# Groin Injuries in Athletes - Development of Clinical Entities, Treatment, and Prevention

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**The thesis is based on the following publications:**

I
Hölmich P. Adductor-related groin pain in athletes
Sports Medicine and Arthroscopy Review 1997; 5:285-291

II
Hölmich P, Hölmich LR, Bjerg AM. Clinical examination of athletes with groin pain: an intraobserver and interobserver reliability study. Br J Sports Med 2004; 38:446-451

III
Hölmich P. Long-standing groin pain in sportspeople falls in three primary patters, a clinical entity approach: a prospective study of 207 patients. Br J Sports Med 2007; 41:247-252

IV
Hölmich P, Uhrskou P, Ulnits L, Kanstrup I-L, Nielsen MB, Bjerg AM, Krogsgaard K. Effectiveness of active physical training as treatment for long-standing adductor-related groin pain in athletes: randomised trial. The Lancet 1999; 353:439-443

V
Hölmich P, Nyvold P, Larsen K. Continued significant effect of physical training as treatment for overuse injury: 8-12 year outcome of a randomized clinical trial. Am J Sports Med 2011; 39:2447-2451

VI
Hölmich P, Larsen K, Krogsgaard, Gluud C. Exercise program for prevention of groin pain in soccer players: a cluster-randomised trial. Scand J Med Sci Sports 2010; 20: 814-821

VII
Hölmich P, Thorborg K, Dehlendorff C, Krogsgaard K, Gluud C Incidence and clinical presentation of groin injuries in sub-elite male soccer. Br J Sports Med 2013; Accepted 27.07.2013 BJSM Online First, published on August 27, 2013

VIII
Hölmich P, Thorborg K, Nyvold P, Klit J, Nielsen MB, Troelsen A. Does bony hip morphology affect the outcome of treatment for patients with adductor-related groin pain? Outcome 10 years after baseline assessment. Br J Sports Med 2013; Accepted 12.06.2013 BJSM Online First, published on July 11, 2013

**Introduction**

Groin injuries in connection with physical activity, in particular sports, are very common and in football they are among the most common and most time-consuming injuries. The difficulties in understanding the etiology and pathology of groin injuries are partly a result of the groin being an anatomical region connected to several other regions and also an area where pain from pathology elsewhere often radiates. The complexity of the anatomy and biomechanics is a well-known problem with a continued need for further research. The lack of agreement about a scientific taxonomy of groin injuries and the lack of consensus regarding clinical examination, diagnosis, and treatment is a major problem inhibiting further development of the subject. The use of imaging of groin injuries is still not evidence-based and there is absolutely no consensus. In general this is a field of medicine where the level of knowledge and even more the level of evidence has been quite poor.

As can be seen in Study I of this thesis the literature in the mid-nineties when I started my research in this field was very limited and mainly on Level 4 and 5. Working in elite sports medicine for many years I had developed a specific interest in groin injuries, mainly as a result of the difficulties finding evidence-based knowledge in the literature or among my senior colleagues in orthopaedic surgery, physiotherapy, and sports medicine. In my work with the athletes I had cooperated with excellent physiotherapists and learned a lot regarding the general principles of functional examination and exercise treatment of muscle and tendon injuries. During the 80'es and beginning of the 90'es, I developed a set of clinical tests and treatment algorithms that

were useful. In order to evaluate this scientifically the studies included in this Thesis were conducted.
Today 15 years later we have managed to approach the area scientifically and I have participated in creating tools for research and clinical work. In this process I have also performed clinical studies with results that answer some questions but raise others, hopefully now at a higher level and arising from a broader base.

The aims of the studies included in this thesis were:

- To review the literature to obtain an overview of the issue in order to plan future studies in this field.
- Develop and test clinical examination techniques of the relevant tendons and muscles in the region for reproducibility.
- Since no evidence-based diagnosis existed, to develop a set of clinical entities to differentiate the patients.
- To test the effect of a dedicated training program developed for treatment of long-standing adductor-related groin pain in athletes in a randomised clinical trial comparing it to the treatment modalities currently used.
- To examine the long-term effect of the above mentioned training program.
- To develop a training program for prevention of groin injuries in soccer and test it in a randomised clinical trial.
- To describe the occurrence and presentation in clinical entities of groin injuries in male football and to examine the characteristics of these injuries.
- Evaluate if radiological signs of femuro-acetabular impingement (FAI) or dysplasia are associated with the clinical outcome of treatment of long-standing adductor-related groin pain, initially and at 8-12 year follow-up.

*The clinical entity approach*

In the mid nineties the taxonomy of groin injuries in the current literature was quite confusing, no consensus existed and no standardised way to approach the problems had been described. In Study I the literature was studied to generate the basis for the research, in Study II a set of standardised examination techniques were developed and tested for reproducibility and in Study III these techniques were used to create the clinical entity approach in order to identify the anatomical structures causing groin pain, and to use these entities as the diagnostic starting point for the treatment strategy.

Study I

**Introduction**
In the mid-nineties the literature about groin injuries in athletes was based mainly on case stories, retrospective studies, and reviews. In preparing the studies constituting this thesis, the literature was studied in detail, both the above-mentioned studies but also older studies including literature not often cited in the Anglo-Saxon literature[1-4].

**Material & methods**
**Study I** is based on a survey of the existing literature about groin injuries in athletes available in the mid 90'es. The design was a review of a narrative character, not a systematic review. At the time of publication no level 1 or 2 studies were available. This literature study and the author's clinical experience was the foundation of the theories that has later been investigated and is the subject of this thesis and is in many ways the early outline for the present thesis.

**Results**
As **Study I** is a review of a narrative character and not a systematic review no results of statistical or other mathematical nature could be calculated. However, summarising the main findings of the review of the literature yields the following:

Groin injuries are well known in many sports, including soccer, ice hockey, running, tennis and basketball. No studies specifically dealing with the epidemiology of groin injuries had been published, but it could be calculated from Scandinavian epidemiologic literature focusing on soccer in general, that the injury incidence rate was between 10 and 18 groin injuries per 100 soccer players per year.[5-7] Groin injuries with pain related to the adductors were among the most commonly reported in the literature. In papers dealing with the unspecific diagnosis of 'osteitis pubis', the symptoms and signs described were predominantly adductor-related. Taking this into account it could be summarised that the most common site for groin pain is the adductor muscles, particularly in the area of the insertion into the pubic bone.[8-10]

The etiology of the adductor-related injury is not known. The adductors act as important stabilisers to the hip joints.[11] There are indications in the literature that the small insertion area of the adductor longus and the gracilis has a poor blood supply[1 12 13] and that these muscles are particularly exposed to traumatic strain during tackling in soccer[1-3 14], but evidence for these theories are lacking.

The acute adductor-related groin injury is characterised by a 'pull' in the muscle, followed by a sharp pain and a possible swelling, discoloration of the overlying skin and sometimes a palpable defect. The longstanding adductor-related groin pain is characterised by pain when sprinting, making cutting movements, kicking, and tackling.[15 16]

The imaging used in the diagnosis of athletes with groin injuries is either plain x-ray or ultrasonography.[17 18] With a bone scintigram increased uptake uni- or bilaterally in the pubic bone next to the pubic symphysis can be seen[19 20]. MRI was quite new at the time of the review and only one paper could be identified. They found signal changes much like what was found on bone scan.[21] No systematic research in imaging of groin injuries was available.

The non-surgical treatment of groin injuries found in the literature was based on the experience of clinical practise, and no controlled trials were available then. If the injury was refractory to non-surgical treatment, a number of uncontrolled studies suggest surgical treatment. Either tenotomy of the adductor longus tendon, gracilis tendon, or adductor brevis tendon alone or in combination has been suggested, sometimes in combination with a fascioplasty of the rectus abdominis muscle.[22 23] Most of the studies have excellent results but are not controlled. One study have shown significant decrease of isokinetic strength of adduction after tenotomy.[24]

Strength training of the adductors[25], stretching of the adductors[26], and heat retainers[27] have all been suggested to prevent injuries, but no evidence of these theories was available.

**Discussion**

The review in **Study I** has shown that the literature was not providing much scientific evidence on how to define, examine, treat, or prevent groin injuries. The term 'osteitis pubis', although very unspecific, was still widely used. The term originates from infections in and around the pubic symphysis seen primarily after suprapubic surgery.[12] It has been shown by Harris et al in 1974 in an excellent study, that the radiologic change are primarily a result of the stress on the symphysis joint and the adjourning pubic bones because of the amount of activity (especially soccer) rather than being a sign of a groin injury.[8]

The conclusion of Study I was that adductor-related groin pain is common in athletes with groin injuries and in many cases can develop into long-standing problems, and treatment and prevention including strengthening, stretching, and proprioceptive training was suggested.

Study II

**Introduction**

As described in Study I groin pain is associated with many different sports and represents a diagnostic and therapeutic challenge. However, the definitions of and diagnostic criteria for groin pain in athletes are not clear, and in the literature no consensus is provided. To compare the results of research and treatments, the tools used to diagnose and evaluate the degree of groin injury must be clearly defined and reproducible. **Study II** was designed to define and examine the reproducibility of a number of clinical examination tests.

The adductor muscles, iliopsoas muscle, abdominal muscles, and the symphysis joint are some of the most common anatomical structures to be painful in athletes with groin pain. Techniques to evaluate pain related to these anatomical structures as well as the strength and flexibility of the mentioned muscles are therefore important tools in the clinical examination of athletes with groin pain.[28] There was no reference in the literature how these tests should be performed.

The purpose of **Study II** was to evaluate the intra-observer and inter-observer variation in the results of standardised clinical examination techniques for groin pain in athletes

**Material & methods**

A rigid study design aiming to blind the examiners as much as possible was used in **Study II** to evaluate a number of clinical examination techniques for groin pain in athletes. The examiners were 2 medical doctors and 2 physiotherapists and they examined 18 athletes, 9 with groin pain and 9 without. All subjects were examined twice in a randomised order and the examiners were blinded to whether the athletes had groin pain or not. To further blind the examiners the subjects all wore the same type of hospital underwear and the upper half of their body was hidden behind a curtain hanging down over the lower abdomen. They were asked to assess their pain to the various tests but communicated only with a secretary sitting with them behind the curtain to blind the examiners to the result of the tests.

**Figure 1**: Modified Thomas test

The examinations included were bilateral evaluation of adductor muscle related pain and strength using palpation at the adductor insertion at the pubic bone, adduction against resistance and passive stretching of the adductor muscles; iliopsoas muscle related pain, strength and flexibility using palpation above the inguinal ligament, isometric strength test in hip flexion and a modified Thomas test (Figure 1); abdominal muscle related pain and strength using palpation of the abdominal muscle insertion at the pubic bone and a functional sit-up test and symphysis joint tenderness at palpation.

*Statistical analysis*

To determine the degree of agreement within and between the observers, we used percentage of agreement, which is a simple calculation of the number of tests with agreement against the total number of tests performed, and kappa statistics, which takes into account the agreement expected solely on the basis of chance. Kappa values of 0.41–0.60 indicate moderate agreement, 0.61–0.80 good agreement, and 0.81– 1.00 very good agreement[29]. To determine the kappa value for the inter-observer agreement between four observers, the method suggested by Siegel and Castellan was used[30]. As the study had a skewed distribution of the marginals, a problem to which kappa statistics is very sensitive, we also included percentage of agreement for the interpretation of the results. The value for percentage of agreement for the inter-observer agreement is calculated as the mean of the six values for agreement between the four observers. In some of the tests, the structures to be tested were paired, and two similar tests were performed, one on the right and one on the left side. As the side tested was not the subject of this reliability study, a mean value of the kappa values and the percentages of agreement of the two sides was calculated as the final result of each test.

**Results**

Regarding the *intra-observer* reliability (Table 1) the kappa values were above 0.60 in 11 of the 14 tests and above 0.80 in six tests. In three tests, the values were below 0.60. The percentage of agreement ranged from 85.4 to 96.5. In three tests, there was discrepancy between the kappa values and the percentage of

agreement: (a) the kappa value of the psoas functional pain test was 0.31, but the percentage of agreement was 90.3; (b) the kappa value of the abdominal strength test was -0.03, but the percentage of agreement was 94.4; (c) the kappa value of the abdominal oblique functional pain test was 0.51, but the percentage of agreement was 91.0

| | Percentage of agreement | | | κ value | | |
|---|---|---|---|---|---|---|
| Test | Right | Left | Mean | Right | Left | Mean |
| Adductor functional pain (1A) | 95.8 | 97.2 | 96.5 | 0.91 | 0.91 | 0.91 |
| Adductor palpation pain (2A) | 95.8 | 94.4 | 95.1 | 0.88 | 0.91 | 0.89 |
| Adductor stretching pain (3A) | 94.4 | 93.1 | 93.8 | 0.66 | 0.68 | 0.67 |
| Symphysis palpation pain (4A) | | | 93.1 | | | 0.84 |
| Rectus abdominis palpation pain (5A) | 94.4 | 90.3 | 92.4 | 0.75 | 0.86 | 0.81 |
| Abdominal functional pain (6A) | | | 93.1 | | | 0.63 |
| Abdominal oblique functional pain (6C) | 88.9 | 93.1 | 91.0 | 0.58 | 0.44 | 0.51 |
| Psoas palpation pain (7A) | 94.4 | 93.1 | 93.8 | 0.81 | 0.87 | 0.84 |
| Psoas functional pain (8A) | 87.5 | 93.1 | 90.3 | 0.52 | 0.11 | 0.32 |
| Psoas stretching pain (9B) | 94.4 | 97.2 | 95.8 | 0.91 | 0.72 | 0.81 |
| Adductor strength (1B) | 93.1 | 93.1 | 93.1 | 0.58 | 0.72 | 0.65 |
| Abdominal strength (6B) | | | 94.4 | | | −0.03 |
| Psoas strength (8B) | 83.3 | 87.5 | 85.4 | 0.64 | 0.59 | 0.61 |
| Psoas flexibility (9A) | 90.3 | 94.4 | 92.4 | 0.83 | 0.66 | 0.74 |

NB There are no values for left and right for symphysis palpation pain (4A), abdominal functional pain (6A), or abdominal strength (6B).

**Table 1:** Intraobserver agreement and k values in the examination of athletes with groin pain

The tests for *inter-observer* reliability showed overall good agreement between the four observers. In the tests for pain, the inter-observer kappa values were above 0.60 in eight tests and above 0.80 in five. In two tests, the values were below 0.60. The percentages of agreement were above 80 in ten pain tests and above 90 in eight pain tests. In two pain tests, there were discrepancies between the kappa values and the percentage of agreement: (a) the kappa value of the abdominal oblique functional pain test was 0.41 whereas the percentage of agreement was 87.0; (b) the kappa value for the abdominal functional pain test was 0.57 whereas the percentage of agreement was 90.3. The only test that had both a low kappa value and a low percentage of agreement was the iliopsoas strength test. The other tests for strength and flexibility had kappa values of 0.05–0.29; in contrast with these low values, the percentages of agreement for the same tests were 83.2–92.6.

**Discussion**

In **Study II** all but one of the included clinical examination tests for pain, strength, and flexibility of the adductor muscles, the iliopsoas muscles, the abdominal muscles, and the symphysis joint were found to be reproducible and subject only to limited intra-observer and inter-observer variation.

The test for iliopsoas strength was the only test without a satisfactory kappa value or percentage of agreement. The test was performed with the subject in the supine position flexing his leg maximally to try to isolate the iliopsoas muscle from the other hip flexors. The subject was instructed to keep the leg in that position while the examiner tries to extend it by pulling it with one arm wrapped around the femur just proximal to the knee. This is a strength-demanding test for the examiner and since the observers were of different sex and physical build the strength needed to judge the strength of the patients hip flexion might be too small in some of the examiners compared to the others. This is in concordance with a recent study examining strength testing of the hip related muscles where gender and as such physical strength resulted in systematic measuring error.[31] This was in a later study overcome by pulling against a strap fixed to the floor or the wall, not depending on the examiners strength.[32] In **Study II** the pain elicited by the test could be reproduced satisfactory. In the intra-tester study the iliopsoas strength test showed good reproducibility.

During the pilot study preparing **Study II** it became clear that to master manual techniques they have to be practiced, even if they as such are not technically demanding. The precision in the details is important to provide a meaningful basis for clinical and scientific use.

The combination of anatomical knowledge, palpation skills and biomechanical understanding of the function of the relevant muscles is a good foundation for development of reproducible examination tests. No previous studies had described tests for groin pain and tested them systematically before this study.

Study III

**Introduction**

Groin pain in athletes is known from sports such as all the football codes, ice hockey, running, tennis, basketball, and others[7 33 34] No comparative prospective studies were published considering matched populations and the rate of exposure between different sports. Renström and Peterson in 1980[33] described differential diagnoses among 55 athletes from different sports with groin pain. Adductor longus pain comprised 62%, rectus abdominis pain 22% and other locations 16%. Lovell in 1995, in a retrospective review of 189 cases of groin pain in athletes, found more than one diagnosis accounting for the groin pain in 27% of the patients.[35]

A major limitation in the field of groin pain research is that there is no agreement about a scientific taxonomy. Thus, the literature provides no consensus on diagnostic criteria for the various causes of groin pain among athletes. In fact, the cause of chronic groin pain remains very much in debate and most studies are not based on systematic clinical assessments using reliable examination methods, and well-defined diagnostic entities are not reported. Therefore, the prospective **Study III** aimed to describe the range of clinical syndromes detected when a reliable, standardized physical examination method was used to assess sports-related groin pain among 207 consecutive patients. Although clearly limited by being descriptive in nature, such a study could provide an important perspective as to the structures that warrant thorough physical examination, particularly if more than one structure is commonly found to be abnormal.

**Material & methods**

Two hundred and seven consecutive patients with complaints of groin pain in connection with or after sports activities for more than 2 month were included. Age, gender and sports activities were recorded. A standardised clinical examination protocol was used including both the tests developed and tested for reproducibility in Study II as well as a number of standardised tests all described in the literature and used in a standardised manner in all patients.[36] The aim of the testing was to identify which anatomical structures were associated with groin symptoms and to exclude other aetiologies. In each case the findings were compared to the non-symptomatic side. When clinically indicated,

supplementary imaging techniques were used. The findings were used to classify the groin injury into a number of clinical entities based on the relation to anatomical structures (Table 2). When more than one clinical entity was found it was attempted to rank these in a descending order of clinical importance into primary, secondary and tertiary entity, an approach found useful by Lovell et al.[35]

| Clinical entity | Diagnostic criteria |
|---|---|
| Adductor-related pain | Palpatory pain at the muscle origin at the pubic bone and pain with adduction against resistance |
| Iliopsoas-related pain | Palpatory pain of the muscle through the lower lateral part of the abdomen and/or just distal of the inguinal ligament and pain with passive stretching during Thomas' test |
| Rectus abdominis-related pain | Palpatory pain of the distal tendon and/or the insertion at the pubic bone, and pain at contraction against resistance |
| Snapping iliopsoas | A painful snapping in the groin when extending the maximally flexed hip and visible snapping with ultrasonography |
| Piriformis-related pain | Palpatory pain and pain with passive stretching |
| Pelvic floor-related pain | Palpatory tenderness of the edge of the muscles posteriorly, and painful contraction of the muscles |
| Sacrotuberal ligament pain | Palpatory pain of the ligament, both through the gluteal region and through the rectum |
| Sacroiliac joint dysfunction | Positive Gillet's test and/or forward-bending test and pain with the Patrick's test and/or the sacroiliac shear test |
| Pain of thoracolumbar origin | Pain at the level of thoracic segment 10 to lumbar segment 1 with the skin-rolling test, and the facet joint palpation and the springing test |
| Hip arthrosis | Radiological signs of arthrosis, subchondral sclerosis, subchondral cysts, narrowed joint space and osteophytes |
| Stress fracture | Bone scintigraphic signs of a stress fracture and palpatory pain at the corresponding anatomical site |
| Hernia | The presence of a visible and/or palpable inguinal mass and/or when a massive cough impulse was present |
| Sports hernia | No hernia present (as described above) as well as tenderness of the external inguinal ring and tenderness in the area of the conjoint tendon and close to its insertion at the pubic tubercle |

**Table 2:** Diagnostic criteria used in the examination of 207 consecutive athletes with groin pain

**Results**

In **Study III** 207 patients (11 women and 196 men) with sports-related groin pain were included and examined with a standardised clinical program. The women included had a median age of 26 years (range 16 to 48 years), and the men included had a median age of 28 years (range 16 to 50 years). Football was the most common sport among men (135 (69%)), whereas running was the most common among women.

Thirteen different clinical entities were detected. Adductor-related pain was considered the primary clinical entity in 119 (57.5%) patients (all men). Iliopsoas-related pain was the primary clinical entity in 73 (35.3%) patients. Other primary clinical entities were relatively rare. (Table 3)

| Clinical entity | Primary, n (%) | Secondary, n (%) | Tertiary, n (%) |
|---|---|---|---|
| Adductor-related pain | 119 (57.5) | 7 (3.4) | |
| Iliopsoas-related pain | 73 (35.3) | 40 (19.3) | 8 (3.9) |
| Sports hernia | 3 (1.4) | | 1 (0.5) |
| Snapping Iliopsoas | 2 (1) | | |
| Pelvic floor-related pain | 2 (1) | | |
| Rectus abdominus-related pain | 2 (1) | 12 (5.8) | 6 (2.9) |
| Sacrotuberal ligament pain | 1 (0.5) | 6 (2.9) | 1 (0.5) |
| Sacroiliac joint dysfunction | 1 (0.5) | 1 (0.5) | |
| Hip arthrosis | 1 (0.5) | 2 (1) | |
| Pain of thoracolumbar origin | 1 (0.5) | | |
| Hernia | 1 (0.5) | | |
| Piriformis-related pain | | 1 (0.5) | |
| Stress fracture | 1 (0.5) | | |
| Total | 207 (100) | 69 (33.3) | 16 (7.7) |

**Table 3:** Primary, secondary and tertiary clinical entities in 207 athletes with groin pain

Iliopsoas-related pain was the primary clinical entity in nine women, one woman had a snapping psoas and one had a stress fracture of the inferior pubic bone. Only one case of adductor-related pain was seen in a woman, and categorised as secondary to a case of iliopsoas-related pain. At least two clinical entities were found in 69 (33.3%) patients and 16 (7.7%) patients had three entities. No more than three entities were found in this study. A total of 48 patients had iliopsoas-related pain as secondary or tertiary clinical entity, 46 of these had the adductors as the primary origin of pain.

The biggest subgroup of athletes was the football players (n=137). Adductor-related pain was the most common entity (72%) and the most common primary entity (69%). Seventy-two football players had iliopsoas-related pain and it was the primary origin of pain in 26%, but was in most cases considered a secondary clinical entity (60%). Pain related to the rectus abdominis was found in 15 football players and was in almost all cases considered secondary to adductor-related pain.

Totally 37 runners were included (long distance, middle distance, recreational, orienteering, hurdles and sprint), and among these, iliopsoas was the most prevalent clinical entity accounting for two- third of the entities. Seven of the 11 female patients were runners and six of them had iliopsoas as their primary origin of pain.

**Discussion**

The systematic set up in **Study III** of examining athletes with groin pain using clinical standardised examination methods combined with a set of clinical entities is an attempt to move the clinical evaluation of long-standing groin pain from a diagnostic label paradigm to one where clinical entities are considered. This may, more accurately, reflect diagnostic limits. Since no gold standard exists regarding diagnosis for most of the soft tissue related groin pain, this approach offers a possibility to identify the anatomical structures that are painful in athletes with groin pain and thereby differentiate between the different pathologies. This is no attempt to label the groin pain with a diagnosis at this stage, but merely to create a basis for which the further research into "real diagnoses" can begin and to be able to compare cohorts of patients in relation to epidemiology, investigations, treatment, and prevention.

A major clinical implication of this study including a large cohort of patients is the fact that multiple entities are present in well over one third of patients. This behoves clinicians to systematically examine the other regions, even when one cause has been found for a patient's long-standing groin pain.

The cohort in this study is a reflection of the referral pattern for the author and for the way the 'world of groin and hip problems in athletes' looked like when the study was done. The hip joint was not a major focus area in athletes as it is today with the increasing knowledge of femoracetabular impingement (FAI) and also the concept of incipient hernia (also known as sports hernia, pubalgia etc.) was not a well developed focus of the authors examination strategy. Further clinical entities might have been included today and the frequency of the different entities might be different, although the frequencies found in Study VII and in the UEFA injury study[37] are in concordance with **Study III**. Especially the "hip joint related" cause of long-standing groin pain is

an area that needs further scientific attention. However, it is the authors' clear impression that the adductor-, iliopsoas-, and abdominal-related entities still are among the most frequent and in that order.

*Treatment and prevention - RCT's*

The most common clinical entity in soccer: adductor-related groin pain was the target of the randomised treatment trial in **Study IV**. A program of active exercises for the pelvis related muscles and the adductors in particular was compared to a program consisting of the most commonly used passive treatment modalities, and was found to be significantly better. The long-term results of this treatment program was examined in **Study V** and again the active exercise program was found to be superior and the patients were still significantly better than those from the passive program. Based on the ideas from the treatment program an exercise programme aimed at prevention of groin injuries was designed and tested in **Study VI** in a cluster-randomised clinical trial in male football. The program reduced the risk of groin injury with 31% however this was not statistically significant. Physiotherapists assigned to the clubs followed all the players included in this trial and all groin injuries were examined using the entity approach. The distribution and characteristics of the groin injuries are described in **Study VII**.

*Study IV*

**Introduction**

The target of the randomised clinical trial **Study IV** was the entity that in the literature including Study III is the most common cause for groin pain in athletes: adductor-related groin injury. The adductors are a frequent cause of groin pain and are known to cause long-standing problems.[33 35] The non-operative treatments mentioned in the literature of groin pain in athletes were not based on randomised clinical trials.[38-40] Most of the studies on operative treatment of groin injuries were retrospective[23 24 41 42], and the few prospective studies were not randomised.[43] In sports medicine various training programs to treat overuse injuries in particular have been designed primarily on an empirical basis. However, the efficacy of training programs for a few diagnostic entities such as functional instability of the ankle and low-back pain[44 45] have been documented in randomised clinical trials.

As discussed in Study I, muscular imbalance of the combined action of the muscles stabilising the hip joint could, from an anatomical point of view, be a causative factor of adductor-related groin pain. Muscular fatigue and overload might lead to impaired function of the muscle and increase the risk of injury. The adductor muscles act as important stabilisers of the hip joint.[11] They are exposed to overloading and risk of injury if the stabilisation of the hip joints is disturbed. The purpose of **Study IV** was to compare an active training programme with a conventional physiotherapy programme in the treatment of severe and incapacitating adductor-related groin pain in athletes.

The treatment modalities were: a treatment without active training (PT) with elements of both passive and active therapy put together according to the contemporary practice among physicians and physiotherapists working in the field of sports injuries at the time of the study, and an active training programme (AT) aimed at improving the coordination and strength of the muscles stabilising the pelvis and hip joints, in particular the adductor muscles.

**Material & methods**

Athletes with longstanding groin pain were examined and if fulfilling the inclusion criteria offered to participate in a randomised clinical trial (RCT) comparing an active treatment program (AT) with a passive treatment program (PT). The AT consisted of a number of exercises aimed at muscular strengthening of the pelvic related muscles with special emphasis on the adductor muscles as well as exercises aiming at training the muscular coordination related to the postural stability of the pelvis. The exercises were introduced in two phases progressing the load and difficulty.

**Elements of AT**

**Module 1 (first 2 weeks)**

1) Static adduction against soccer ball placed between feet when lying supine; each adduction 30 s, ten repetitions.

2) Static adduction against soccer ball placed between knees when lying supine; each adduction 30s, ten repetitions.

3) Abdominal sit-ups both in straightforward direction and in oblique direction; five series of ten repetitions.

4) Combined abdominal sit-up and hip flexion, starting from supine position and with soccer ball placed between knees (folding knife exercise); five series of ten repetitions.

5) Balance training on wobble board for 5 min.

6) One-foot exercises on sliding board, with parallel feet as well as with 90° angle between feet; five sets of 1 min continuous work with each leg, and in both positions.

**Module II (from third week; module II was done twice at each training session)**

1) Leg abduction and adduction exercises lying on side; five series of ten repetitions of each exercise.

2) Low-back extension exercises prone over end of couch; five series of ten repetitions.

3) One-leg weight-pulling abduction/adduction standing; five series of ten repetitions for each leg.

4) Abdominal sit-ups both in straightforward direction and in oblique direction; five series of ten repetitions.

5) One-leg coordination exercise flexing and extending knee and swinging arms in same rhythm (cross-country skiing on one leg); five series of ten repetitions for each leg.

6) Training in sideward motion on a "Fitter" (rocking base curved on top and bottom; user stands on platform that rolls laterally on tracks on top of rocking base) for 5 min.

7) Balance training on wobble board for 5 min.

8) Skating movements on sliding board; five times 1 min continuous work.

No stretching of the adductors was allowed. The PT program was constructed from the passive treatment modalities used in physiotherapy for these problems at the time of the initiation of the trial (1991). The main author had made an unofficial survey among Scandinavian doctors and physiotherapists working in sports medicine and the methods included in the PT were those most frequently mentioned. The elements of the PT were transverse friction massage, transcutaneous electrical nerve stimulation, laser and stretching. The AT was given 3 times a week as a group treatment and the PT 2 times a week as an individual treatment. There was no difference in the mean number of individual patient/physiotherapy attendances at the end of the study. The patients received treatment for a minimum of 8 weeks and a maximum of 12 weeks. No patients were allowed to receive any other treatment during the trial. Riding a bike was allowed during the treatment period if it did not cause any pain and jogging was allowed after 6 weeks of treatment if it could be done pain free. After end of treatment all patients were given identical written instruction about sports-specific gradual rehabilitation.
The inclusion criteria were: male, age 18–50 years and groin pain due to sport for at least 2 months. They should also have a desire to continue sports at the same level of competition as before the injury, pain at palpation of the adductor tendons or the insertion on the pubic bone, or both, and groin pain during active adduction against resistance. Moreover, a minimum of two of the following four criteria had to be met: 1) a characteristic history of, for instance, groin pain and muscle stiffness in the morning, groin pain at night, groin pain with coughing or sneezing; 2) pain at palpation of the symphysis joint; 3) increased scintigraphic activity in the pubic bone; 4) radiographic signs of osteitis pubis around the symphysis joint.
The exclusion criteria were: 1) clinical findings indicating inguinal or femoral hernia; 2) evidence of prostatis or chronic urinary-tract disease; 3) pain of the vertebrae from the tenth thoracic segment to the fifth lumbar segment, including the facet joints; 4) presence of malignant disease; 5) coexisting fracture of the pelvis or the lower extremities; 6) other lesions of the lower extremities preventing the patient from fulfilling the treatment program; 7) clinical findings showing nerve entrapment of the ilioinguinal, genitofemoral, or lateral femoral cutaneous nerves; 8) radiographic evidence of hip-joint osteoarthritis or any other hip-joint disease; and 9) bursitis of the hip or groin region.

For the per-protocol analysis, exclusion criteria after randomisation were: disease preventing the patient from completing the treatment programme and absence from more than 25% of the treatment sessions.

Level and type of athletic activity and characteristics of the groin injury history was recorded in a standardised manner. A standardised clinical examination including the techniques from Study II, a plain standard anterior-posterior x-ray, a planar bone scintigraphy and a measurement of maximum oxygen consumption ($VO_2$ max) was obtained and recorded at entry to the trial. The $VO_2$ max test was repeated after end of treatment period. The range of motion of the hip joint was tested in supine position using a goniometer with increments of 5 degrees.
After collecting all data, patients who were included in the study were randomly allocated by sealed, opaque, and serially numbered envelope to AT or PT by means of block randomisation (block size four). The secretary at the physiotherapy office, upon request, opened the next envelope, once a new patient was ready for randomisation. The result of the randomisation was told to the physiotherapist in charge of the allocated treatment and she arranged the first treatment session with the patient. The examining physician was not involved in the randomisation and he was not at any time aware of the result. Double data entry was done and the data manager as well as the statistician was unaware of treatment allocation. The patient was on both the 4-week and the 4-month clinical examination and interview told not to reveal the treatment he was receiving to the examining physician. The outcome measures of successful treatment of the trial were: i) no pain at palpation of the adductor tendons and the adductor insertions at the pubic bone and no pain during active adduction against resistance ii) no groin pain in connection with or after athletic activity in the same sport and at the same level of competition as before the onset of the groin pain and iii) return to the same sport and at the same level without groin pain. If all 3 measures were reached, the result was labelled *excellent*, if 2 measures were reached, the result was *good*, if 1 measure was reached, the result was *fair* and if no measures were reached, the result was *poor*. Level of sport was defined as exercise (1 to 2 times a week), competitive (3 – 4 times a week) and elite (>5 times a week). The patients' subjective global assessment of their groin problems regarding both function and pain as compared with their situation before they started the treatment program was also registered. The possibilities were much better, better, not better, worse, and much worse.

*Statistical analysis*
Univariate and multiple logistic regression analysis were done. Significant ($p<0{\cdot}05$) variables in the multiple regression analysis were found by the backward elimination method. Tests for interaction between significant variables were done in multiple-regression analysis. Results were given as odds ratios and 95% CIs, p values were two tailed. Mantel-Haenszel $X^2$ was used to test for linear trend for the outcome measure and the subjective global assessment. The type-1 error was fixed at 5%. The sample size of the study gave 80% power to detect a difference in effect between the treatments of 35% at a significance level of 5%.

**Results**

Sixty-eight athletes were included and 59 completed the study. (Figure 2) Five withdrew from the active treatment group (AT) and four from the passive treatment group (PT). The only significant difference in baseline characteristics between treatment groups was that more patients in the PT group had bilateral groin pain ($p=0.008$).

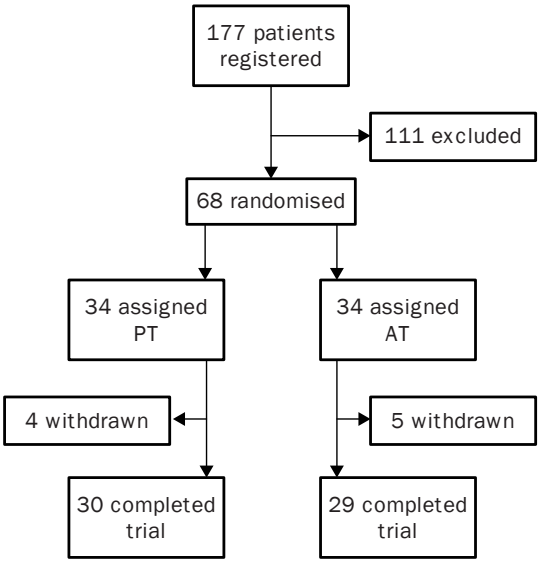


**Figure 2**: Trial profile Study IV

The analysis of effect of treatment was done according to intention to treat. We found a significant difference in favour of AT (p=0.001). Treatment, unilateral or bilateral, and severity of pain were predictors of outcome in the univariate analysis. In the multiple-logistic-regression analysis, only treatment or bilateral symptoms were independent predictors. After adjustment for unilateral groin pain, the odds ratio for the AT treatment was 12.7 (95% CI 3.4–47.2). (Table 4) There were no significant interactions between the explanatory variables. A per-protocol analysis including the 59 patients who completed the study did not show appreciably different results.

| | Odds ratio (95% CI) | |
|---|---|---|
| | Univariate analysis | Multiple logistic-regression analysis |
| **Treatment** | | |
| AT | 15·7 (4·4–55·7) | 12·7 (3·4–47·2) |
| PT* | 1 | 1 |
| **Groin pain** | | |
| Unilateral | 9·8 (2·0–46·9) | 6·6 (1·2–37·2) |
| Bilateral* | 1 | 1 |
| **Level of pain at entry** | | |
| Moderate | 3·3 (1·1–9·7) | · · |
| Severe* | 1 | · · |

*Reference category.

**Table 4**: Univariate and multiple logistic-regression analysis of the three significant variables influencing outcome measures

Based on a per-protocol analysis there was a significant (p=0.006) linear trend towards better subjective global assessment of effect of the AT treatment. Almost all patients (26 of 27) rated as excellent assessed their condition to be much better. The linear trend was significant (p=0.001). In the AT treatment group, 23 (79%) of the athletes completing the study returned to sports activity at their previous level without any symptoms of groin pain. The median time from entering the study until complete symptom-free return to sport was 18.5 weeks (range 13–26). The range of motion of the hip-joint abduction increased significantly in both treatment groups (p=0.0004), and no difference was found between the groups. The adduction strength improved significantly in the AT group compared with the PT group (p=0.001) but the VO2-max values of the two treatment groups did not change during the treatment period.

**Discussion**

The most frequent clinical entity – adductor-related groin pain – was the target of the exercise-based treatment program tested in the RCT of **Study IV**. We found convincing positive results of the AT program compared to the PT program with an odds ratio of 12.7 and 79% of the athletes with long-standing adductor related groin pain treated with the AT program returning to their previous level of sport without any groin pain. It was one of the first studies to show evidence-based that exercise therapy could be an excellent solution treating musculo-tendinous pain in connection with physical activity. The cohort randomized in this study were athletically disabled. They had been injured for 9 months (median), and most trained three to four times a week but at study entry 75% had ceased to participate in sports because of groin pain. The PT group used methods derived from physiotherapy: manual techniques (transverse friction massage), electrotherapy (laser and transcutaneous electrical nerve stimulation), and exercise therapy (stretching) and this were chosen, as it was the most prevalent type of therapy when the study was initiated in the beginning of the 1990'es. Treatments of the same nature such as ultrasound (59%), soft laser (48%), massage (47%) and stretching (56%), had been used by many of the patients included in this study. Active training exercises similar to those used in the AT group had been tried by about 20% of patients. A control group not receiving any therapy would have been ideal from a scientific point of view, but since most of the patients had abstained from sport for 4 months without improvement of symptoms and were judged in need of therapy, such a control group was considered to be unethical.

Anecdotically the PT group had a very good effect of the treatment initially, but after they started to return to sport (using the same program and getting identical instructions as the AT group) the groin pain returned in most of them. Only 14% in the PT group returned to their previous level of sport without any groin pain.

The patients in the PT group used stretching exercises for the adductor muscles both during treatment with the physiotherapist and as home exercise on the days between treatment days. The patients in the AT group were not allowed to do stretching exercises for the adductor muscles at all; nonetheless they had the same increase of hip-joint range of motion as the PT group. In the AT group, pain was initially a limiting factor to the range of motion in some of the exercises, but, as the muscle coordination and strength increased and the groin pain decreased, the load and the range of motion increased. Tolerance towards an increased range of motion might thereby be achieved.[46] Another possibility is that stretching of the adductor muscle and thereby pulling on the insertions at the pubic bone might worsen the injury. Since both treatment groups include several elements it is not clear if any single element is more important for the result than others, however, the results of our study do not support a recommendation to use stretching as a treatment for adductor-related groin injury.

*Study V*

**Introduction**

Two recent systematic reviews[47 48] have found only one high-quality paper on the treatment of long-standing groin pain. (Study IV) This randomized clinical trial resulted in a return of 79% of the athletes with adductor-related groin injury to the previous level of sport without any groin pain compared with 14% in the control group. As muscle and tendon injuries are a major general health problem **Study V** was performed to investigate the long-term effect of this treatment.

The increased public health concern about lifestyle-derived diseases including obesity has resulted in strong recommendations about the need for physical activities. However, muscle and tendon injuries are a common adverse effect of physical activity at any level, with notable costs to society as well as the athlete, whether recreational or competitive. The treatment of these injuries is a challenge, and recurrent injuries are common. The risk of sustaining a hamstring or a groin injury in soccer is almost doubled if the athlete previously had a similar injury.[49-51] Training with specific exercises as a treatment for musculoskeletal injuries has been used in the general treatment of exercise-related overuse pain as well as in sports medicine and has gained increasing popularity.[52-54] However, the long-term effect of these treatment principles is not known.

The aim of **Study V** was to evaluate the long-term effect of the exercise program used in Study IV.

**Material & methods**

The 59 patients who fulfilled the RCT described in Study IV were invited to participate in this 8 -12 year follow-up study, and 47 (80%) accepted (Figure 3).

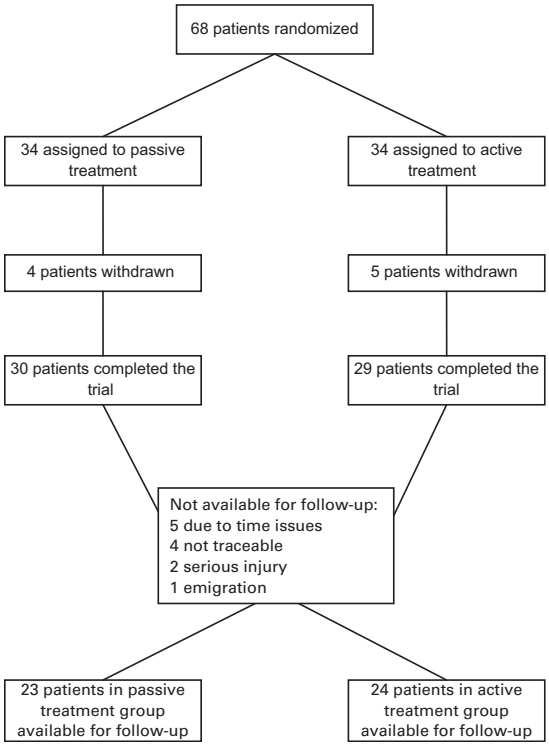


**Figure 3:** Trial profile Study V

The study was designed as closely as possible to the primary RCT (Study IV) including a personal interview and a standardised clinical examination. The investigating physician was not involved in the original study and was unaware of the original treatment allocations. The participants were all informed both in writing and at arrival at the office for the examination and interview not to reveal what type of treatment they had received in the RCT. The questionnaire that was used for the interview was in principle the same as the one used in the primary RCT, but relevant supplementary information regarding the 8 – 12 years that had passed since they finished the first study was obtained. The standardised examination protocol was identical to the one used in the original trial including a number of the reproducible techniques from Study II. The examining physician received specific training in performing the physical examinations prior to the study. The outcome measures were essentially the same as those used in the primary trial, however, since the mean age was now nearly 43 years, most of the participants in both groups had reduced their athletic activity and were participating in sport less times a week than at the time of their groin injury. The reasons for this were in most cases age and lack of time. In 13%, the groin pain was the reason for reducing athletic activity. This decrease in level of sport was taken into account as part of the outcome measurement, and the demand for sports activity at the same level as before they were injured was decreased to sports activity one level below the initial level at the time of their injury.

*Statistical analysis*

The levels of the treatment outcome variable were excellent versus good, fair, and poor. The Cochran-Armitage $X^2$ distributed test for trend in proportions was used for the treatment outcome variable and the subjective global assessment variable.

**Results**

No significant differences were found regarding age, present sports activity, reasons for activity reduction, or time to follow-up among the 47 of 59 individuals available for follow-up. The 12 individuals (20%) not participating did not differ in terms of age. During the follow-up period of 8 to 12 years, the majority of participants had reduced their athletic activity level, but there was no difference between the 2 treatment groups in terms of athletic activity reduction ($p = 0.508$). In 39 (83%) of the participants, the groin injury was caused by soccer. In the remaining 8 (17%) participants, the causative sport was European handball (n = 2), badminton (n = 2), running (n = 2), ice hockey (n = 1), and rugby (n = 1). At follow-up, 4 (9%) individuals had stopped with any kind of sports activity, and 28 (72%) were still playing soccer.

The distribution of outcomes showed a significant difference in favour of the AT treatment ($p = 0.047$). Also the subgroup of soccer players (n = 39) showed a significant difference in favour of the AT ($p = 0.012$). (Table 5)

Treatment Outcome of AT and PT Groups for the Participating Soccer Players (n = 39)[a]

| Treatment Outcome | AT | PT |
|---|---|---|
| Excellent | 11 (55%) | 3 (16%) |
| Good | 7 (35%) | 11 (58%) |
| Fair | 2 (10%) | 3 (16%) |
| Poor | 0 | 2 (10%) |

[a]Difference between groups, $P = .012$. AT, active treatment; PT, passive treatment.

**Table 5**

No participant assessed his subjective global assessment of the effect of treatment as worse or much worse. There was a trend toward better subjective global assessment of the effect of the AT treatment, both in the whole group (p = 0.126) as well as in the subgroup of soccer players (p = 0.058).

**Discussion**

This prospective 8- to 12-year follow-up study of the patients with long-standing adductor-related groin pain included in Study IV, showed a continued significant effect of the AT treatment both for the whole group and for the subgroup of 39 (83%) soccer players. This is the first time the effect of an exercise treatment for overuse injuries to the musculoskeletal system has been shown to be long lasting (8-12 years). It is an important quality of any treatment, but it seems even more encouraging that a non-invasive and non-pharmacological method has this ability. The cause for this long-lasting effect is not known, but a number of points can be made regarding the content of the original treatment program.

Strengthening of the abductor and especially the adductor muscles is a major part of the AT treatment. Eccentric hip strength is important for fundamental skills in soccer, such as kicking, accelerating, and sudden change of direction, and soccer-relevant diagonal kicking angles seem to increase the demands of hip adduction strength of the kicking leg.[55 56] A recent study has indicated that the mere training and playing of soccer does not induce a specific eccentric adduction strength increase compared with controls, whereas this is the case regarding eccentric abduction strength perhaps leading to an unbalanced ratio between the two muscle groups.[57] This adds to the explanation for the frequent adductor-related problems and to why the specific strengthening of the femoral adductor muscles including static, concentric, and eccentric exercises in the AT treatment could be an important part of the long-standing effect.

Since Study IV was conducted, eccentric exercises and core stability (core strengthening) have gained increased attention. Both of these training principles were utilized in the original program and might be part of the reason for the positive and lasting effect. Eccentric exercises seem to be of major value in the treatment of tendon-related overuse injuries.[52 58-60] A number of the exercises used included eccentric strengthening (especially module I, exercise 6 and module II, exercises 1, 3, and 5)[61]. The explanation for the beneficial effect of eccentric exercises on tendon-related problems is not clear.[62] The primarily damaged tissue in adductor-related groin pain is (although not proven) probably the enthesis of the tendon at the pubic bone.[63] The beneficial effect in the AT treatment is not necessarily a direct effect on the tendon or the entheses but rather an important strengthening of the eccentric ability to control and stabilize, a quality crucial to production, transfer, and control of force and motion in physical activity. This is however, not known.

Core stability (core strengthening) is another training concept that has developed especially during the last 10 to 15 years; it is now considered to be an important element in the exercise treatment of musculoskeletal problems. Core stability is defined as the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer, and control of force and motion to the terminal segment in integrated athletic activities.[64 65] The exercises utilized in the original study include this principle (especially module I, exercises 4 and 6 and module II, exercise 5) [61].

The principles of core stability are explained from the numerous studies regarding exercise treatment of low back pain (LBP). Patients with chronic LBP have atrophy of the multifidi muscles and weak spine extensor muscles as well as delayed contraction of the transverse abdominis muscle in anticipation of limb movement. Those with back pain have been found more likely to have deficits in spinal proprioception, balance, and ability to react to unexpected trunk perturbation compared with pain-free controls. Muscular changes such as weakness and poor endurance or ineffective neural control may contribute to this inability. Multifidi muscle recovery is not spontaneous in itself on the remission of painful symptoms, and the consequent lack of localized muscle support may be one reason for the high recurrence rate of LBP. Studies supporting the theory that specific exercise training can prevent recurrence are promising and indicate that a ''specific exercise treatment'' approach directed at specific muscles may provide a significant and viable treatment approach.[53 66-69]

This ''specific exercise treatment'' approach is similar to the approach used in the RCT in Study IV for the treatment of long-standing adductor-related groin pain. [61] To perform with skill, the position and the motion of the pelvis should be controlled. A delicate balance exists between numerous muscles and ligaments originating from and/or inserting into the pelvis, all contributing to this function. The synergies between the muscles acting across the pelvis, sacroiliac joints, and hip joints are determining to allow optimum production, transfer, and control of force and motion to the terminal segment in integrated athletic activities.[63] The excellent result of the primary AT treatment and the lasting effect after 8 to 12 years could be attributed in part to this specificity in enhancing muscular strength and endurance as well as neural control. Further biomechanical research may explain whether this is true.

A recent study from our research group has evaluated the exercise intensity of eight hip adduction exercises frequently used in the prevention and treatment of adductor-related groin injuries using surface EMG to measure muscle activity.[70] The results show that four of the exercises for the adductor muscles that were used in Study IV/V can be considered strength training, as they elicit an intensity higher than 60% of maximum, which is documented to be conducive of muscle strength gains.[71] Furthermore, it could be assumed that it is possible to regulate the intensity of some of the exercises by changing the RM, both to a higher or lower relative load or by pressing submaximally on the

ball in the isometric exercises.[70]

It is possible that none of the above-mentioned factors have contributed to the continued significant effect. We have, however, strived to make sure that, as many confounders as possible have been ruled out to optimize the comparison. The limitations of this study are the lack of precise and controlled knowledge of the participants' possible activities in the 8- to 12-year follow-up period regarding supplementary treatment and physical activity. The strengths of this study are the use of a blinded independent examiner, the use of a standardized examination protocol and questionnaire similar to the one used in the original RCT, the use of the same outcome measurement and subjective global assessment, and a high follow-up rate (80%).

A high risk of recurrence exists especially for overuse injuries, and previous injury is an important risk factor for exercise-related injuries.[50 72 73] The present results indicate that this risk can be reduced in the case of long-standing adductor-related groin pain, and further studies must show whether the principles of the present treatment program can be successfully applied to other injuries.

Study VI

**Introduction**

Groin pain in athletes is a major problem, particularly among football players, where it is a serious and very common injury, which may end the sports career. Treatment of these injuries may take months and is costly both for the player and for the health service system and it would be of great value to be able to prevent some of these injuries. **Study VI** is a cluster randomised clinical trial attempting to do so.

In Study IV, it was shown in a randomised clinical trial that a training program including strength training of the adductor, abdominal and low-back muscles, combined with coordination and balance exercises, was significantly better in treating long-standing adductor-related groin injuries in athletes than traditional ''passive'' treatment.

Based on our experiences with this training program, we developed a new training program with the aim of preventing groin injuries in football based on similar principles of strengthening the pelvis related muscles, improving their coordination and enhancing eccentric strength and core stability. The purpose of **Study VI** was to investigate the preventive effect of this specific training program in male football players. The effect of the program was evaluated with a cluster randomized clinical trial by comparing an intervention group (IG) with a control group (CG) that received warm-up and training as usual.

**Material & methods**

From the divisions with competitive level amateur football players in Copenhagen and Zealand 110 clubs were invited to participate and 78 clubs accepted to participate. Before randomisation they were stratified according to level and to whether the clubs were urban or non-urban based. A cluster-randomised design was used because of the fear of spill over to the controls if the study was carried out on the individual level in the clubs. The football club was used as the unit of randomisation. Both the players as well as the coaches gave written informed consent to participate in the trial.

A physiotherapist was allocated to each club. The physiotherapist was responsible for the implementation of the intervention, collection of a self-administered questionnaire including base-line data and of the registration of all injuries and the examination of the players with groin injury. The players and coaches were informed of the allocation after the questionnaires were collected. Due to the nature of the intervention the participants, physiotherapists and coaches could not be blinded, however, the data manager, statistician and authors were all blinded to the result of the randomisation. The study was carried out during the season 1997/98, (September 13$^{th}$ 1997 to July 5$^{th}$ 1998) and included 33 weeks of active playing and 9 weeks around Christmas with no training or matches.
The treatment program from Study IV inspired the creation of the intervention program and 4 of the exercises were adapted from that program. Two more exercises were included in the prevention program. One was an in-field partner exercise that was developed specifically for this trial, with the intention to strengthen the adductor and abductor muscles of the femur both eccentrically and concentrically. The other exercise was a stretching exercise for the iliopsoas; this was included since pain in combination with tightness of the iliopsoas muscle in our clinical experience often was a significant problem.

The exercises were:

1) Isometric adduction against a football placed between the feet when lying supine, the first toe pointed straight forward and pressure against the ball as hard as possible; each adduction 10 s, five repetitions (stimulating the adductor muscle group and the torso-to-pelvis stability).
2) Isometric adduction against a football placed between the knees when lying supine with flexed hips and knees and feet flat on the surface, the first toe pointed straight forward and pressure against the ball as hard as possible; each adduction 10 s, five repetitions (stimulating the adductor muscle group and the torso-to-pelvis stability).
3) Combined abdominal sit-up and hip flexion, starting from the supine position and with a football placed between the knees (''folding knife exercise''); two series of 20 repetitions performed rhythmically in a slow pace (stimulating the coordination of both eccentric as well as concentric work of the torso muscles and the hip- and pelvis-related muscles).
4) One-leg coordination exercise flexing and extending the knee and swinging the arms in the same rhythm (''cross- country skiing on one leg''); 1 min two times for each leg (stimulating the neuromuscular coordination utilizing the principles of core stability including the muscles of the torso as well as of the lower extremities).
5) Hip adduction against a partner's hip abduction. In the sitting position, supported by the hands placed on the ground behind the trunk, one player places his straight leg with the feet and lower shin on the outside of his partner's feet and lower shin. He adducts as the partner

abducts eccentrically and slowly gets his feet pressed together. He then abducts concentrically as the partner adducts eccentrically and is slowly brought into abduction. They work like this for 1min and then shift positions; two series of 1 min in both positions (stimulating concentric and eccentric strength of both the adductor and the abductor muscles).

6) Stretching of the iliopsoas muscle with a standardized technique; 20s stretch for each leg repeated twice (securing the length of the iliopsoas muscle, given the common secondary involvement of the muscle).

The program was developed to be easy to perform in the field, the gym or elsewhere without the need for specific equipment. It should not be too time consuming, too technically difficult to perform or too difficult to incorporate into the normal fitness and warm-up program in the football club.

The clubs in the CG were warming up and training as usual according to the standards of the coach education program of the DBU (http://www.dbu.dk) not changing any normal routines. The coaches in the clubs registered the number of hours and sessions of training (including the intervention program when relevant) and the number of matches. The registration was carried out at the team level. The physiotherapist also checked at random whether the intervention program was performed correctly. All injuries were reported to the physiotherapist, who attended the club at least every second week and at shorter intervals if needed because of injuries. All injuries assessed as a groin injury by the physiotherapist were recorded.

The injury definition was chosen as a result of the overuse nature of most groin injuries. In many instances a player can continue playing in spite of a groin injury. They will have some pain during or after activity, and the load they are able to endure may be affected by the injury, but they would not necessarily be registered as injuries if a time-loss (missing at least one training session or one match) or medical attention (need of examination or treatment by medical staff) definition was used. As a result of this we chose to use the following definition: “any physical complaint that is the result of participating in football training or a football match incapacitating the player when playing football and/or demanding special medical attention for the player to be able to participate or preventing him from participating in training or a match.” We later found this definition to be in concordance with the consensus statement by the Injury Consensus Group under the auspices of Federation Internationale de Football Association published in 2006 [74] as well as with the view of the recent publication by Clarsen et al [75] suggesting that overuse injuries are underreported when using the time-loss injury definition.

The sample size needed to detect a 50% reduction of groin injuries from 10% to 5% was calculated. The intra-cluster coefficient was estimated to 0.08, the cluster size to 20 players and with a power of 80% and a significance level of 5% it was calculated that 80 clubs with altogether 1600 players were needed.

*Statistical analysis*

The primary outcome measure was time until the first groin injury. This is a rather complex response variable to analyse in the presence of clustering, because it is not normally distributed, and it may be censored. Therefore, the approach adopted here was to first investigate whether clustering of groin injuries at the club level was at all present, and then subsequently choose a proper analysis for the primary response variable, depending on whether the groin injuries clustered. If there was no within-club correlation at the club level, then the clustering may be disregarded in the analysis of the primary endpoint: time until first groin injury.

Tests for marginal associations between each of the covariates and the time until groin injury were carried out using log-rank tests. Cox’s proportional hazards model [76] was used for multiple regression analysis of time until groin injury, and likelihood ratio tests were used for hypothesis testing, including tests for interaction between covariates. The assumption of proportional hazards was investigated using the chi-square distributed test suggested by Grambsch and Therneau [77]. The significance level was 5% in all hypothesis testing.

**Results**

Of the 120 eligible football clubs invited to participate in **Study VI**, 78 clubs accepted to participate, but when the inclusion of players and the implementation of exercises had to begin, 23 clubs could not cope with the task and withdrew immediately without including any players. During the trial, another 11 clubs withdrew: five from the experimental and six from the control group. Forty-four clubs, 22 clubs in each group, completed the trial, represented by 977 players, of who 907 presented with complete data (Figure 4). The analysis of the number of groin injuries at the club level revealed no within-club correlation, i.e., the intra-class correlation equalled zero. Therefore, the cluster sampling could be disregarded in the analysis of the primary response variable: time until first groin injury.

Results from the univariate analysis of each of the covariates on the 907 complete cases shows no significant effect of the intervention (HR = 0.69, P = 0.18), although the estimate suggests a 31% smaller hazard in the intervention group compared with the control group.

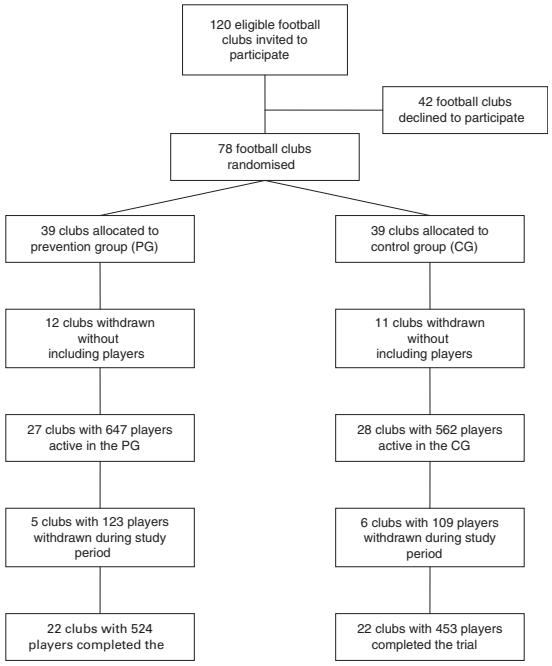


**Figure 4:** Trial profile Study VI

Having had a previous groin injury almost doubled the hazard of developing a new groin injury (HR = 1.97, P = 0.015), and playing at a higher level almost tripled the hazard of developing a groin injury (HR = 2.58, P < 0.001). There was no effect of the type of work (P = 0.91), age (P = 0.50), or the position played on the field (P = 0.65) of the player on the time until groin injury, and it did not matter whether the club was urban or non-urban (P = 0.09). (Table 6) The results from the same analysis carried out on the 977 available cases did not show any relevant differences.

| Variable | HR | 95% confidence interval | *P* value |
|---|---|---|---|
| Intervention | | | 0.18 |
| No | 1 | | |
| Yes | 0.69 | [0.40–1.19] | |
| Age | | | 0.50 |
| Per additional year | 0.98 | [0.92–1.04] | |
| Previous groin injury | | | 0.015 |
| No | 1 | | |
| Yes | 1.97 | [1.13–3.42] | |
| Level of play | | | <0.001 |
| Low | 1 | | |
| High | 2.58 | [1.49–4.46] | |
| Location of club | | | 0.09 |
| Urban | 1 | | |
| Non-urban | 1.80 | [0.90–3.60] | |
| Physical work | | | 0.91 |
| Not working | 1 | | |
| Not physically demanding | 0.89 | [0.38–2.05] | |
| Slightly demanding | 1.28 | [0.53–3.07] | |
| Demanding | 1.21 | [0.53–2.78] | |
| Very demanding | 1.07 | [0.41–2.80] | |
| Position on field | | | 0.65 |
| Mixed | 1 | | |
| Goalkeeper | 0.68 | [0.22–2.07] | |
| Defence | 0.85 | [0.41–1.79] | |
| Midfield | 0.63 | [0.30–1.33] | |
| Striker | 0.52 | [0.19–1.47] | |

**Table 6:** Log rank tests and maximum likelihood estimates from the univariate Cox regression analysis of the 907 complete cases

In the multiple regression analysis exactly the same variables were significant as in the univariate analyses: having had an injury previously and playing at a high level increase the hazard (HR = 1.95, P = 0.017 and HR = 2.56, P < 0.001), while neither the intervention nor the other covariates had a significant effect on the time until groin injury.

**Discussion**

**Study VI** was the first RCT in the literature to specifically target prevention of overuse injuries in sport using exercise programs, also this was the first RCT aimed specifically at the prevention of groin injuries.

The 31% reduction in risk found in this study was not statistically significant (P = 0.18). We based our sample size estimation on a relative risk reduction of 50% based on our experience with the treatment effect of a similar training program used for treating groin injuries (Study IV).[61] This may have been too optimistic. Second, we had anticipated that 10% of the football players in the control group would develop a groin injury. In fact, only 8% did so. Third, we experienced even larger difficulties with getting clubs to participate and remain in the trial than anticipated. These factors all increase our risk of type II errors, i.e., risk of overlooking a real intervention effect. The compliance of the players to perform the exercises with both the intended frequency and the intended intensity could also have been a problem. We chose the most feasible solution and had the coaches supervise and register the participation in the prevention program. A trial including a much lager sample size, as we originally intended, is needed to definitely test the potential beneficial or harmful effects of our preventive training program. With the number of players who completed this study, no significant effect of the prevention program could be shown. A 31% reduction of the risk of developing a groin injury would, however, if true, be a considerable advantage that would make it worthwhile for the football players to complete the program.

The strength of this study is that the randomization was computer generated and that the allocation was unknown to the data manager, the statistician, and the authors, thus preventing allocation bias. The registration and examination techniques used were systematic and uniform in order to prevent registration bias. The limitations of this study were that a large number of eligible clubs did not participate and that a number of clubs that were randomized exited the study but without including players. However, no sign of allocation bias was found when comparing the baseline characteristics. Risks of assessment bias exist because the registration of the injuries was not blinded due to the nature of the intervention and the practical circumstances. Missing data in some cases could lead to attrition bias but no sign of this was found when comparing the full data with the complete data.

Twenty-three clubs withdrew before including players. This was a matter of clubs agreeing to participate, but when faced with the start of the tournament they could not cope with the task. Because this group was evenly distributed between the two allocations, we do not find this alarming from a trial quality point of view but very unfortunate from a sample size point of view. The dropout after entering the study with players was 11/55 clubs (20%) and 232/1209 players (19%) without difference between the two groups.

The risk of sustaining a groin injury was almost doubled if the player had a previous groin injury. This was in concordance with the results of previous studies.[49 72]

Playing football at the highest level in this study (Denmark, Zealand, and Copenhagen series) compared with the other levels included in this study almost tripled the risk of a groin injury. This is the first time it has been shown that the risk of sustaining a groin injury increases with the competition level.

The design of the present study is the result of an analysis of risk factors and incidence. According to previously described guidelines for the prevention of injuries[78], we have identified the incidence and risk factors of groin injuries from the available literature, we have aimed at developing a program that is likely to reduce the risk of groin injury, and we have evaluated this in a randomized clinical trial.

Muscle strength is a possible risk factor for adductor-related groin injuries [55 79-81] and the preventive program tested includes concentric as well as eccentric strengthening and coordination exercises for the muscles related to the pelvis, with special emphasis on the adductor and abductor muscles. The exercises used in the present study include eccentric strengthening in exercises number 3, 4, and especially 5, and eccentric exercises were also utilized in the original treatment protocol for adductor-related groin pain (Study IV).[61]

The exercises utilized in Study IV as well as in the prevention program of the present study includes the principle of core stability (core strengthening)[64], and in the present study especially exercises number 3 and 4 stimulate the core stability both regarding the lumbar spine and the pelvis, as the trunk position must be stabilized to perform the exercises correctly.

A preventive program utilizing exercises would probably not have effect from the first day, as the idea is to strengthen certain physical abilities and thereby prevent injuries. This will take some time, but it is not known how long. We started data collection at the same time as the program was initialized and as can be seen in Figure 5 it took a couple of weeks before a difference between the two curves became apparent. Ideally it would probably be beneficial to start the program as early as possible and preferably pre-season in order to gain the effect before the highest intensity of load was reached.

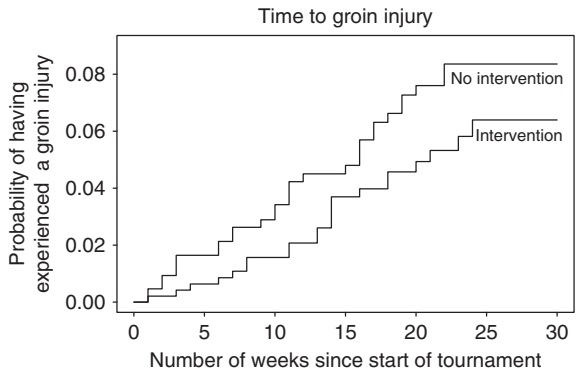


**Figure 5**: Time to groin injury *Study VII*

**Introduction**

The term "adductor-related groin pain" was coined in the literature in 1997 in Study I and the concept of a clinical entity approach to groin injuries in athletes was presented in Study III in 2007. This approach utilising standardised reproducible examination techniques to identify the anatomical structures causing the groin pain was applied to a cohort of 998 male sub-elite soccer players followed during a full season in **Study VII**.
In the majority of the literature, groin injuries are described as a single injury not taking into account that a large number of structures can be injured and as such cause groin pain. More details of which anatomical structures are injured, the distribution of the injuries, the etiology of the injuries, and the consequences of the various injury types are all necessary to understand the nature of groin injuries and to be able to develop relevant and specific treatment and prevention. **Study VII** utilised the clinical entity approach in a cohort of sub-elite male soccer players followed for a full season. The primary aim was to describe the occurrence and clinical presentation of groin injuries in this cohort and secondly to examine the characteristics of these injuries.

**Material & methods**
All groin injuries sustained by the participants of Study VI were examined and analysed. The cohort consists of 44 clubs that completed the trial, representing 998 players with data relevant for this study of which 907 had complete data.
Since no significant differences between the two intervention groups in the RCT of Study VI could be found with respect to type of groin injury (P=0.76), age (P=0.29), or length of injury (P=0.15), the whole cohort is presented as one group in this study although adjustment for the intervention was performed in the statistical analysis.

*Injury definition*

A groin injury was defined as any physical complaint in the groin related to participation in soccer training or match, incapacitating the player when playing soccer or demanding special medical attention for the player to be able to participate or preventing him from participating in training or match. This definition is in concordance with the consensus statement by the Injury Consensus Group under the auspices of Federation Internationale de Football Association (FIFA) published in 2006.[74] A traumatic injury was defined as an injury with a sudden onset and a known cause, and an overuse injury was defined as an injury with an insidious onset and no known trauma.[74] The groin injuries were classified into clinical entities according to the definitions described previously in Study III (Table 7).[63]

| | Adductor-related | Abdominal-related | Iliopsoas-related |
|---|---|---|---|
| Pain with adduction of the legs against resistance | X | | |
| Pain with palpation of the adductor longus insertion | X | | |
| Pain with palpation of the abdominal muscle insertion | | X | |
| Pain with abdominal flexion against resistance | | X | |
| Pain with palpation of the iliopsoas | | | X |
| Pain with the Thomas test | | | X |

**Table 7:** Tests required for the three examined clinical entities of groin injury[63]

*Injury assessment*

A physiotherapist allocated to each club before randomization was, in cooperation with the trainer, responsible for collecting data. The physiotherapist also collected self-administered questionnaires from all players providing information about the age, dominant leg, playing position, and previous injury (sustained during 1996 and 1997 until the start of the trial, altogether 20 month) to groin, knee, ankle and lower extremity muscle. All injuries during the study period were reported to the physiotherapist who attended the club at least every second week and at shorter intervals if needed because of injuries. Prior to the trial, the physiotherapists were trained in the use of the questionnaire and in how to perform an examination using a standardised protocol [36 63] to classify the groin injuries correctly. To be classified into a groin injury entity according to the classification a set of two paired tests should be positive (Table 7).[63]

Any time loss from training and/or match was registered and the definition and classification used regarding this was in accordance with the FIFA consensus.[74]

The season (from September 13, 1997 to July 5, 1998) included 33 weeks of active training and playing and 9 weeks around Christmas with no training or matches. The coaches in all clubs registered the number of hours and sessions of training and the number of matches. No separate registration of whether the injuries were sustained during training or match was done.

*Statistical methods*

Injury incidence per 1000 played hours was computed considering the players to be at risk during all training sessions and matches they participated in during the study. Injury time was analysed using multiple regression on the log of the injury times as the data was highly skewed. Effects are thus reported at relative injury time (RIT), e.g., RIT 2.0 meaning a two-fold increase in the injury time. We included age, intervention, and pairwise interactions between entities in the initial model. We then simplified the model using a stepwise backwards elimination (adjusting for the intervention) procedure according to Akaike's Information Criterion (AIC) [82] The risk of missing a training session/match was analysed using logistic regression. We included age, entities, type of injury (traumatic/overuse), and intervention as potential risk factors in a multivariate model and simplified it using backwards elimination (adjusting for the intervention). The risk of a groin injury during the study period was analysed using Cox proportional hazard model considering previous injuries, age, intervention, and duration of previous groin injury as potential factors. The model was simplified using backwards elimination (adjusting for the intervention). All analyses were done in the statistical software R version 2.14.2.[83] P-values below 0.05 were considered significant.

**Results**

During a full season the players included in **Study VII** spend in total 144.757 hours on training and match. The total number of injuries (any anatomical part) registered among the 998 players was 494 and the incidence of injuries was 3.41 injuries/1000 hours.

Fifty-eight groin injuries were recorded in 54 players; the incidence of groin injuries was 0.40 injuries/1000 hours. The distribution of injuries among the clinical entities, type of onset (traumatic versus overuse), incidence/1000 hours, leg distribution (dominant compared to non-dominant), and median injury time is shown in Table 8. Sixteen groin injuries (27%) could not be classified as specific clinical entities since they did not have both tests positive to fulfil the specified criteria. One player had no positive tests and the remaining 15 players had one relevant test positive. Thirteen of the 54 players (24%) with groin injury had more than one groin injury entity.

| | Adductor | Abdominal | Iliopsoas | Unknown | Total |
|---|---|---|---|---|---|
| Number of injuries (% of all entities found) | 30 (51) | 11 (19) | 18 (30) | 16 | 58 |
| Incidence of injuries/1000 h training and match | 0.207 | 0.076 | 0.124 | | 0.401 |
| Percentage of traumatic injuries | 39 | 56 | 35 | | 39 |
| Percentage of overuse injuries | 61 | 44 | 65 | | 61 |
| Percentage located on the dominant side | 63 | 64 | 63 | | 68* |
| Median injury time (range) in days | 19 (2–208) | 58 (7–208) | 16 (1–208) | | 16 (1–208) |

*p=0.047.

**Table 8**: Distribution and characteristics of the clinical entities of groin injuries (Numbers does not add up to the total because some players have more than one entity)

Injury time was moderate (8-28 days) in 43% and severe (>28 days) in 33%. Injury time was significantly related to the entities adductor- and abdominal-related injury and their interaction. Adductor-related injuries with no abdominal-related injury had significant longer injury times compared to injuries with no adductor-related and no abdominal-related injury (RIT 2.28, 95% CI 1.22 to 4.25, P=0.0096). Having both adductor-related and abdominal-related injury also increased the injury time significantly compared to injuries with no adductor-related and no abdominal-related injury (RIT 4.56, 95% CI 1.91 to10.91, P=0.001). Having both adductor-related and abdominal-related injury tended to increase the injury time, although not significantly, compared to adductor-related injuries with no abdominal injury (RIT 2.00, 95% CI 0.82 to 4.86, P=0.13). The intervention group had shorter injury times, although not significantly, compared to the control group (RIT 0.56, 95% CI 0.32 to 1.00, P=0.0518).

The incidence of traumatic groin injuries was 0.14 injuries/1000 hours (n=20/51; 39%) and the incidence of overuse injuries 0.21 injuries/1000 hours (n=31/51; 61%). Twenty percent of the traumatic of groin injuries involved contact to another player. The groin injuries were located in the dominant leg (preferred kicking leg) in 68% of the patients, distributed evenly among the entities (Table 8).

In 39 of 58 injuries, time-loss was encountered with at least one training session or one match being missed. Twenty-six players missed at least one match and thirty-eight players missed at least one training session because of a groin injury. There was no significant relation between the sustained entity and the risk of a time-loss injury. The age of the player seemed to be a risk factor for missing at least one match (per additional year of age: OR 1.15 (95% CI 1.00 to 1.32); P= 0.05) and for missing at least one training session, although statistically insignificant (per additional year of age: OR 1.17 (95% CI 0.98 to 1.40); P=0.08).
Having had previous groin injury in the 20-month period prior to the start of the study significantly increased the risk of groin injury (HR 2.13, 95% CI 1.23 to 3.67, P=0.0068). Groin injuries

were generally located in the same side as previously reported groin injuries.
Previous ankle, knee or lower extremity muscle-injury did not predict an increased risk of groin injury. Playing position did not seem to affect the risk of groin injury. No significant difference was found in the risk of groin injury between goalkeepers and field players (P=0.85).

**Discussion**

**Study VII** found that in male soccer at the subelite level, adductor-related groin injury was the most common entity found followed by iliopsoas-related and abdominal-related injuries. This is in line with the later UEFA study by Werner et al. finding adductor-related injuries to be the most common groin injury at the elite level.[37] The incidence of groin injuries in the present study (0.40 groin injuries/1000 hours) is lower than in the elite study from UEFA Champions League (1.1 groin injuries/1000 hours). Other studies on comparative cohorts from the Nordic countries, playing at similar level as in the present study, have shown injury incidences ranging from 0.6 to 0.8/1000 hours, which suggests that players at the subelite level may suffer fewer groin injuries than the elite. [49 79 84]
The classification into the clincal entities was done according to the proposed set of criteria developed in previous studies (Studies II & III) utilising a number of reliable examination tests.[36 63] To be classified into a clinical entity two positive tests were needed. In 16 of the players with groin injury this was not possible (Table 8). This could be a result of the entity classification system not being able to indentify all types of groin injuries in the athletes, as the groin pain could also relate to other structures not examined systematically in this study. This could include pain from structures such as the low back, the sacroiliac joints, peripheral nerves, the hip joint, or other muscles and tendons not specifically examined in this study.
Previous studies of clinical presentation have found more than one cause for the groin pain in large cohorts of athletes.[35 63] This finding is confirmed in the present study as 24% of the injured players had more than one clinical entity.
Severe injuries (injury time >28 days) accounted for 33% of all groin injuries, confirming that groin injuries often are a longstanding problem. Having an adductor-related groin injury doubles the injury time compared to injuries with no adductor and no abdominal pain and if it is combined with an abdominal-related groin injury the injury time is more than quadrupled compared to groin injuries with no adductor and no abdominal pain. There were too few abdominal-related groin injuries in this study to analyse them separately but in combination with adductor-related groin injuries it is clear that they are potentially a major problem. They probably represent a group of patients with a combined injury, where the adductor injury is accompanied by an injury to the rectus abdominis, and/or the oblique abdominal muscles including the possibility of an incipient hernia (posterior wall insufficiency).[85 86] Recent studies on the anatomy of the region have indicated that there is a close anatomical connection and perhaps dependency between the adductor muscles, rectus abdominis muscle, and the oblique abdominal muscles.[87-89]

There are indications in the literature that the balance of strength between the adductor and abductor muscles is a possible risk factor for getting groin injuries.[79 90 91] We have shown that soccer seems to be a strengthening activity for the hip abductors but not for the eccentric strength of the hip adductors to the same extent.[57] Soccer is a sport where repeated kicking and change of direction places great stress upon the adductors and these muscles could thus to be at risk of being injured. The high proportion of injuries in our study located in the dominant side (68%) could also be related to this mechanism, as the adductor longus muscle appears to be at risk of strain injury during its transition from hip extension to hip flexion probably because of a high eccentric load on the kicking leg during the swing phase.[55] Further research into the role of the adductor muscles and the possibility of prevention, by focusing on improving eccentric strength capacity of the adductor muscles is warranted.[92]

Traumatic injuries constituted 39% of the groin injuries and only 20% of those were contact injuries. Other studies have found less traumatic injuries (24-27%) not giving any information about the percentage of contact involved.[37 93] The traumatic acute groin injury is a topic supported by very limited literature. We found a relatively high frequence of players where a traumatic event leads to groin injury, but only in one of five situations contact with another player was reported. This implies that the majority (80%) of the traumatic injuries are probably happening as the result of kicking, sprinting, or sudden changes of direction, movements where the groin related muscles are involved at high speed, often with a forceful eccentric element. Further research of the natural history of traumatic/acute groin injuries would be helpful to plan treatment and to develop prevention of these injuries.

As in other studies, previous groin injury is a significant risk factor for a new groin injury [49 73 79], and additionally we found the injuries to be located in the same side as the previously reported groin injuries. Whether it was the same clinical entity that happened again is not possible to establish, as the clinical entity of the previous injuries was not known. The fact that the subsequent injury occurs at the same side could be an indication that the injury is the same and/or that the muscles and tendons of the previously involved side is more vulnerable to injury. This could be a result of suboptimal strength or endurance capacity obtained after the injury. This is in concordance with the suggestions by Hägglund et al. that insufficient treatment and rehabilitation of an injury may provide a possible explanation for re-injuries.[50]

There is consistency in the literature to support increased age as risk factor for injuries in the hamstring and calf muscles,[49 72 94] but not for groin injuries. However, we found that the age of the player seemed to be a risk factor for missing at least one match and for missing at least one training session. This has not been described before. The reason that age seems to be a risk factor could be due to the body's collagen tissue changes with advancing age, rendering the body less adaptable to quick force changes or fatigue.

The clinical examination techniques in this study are intra- and inter-observer reliable but no specific validation was made. However, since there is no consensus on diagnostic definitions and no 'gold-standard' exists regarding groin injuries in athletes, it is difficult to assess validity of the tests. The present clinical entity concept represents a diagnostic set-up aiming to identify the injured anatomical structures and with further development into evidence-based diagnosis, hopefully, real validity studies can be performed.

In 1980 the paper by Renström and Peterson introduced the idea of separating groin injuries into diagnoses corresponding with the anatomy.[33] This was further developed and presented as the clinical entity concept in 2007 (Study III).[63] This concept, relating the groin pain to the anatomical structures, is still a fairly rough way of separating the injuries of the groin, however, it allows for further diagnostic methods to be more precisely aimed as well as it can direct the treatment strategy. Using this approach in a randomised controlled trial we showed that a specific exercise treatment directed at the adductor muscles and their function was very successful (Study IV).[61]

The clinical entities approach has been widely used in research since 2007 [37 95-102] and the increasing use of this approach offers the ability to categorize the term 'groin injury' into more specific entities. Hopefully, as research systematically uncovers the pathology and etiology of the injuries in each entity, it will be possible to develop evidence-based diagnoses.

Chapter 4:
Femuro Acetabular Impingement (FAI) and groin pain

During the last 10-15 years the hip joint in young physically active adults has been the focus of increasing attention. Injuries to the hip joint can give groin pain and the interaction between FAI and the soft tissue entities of the groin seem to be important to understand the injuries. In Study VIII the impact of having various morphologies of the hip joint on the result of the exercise treatment for adductor-related groin pain is examined as well as the risk of developing osteoarthritis of the hip over a 10-year observation period.

Study VIII

**Introduction**
In the traditional perception of groin pain in athletes the injuries are located in the muscles, tendons, pubic bone and nerves of the groin region.[35 63 84 103] With the increasing knowledge of the etiology of painful conditions related to the hip joint in younger adults the bony morphology and its biomechanical influence on cartilage and labral integrity have become integrated parts of the understanding of groin and hip pain and these issues are the focus of **Study VIII**. [104] During this past decade, the concept of femoroacetabular impingement (FAI) has been refined [105] and the mechanisms of damage to the labrum and cartilage of the hip joint are now considered additional sources of groin pain and potential joint deterioration in young, physically active patients.

Pincer impingement is determined by a cross-over sign on the AP pelvis radiographs (Figure 6). The anterior and posterior acetabular walls were traced and marked with lines. Any overlap between the anterior and posterior wall lines is deemed a sign of pincer. A non-spherical femoral head characterizes cam with excessive bone formation at the femoral head-neck junction. The alpha angle is measured between the axis of the femoral shaft and a line drawn from the center of the head to where the sphericity is lost (Figure 7). The lateral center edge angle (CE) is calculated by measuring the angle between a line through the center of the femoral head, perpendicular to the transverse axis of the pelvis, and a line through the center of the femoral head, passing through the most superolateral point of the sclerotic weight-bearing zone of the acetabulum (Figure 8)

In the literature there is evidence that a pathologic center-edge (CE) angle of the hip joint (less than 25 degrees or above 40 degrees) as well as morphology causing FAI are significant risk factors for developing early osteoarthritis. [106 107]

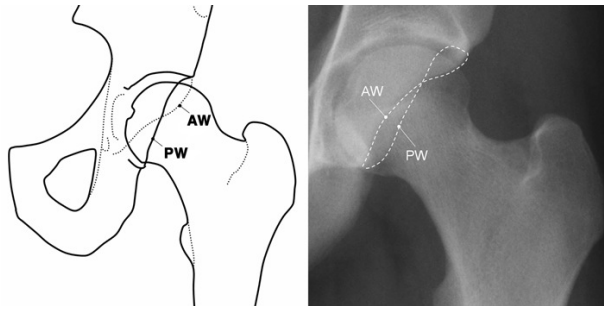


**Figure 6:** Cross-over sign (figure of eight) AW: anterior wall of acetabulum & PW: posterior wall of acetabulum

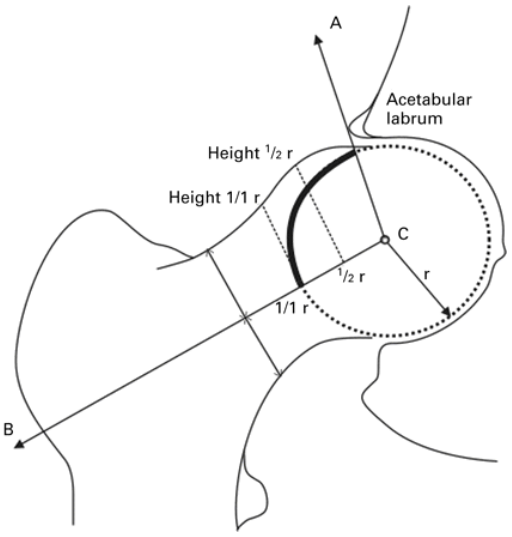


**Figure 7**: Measurement of alpha angle representing cam impingement (angle between line A and line B)

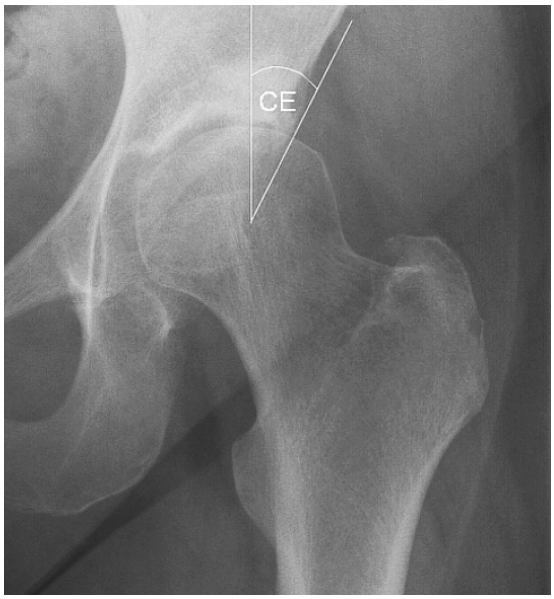


**Figure 8:** Measurement of CE angle

Adductor-related groin pain is now, due to the above research, a well-established entity and is considered a major cause of groin pain in athletes. [28 37 63 97 98 101 108 109] The co-existence of adductor-related groin pain and bony morphology/pathology such as FAI or hip dysplasia has been demonstrated in previous studies.[101] However, the influence of hip joint morphology on the overall outcome of treatment of adductor-related groin pain both in short- as well as long-term is not well understood.
**Study VIII** investigates if the clinical outcome at 8 – 12 year follow-up on the treatment of longstanding adductor-related groin pain as presented in Study V, was influenced by the bony morphology of the hip joint.[61] Study V and **Study VIII** are the follow-up studies of Study IV, a randomized controlled trial (RCT) that found an active treatment program (AT), consisting of strength training of the adductor, abductors, low back and abdominal muscles in combination with balance and coordination exercises, to give significantly better results than traditional passive treatment (PT) without any active training component, in the treatment of longstanding adductor-related groin injuries in athletes. Seventy-nine % of athletes treated with the AT could return to their previous level of sport without any groin pain, compared to only 14% in the control group. An 8–12 year follow up study (Study V) found the beneficial short term effect of the exercise program used in the index study to be lasting both for the group as a whole, and particularly for the large subgroup of football players. [110] As this study was commenced in the early 1990es, before specific examination and treatment methods for FAI and hip dysplasia were standard procedure, diagnostic criteria and methods establishing these diagnoses were not included in the index study. Before inclusion into the RCT the participants were examined radiologically for osteoarthritis, but not evaluated for FAI and hip dysplasia.
The primary purpose of **Study VIII** was therefore, using a descriptive and exploratory approach, to evaluate if radiologic signs of FAI or dysplasia, in the original x-ray material seemed to affect the clinical outcome of the treatment, initially and at 8-12 year follow-up.

**Material & methods**

Of the 59 participants who were assessed for follow-up in the index study 47 could be included in this study. A weight bearing anterior-posterior (AP) pelvic radiograph was taken at baseline before inclusion into the RCT (Study IV) and this was repeated at the follow-up. The following radiographic parameters were assessed in all hips: the CE angle of Wiberg, [111] the alpha angle, [112] the presence of a cross-over sign, [113] and the Tönnis grade of osteoarthritis (Figures 6-8). [114] On the weight bearing AP pelvic radiographs taken at follow-up the Tönnis grade of osteoarthritis was assessed. A single observer who was blinded to which side was affected as well as to the allocation in the RCT assessed all the radiographic parameters.
Femoral head asphericity as seen in cam deformity was in this study defined by cut-off values of the alpha angle of 55 degrees and 69 degrees, respectively. Generally, an alpha angle < 55 degrees is considered normal, however, an alpha angle > 69 degrees has been suggested as the cut-off defining definite bony pathomorphology when evaluated on the AP pelvic radiograph. Both the group with alpha angles > 55 degrees and the group with alpha angles > 69 degrees were analysed, since the concept of an alpha angle > 55 degrees being a sign of cam deformity is commonly adapted among hip arthroscopy surgeons. [112 115] The cross-over sign is present when crossing of the anterior and posterior acetabular rims assessed on the AP pelvic radiograph is seen [113] A pathologic CE angle is defined as less than 25 degrees or above 40 degrees. [111]

*Statistical analysis*

Data that was normally distributed was presented as mean values with ranges, and comparisons between groups were made using a two-sample t-test. Data that was not normally distributed was presented as median values with ranges, and comparisons between groups were made using the two-sample Wilcoxon rank-sum (Mann-Whitney) test. Binomial data was presented as proportions, and comparisons made by Fischer's exact test where appropriate. Inter observer variability was assessed according to the Bland-Altman method and presented as difference of the mean and 95% limits of agreement. [116 117] P-values < 0.05 were considered statistically significant.

**Results**

The radiographs examined in **Study VIII** from the primary examination in Study IV showed no significant difference between the 2 treatment groups regarding the CE angle, alpha angle, presence of crossover sign or Tönnis grade.
The distribution of Tönnis grades of osteoarthritis did not differ between the 2 groups at follow-up. Totally 7 patients (n=47) developed an increase of 1 in Tönnis grade. (Table 9)

| | AT (n=24) | | | PT (n=21) | | |
|---|---|---|---|---|---|---|
| Tönnis grade | 0 | 1 | 2 | 0 | 1 | 2 |
| RCT* | 20 | 3 | 1 | 16 | 4 | 1 |
| Follow-up** | 15 | 8 | 1 | 15 | 4 | 2 |

*p=0.567 (two-sample Wilcoxon rank-sum (Mann-Whitney) test).
**p=0.650 (two-sample Wilcoxon rank-sum (Mann-Whitney) test).
AT, active treatment; PT, passive treatment; RCT, randomised controlled trial.

**Table 9:** Distribution of Tönnis grade in the AT and PT groups at time of RCT and of follow-up

No increase in Tönnis grade was seen in the 14 patients with pathological CE angle.
In the AT group the proportion of patients with a decrease in the overall outcome was significantly higher for patients with an alpha angle > 55 degrees compared with patients with alpha angles < 55 degrees (p = 0.047). (Table 10)

| | α>55 | α<55 |
|---|---|---|
| Increase or no change | 5 | 9 |
| Decrease | 8 | 2 |

p=0.047 (Fisher's exact test).
AT, active treatment.

**Table 10**: Changes in the outcome score related to α angle in the AT group (n=24)

**Discussion**

In this cohort of patients with long-standing adductor-related groin pain we found no evidence that coexistence of morphological changes in the hip joint prevented a successful result of an exercise treatment programme. Our findings at follow-up indicated that there was a statistically significant decrease in the overall outcome for patients with an alpha angle > 55 degrees compared with patients with alpha angles < 55 degrees in the AT group.
The present study included athletes with long-standing adductor-related groin pain. Some of these patients also had radiographic hip joint related morphological varieties, such as FAI and hip dysplasia. They could as such, be evaluated as "hip joint patients" rather than "adductor-related patients", and one could consider treatment of the bony morphology. This study demonstrates that when the clinical entity of adductor-related groin pain is diagnosed [63] and the patient is treated with an exercise programme [61] we find in retrospect no indication of bony morphologies having had any negative influence on outcome. In other words: it seems possible to treat a muscle tendinous problem in the hip and groin region successfully even in the presence of radiographic signs of hip joint morphological varieties. We found no difference in distribution of the radiographic findings between the two treatment groups, supporting that it was the treatment only that was responsible for the excellent result of the active treatment in Study IV.
In the literature there is evidence that a pathological CE angle (less than 25 degrees or above 40 degrees) as well as morphology causing FAI are significant risk factors for developing early osteoarthritis. [106 107] This increased risk of osteoarthritis is probably a result of injuries to the labrum and/or the cartilage of the hip joint. The lack of osteoarthritis development in the current study could reflect that the morphological changes as seen on the radiographs did not result in intra articular cartilage or labral injuries, and that the complaints and symptoms in the original study were related to the extra articular injuries. The observation time being too short for development of radiological signs of osteoarthritis could also be an explanation. The observed increase in Tönnis grade could on the other hand be a reflection of the expected age development. The median age of 42.5 years with a range up to 62 years of at the time of follow-up is where one would expect early radiologically verified osteoarthritis to appear.
The slight reduction of the clinical result at follow-up in the group with an alpha angle > 55 degrees seen in the AT group could be a reflection that FAI has resulted in injury to the joint. Another possibility is that the range of motion restrictions due to FAI creates compensatory patterns that affect extra-articular pelvic structures and could lead to development of muscle and tendon overload, such as long-standing adductor-related groin pain. [28 118]
The low number of patients and the lack of precise knowledge of the participants' activities and additional treatment or cross over between groups during the follow-up regarding physical activity is a limitation to this study. Information regarding this was not sought since this would be susceptible to heavy reporting bias.
The study was not originally designed for examining possible radiological hip joint morphology and its impact on the result of the exercise treatment. The study is however, based on a prospective randomised design with blinded independent examiners and a systematic reproducible and standardised clinical and radiological evaluation.
In conclusion, the findings at follow-up indicate that the presence of an alpha angle above 55 degrees reduces the clinical result at long-term follow-up in the group receiving the active exercise treatment. There were no signs that surgically untreated FAI or CE angle led to increased osteoarthritis during the observation period (8 – 12 years). The entity of adductor related groin pain in younger physically active adults continues to be a relevant entity for treatment even in the presence of morphological changes to the hip joint.

*Perspectives*

The papers included in this thesis are the first steps to create a base for a scientific evidence-based evaluation of groin injuries in athletes. The clinical entity approach utilizing reproducible clinical examination methods to identify the anatomical structures related to the groin pain is a tool to increase the level of specificity in the diagnosis of groin injuries. A groin injury is often considered as one specific injury covering everything in contrast to a 'knee injury' that is defined by the specific structures injured like meniscus injury, ACL injury, cartilage injury etc. The groin is an anatomical region like the knee and not a single structure, and as such 'groin injuries' is a multitude of different injuries involving the various anatomical structures in the region; sometimes as a single-structure injury and sometimes involving more structures. The specific injuries associated with the various anatomical structures should be identified in order to develop treatment methods directed at this specific anatomical structure.
The 'damage' that has happened to the structure can probably in most cases be further differentiated leading to 'real' diagnosis. Further scientific work is needed to establish the pathology. Recently a review paper from our research group found the evidence for use of MRI, ultrasound and x-ray in the diagnosis of groin injuries very limited[109]. Systematic and reliable imaging methods need to be established. Pathoanatomical description of the injuries as seen on imaging is needed to better understand the injuries. The radiological findings in patients need to be compared to non-symptomatic age-, gender-, and sports-matched controls to understand what is pathology and what is a 'normal' finding in imaging due to the activity-related load to the structures. Currently, a PhD project is investigating these questions at our research center and results will be published during the next year.
The clinical examination methods for groin pain has recently been the subject of a systematic review[119] and Study II and one other study[108] were the only studies qualified to be included in the review. Strength testing of the muscles related to the hip and groin has been the focus of a series of studies from our research center. [31 32 57 120-122] We have standardised the techniques and examined the reliability. With these instruments we have

further described normative data related to soccer players and examined the value of specific strengthening methods. [92 120] These examination tools can potentially be used for development of evaluation of injured athletes to qualify return to sport and decrease the risk of re-injury. [122] The lack of evidence-based diagnosis makes it difficult to perform meaningful validity studies of the examination methods, both clinical and imaging, as the examination method tested is often part of the premises for the condition used as 'gold standard' for the validity test.
The clinical outcome in Study IV was a combined patient and examiner based evaluation, combining return to sport at the same level as pre-injury without groin pain and no pain at clinical examination. Patient Related Outcome questionnaires (PRO) are today considered as the best measure to evaluate the results of treatment [123]and with the recent development of reliable, valid and responsive outcome scores, such as the Copenhagen Hip And Groin Outcome Score (HAGOS) that was developed at our research center, it is now possible to objectively evaluate patient-reported groin- and hip-symptoms and function.[124] This outcome score has the potential to become a very important tool for evaluating the athletes both as a monitoring tool at team level, as an evaluation of the progress during treatment and as an evaluation after treatment and at long-term follow up. It is designed for all physically active patients with hip and groin pain and as such it can be used both in the surgical as well as the non-surgical treatment for hip and groin pain.

The entity approach was very useful to differentiate the injured players in Study VII and the approach is gaining increased attention in the literature. It is being used in a number of studies including the excellent studies from the UEFA group [37 50 72 95-102 125] and has also being included in the UEFA Football Doctor Education Program. The ambition for the clinical entity approach is as a first step to categorize groin injuries in order to be able to compare results of clinical examinations, imaging and treatment. This should hopefully lead to further studies into the individual clinical entities to look for the specific pathologies associated with the pain. Evidence-based diagnoses can then be identified within the clinical entities, and they should be funded on pathoanatomical findings, on the outcome of clinical tests, and on the results of imaging and other paraclinical tests. When these evidence-based diagnoses have been identified, the treatment and prevention of hip and groin injuries can be taken to the next level.

The exercise treatment program used in Study IV for adductor-related groin injuries is a demanding and time consuming program. It is not know if all of the elements of the program are needed to successfully treat the longstanding adductor-related groin injury. The program is anecdotically widely used all over the world today, but only one study has included the program in a scientific study.[95] A fast-tack version of the program could perhaps be developed but should be tested in a randomised study against the original program before being implemented. The convincing long lasting effect documented in Study V is encouraging and should be taken into consideration if planning another or a shorter program, since the specific approach including all pelvis-related muscles, training coordination, eccentric strength, and core stability might be a key factor in the long-lasting success of the program.

The 31% reduction of groin injuries found in Study VI was not statistically significant, but still encouraging and a prevention program along the same lines but targeted at specific at-risk groups is a possibility for a future prevention study. Recently our research group has examined simple strength training of the adductor muscles and the hip flexors using rubber bands in two RCT's, [92] and found the methods to be very efficient and potentially suitable to include in a preventive program. Randomised studies are needed to explore this further.

Study VIII indicated that it is possible to recover from a long-standing groin injury and return to sport without pain in spite of potentially pathologic hip joint morphology. This underlines some of the challenges we are facing when treating athletes with hip- and groin-related problems. The complexity of the factors to consider when treating injuries in this region has increased as a result of new knowledge regarding the morphology and possible pathologies of the young adult hip, and due to the technical development of hip arthroscopy. Further research to investigate the role of the various morphologies of the hip joint including the possible etiologic association with soft tissue groin injuries will be interesting to follow. Groin pain can be the result of both injuries to the hip joint; primarily labral lesions and/or cartilage lesions, or it can be the result of injury to muscles and tendons but also any of the other structures constituting the pelvis. Knowledge of all types of etiology is essential to diagnose, treat, prevent and to develop research in this area.

- Adductor-related injuries were most common among soccer players while iliopsoas-related injuries were most common among runners.
- An active exercise program focusing on strength and coordination of the muscles related to the pelvis with specific emphasis on the adductor muscles was very efficient in treating athletes with long-standing adductor-related groin injury. In a RCT it was clearly superior to conventional passive therapy.
- The above-mentioned training program still had a significant effect at 8 – 12 year follow-up compared to the passive program. Especially among soccer players the long-term effect was evident.
- A training program aimed at prevention and based on the ideas of the above-mentioned treatment program could reduce the number of groin injuries in soccer players during a full season with 31%; this was however, not statistically significant.
- In soccer, adductor-related groin injury was the most common injury (51%), followed by iliopsoas-related (30%) and abdominal-related (19%). Injury time was more than four times as long with adductor- and abdominal-related injury in combination. Previous groin injury doubled the risk of groin injury.
- The morphological changes seen on x-ray related to femuro-acetabular impingement and dysplasia in the hip joint did not seem to influence the clinical outcome of the exercise treatment for long-standing adductor-related groin pain. Neither did it cause increased development of osteoarthritis after 10 years.

With these findings an evidence-based suggestion for classification of groin injuries in connection with sport is available. The specific diagnoses that exist within the clinical entities should now be scientifically investigated and differentiated to further develop more specific treatment and prevention strategies. The etiology of the injuries can now be examined scientifically, and measure-

ment methods to examine strength, range of motion and the effect of the treatment based on the patients perception has been developed and can be implemented in the future research. With the new knowledge about the morphological variations of the hip joint, including FAI and their relation to development of groin pain and early osteoarthritis of the hip joint, a new chapter has been opened offering major scientific challenges. Hopefully this will lead to a better understanding of the injuries related to the pelvis, hip, and groin in connection with physical activity and in time lead to new and even better treatment and prevention strategies.

**Summary**

The doctoral thesis is based on 8 papers published in peer-reviewed journals and a review of the literature. The papers are published between 1997 and 2013 in cooperation with Sankt Elisabeth Hospital, Herlev Hospital, Glostrup Hospital, Rigshospitalet, Hvidovre Hospital, Amager Hospital, Copenhagen Trial Unit, and Institute of Preventive Medicine, Copenhagen.
Groin injuries in sport are very common and in football they are among the most common and most time-consuming injuries. These injuries are treated very differently around the world. There is no consensus in the literature regarding definitions, examination methods, diagnosis or treatment and in general the level of evidence is very low. There is a need for identification of the painful anatomical structures, how to examine them and how to define clinical entities to develop effective treatment and prevention.

The aim of these studies were:

- To review the literature to create an overview of the ideas and the knowledge in order to plan future studies in this field.
- Develop and test clinical examination techniques of the relevant tendons and muscles in the region.
- Since no evidence-based diagnosis exist; to develop a set of clinical entities to identify the different groups of patients.
- To test the effect of a dedicated exercise program developed for treatment of long-standing adductor-related groin pain in athletes in a randomised clinical trial comparing it to the treatment modalities used at that time.
- To examine the long-term effect of the above mentioned training program for treatment of long-standing adductor-related groin pain.
- To develop a training program for prevention of groin injuries in soccer and test it in a randomised clinical trial.
- To describe the occurrence and presentation in clinical entities of groin injuries in male football and to examine the characteristics of these injuries.
- Evaluate if radiological signs of femuro-acetabular impingement (FAI) or dysplasia affect the clinical outcome of treatment of long-standing adductor-related groin pain, initially and at 8-12 year follow-up.

The main findings of the 8 papers were:

- No randomised trials existed in this area; there was no consensus in the literature and the majority of the literature was Level 4 and 5. From the existing literature and the authors experience an injury mechanism was suggested and the term 'adductor-related groin injury' was suggested.
- A well-defined clinical examination of the adductor-, iliopsoas, and abdominal muscles and the symphysis joint for pain, strength, and flexibility was reproducible with only limited intra- and inter-observer variation.
- By utilising a well-defined classification long-standing groin injuries could be classified with a system of clinical entities.

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