External Rotatory Impingement Test, DIRIT = Dynamic Internal Rotatory Impingement Test, PRIMT = Posterior Rim Impingement Test

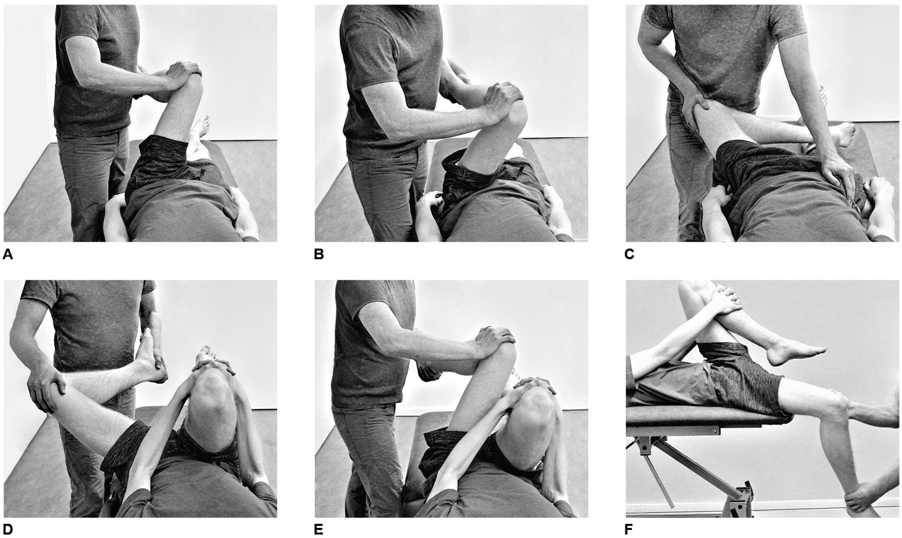


**Figure 4:A-F**
Hip impingement tests.

## Patient-reported outcomes

All patient-reported outcomes, except the pain mannequin, were collected using the electronic survey software SUNET (Artologic®, Sweden).

*Copenhagen Hip and Groin Outcome Score (HAGOS)*

HAGOS is a disease-specific questionnaire and is a validated instrument in the assessment of longstanding hip and groin pain in the young to middle-aged population (50). The questionnaire includes six subscales; pain, symptoms, activities in daily living, physical function in sports and recreation, participation in physical activity, and quality of life. The score for each subscale ranges from 0–100, where 0 indicates extreme problems and 100 no problems.

*Hip Sports Activity Scale (HSAS)*

Current activity level, as well as pre-injury activity level, and during adolescence was evaluated with HSAS. The questionnaire includes 8 levels of activity where level 0 indicates no participation in recreational or competitive sports and 8 indicates participation in competitive sports at elite level. HSAS is a valid and reliable questionnaire for assessing activity level (51).

*Medical Outcomes Study 36-Item Short Form Health Survey (SF-36),*

Perceived general physical and mental health was evaluated with the SF-36, which includes eight subscales: physical functioning, physical role functioning, bodily pain, general health perception, vitality, social role functioning, emotional role functioning, and mental health. A combined physical component score and mental component score is also calculated. The score for each subscale ranges from 0-100, where 0 indicates extreme problems and 100 no problems (52).

*Pain mannequin*

Pain localization and pain distribution was registered by the participants on a full-body mannequin where the patients were instructed to outline the area of their pain. Nine separate areas were defined :1) lower back, 2) groin, 3) buttocks, 4) anterior thigh, 5) posterior thigh, 6) anterior knee, 7) posterior knee, 8) anterior lower leg, and 9) posterior lower leg.

# Physical impairment testing

## Test procedure

All tests were performed by one tester (AP) accompanied by one assistant. The participants were asked not to participate in any high-intensive training/activities 48 hours prior to the tests. Before the tests, the participants performed a 10 min warm-up including five minutes cycling on a stationary bike (75W) at self-selected pace and 5 min dynamic and static stretching of the lower extremities. The participant´s body mass and height were measured. Total leg length (anterior superior iliac spine (ASIS) to the medial malleolus), thigh length (ASIS to the medial knee joint line), and lower leg length (medial knee joint line to the medial malleolus) were measured in a supine position.

## Passive hip range of motion

Hip ROM in flexion, internal/external rotation with 90° hip flexion, internal rotation in neutral hip position, and abduction was measured according to Pua et al (53) with a digital inclinometer and a digital goniometer (Commander Echo (JTECH Medical, Salt Lake City, Utah, USA)). (Table 3) (Figure 5)

**Table 3**
Overview of the position of the participant´s position, equipment, procedure, and outome of passive hip ROM.

| Passive hip ROM | Participant´s position | Equipment and procedure | Outcome |
|---|---|---|---|
| Flexion | Supine. The contralateral thigh was fixed with a belt. | The digital inclinometer was attached to the lateral side of the thigh, 10 cm proximal of the knee joint. | Mean (°) of two repetitions at end range. |
| Internal rotation with 90° hip flexion | Sitting. For stabilization of the pelvis and trunk, the participant was instructed to hold on to the edge of the table. | The digital inclinometer was attached on the anterior aspect of the leg, 10 cm proximal to the medial malleolus | Mean (°) of two repetitions at visual pelvic movement. |
| External rotation with 90° hip flexion | Sitting. For stabilization of the pelvis and trunk, the participant was instructed to hold on to the edge of the table. | The digital inclinometer was attached on the anterior aspect of the leg, 10 cm proximal to the medial malleolus | Mean (°) of two repetitions at visual pelvic movement. |
| Internal rotation in neutral hip position | Prone. The pelvis was stabilized with a belt. | The digital inclinometer was attached on the posterior aspect of the leg, 10 cm proximal to the medial malleolus | Mean (°) of two repetitions at end range. |
| Abduction | Supine. Contralateral leg hanging down on the edge of the table to stabilize the pelvis. | The digital goniometer was placed along the femur and a line drawn between the anterior superior iliac spines. | Mean (°) of two repetitions at end range. |

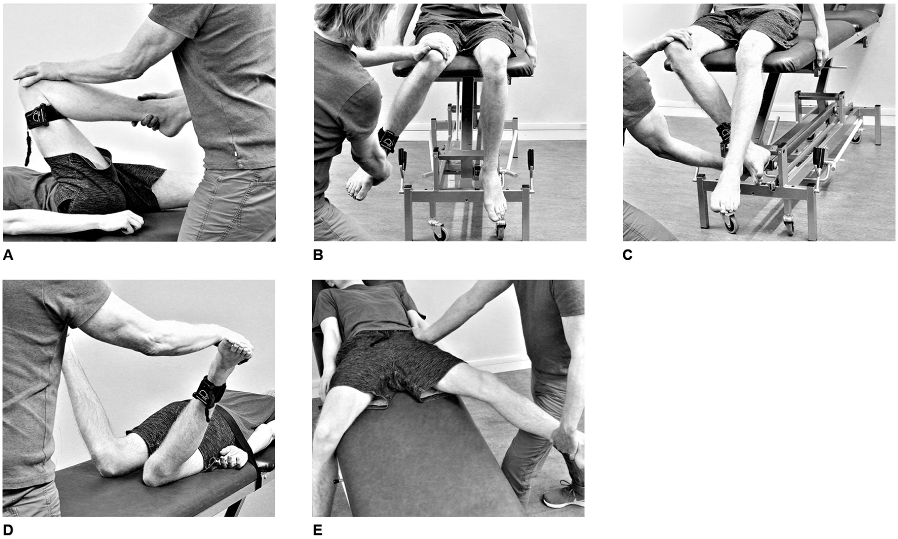

**Figure 5:A-E**
Measurement of passive hip ROM in A: Flexion, B: Internal rotation with 90° hip flexion, C: External rotation with 90° hip flexion, D: Internal rotation in neutral hip position, E: Abduction.

## Muscle function

### *Isometric hip strength*

Isometric strength for hip adduction, abduction, flexion, internal rotation and external rotation was measured with a hand-held dynamometer (Power Track II Commander (JTECH Medical, Salt Lake City, Utah, USA)). A modified version of a test protocol described by Thorborg et al. (54, 55) was used. The starting leg was selected in an alternating fashion. (Table 4) (Figure 6)

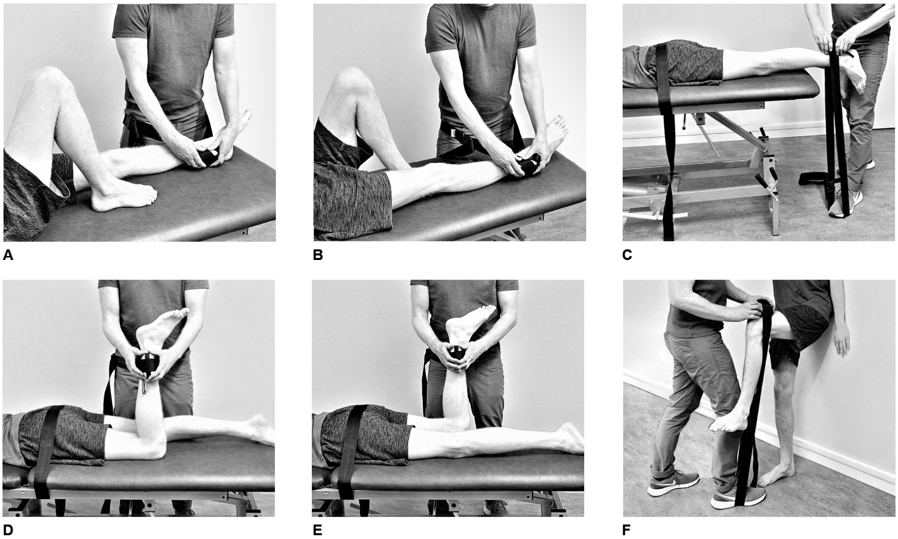


**Figure 6:A-F**
Measurement of isometric hip strength in A: Adduction, B: Abduction, C: Extension, D: Internal rotation, E: External rotation, and F: Flexion.

### *Double leg lowering test*

The double leg lowering test tests a person's ability to stabilize the pelvis and the lumbar spine in the sagittal plane (56). For this study, a modified double leg lowering test was developed for direct measurement of the pelvic tilt and the degree of maximal hip extension during the test. This was achieved by an iPod-based tilt sensor (Apple Inc.) attached to the pelvis by a fixation belt and a digital inclinometer (Commander Echo (JTECH Medical, Salt Lake City, Utah, USA)) attached to the thigh. (Table 4) (Figure 7)

**Figure 7**
Double leg lowering test.

**Table 4**
Overview of the position of the participant´s position, equipment, procedure, and outome of muscle function testing.

| Muscle function | Position | Equipment and method | Outcome |
|---|---|---|---|
| Isometric adduction | Supine. Opposite foot was placed on the table. Participant held on to the edges of the table for stabilization. | The handheld digital dynamometer was placed on the medial aspect of the leg, 10 cm proximal to the medial malleolus. The dynamometer was fixed with a belt around the assessor. | Maximum torque of three trials normalized by bodyweight (Nm/kg) |
| Isometric abduction | Supine. Opposite foot was placed on the table. Participant held on to the edges of the table for stabilization. | The handheld digital dynamometer was placed on the lateral aspect of the leg, 10 cm proximal to the medial malleolus. The dynamometer was fixed with a belt around the assessor. | Maximum torque of three trials normalized by bodyweight (Nm/kg) |
| Isometric extension | Prone. Fixation belt over the pelvis. Palms placed on the table. | The handheld digital dynamometer was placed on the dorsal aspect of the leg, 10 cm proximal to the medial malleolus. The dynamometer was fixed with a belt anchored to the floor by the assessor's foot. | Maximum torque of three trials normalized by bodyweight (Nm/kg) |
| Isometric internal rotation | Prone. Fixation belt over the pelvis. Palms placed on the table. | The handheld digital dynamometer was placed on the lateral aspect of the leg, 10 cm proximal to the medial malleolus. The dynamometer was fixed with a belt around the assessor. | Maximum torque of three trials normalized by bodyweight (Nm/kg) |
| Isometric external rotation | Prone. Fixation belt over the pelvis. Palms placed on the table. | The handheld digital dynamometer was placed on the medial aspect of the leg, 10 cm proximal to the medial malleolus. The dynamometer was fixed with a belt around the assessor. | Maximum torque of three trials normalized by bodyweight (Nm/kg) |
| Isometric flexion | Standing with the hip in 90° flexion. Fixation belt over the thigh. Head, pelvis and palms against a wall. The opposite heel placed 10 cm from the wall. | The handheld digital dynamometer placed on the thigh, 10 cm proximal to the knee joint. The dynamometer was fixed with a belt anchored to the floor by the assessor's foot. | Maximum torque of three trials normalized by bodyweight (Nm/kg) |
| Double leg lowering test | Supine. Both legs straight and elevated into 70° hip flexion. | The tilt sensor was attached between the iliac crest and the greater trochanter by a fixation belt.<br>The digital inclinometer was attached to the lateral side of the thigh 10 cm proximal to the knee joint. The subject was instructed to keep the lumbar spine flat on the floor while the assessor let go of the legs and lowered under control by the participant. | The hip extension was measured when the tilt sensor registered 10° posterior pelvic tilt. Mean (°) of three trials served as outcome. |

## Functional tasks

### *Y-balance test*

Dynamic balance control was assessed with the Y-balance test as described by Plisky et al (57). (Table 5) (Figure 8)

**Figure 8**
Y-balance test.

*Hop performance*

For hop performance in the frontal plane, the 30-second side-hop test was used, and for hop performance in sagittal plane the single leg hop for distance was used. (Table 5) (Figure 9)

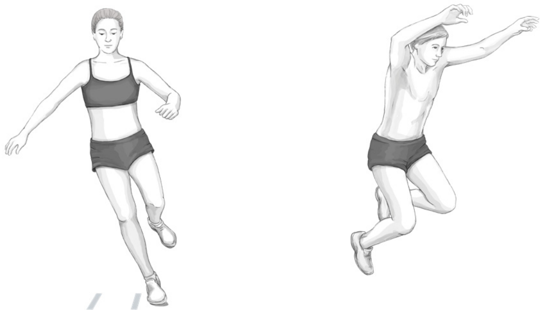

**Figure 9**
The 30-second side-hop test and single leg hop for distance. ©Frida Nilsson

*Standing active single leg raise*

During the standing active single leg raise (SASLR), the peak range of medial to lateral and anterior to posterior pelvic tilt was measured. This test was performed according to protocol by Chaudhari et al (58, 59). (Table 5) (Figure 10)

**Figure 10**
Standing active single leg raise.

**Table 5**
Overview of the position of the participant´s position, equipment, procedure, and outome of functional tasks.

| Functional tasks | Position | Equipment and method | Outcome |
|---|---|---|---|
| Y-balance test | Standing on one leg. | The participant was instructed to reach with the foot forward, 45° posterior/laterally and 45° posterior/medially as far as he/she can without losing balance. A lightweight plastic box was pushed along a bar by the participant in all three directions. | The maximum distance (cm), of three trials in every direction was measured. The percentage of total leg length (%LL) served as outcome. |
| Side-hop 30 seconds | Standing on one leg. | A distance of 40cm was marked by tape on the floor. The subject was instructed to jump across the distance without touching the tape as many times as possible during 30 seconds. The test was performed one time on each side. | The test was filmed and the number of jumps during 30 sec was counted and served as outcome. |
| Singe-leg hop for distance | Standing on one leg at starting point | The participant stands on one leg and was instructed to jump as far as he/she can and land on the same leg. | Maximum distance (cm) of three jumps (starting point to posterior margin of the heel served as outcome. |
| Standing active single leg raise | The participant was standing with the feet 40 cm apart. | An iPod tilt sensor was placed on the sacrum with a fixation belt. The participant was instructed to lift his/hers foot above a 10 cm box without touching it and return to the starting position. | The range in degrees (°), medial to lateral pelvic tilt, was measured. The mean range of three trials served as outcome. |

# Diagnostic imaging

From a Lauenstein (frog-leg lateral) projection, the alpha angle was calculated between a line from the centre of femoral head to the centre of the femoral neck, and a line from the centre of the femoral head to the point where the femoral head loses its spherical appearance antero-laterally (Figure 11). Values ≥60 degrees were used as the cut-off defining a cam morphology (60).

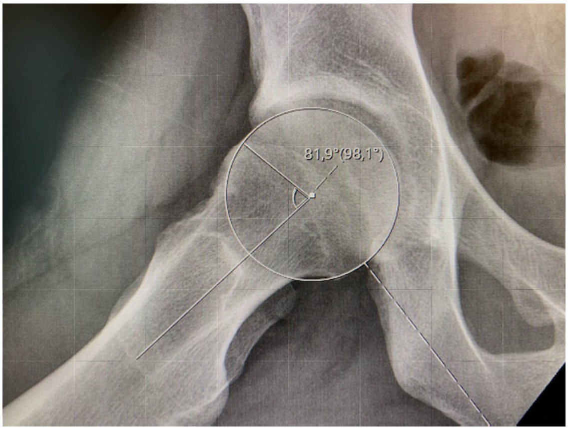


**Figure 11**
Alpha angle.

From an anteroposterior pelvic projection, the LCE angle was identified and calculated. A first line connecting the inferior acetabular teardrops was drawn as a reference line. A second line was drawn with a 90° angle to the reference line through the centre of the femoral head. A third line from the centre of the femoral head to the superolateral sourcil of the acetabulum was drawn. The LCE angle was calculated between the second and third line. An LCE angle ≥40° indicated the presence of a pincer morphology and an LCE angle ≤20° indicated hip dysplasia (Figure 12) (60).

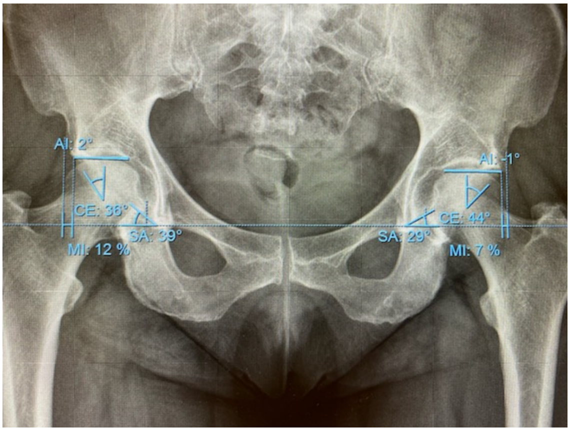


**Figure 12**
LCE angle (presented as CE in figure)

Fifty-four patients had MRI examination according to clinical indication. Records of any hip morphology, labral tear or chondral lesions visual on MRI were extracted from the patient's medical record. Nineteen patients underwent arthroscopic examination and data on any findings of hip morphology, acetabular labral tear or chondral lesions from the arthroscopic examination were extracted from the patient's medical record.

# Intra-articular block injection

The intra-articular block injection was performed under fluoroscopic guidance. To confirm the intra-articular position of the needle, 1ml of contrast agent was injected prior to the block injection containing a mixture of 2ml triamcinolon, 4ml ropivacaine and 4ml lidocaine. Pre injection the patients rated their pain on a VAS, from 0 (no pain) to 100 (maximal pain) mm and repeated the rating one, two and four hours post injection. The patients who rated at least 50% decrease of pain post injection were categorized as responder to block injection (61).

# Categorization of the patients into hip-related pain of non-hip-related pain

*Paper I and II*

In paper 1 and II the participants were categorized as having either hip-related pain or non–hip-related pain. For participants to be categorized as having hip-related groin pain, diagnostic criteria based on current best evidence as described in Table

6 had to be met. In this thesis all patients whose primary intra-articular source of pain could not be established, i.e., those who did not fulfil the criteria of having hip-related pain, were categorized as having non–hip-related pain. This group was not further categorized according to diagnostic criteria and should be considered heterogeneous, even though all patients were referred to the department of orthopedics due to similar symptoms.

**Table 6**
Diagnostic criteria for hip-related pain (paper I and II)

| CRITERIA | |
|---|---|
| 1 | Symptoms of hip-related pain. |
| 2 | Passive range of motion (ROM) affected (decreased ROM or pain). |
| 3 | Pain provocation during at least one hip impingement test. |
| 4 | Radiological findings corresponing to FAI morphology or dysplasia, or MRI/MRA findings of FAI morphology and/or labral and/or chorndral lesions. |
| 5 | Responder to intra-articular block injection. |

### *Paper III*

To evaluate diagnostic accuracy of the clinical investigation to identify participants with FAI-syndrome the reference standard the following criteria described in Table 7 had to be met

**Table 7**
Reference standard for FAI-syndrome (paper III)

| CRITERIA | |
|---|---|
| ! | Symptoms of FAI-syndrome |
| 3 | Radiological findings corresponing to FAI morphology |
| 4 | Responder to diagnostic intra-articular injection |

### *Paper IV*

In paper IV the participants were categorized in two groups based on calculation of the alpha angle. Alpha angle ≥60° or <60°.

## Statistical methods

All calculations were performed in SPSS for Windows, version 22.0 (IBM Corp., Armonk, New York, USA) and in Excel.

### *Paper I*

All variables were tested for skewness using Kolmogorov-Smirnov test. An independent t-test was used for between-group analysis of the HAGOS and the SF-36. Comparison of the HAGOS and SF-36 scores of the patients and normative data was performed by calculating the 95% confidence interval for all groups (95% CI = ±1.96×SE). For between-group analysis of the HSAS score, the Mann-Whitney U-test was used. Pain distribution was calculated as frequency, percent and 95% confidence interval using the equation:

$$95\%\ CI = \pm 1.96 \times \sqrt{\frac{px(1-p)}{n}}$$

The chi-square test was used to compare between-group differences in sex and pain distribution.

*Paper II*

All variables were analysed for skewness using Kolmogorov-Smirnov test. No differences were found between legs in the control group, so values from the right leg were used in the analysis. For patients with bilateral symptoms, data from the most affected hip, based on the patient's subjective perception, were chosen.
Values for all variables and all groups were displayed as observed means and standard deviations (SD). For between-group analysis, an analysis of covariance (ANCOVA) was performed with each variable as dependent variable and sex as covariate due to uneven distribution of male and female patients in the patient groups. The confidence intervals of the mean differences and associated p-values were Bonferroni adjusted due to multiple comparisons.

*Paper III*

For inter-rater agreement analysis, the Cohen's kappa statistic was used and interpreted as described in Table 8 (62). Absolute agreement was also included and expressed in percentages. Only tests showing at least moderate inter-rater agreement were included in the analysis of diagnostic accuracy. The results from one rater (the orthopaedic surgeon) in the clinical assessment were used in the analysis of diagnostic accuracy. Sensitivity, specificity, positive predictive values (PPV), and negative predictive values (NPV) were calculated for each test using cross-table analysis. (PPV and NVP were included in paper III)

**Table 8**
Interpretation of kappa values.

| Kappa | Interpretation |
|---|---|
| < 0.00 | Poor agreement |
| 0.00-0.20 | Slight agreement |
| 0.21-0.40 | Fair agreement |
| 0.41-0.60 | Moderate agreement |
| 0.61-0.80 | Substantial agreement |
| 0.81-1.00 | Almost perfect agreement |

*Paper IV*

A linear regression model was used for the association analysis between alpha angle and passive hip ROM. A univariate linear regression was made for each direction of hip ROM. Sex was added to the model due to the uneven distribution of women in the two groups.

A receiver operating characteristic (ROC) curve analysis was used for calculating diagnostic accuracy. The area under the curve (AUC) was determined for ROM variables whether any variables were suitable for predicting the alpha angle. The ROM threshold identifying participants above or below the alpha angle cut-off with the highest sensitivity and specificity was detected.

# Results and discussion

## Description and comparison of groups (Papers I and II)

### Participants

Eighty-one participants were included in the cohort. Age, sex, BMI, prevalence of bilateral symptoms, and prevalence of alpha angle ≥78° are described in Table 9.

There were more men in the hip-related pain group ($p<0.01$), but no group differences regarding age, BMI, or prevalence of bilateral symptoms were observed ($p\geq0.066$). Fourteen percent of all participants had an alpha angel ≥78°, indicating high risk for early-onset hip osteoarthritis. The ages of the participants are in line with previous cohorts of patients with longstanding hip and groin pain in tertiary care (36, 63, 64). The higher prevalence of men categorized as having hip-related pain may be due to the higher prevalence of cam-type FAI syndrome seen in men (65).

Eleven participants could not be categorized as having hip-related pain or non-hip related groin pain due to either declined block injection or missing data from follow-up after block injection. The participants who were not categorized did not differ from patient groups in patient characteristics, patient reported outcomes, or in any objectively-measured physical impairment.

**Table 9**
Patient characteristics in all patients, patients with hip-related pain, patients with non-hip-related groin pain, and comparion between the patient groups (p-value)

| | All patients n=81 | Hip-related pain n=33 | Non-hip-related groin pain n=37 | Hip-related pain VS non-hip-related groin pain (p-value) |
|---|---|---|---|---|
| Age ((years)(SD)) | 35 (9) | 35 (10) | 35 (8) | 0.925 |
| Women (n)/(%) | 40/49 | 10/30 | 23/62 | <0.01 |
| BMI ((kg/m²)(SD)) | 24.8 (3.9) | 26.0 (4.3) | 24.2 (3.5) | 0.066 |
| Bilateral symptoms (n)//(%) | 13/16 | 5/15 | 4/11 | 0.588 |
| Alpha angle ≥78 (n)//(%) | 11/14 | 9 | 1 | NA |

## Prevalence of hip-related pain

Forty-seven percent of patients (n = 33) were categorized as having hip-related pain according to described criteria. All but one patient (97%) in the hip-related pain group had FAI syndrome (Table 10).

A previous larger cross-sectional study of 499 participants with similar mean age and distribution of sex as the cohort in this thesis (38 years, 54% women), reported a prevalence of 57% for hip-related pain (66). The same diagnostic criteria were used in that study that were used in this thesis They also reported a prevalence of 97% FAI syndrome in the hip-related pain group which is similar to our findings (66). Since patients with non–hip-related pain are less likely to benefit from surgery, these patients are best treated in a primary care setting and should avoid waiting for evaluation by orthopaedic surgeons and potentially postponing adequate treatment. Implementing the diagnostic criteria for hip-related pain in primary care, may potentially improve the management of patients with hip and groin pain and only patients who would potentially benefit from surgical treatment would be referred to tertiary care.

**Table 10**
Prevalence of the different diagnosis assosiated with hip-related pain

| Diagnosis | N (%) |
|---|---|
| FAI-syndrome | 32 (97) |
| • Cam-type | 21 |
| • Pincer-type | 9 |
| • Mixed-type | 2 |
| Labral and/or chondal lesion without osseous morphology related fo FAI-syndrome | 1 (3%) |

## Patient reported outcomes

### *Pain*

Seventy-five percent of the patients reported more than 12 months duration of symptoms and more than half of the patients reported that they had symptoms several years. All patients but one (98%) reported groin pain, 68% reported buttock pain, 43% reported pain in the lower extremities, and 23% reported low back pain. No differences in pain duration or pain distribution between patients with hip-related pain and those with non-hip-related pain were noted ($p \geq 0.171$)

Pain duration as well as pain distribution are both consistent with the findings reported by Clohisy et al (67) which investigated patients with FAI-syndrome undergoing surgery. Pain distribution was also similar to patients with hip-related pain caused by hip osteoarthritis reported by Poulsen et al (68). However, Lesher et al (69) reported that buttock pain was the most commonly reported pain localization and groin pain was only reported by 55% of the patients with hip join pain. In that study (69) an older population (mean age 61 years) were investigated and possible co-morbidity of extra-articular pain such as lateral hip pain (70) and low back pain might explain the differences compared to our findings. In our cohort 23% of the participants reported pain in the lower back despite that patients with low back pathology were excluded. Even though the reported pain in the lower back cannot be confirmed as true low back pain, low back strain due to hip ROM restrictions or altered movement strategies may be an explanation (71-73). Possible low back pain in patients with longstanding hip and groin pain should be taken in consideration in the treatment of this patient group.

Pain distribution can be used to evaluate pain severity but may also be used in diagnostics where lesions in different structures may lead to different pain distributions. To my knowledge Paper I is the first study that compares pain distribution between hip-related and non–hip-related pain. The lack of difference between patient groups, indicates that pain distribution cannot be used to distinguish patients from having, or not having, hip-related pain.

**Table 11**
Duration of pain and pain distribution (n/%) in all patients, patients with hip-related pain, patients with non-hip-related groin pain, and comparion between the patient groups (p-value)

| | **All patients n=81** | **Hip-related pain n=33** | **Non-hip-related groin pain n=37** | **Hip-related pain vs. non-hip-related groin pain (p-value)** |
|---|---|---|---|---|
| Duration of pain (n)/(%) | | | | |
| 3-6 months | 2/3 | 1 | 1 | 1.00 |
| 6-12 months | 13/18 | 4 | 6 | 0.490 |
| More than 12 months | 16/22 | 6 | 8 | 0.544 |
| Several years | 38/53 | 18 | 15 | 0.363 |
| Pain distribution (n)/(%) | | | | |
| Groin | 78/98 | 32 (97) | 36 (100) | 0.293 |
| Buttock | 54/68 | 22 (67) | 25 (69) | 0.805 |
| Lower extremity | 34/43 | 12 (36) | 19 (53) | 0.171 |
| Lower back | 18/23 | 9 (27) | 6 (17) | 0.286 |

### *Activity level*

Compared to patients with non-hip related pain, patients with hip-related groin pain reported higher activity level during adolescence, as well as higher pre-injury activity level ($p \leq 0.034$). (Table 12)

High activity levels during adolescence, especially in high impact sports, are believed to influence the development of cam morphology during skeletal growth (41, 74). Since the prevalence of cam-type FAI syndrome was 63% in the hip-related group, our findings may support this explanation. However, the HSAS used in Paper

I to measure activity levels does not reflect the actual mechanical strain on the hip joint in terms of intensity, frequency, or duration. Therefore, the clinical significance of the findings may be questioned. This aside, information on activity levels during adolescence gathered during patient history may aid clinicians in the diagnostic process.

**Table 12**
Activity level (HSAS) ((median(IQR)) in all patients, patients with hip-related pain, patients with non-hip-related groin pain, and comparion between the patient groups (p-value)

| | All patients n=81 median (IQR) | Hip-related pain n=33 median (IQR) | Non-hip-related groin pain n=37 median (IQR) | Hip-related pain VS non-hip-related groin pain (p-value) |
|---|---|---|---|---|
| HSAS | | | | |
| Activity level during adolescents | 5 (3-7) | 5 (5-7,5) | 5 (3-5) | 0.013 |
| Pre-injury activity level | 4 (3-5.75) | 5 (4-6.25) | 4 (3-5) | 0.034 |
| Current activity level | 2 (1-3) | 2.5 (1-4.25) | 1 (0-3) | 0.134 |

*HAGOS and SF-36*

The participants reported the worst scores on the subscales “quality of life” and “participation in physical activity” in HAGOS, and on the subscales “physical role functioning” and “bodily pain” in SF-36. The best scores were reported on the subscale “activity in daily living” in HAGOS, and the subscale “physical functioning” in SF-36. Based on previous reported scores from healthy populations, the participant reported worse scores on all subscales in both HAGOS and SF-36 (75, 76). No between-group differences in any subscale in either HAGOS or SF-36 were found ($p \geq 0.224$). (Table 13)

In line with the results from Paper I, low scores in patient-reported outcomes regarding hip-specific disability and general health in patients in tertiary care, have previously been reported (11, 15, 16, 64). Patient-reported general health in the present cohort is also comparable to the outcomes reported by patients with hip osteoarthritis (77). These findings reflect the clinical experiences of patients with longstanding hip and groin pain, where young to middle-aged physically active patients are able to function in daily life activities despite pain, but are unable to participate in sports and struggle to maintain their desired activity levels. The low score on the subscale “quality of life” in HAGOS might be affected by both longstanding pain, low physical function and/or being unable to maintain physical activity levels (78).

Based on the result from Paper I and previous reported results on patient reported outcomes (11, 15, 16, 64) optimal treatment options to improve patient-reported outcomes for all patients referred to tertiary should be prioritized.

**Table 13**
Scores on HAGOS and SF-36 ((mean(SD)) for all patients, patients with hip-related pain, patients with non-hip-related groin pain, and comparion between the patient groups (p-value)

| | **All patients n=81 Mean (SD)** | **Hip-related pain n=33 Mean (SD)** | **Non-hip-related groin pain n=37 Mean (SD)** | **Hip-related pain VS non-hip-related groin pain (p-value)** |
|---|---|---|---|---|
| HAGOS | | | | |
| Symptoms | 56.6 (15.4) | 54.7 (13.9) | 56.8 (17.2) | 0.603 |
| Pain | 57.7 (17.0) | 58.4 (17.6) | 56.3 (17.0) | 0.635 |
| ADL | 62.6 (21.2) | 61.9 (22.0) | 62.7 (21.4) | 0.884 |
| Sport/Rec | 47.8 (23.3) | 45.8 (22.0) | 51.7 (24.5) | 0.318 |
| PA | 29.9 (28.0) | 31.0 (29.4) | 32.3 (29.0) | 0.871 |
| QOL | 28.5 (14.6) | 27.4 (16.7) | 29.8 (14.3) | 0.543 |
| SF-36 | | | | |
| Physical functioning | 68.9 (19.6) | 70.2 (20.2) | 67.7 (20.6) | 0.630 |
| Physical role functioning | 44.1 (38.3) | 45.0 (37.9) | 39.8 (39.6) | 0.603 |
| Bodily pain | 49.4 (15.1) | 51.0 (15.4) | 49.1 (16.3) | 0.633 |
| General health perception | 51.0 (11.5) | 49.8 (13.4) | 53.4 (9.5) | 0.224 |
| Vitality | 57.9 (12.2) | 59.5 (13.2) | 57.7 (11.5) | 0.558 |
| Social role functioning | 54.5 (11.0) | 53.8 (8.8) | 54.7 (11.8) | 0.725 |
| Emotional role functioning | 68.5 (39.5) | 68.9 (41.9) | 63.5 (40.0) | 0.609 |
| Mental health | 67.1 (8.6) | 67.2 (8.2) | 67.6 (7.3) | 0.830 |
| Physical component score | 53.4 (10.3) | 54.0 (9.9) | 52.5 (11.3) | 0.581 |
| Mental component score | 62.0 (11.2) | 62.3 (11.5) | 60.9 (10.8) | 0.608 |

ADL=Activities in daily living, Sport/Rec=Physical function in sport and recreation, PA=Participation in physical activity, QOL=Quality of life.

## Physical impairments

### *ROM*

Only patients with hip-related groin pain showed limited hip ROM and the only observed affected movement was internal rotation. In patients with hip-related pain, internal rotation with neutral hip position was restricted compared to both patients with non–hip-related groin pain as well as in controls ($p \leq 0.026$), while internal rotation with 90° hip flexion was restricted only compared to patients with non–hip-related groin pain ($p \leq 0.026$). (Figure 13)

Restricted hip internal rotation has been reported in heterogenous group of athletes with hip and groin pain (14). However, in a more homogenous group with patients diagnosed as having FAI-syndrome the results are conflicting. Diamond et al (24) reported in a systematic review decreased hip ROM in patients with FAI-syndrome compared to controls, while Freke et al (37) did not. The conflicting results may be due to inconsistent diagnostic criteria were the diagnosis of FAI-syndrome in several included studies were based solely on imaging findings and the use of cut-off values for alpha angle was inconsistent.

Restriction of hip ROM in patients with hip-related pain, especially internal rotation with flexed hip in patients with FAI-syndrome, is considered to be a consequence of osseous morphology (25). However, the findings in paper II of restricted internal rotation in both flexed hip and in neutral hip positions suggest that bony interaction may not be the only factor limiting hip ROM, and restriction due to capsular thickness (79) and/or involuntary muscle contraction (80) must be considered. ROM restrictions due to soft tissue may also be a modifiable by manual and/or exercise-based therapy and therefore a potential topic for further study.

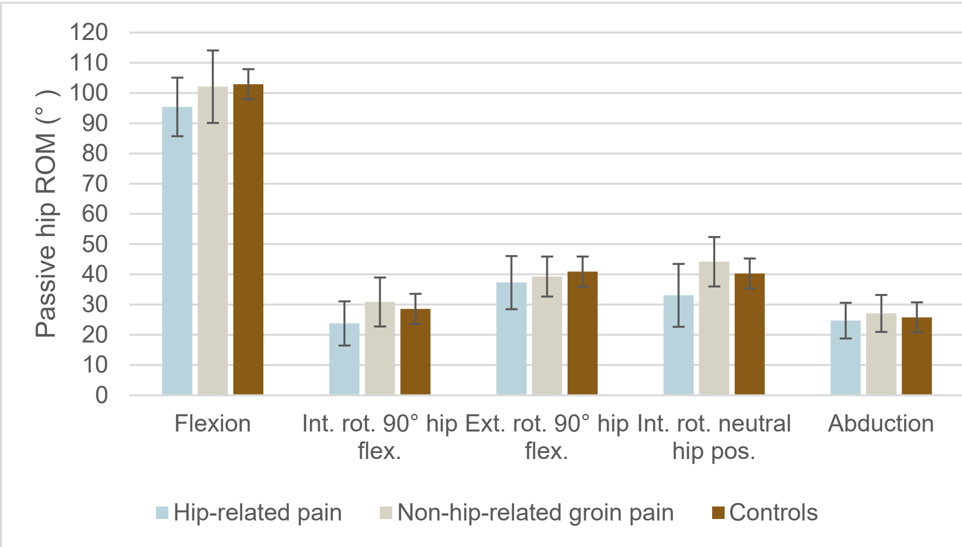


**Figure 13**
Observed passive hip ROM in patients with hip-related pain, patients with non-hip-related groin pain, and in healthy controls. Values are display as mean (°) and standard deviation. When adjusted for sex, no differences were observed between patient groups or between patient groups and the control group in flexion, external rotation with 90° hip flexion, or abduction ($p \geq 0.066$) the hip-related pain group showed restriction in internal rotation with neutral hip position compared to both patients with non-hip-related groin pain as well as controls ($p \leq 0.026$), internal rotation with 90° hip flexion was restricted only compared to patients with non-hip-related groin pain ($p \leq 0.026$).

### *Muscle function*

In paper II, no differences in isometric hip strength in any direction, or in the double leg lowering test between participants with hip-related pain and those with non–hip-related groin pain were noted ($p \geq 0.96$). Both participants with hip-related pain and those with non–hip-related pain had worse muscle function compared to controls ($p \leq 0.048$). (Figure 14, 15)

As previously reported, patients with hip-related pain have worse isometric hip muscle strength compared to controls (24, 37). However, in a systematic review, Freke et al (37) reported worse isometric hip strength in all muscle groups except the hip extensors, whereas results in paper II showed worse isometric strength in all muscle groups. Mosler et al (14) reported in a systematic review and meta-analysis only worse isometric strength in hip adductors in athletes with non-specific longstanding groin pain compared to non-symptomatic athletes. However, the athletic population investigated by Mosler et al. might not be comparable to our cohort with young to middle-aged physically active patients referred to tertiary care.

The inclusion of trunk strength training is suggested in exercise-based treatment in patients with longstanding hip and groin pain (81). Impaired trunk strength compared to controls is seen in patients with FAI syndrome (37) and in patients post hip surgery (38). Impaired trunk strength may result in reduced pelvic control and reduced acetabular retroversion, which may affect hip impingement. The double leg lowering test tests the ability to maintain lumbar-pelvic control in the sagittal plane during eccentric contraction of hip flexors, and worse performance in both patient groups compared to controls was observed in in paper II.

Decreased muscle function may be due to physical deconditioning and/or altered movement strategies (82). Additionally, strength testing may be influenced by pain inhibition, or fear of worsening pain. However, none of the participants discontinued strength testing due to pain. Nonetheless, we acknowledge the possibility that these factors might have influenced the results.

Exercise-based treatment aiming to improve hip strength has shown good results in improving patient-reported outcomes in patients with FAI syndrome and patients with adductor related groin pain, (15, 45, 83) and based on the results from paper II and previous studies, (24, 37) exercise-based treatment should include strength training for all hip muscle groups and trunk for both patients with hip-related pain and those with non–hip-related groin pain.

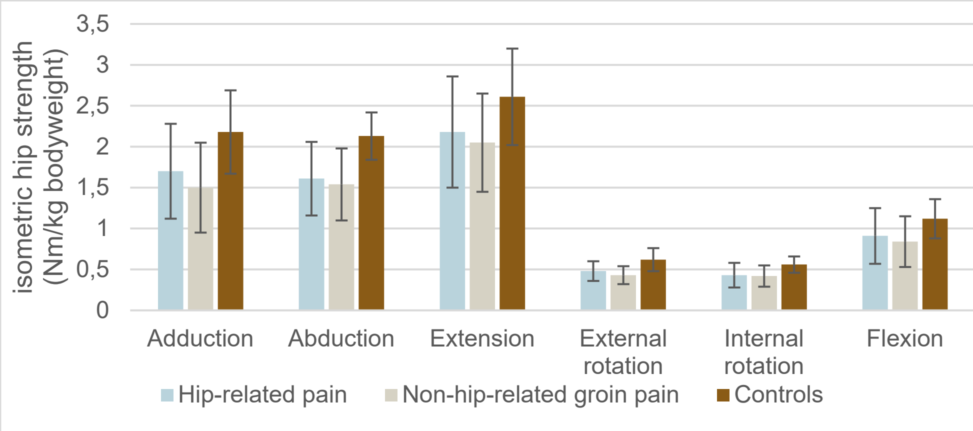


**Figure 14**
Observed isometric hip strength in patients with hip-related pain, patients with non-hip-related groin pain, and in healthy controls. Values are display as mean (Nm/kg bodyweight) and standard deviation. When adjusted for sex, no differences were observed between patient groups in any direction (p=1.0) but both patient groups hade worse isometric strength compared to controls (p≤0.003).

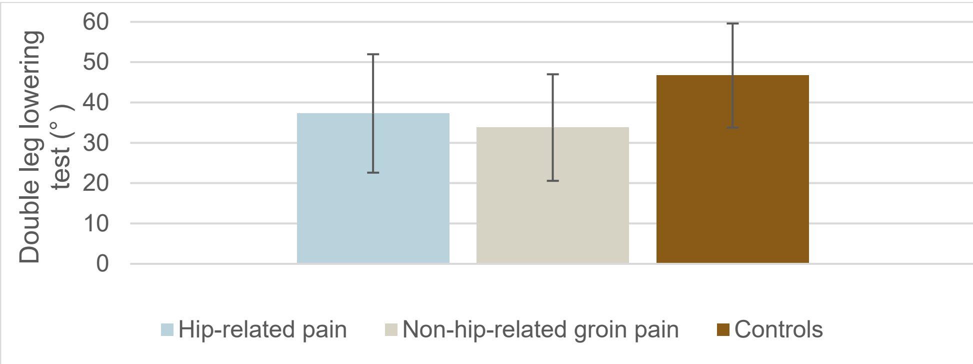


**Figure 15**
Observed results from the double leg lowering test in patients with hip-related pain, patients with non-hip-related groin pain, and in healthy controls. Values are display as mean (°) and standard deviation. When adjusted for sex, no differences were observed between patient groups (p≥0.960) but both patient groups hade worse result compared to controls (p≤0.048).

*Functional tasks*

Both patients with hip-related pain and those with non–hip-related pain had worse dynamic balance control and worse hop performance compared to controls (p≤0.05). No differences were found in dynamic balance control or hop performance between the patient groups (p ≥0.136). In SASLR no differences were found between the patient groups or between patients and controls (p≥0.099). (Figure 17–19)

This is in line with the results reported by Freke et al. (36) who showed that patients in tertiary care scheduled for hip arthroscopy had worse dynamic balance control in the star excursion test compared to controls. Kemp et al. (38) reported bilateral impaired performance compared to controls in the single-leg hop for distance 12 to 24 months after arthroscopic surgery. Impaired hop performance is also seen in the athletic population where Kivlan et al. (84) found worse hop performance in dancers with FAI syndrome compared to uninjured dancers. Several participants declined to perform the hop test due to pain or fear of pain (43% for the 30-second side-hop test and 33% for the single-leg hop for distance). Therefore, the results from hop performance tests should be interpreted with caution. The SASLR is a novel test designed to measure pelvic movement during a task on one leg and has not previously been tested in patients with hip and groin pain. No differences were found between patient groups or between patients and controls. However, the test might not be demanding enough and therefore cannot detect any differences in pelvic movement.

Based on previous results and the results from paper II, patients referred to tertiary care due to longstanding hip and groin pain appear to have reduced function in functional tasks, regardless of whether they have hip-related pain or non–hip-related groin pain. Exercise-based treatment to improve dynamic balance and hop performance should be included for both patients with and without hip-related pain.

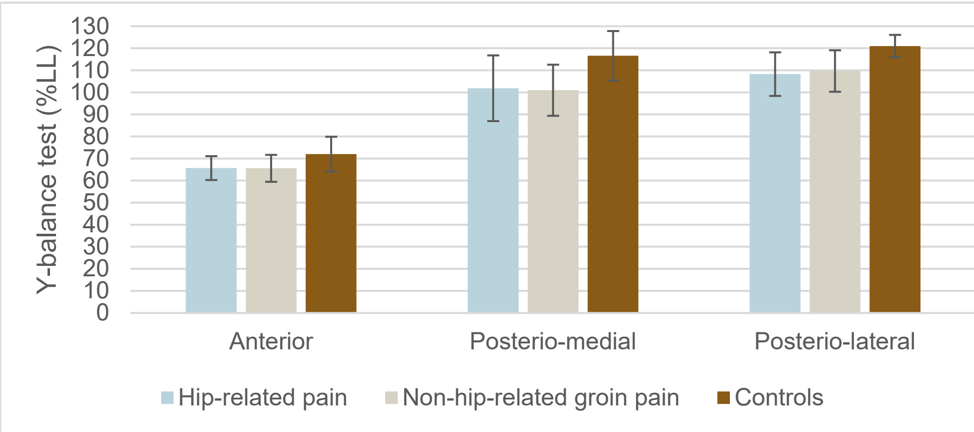


**Figure 16**
Observed results from the Y-balance test in patients with hip-related pain, patients with non-hip-related groin pain, and in healthy controls. Values are display as mean (%LL) and standard deviation. When adjusted for sex, no differences were observed between patient groups (p=1.0) but both patient groups hade worse result compared to controls (p≤0.004).

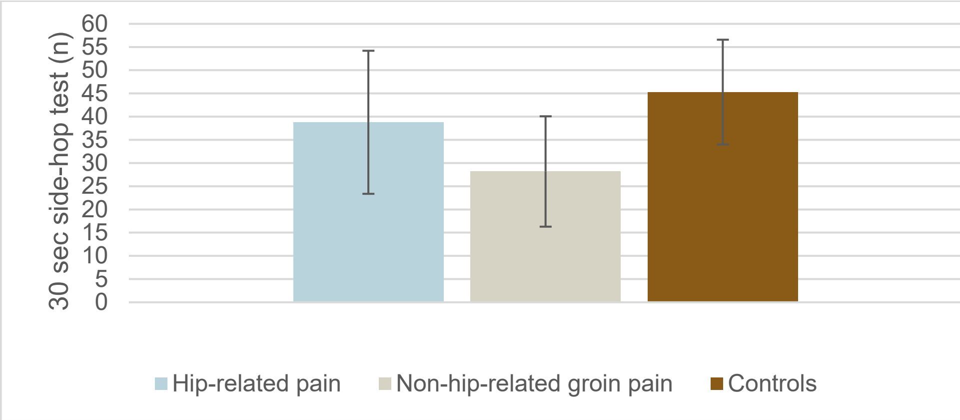


**Figure 17**
Observed results from the 30 sec side-hop test in patients with hip-related pain, patients with non-hip-related groin pain, and in healthy controls. Values are display as mean (n) and standard deviation. When adjusted for sex, no differences were observed between patient groups ($p \geq 0.136$) but both patient groups hade worse result compared to controls ($p \leq 0.05$).

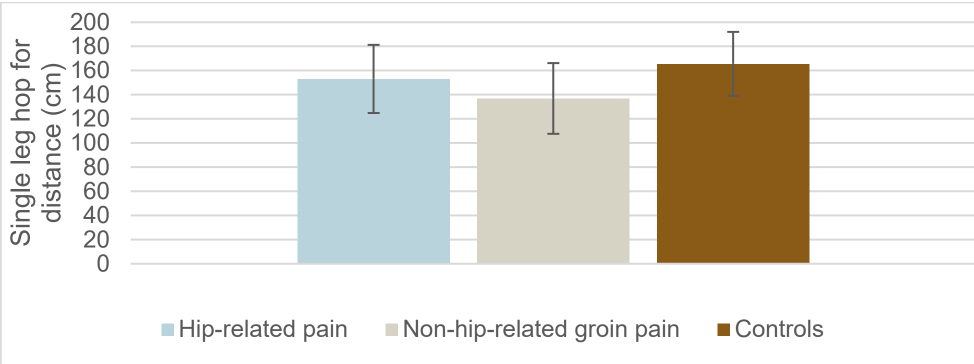


**Figure 18**
Observed results from the single leg hop for distance in patients with hip-related pain, patients with non-hip-related groin pain, and in healthy controls. Values are display as mean (cm) and standard deviation. When adjusted for sex, no differences were observed between patient groups ($p=1.0$) but both patient groups hade worse result compared to controls ($p \leq 0.007$).

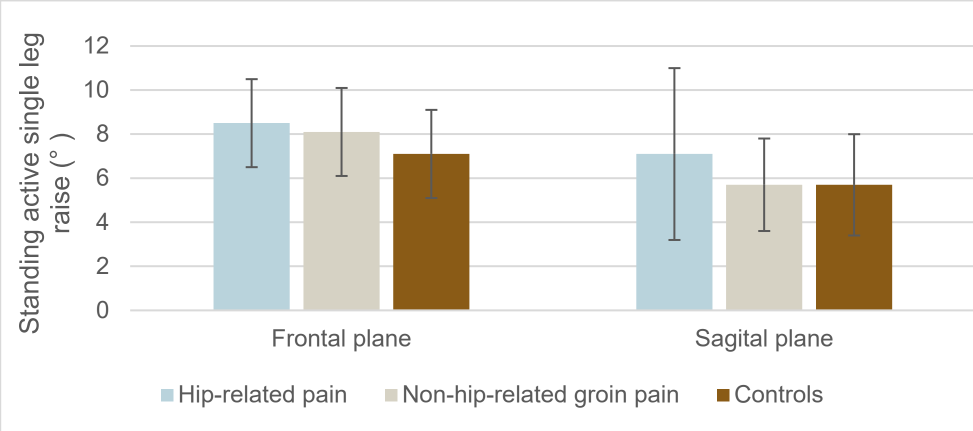


**Figure 19**
Observed results from the standing active single leg raise in patients with hip-related pain, patients with non-hip-related groin pain, and in healthy controls. Values are display as mean (°) and standard deviation. When adjusted for sex, no differences were observed between patient groups or between patients groups and controls ($p \geq 0.099$)

# Inter-rater agreement and diagnostic accuracy of the clinical assessment for identifying patients with FAI-syndrome and cam-morphology (Papers III and IV)

## Participants

In paper III, the first 69 participants included in the cohort (138 hips) were assessed by two raters, both an orthopaedic surgeon and a physiotherapist, and were included in the inter-rater-agreement analysis. Seventeen participants were excluded from the analysis of diagnostic accuracy due to missing data from radiographs (n=6) and from the diagnostic block injection (n=11). Therefore, 64 participants (69 hips) were included in the analysis.

In paper IV nine participants were excluded due to missing data from radiographs (n=6) or from ROM measurement due to equipment malfunction (n=3). Therefore, 72 participants were included in the analysis.

**Table 14**
Inter-rater agreement and diagnostic accuracy for impingement tests and passive hip ROM Inter-rater agreement displayd as absoulute agreement (%) and kappa value with 95%CI. Diagnostic accurace displayed as sensitivity and specificity (%) with 95%CI.

| | **Inter-rater agreement** | | **Diagnostic accuracy** | |
|---|---|---|---|---|
| | **Absolute agreement (%)** | **Kappa value (95% CI)** | **Sensitivity % (CI 95%)** | **Specificity % (CI 95%)** |
| Impingement tests | | | | |
| AIMT | 83 | 0.665 (0.540; 0.790) | 80 (67-93) | 26 (12-41) |
| FADIR | 82 | 0.638 (0.509; 0.767) | 80 (67-93) | 24 (9-38) |
| FABER | 81 | 0.623 (0.498; 0.748) | 54 (38-71) | 38 (22-54) |
| DEXRIT | 80 | 0.549 (0.402; 0.695) | 60 (44-76) | 46 (29-62) |
| DIRIT | 81 | 0.561 (0.289; 0.640) | 54 (38-71) | 51 (35-68) |
| PRIMT | 80 | 0.357 (0.168; 0.546) | - | - |
| Passive hip ROM | | | | |
| Flexion | 82 | 0.447 (0.262; 0.632) | 51 (35-68) | 68 (52-83) |
| Internal rotation with 90° hip flexion | 78 | 0.472 (0.312; 0.632) | 56 (39-73) | 63 (48-79) |
| Internal rotation with neutral hip position | 85 | 0.431 (0.236; 0.626) | 29 (13-44) | 94 (86-100) |
| External rotation with 90° hip flexion | 90 | 0.553 (0.346; 0.760) | 37 (21-53) | 79 (66-93) |
| Abduction | 87 | 0.514 (0.319; 0.709) | 46 (29-62) | 79 (66-93) |
| Extension | 91 | 0.211 (-0.07; 0.494) | - | - |

AIMT = Anterior Impingement Test, FADIR = Flexion/Adduction/Internal Rotation, FABER = Flexion/Abduction/External Rotation, DEXRIT = Dynamic External Rotatory Impingement Test, DIRIT = Dynamic Internal Rotatory Impingement Test, PRIMT = Posterior Rim Impingement Test , ROM=Range of motion

## Inter-rater agreement of hip impingement tests

Three of the hip impingement tests (AIMT, FADIR, and FABER) showed substantial agreement (kappa >0.6) between two experienced raters. For the DEXRIT and DIRIT the inter-rater agreement was moderate (kappa >0.4) and for the PRIMT only fair agreement (kappa >0.2) was noted. The absolute agreement ranged from 80 to 83% for all hip impingement tests (Table 14).

Inter-rater agreement is essential for clinical tests, especially when the patient is referred to different healthcare providers. Tests demonstrating low inter-rater agreement might be interpreted differently by clinicians and influence decision-making regarding further investigation and treatment options. However, reports of inter-rater agreement for hip-impingements test in patients with hip and groin pain are scarce. Prather et al. (85) reported absolute agreement of 98–100% for the FABER test and the FADIR test between two raters in asymptomatic volunteers. However, since almost no one had any positive outcome in the test the results cannot be generalized to patients with hip and groin pain. In patients with hip and groin pain, Martin et al. (86) reported substantial agreement for FABER tests and moderate agreement for the FADIR test between two raters, which is in line with the results from paper III. Ratzlaff et al. (87) reported absolute agreement above

75% for FABER, FADIR, and AIMT between 9 different raters. However, in that study, no kappa values were reported and any comparison is difficult. To my knowledge paper III is the first to report inter-rater agreement for DEXRIT, DIRIT and PRIMT and any comparisons to previous studies are not possible.

Based on the result in paper III and previously reported findings (86, 87) outcomes from FABER, FADIR and AIMT, observed by different raters, can be used in both research and clinical practice. In DEXRIT and DIRIT, results from different raters should be interpreted with caution due to moderate agreement. The low inter-rater agreement and the low prevalence of positive findings suggests that the PRIM test might not be suitable for this patient group.

## Inter-rater agreement of passive hip ROM

In passive hip ROM rated dichotomously as either normal or decreased, with or without pain, the inter-rater agreement was at most moderate (kappa >0.4) for all directions except extension which showed only fair agreement (kappa >0.2). Absolute agreement ranged from 78 to 90% for all tests (Table 14).

Evaluation of hip ROM is important during screening of patients with hip and groin pain in clinical practice. The inter-rater agreement for measurement of hip ROM using a goniometer or inclinometer is well documented (53, 80, 85, 88). However, during the initial patient screening, hip ROM is often judged as either decreased or normal, not including any measurement of ROM. To my knowledge, paper III is the first study to report inter-rater agreement for passive hip ROM rated dichotomously without any instrument. Rating of hip ROM in degrees without any instrument in patients with hip osteoarthritis has shown poor to moderate agreement (89). However, in that study the hip ROM was rated in degrees and not dichotomously, which might explain the lower agreement. Different ratings of hip ROM between two clinicians may be influenced by difficulties in isolating hip ROM due to pelvic movement, or involuntary hip muscle contraction during the test (80, 88). Also, ROM ratings were not based on patient reactions such as pain, but on references to the non-symptomatic hip, or the clinicians' experience with patients with bilateral symptomatic hips. This may explain why hip ROM ratings showed generally lower levels of agreement compared to hip impingement tests.

Based on the results from paper III, results obtained from different rates in hip ROM tests rated as either decreased or normal, and should be interpreted with caution.

## Diagnostic accuracy for hip impingement tests

The FADIR and AIMT both showed the highest sensitivity (at 80%), whereas the FABER, DEXRIT and DIRIT showed a sensitivity of no more than 60%. The specificity ranged from 24 to 51%, where DIRIT showed the highest specificity

(51%) and FADIR the lowest (24%). The PRIMT was excluded from the diagnostic accuracy analysis due to low inter-rater agreement (Table 14).

The results of high sensitivity and low specificity of the hip impingement test confirms the results reported by Reiman et al. in a systematic review and meta-analysis (23). However, several studies included in this review (23) used only diagnostic imaging as a single reference standard (90-94). Due to high prevalence of hip morphology associated with FAI syndrome reported in the asymptomatic population (55%) (32), the validity of the diagnostic accuracy may be questioned. Also, several different cut-off values of alpha angles and LCE-angles were used in the included studies. In paper III, symptoms, imaging findings, and diagnostic block injection served as diagnostic criteria for FAI syndrome. Only a few studies investigating the diagnostic accuracy of hip impingement tests have used intra-articular block injection as a diagnostic criteria (95, 96). Although there is insufficient evidence of the diagnostic value for intra-articular block injection for identifying FAI syndrome (31), a combination of symptoms, diagnostic imaging and intra-articular block injection may increase diagnostic accuracy. Despite this, diagnostic accuracy in our study did not improve.

Based on the results from paper III and previous reported results, FADIR and AIMT may be used during initial screening and may be used to exclude patients from having FAI syndrome when they test negative

## Diagnostic accuracy for hip ROM tests

Passive ROM in internal rotation with 90° hip flexion showed the highest sensitivity, at 56%, and internal rotation in neutral hip position showed the lowest sensitivity, at 29%. The specificity of the passive ROM tests ranged from 63% to 94% where internal rotation in neutral hip position displayed the highest specificity (94%) and internal rotation with 90° hip flexion the lowest (63%). Passive ROM in extension was excluded from the diagnostic accuracy analysis due to low inter-rater agreement (Table 14).

Contrary to the hip impingement test the passive hip ROM test exhibited high specificity and low sensitivity. To my knowledge, paper III is the first to investigate the diagnostic accuracy of passive hip ROM to identifying patients with FAI syndrome. Limited hip ROM, especially in the impingement position (internal rotation with 90° hip flexion), is considered to be an important clinical sign in patients with FAI syndrome (2). However, as previously mentioned, reports of limited hip ROM in patients with FAI syndrome compared to controls are contradictory (24, 37). The results in paper III showed the highest specificity in identifying patients with FAI syndrome in internal rotation with neutral hip position, external rotation at 90°, and abduction. However, none of these directions are associated with the impingement position. This might indicate that restrictions in hip ROM in patients with FAI syndrome is not only due to bony morphology, but also due to soft tissue restrictions such as capsular thickness (79) and muscle contractions (80).

Even though hip ROM tests with high specificity can correctly identify patients with FAI syndrome when positive, the low sensitivity leads to many false negative tests. The high proportion of false negative tests might be due to difficulties in detecting small restrictions, as only clear restrictions are identified. Also, restrictions in several directions of hip ROM might be associated with more severe intra-articular impacts. In osteoarthritis, restriction in several directions is associated with more severe cases (97). Since FAI syndrome, especially with large cam morphology, is associated with the development of early onset of hip osteoarthritis (40, 98-100), this might indicate that patients with more severe joint impacts are identified.

Based on the findings in paper III, hip ROM tests, especially internal rotation with neutral hip position, can identify patients with FAI syndrome when positive. However, further studies are needed to confirm these results.

## Association between hip ROM and cam morphology and diagnostic accuracy for hip ROM to identify patients with cam morphology

**Table 15**
Tabeltext is better placed above the table.

| Passive hip ROM | Assocciation ($R^2$) | P-value | AUC (CI 95%) | Cut-off | Sensitivity (%) | Specificity (%) |
|---|---|---|---|---|---|---|
| Flexion | 0.276 | 0.239 | - | - | - | - |
| Internal rotation with 90° hip flexion | 0.353 | **0.003** | 0.896 (0.825; 0.968) | 27° | **81%** | **85%** |
| Internal rotation with neutral hip position | 0.293 | 0.080 | - | - | - | - |
| External rotation with 90° hip flexion | 0.323 | **0.014** | 0.638 (0.510; 0.766) | 41° | 72% | 50% |
| Abduction | 0.312 | **0.027** | 0.679 (0.552; 0.806) | 27° | 72% | 60% |

AUC= Area Under the Curve

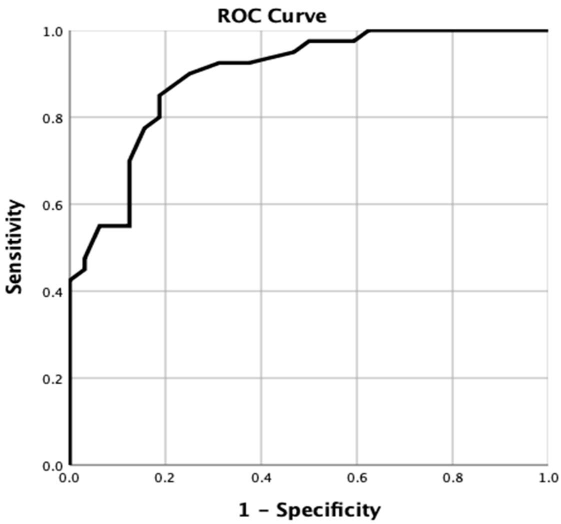


**Figure 20**
ROC-curve analysis of internal rotation with 90° hip flexion.

Association between alpha angle and hip ROM in internal rotation with 90° hip flexion, external rotation with 90° hip flexion, and abduction was reported. A cut-off value of 27° in internal rotation with 90° hip flexion had the highest diagnostic accuracy (AUC 0.896) (Figure 20) with a sensitivity of 81% and specificity of 85% to identify patients with an alpha angle above and below 60°. External rotation and abduction displayed lower diagnostic accuracy (AUC 0.638 and 0.679, respectively) (Table 15).

Previous studies have shown an association between hip ROM and alpha angle in asymptomatic people (101-103). However, the association between cam morphology and hip ROM in patients with FAI-syndrome is less thoroughly investigated. Although, two studies have shown an association between hip ROM and alpha angle in patients with FAI syndrome, which is in line with our results (104, 105).

To the best of my knowledge, paper IV is the first study to investigate the diagnostic accuracy of detecting patients with cam morphology with measurement of hip ROM. Our results from paper III showed that hip ROM, rated dichotomously, may be used to detect patients with FAI syndrome with high specificity. Yet, the directions of hip ROM with the highest specificity (internal rotation with neutral hip position, external rotation and abduction) are not associated with the restricted hip ROM theoretically caused by cam morphology. However, to detect cam morphology, the results indicate that measurement of hip ROM in the impingement position may be most useful with a cut-off of 27°, which seems to have the highest diagnostic accuracy.

Some clinical considerations are necessary to keep in mind when using this cut-off in clinical practice, since hip ROM may be influenced by several factors other than cam morphology. First, females have generally more hip ROM compared to men and the cut-off value may therefore differ between men and women (106). Second, even though care was taken to ensure neutral position of the pelvis, the position of the pelvis may influence hip ROM, especially in rotation (107). Third, other bony morphology, such as femoral torsion, acetabular version, and pincer morphology may also affect hip ROM.

Based on the results from paper IV, measurement of hip ROM in internal rotation in 90° hip flexion may be used to identify presence of cam morphology where a cut-off value of 27° has the highest diagnostic accuracy. However, further studies are needed to confirm the results. Also, to identify patients with FAI syndrome the restricted hip ROM should always be interpreted in light of symptoms and other clinical signs which would indicate FAI syndrome.

## Methodological considerations

*Papers I–II*

This thesis is not without limitations. All four papers included in this thesis have a cross-sectional design and are based on the same cohort. Due to the nature of this design, any causal inference is not possible. Also, due to limited previous research on physical impairment in patients with hip and groin pain prior to this PhD project, no pre-defined sample size calculation was made. However, all patients included in this cohort were consecutively recruited to the Department of Orthopaedics during approximately two years and 90 patients were estimated to be sufficient to show any possible differences in patient-reported and objectively-measured impairments.

In papers I and II, the categorization of patients into either having hip-related pain or non–hip-related pain was made after patient recruitment. An effect of this was that the distribution of sex in the different groups was uneven. Even though care was taken to adjust for the effect of sex during the between-group analysis regarding physical impairment, an even distribution of sex in the groups would have been preferable.

In paper II, no radiological data were available on healthy controls due to ethical reasons, and any possible hip morphology in this group was unknown. Since the prevalence of hip morphology such as cam morphology is high in the asymptomatic population (32, 108), it is not possible to exclude such morphology in this group. Cam morphology may influence hip ROM especially in internal rotation and might have masked any differences between patients with hip-related pain and controls (103).

Even though the test leader during the physical impairment testing was blinded as to patient group, he was not blinded as to whether the participant was patient or control. This knowledge may have unintentionally influence verbal encouragement given during the physical impairment testing.

In paper I HSAS was used to investigate patient-reported activity level. Even though this instrument is reliable and validated for this patient group, it does not offer any information on frequency, duration, and intensity of the activity and, therefore, not the actual load on the hip. Also, pre-injury activity levels, as well as activity levels during adolescence, are reported in retrospect which may be a source of error.

*Limitations in paper III-IV*

In paper III, Cohen's kappa was used to display inter-rater agreement and the PRIMT and ROM in extension were both excluded due to low kappa values (kappa <0.4) even though absolute agreement was similar to the other tests. Since Cohen's kappa is influenced by the prevalence of positive and negative outcomes of a test, the low kappa may have been due to low prevalence of positive outcomes.

Another limitation in the investigation of inter-rater agreement was that only two raters were included. Thus, results may not be generalizable to several raters. However, two raters were chosen due to ethical reasons since the tests reproduce the patient's pain and cause discomfort.

A dilemma and a limitation when investigating diagnostic accuracy of clinical tests used to identify patients with FAI syndrome, is that no proper gold standard is available. Several studies only use imaging findings of hip morphology as a reference standard. However, hip morphology does not correspond to FAI syndrome. A diagnosis of FAI syndrome is based on four conditions; 1) symptoms related to FAI syndrome, 2) positive clinical signs, 3) hip morphology, and 4) responding to intra-articular block injection. When investigating the diagnostic accuracy of clinical tests, one condition will be missing and you only test the ability to identify patients who have symptoms, hip morphology and respond to intra-articular block injection.

Also, a limitation in many studies investigating diagnostic accuracy of tests used to identify FAI syndrome is that patients included in the studies are often candidates for hip surgery and therefore have a high pre-test probability of having FAI syndrome. Patients in the present cohort were not all candidates for surgery but the pre-test probability of having FAI syndrome was 51%. Further investigation in primary care settings, in a more heterogenous group of patients with hip and groin pain, is warranted.

Due to the exploratory design of paper IV the results should be interpreted with caution. Similar to paper II the distribution of sex was uneven between the group with high and low alpha angles. Even though adjustments for the effect of sex were included in the analysis, groups with even distributions of sex would be preferable. Also, with a larger sample size, calculation of separate cut-off values for men and women regarding hip ROM would be possible.

# Clinical relevance and future perspectives

In clinical practice, diagnostics and treatment of patients with longstanding hip and groin pain is often a challenge. To distinguish between patients with hip-related pain and those without is important since the treatment options may differ. Also, potential benefits of surgical treatment are primarily seen in patients with hip-related pain, and if high quality non-surgical treatment fails, they may be candidates for referral to tertiary orthopaedic care. The results of this thesis, which included a 50% prevalence of hip-related pain in patients referred to the orthopedic department, indicated that the diagnostic criteria may be underused in primary care.

Our results from the investigation of diagnostic accuracy for identifying patients with FAI-syndrome may potentially improve early screening of patients with longstanding hip and groin pain. First, by using a hip impingement test with high sensitivity one is able to rule out a diagnosis of FAI-syndrome for patients for whom the test result is negative. Second, if the hip impingement tests are positive, by using ROM tests with high specificity, one can rule in a diagnosis of FAI-syndrome for patients that test positive. Finally, by measuring the level of restriction of hip ROM in internal rotation, one may potentially identify cam-morphology without imaging. Also, while noting patient history, clinicians may use high activity level during adolescence as a possible predictor for cam morphology. Further investigation of this diagnostic procedure in a primary care setting is warranted.

The results from physical impairments presented in this thesis may guide clinicians in providing relevant exercise-based treatment to improve physical impairments in patients with longstanding hip and groin pain. The results may also provide relevant methods for evaluation of physical function as well as evaluation of treatment. Our results from the comparisons of physical impairments between the patient groups indicates that the functional limitations may be more important than the clinical diagnosis when providing relevant exercise-based treatment to improve muscle function and performance in functional tasks. Evaluation of the possible effect of manual treatment or exercise-based treatment to improve hip ROM restrictions not related to bony morphology in patients with hip-related pain may be subject for future studies.

No longitudinal data from this cohort was included in thesis. However, long-term longitudinal follow-up 3 and 6 years after recruitment of the original cohort is ongoing, in which patient-reported outcomes and radiological findings of possible signs of early development of osteoarthritis are being collected.

# Conclusions

Half of the patients referred to tertiary care for long standing hip and groin pain had hip-related pain. Those with hip-related pain were mainly men with a high activity level. Both patients with hip-related pain and those with non–hip-related groin pain reported worse perceived general health, worse hip-related symptoms and function, had worse muscle function and worse performance in functional tasks compared to healthy controls, but no differences were observed between patient groups. Only patients with hip-related pain had reduced hip ROM in internal rotation compared to those with non-hip-related groin pain and controls.

Based on these findings, early optimal treatment options, especially exercise-based treatment, for all patients despite diagnosis are needed to improve general health and improve hip-related symptoms and function. Exercise-based treatment should target several aspects of muscle function and performance in functional tasks both for patients with hip-related pain and those with non–hip-related groin pain. Treatment to improve ROM, in particular internal rotation, may be needed for patients with hip-related pain. Also, to further optimize early management, diagnostic criteria for hip-related pain should be implemented in primary care, so that appropriate patients are referred to tertiary care.

Moderate to substantial agreement between two raters for the clinical assessment suggest that results from different raters are reliable. The AIMT and FADIR test can be used to rule out patients with FAI syndrome when negative, while evaluation of ROM in internal rotation with neutral position may be more suitable to rule in patients with FAI syndrome when positive. Reduced hip ROM in internal rotation, external rotation, and abduction appear to be associated with a higher alpha angle, and internal rotation may identify cam morphology with good sensitivity and specificity in a clinical setting.

Based on these findings, a combination of results from hip impingement tests and hip ROM tests may improve diagnostic accuracy in identifying patients with FAI syndrome. Measurement of hip ROM in internal rotation may be used to identify cam-morphology in patients with longstanding hip and groin pain.

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