Longstanding adduction-related groin pain in athletes

Jaap Jansen

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CHAPTER 1

General introduction and outline of the thesis

Although participation in sports is considered important by the Dutch government, it does increase the risk for musculoskeletal injury. Every year, about 3,500,000 sports injuries occur in the Netherlands (Schmikli et al., 2004).
In this thesis, emphasis is placed on sports-related groin injuries.
The incidence of groin injuries is estimated at 5% to 18% of all reported athletic injuries (Morelli & Smith, 2001). However, these data should be interpreted with caution as no universal standards are currently available for the definition or classification of groin injury. In contrast with the knee, the groin does not refer to a well-defined specific anatomic structure. It merely refers to a vaguely described anatomical area of the proximal upper leg, reproductive organs and the lower abdominal region. In the Dutch injury registration system (IPAN) (Schmikli et al., 2004; 2009), the groin region is mentioned as part of the upper-leg/hip region and, therefore, there are no accurate estimations of the different kinds of groin injuries among the Dutch population.
Groin injuries are relatively common in the type of sports requiring lots of turning, accelerations and decelerations such as soccer, field hockey and tennis, as well as in sports with high-intensity hip abduction such as speed skating and ice hockey. In the Netherlands, with 930,000 active soccer athletes and 431,000 injuries each year, indoor and outdoor soccer make a large contribution to the total number of groin injuries. It is know that males are more likely to have a groin injury than females (Hägglund et al., 2009), and that 10% to 18% of all injuries in male soccer are attributed to groin injuries (Nielsen and Yde, 1989). In Dutch professional soccer, about 9% of all injuries are groin injuries (Stege et al., 2008). A groin injury is likely to result in long-term play loss (Renstrom & Peterson, 1980). In addition, previous groin injury is known to significantly increase the risk for recurrences (Maffey & Emery, 2007).
In view of the limited amount of research on sports-related groin injury, additional studies in this field are needed. The studies presented in this thesis were performed to contribute to the (para-)medical knowledge on longstanding adduction-related groin pain (LAGP).
The first part of the thesis deals with etiology and diagnostics (**Chapter 2**), the second part deals with treatment (**Chapters 3 to 5**), and the third part addresses the relation between abdominal muscle behavior and groin pain (**Chapters 6 to 9**). The final chapter **(Chapter 10)** discusses the results and implications of the studies presented in Chapters 2 to 9.

Etiology and diagnosis

The groin region contains many anatomical structures. Muscles, tendons, blood vessels, bursae, the pubic symphysis and hip joint, as well as the intestinal and reproductive organs can all give rise to pain in the groin. In addition, pathologies that are not anatomically located in the groin region can also cause groin

pain, e.g. pathology of the sacroiliac joints or lumbar spine. The fact that several comparable diagnostic signs and symptoms are often called by different names makes the diagnosis even more complicated. Table 1 presents an extensive list of the differential diagnoses.
Several types of mechanisms can lead to a groin injury. An acute groin injury will probably have a different kind of pathology compared with a groin injury that has a gradual etiology. Furthermore, besides a previous injury, there are indications that gender and increasing age are associated with increased risk for injury (Arnason et al., 2004; Emery & Meeuwisse, 2001). However, information on these latter factors cannot be used for the development of rehabilitation protocols or preventive programs for groin injury because previous injury, gender and age are not modifiable. Therefore, more insight is needed into the types of factors that have the potential to be modified. Until now little information is available about which modifiable factors exist for groin injury. Therefore, **Chapter 2** presents a systematic evaluation of the studies that explore the etiology of groin injury.
Because of the extensive list of diagnoses for groin pain, the question arises: how can we identify a diagnosis that is specifically valid for LAGP? Information about gender combined with history and physical examination of the relevant tracts (digestive and urinary) can yield important information to exclude pathologies. Specific information on the etiology of the groin pain may also yield some relevant information. For example, acute sports-related groin injuries are more likely to be associated with overstretching and rupture, whereas gradual sports-related injuries are generally attributed to gradual biomechanical overload, simply because these gradual groin injuries mostly occur in those sports combining high load with endurance. Furthermore, different kinds of groin injuries are likely to be provoked during different kinds of physical tests. For example, during forceful hip flexion, a hip flexor-related groin injury is more likely to be provoked than an adductor-related problem, and a hip adductor-related or pubic symphysis-related groin injury is more likely to be provoked with forceful hip adduction.
In this thesis, the focus is on LAGP. Given the large variety of diagnoses available for LAGP the question arises: how valid can a particular diagnosis be? To address this question, **Chapter 2** presents a systematic review on the validity of diagnostic tools for LAGP besides the literature study investigating etiological factors.

Table 1. Differential diagnoses of athletic groin pain (adapted from LeBlanc and LeBlanc, 2003).

Musculoskeletal	Intestinal
• Acetabular disorders	• Abdominal aortic aneurysm
• Adductor tendinitis	• Diverticular disease
• Avascular necrosis of femoral head	• Hydrocele/Varicocele
• Avulsion fracture	• Inflammatory bowel disease
• Bursitis	• Lymphadenopathy
• Conjoined tendon dehiscence	• Ovarian cyst
• Herniated nucleus pulposus	• Prostatitis
• Hockey player's syndrome	• Testicular neoplasm
• Inguinal or femoral hernia	• Testicular torsion
• Legg-Calve´-Perthes disease	• Urinary tract infection
• Lumbar spine pathology	
• Myositis ossificans	
• Nerve entrapment	
• Osteitis Pubis	
• Osteoarthritis	
• Postpartum symphysis separation	
• Pubic instability	
• Sacroiliac joint problems	
• Seronegative spondyloarthropathy	
• Slipped capital femoral epiphysis	
• Snapping hip syndrome	
• Sports hernia	
• Stress fractures	

Treatment of groin pain

In the second part of the thesis, the focus is on treatment. How do we deal with the problem of LAGP and what are the results of the various treatments? Although most athletes with acute groin injuries can return to sports within four weeks (Hägglund et al., 2009), a certain group of athletes will continue to have complaints. Since obtaining the right diagnosis is a major challenge (see **Chapter 2**), making the correct clinical decision in terms of treatment can often be even more difficult. Despite limitations in our knowledge, athletes with LAGP are confronted with a wide variety of treatments ranging from simple rest to surgery. This raises the question as to exactly what kinds of treatments are available for athletes with LAGP, and what are the levels of evidence for the efficacy of these treatments. This question is addressed in **Chapter 3** by means of a systematic review of the literature.

Furthermore, we wanted to know what physical therapists in the region of

Utrecht (NL) actually do when an athlete with LAGP presents in physical therapy practice. In **Chapter 4** this topic is explored based on a small study using a written questionnaire for local physical therapists familiar with treating athletes with LAGP.
Although physical therapists are generally confident in terms of treatment success, information emerging from these practitioners might be biased. Therefore, to validate their data, a telephone interview questionnaire was held among (ex-) patients treated for LAGP. The results of this study are presented in **Chapter 5**.

Relation between abdominal muscle thickness and groin pain

A very popular clinical test for athletes with LAGP is the so-called 'squeeze test' (Verrall et al., 2005). During this test, the patient is positioned in a supine hook-lying position and is asked to squeeze both legs with maximum effort. If groin pain is provoked, this test is deemed positive. A preliminary interpretation of this provocation test would suggest a lesion of the adductor muscle or enthesis. However, a pain response during the squeeze test is also highly correlated with findings of pubic bone marrow edema (Verrall et al., 2005). This suggests that the anterior pelvis may also be associated with LAGP.
The pelvis is an important anatomical structure that transfers large forces from the spine to the leg and vice versa. Because of the large biomechanical forces, stability of the sacroiliac joints (including the pubic symphysis joints), is considered very important for optimum physical functioning in daily living and even more so in sports. In this thesis, stability refers to the mechanical control of a joint. For the pelvis this includes passive contributions, such as form closure, due to the anatomical design of the joint that is self-locking (Snijders et al., 1993a,b) and the surrounding ligaments, as well as the muscular contribution to stability by increasing compression force, generally referred to as force closure (Snijders et al., 1993a,b; Richardson et al., 2002).
The strong association found between pubic symphysis bone marrow edema and adduction pain led to the hypothesis that pelvic instability may play a role in athletic LAGP. To test this hypothesis Mens and colleagues (2006) studied the effects of wearing a pelvic belt on adduction pain, whereby it was hypothesized that the pelvic belt would contribute to force closure. Their results showed that a subgroup of athletes with LAGP experienced a significant decrease in adduction pain and an increase in isometric adduction force (by more than 20%) when wearing a pelvic belt.
A pelvic belt tightened around the pelvis with at least 50 N significantly improves stability of the pelvis in healthy subjects (Damen et al., 2002), and in women with post-partum pelvic girdle pain (Mens et al., 2006). Furthermore, in women with post-partum pregnancy-related pelvic girdle pain the score on the Active Straight Leg Raise (ASLR) test improved significantly after wearing a

pelvic belt (Mens et al., 2006). The ASLR test score is associated with mobility of the pelvic joints in women with post- partum pregnancy-related pelvic girdle pain (Mens et al., 1999). Mens and colleagues (2006) also found significant improvement on ASLR scores after wearing a pelvic belt among athletes with LAGP who were positive on the ASLR test. This further confirmed the idea that pelvic instability plays a substantial role in a subgroup of patients with athletic LAGP.

The deep abdominal muscles and pelvic floor muscles can play a stabilizing role in terms of force closure over the pelvis (van Wingerden et al., 2004). Richardson et al. (2002) showed that specific recruitment of the m. transversus abdominis can lead to a threefold increase in pelvic stiffness, which is even more than with general abdominal bracing. An *in vitro* study by Pool-Goudzwaard et al. (2004) showed that tensioning the pelvic floor can significantly increase stability of the pelvis.

Due to the positive effects of a pelvic belt on adduction pain and the ASLR test in athletes with LAGP, the mechanism of insufficient muscular force closure of the pelvis in athletes with LAGP was proposed. Therefore, the third part of this thesis focuses on the relation between abdominal muscle behavior and LAGP.

Chapters 6 and 7 test the hypothesis that an association exists between abdominal muscle behavior and clinical status. In **Chapter 6** this is tested using a cross-sectional study design in which the abdominal muscle behavior of athletes with LAGP is compared with that of matched healthy athletes. In **Chapter 7** the hypothesis of association is tested prospectively, by investigating whether changes in clinical status are associated with changes in abdominal muscle behavior.

It was also noted that there is a discrepancy in diagnoses associated with groin pain between different global regions. For example, in Europe LAGP is generally associated with adductor dysfunction (Hölmich et al., 1999, 2007), whereas in Australia LAGP is associated with the diagnosis pubic bone stress injury (Verrall et al., 2005). Since Mens and colleagues (2006) reported that a subgroup experienced a significant decrease in pain and/or an increase in ASLR performance when wearing a pelvic belt, it was considered that both diagnoses may be correct. Therefore, we hypothesized that these different subgroups could have different abdominal muscle recruitment. These insights, together with the results described in Chapter 6, led to the hypothesis that different subgroups of abdominal muscle recruitment exist within the group of athletes with LAGP. This hypothesis is tested in **Chapter 8**.

Cowan et al. (2004) reported delayed recruitment of the m. transversus abdominis in athletes with LAGP during ASLR. The authors suggested that this was a risk factor for developing LAGP. However, due to the cross-sectional design of that study it was not possible to confirm the proposed cause-and-effect relation between delayed recruitment of m. transversus abdominis and LAGP. Moreover, this abnormality might even be caused by the presence of groin pain

itself. To gain more insight into a possible cause-and-effect relationship, we studied the effects of experimental groin pain on abdominal muscle behavior in healthy subjects. The results of this study are described in **Chapter 9**.
The final chapter (**Chapter 10**) discusses the consequences of the findings described in this thesis. The clinical implications for sports medicine and sports rehabilitation are discussed, and recommendations are made for future research.

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CHAPTER 2

Diagnostics in athletes with longstanding groin pain

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Abstract

Chronic adductor dysfunction, osteitis pubis and abdominal wall deficiency are mentioned as pathologies explaining long-standing groin pain (LGP) in athletes. The main objective of this study was to evaluate the validity of diagnostic tests used to identify these pathologies in athletic LGP. Additionally, starting points for intervention were searched for. A systematic literature search was performed to retrieve all relevant diagnostic studies and studies describing risk factors. The methodological quality of the identified studies was evaluated. Seventeen studies provided an insight into pathologies; eight provided relevant information for intervention. Adduction provocation tests are moderately valid for osteitis pubis. A pelvic belt might provide some insight into the role of the pubic symphysis during adduction provocation. Palpation can be used for provocation of adductors and symphysis. Roentgen, bone scan and herniography show poor validity. Bilateral abdominal abnormalities on ultrasound appear to be a valid marker for LGP. Magnetic resonance imaging (MRI) can visualize edema and other abnormalities, although the relation to groin pain is not unambiguous. The methodological quality of the studies ranged from poor to good. MRI and ultrasound should be the primary diagnostic tools after clinical examination.

Introduction

Acute groin injury has a high prevalence in professional football: about 10–13% of all injuries per year occur in the groin region (Hawkins et al., 2001; Arnason et al., 2004). In general, a groin injury heals quickly, but about 13.5% lasts over 3 weeks (Arnason et al., 2004). For these athletes, and athletes with groin injuries with a more insidious onset, treatment is often required. However, diagnosis and treatment in a population of athletes with long-standing groin pain (LGP) is a complex procedure. In the literature, there are three main pathologies mentioned that may offer an explanation for persisting, sports-related groin complaints. These pathologies are (1) chronic adductor dysfunction; (2) osteitis pubis (also known as pelvic ring overload or pubic bone stress injury); and (3) abdominal wall deficiency. The clinician in the field has several tools to identify these pathologies, like taking a medical history and clinical tests, and imaging techniques like roentgen, computed tomography (CT), ultrasound and magnetic resonance imaging (MRI). The first aim of this review was to evaluate the validity of the diagnostic findings that are used to identify these different musculoskeletal pathologies that may explain LGP in athletes. Specific hip disorders that may also explain groin pain are excluded from the review. Our second aim was to investigate as to which factors may be etiological for development of athletic groin pain in general, with the goal to prevent groin injuries, and/or set rehabilitation targets. To answer these questions, a systematic literature search was performed.

Methods

A systematic search was performed to identify all available literature on characteristics of athletes with LGP. A strategy proposed by Devillé et al. (2002) was applied.
The following combination of keywords was used:

(''adduction-related'' OR ''adductor tendinitis'' OR ''osteitis pubis'' OR pubalgia OR ''occult hernia'' OR ''inguinal hernia'' OR ''abdominal wall hernia'' OR groin OR ''adductor strain'' OR ''tendon injury'' OR (sport* AND hernia) OR ''groin disruption'' OR ''hockey player syndrome'' OR bulging OR hockey groin syndrome) AND (validity OR sensitivity OR specific* OR standards OR ''false positive'' OR ''false negative'' OR ''predictive value'' OR reference OR ''roc analysis'' OR ''roc and'' OR ''roc estimated'' OR reliability OR kappa OR interrater OR ''inter rater'' OR ''likelihood ratio'' OR evaluate OR evaluation OR evaluat* OR examine OR examination OR registrated OR registered OR investigat* OR assess OR test OR findings) AND (''MR imaging'' OR ''MRI'' OR ''magnetic resonance'' OR imaging OR ''ultrasound'' OR ultrasound OR ''US echo'' OR laparos* OR ultrasonography OR sonography OR exam* OR ''physical exam'' OR palpate* OR herniography OR peritoneo* OR strength OR ''range of motion'' OR flex* OR diagnose OR diagnosis OR ''roentgen'' OR ''roentgen'' OR ''CT'' OR test OR herniograph* OR task) AND (sport OR sports OR hockey OR football OR soccer OR athlete OR athletes OR rugby OR sportsmen).

The digital databases Pubmed, Embase, Cinahl, Pedro,Cochrane, Scopus, Clinical Evidence and doconline were searched for all relevant titles published up to 1 April 2007. Search strategies were adapted for each of the databases searched. In the first selection round, all titles referring to athletes or sportsmen and groin pain were included. In the second selection round, abstracts were read by two reviewers to include or exclude the article. If an abstract was not available, the full-text article was retrieved when possible. If the article was not available through the Dutch library of Picarta, the authors were contacted. Articles not written in English, German or Dutch were excluded. Reviews, prognostic studies, case reports and series, letters, comments and cadaver studies were also excluded. Articles were also excluded if no comparison was made between the characteristics of athletes with groin pain and healthy subjects, or between the symptomatic and the asymptomatic side/status of the injured athlete. Reference lists of the included articles were hand searched for relevant titles: for these titles, the same procedure was repeated.
To determine the methodological quality of the articles, a checklist was composed by the authors. The checklist was based on the QUADAS-tool (Whiting et al., 2003), and a checklist designed by van der Wurff et al. (2000), both of which are designed to assess the quality of diagnostic accuracy studies. The checklist consists of nine items, which are weighted by means of points (Table 1). A detailed description of the test is important to enable the test to be repeated in practice (1 point). Second, it is important that the population is described in sufficient detail by means of inclusion and exclusion criteria (2 points), or specific characteristics like gender, age, duration of complaints and (level of) sport participation (1 point). Then it must be questioned whether the test under investigation is actually used in (a random selection of) athletes with LGP, so that the test results can be generalized for the population as a whole (1 point). Control data should have sufficient similarities to the group under investigation, so that characteristics are truly related to the disease instead of other characteristics. These data may come from the asymptomatic side of the same patient (1 point) or from a group of (matched) asymptomatic subjects (unmatched 1 point; matched 2 points). The number of patients and controls has to be sufficient to decrease the influence of chance and increase generalizability (total>49: 1 point). Blinding the assessor for clinical symptoms is important to guarantee objectivity (2 points). The experience of the observer(s) is especially important in reading images, because it is known that inexperienced assessors might overlook abnormalities (1 point). In studies describing results of imaging

techniques, a proper description of the abnormalities found has to be present (1 point). The results have to be presented in terms of inferential statistics. This can be done by presenting means and standard deviations, or odds ratios, with P-values (1 point), or sensitivity/specificity-values (2 points). The checklist was applied according to a yes/no method. Two independent reviewers filled out the checklist. After individual scoring, consensus had to be reached by means of discussion between both reviewers.

Table 1. Criteria to quantify methodological quality (modification of Van der Wurff et al., 2000 & the QUADAS-tool by Whiting et al., 2003)

Items	Possible points
A. Is the method used to investigate the characteristics described in sufficient detail?	0/1
B. Was the population under investigation described in sufficient detail?	0/1/2
C. Is the sample of the population representative for the population that will receive the test in practice?	0/1
D. Does the reference group have sufficient similarities with the group of interest?	0/1/2
E. Are sufficient (>49) patients tested in the control/reference group?	0/1
F. Are the observers blinded for the presence or laterality of the subjects' symptoms?	0/2
G. Is there a description of the experience of the observer(s)?	0/1
H. Is there a proper description of the abnormalities?	0/1
I. Are inferential statistics used in the result section?	0/1/2
maximum score*	13

* Articles describing results of physical examination can obtain a maximum score of 11 points

Results

A total of 150 relevant titles were found. Of these, 125 were excluded: 61 titles were reviews; 30 titles were case reports, 13 were not written in English, German or Dutch; in 18 studies, no comparisons were made between asymptomatic subjects/sides and symptomatic athletes/sides; 2 studies were cadaver studies; and one title was only available as an abstract. The studies on laparoscopy as a diagnostic tool were all retrospective case series reporting abnormalities found at surgery. There were no studies comparing findings from both symptomatic and asymptomatic sides in athletes with LGP. Therefore, none was included for review. As a result of this selection, 25 articles were included. A total of 17 articles described characteristics of patients relating to chronic adductor dysfunction, osteitis pubis and abdominal wall deficiency, and eight articles described characteristics possibly related to aetiology. A short description of all the articles retrieved is presented in Table 2.

Description of studies included

A short description of the studies included is given to create a bundled overview of conflicting/consistent findings of different studies about the diagnostic tool in the population under investigation. In general, the populations include sub-elite and/or elite, mostly male athletes involved in sports with kicking and turning like soccer and Australian football. The groin pain is mostly located unilaterally and sometimes bilaterally. In the majority of athletes, groin pain existed for a longer period of time (>12 weeks).
If studies refer to onset of the injury, an acute moment is rarely mentioned.

Clinical diagnostic tests

Only three studies reported on specific clinical findings in athletes with LGP (Slavotinek et al., 2005; Verrall et al., 2005b; Mens et al., 2006). Verrall et al. (2005b) studied the validity of three regularly used provocation tests used in the clinical examination of athletes with LGP. The squeeze test (patient is supine, knees 901, feet on couch, manual resistance to bilateral hip adduction) was not sensitive (40%) enough to identify symptomatic athletes, neither were the single adductor test (30%; patient is supine with one hip flexed 301, and knees extended; manual resistance to hip adduction) and the bilateral adductor test (55%; patient is supine, both hips flexed 301, both knees extended; manual resistance to bilateral hip adduction). Mens et al. (2006) measured isometric hip adduction strength in the same position as the squeeze test described by Verrall et al. (2005b) in a group of athletes with hip adduction-related LGP. Isometric hip adduction strength was significantly less in athletes with adduction-related LGP when compared with healthy athletes, suggestive of adductor dysfunction. Besides adduction strength, Mens et al. (2006) studied the Active Straight Leg Raise test. This test is positive if lifting one straight leg about 20 cm from the couch is experienced as at least minimally difficult. Furthermore, the influence of a pelvic belt (Damen et al., 2002; Mens et al., 2006) on adduction force and Active Straight Leg Raise test performance was evaluated. Performing hip adduction when wearing a pelvic belt decreased groin pain (30/44) and increased maximum adduction force over 20% in 17/44 patients. The Active Straight Leg Raise test was positive in 17/44 patients, and wearing a pelvic belt decreased experienced difficulty in all 17 patients. In asymptomatic athletes, a pelvic belt did not have a significant effect on any of these parameters (Mens et al., 2006).

Table 2: Description of the selected articles

First author[ref]	Investigation	Description of population with groin pain (GP)	N (♂/♀)	Controls	Main results
Verrall et al. (2005b)	Physical exam/ MRI	Australian football players without (CGP) or with (PBSI) pubic BME for at least 6 weeks	47 (47/0)	42 asymptomatic matched athletes	Three tests were evaluated. The single adductor test (SA), squeeze test (SQ) and bilateral adductor test (BA). Sensitivity to detect CGP were 30% (SA), 40% SQ and 55% (BA); to detect positive MRI were 30% (SA), 43% SQ and 54% (BA); to detect PBSI 32% (SA), 49% SQ and 65% (BA). Specificity were 90% (SA), 88% SQ and 95% (BA) for CPG, 91% (SA), 91% SQ and 93% (BA) for positive MRI, and 88% (SA), 88% SQ and 92% (BA) for PBSI. If an athlete had a positive pain provocation test and signs and symptoms of chronic groin pain, the positive predictive value was 86% (SA), 95% (SQ) and 92% (BA).
Slavotinek et al. (2005)	physical exam/ MRI	23 Australian Football players that experienced groin pain during/ after 6 week training period	23 (23/0)	Matched athletes without groin pain	BME was present in 11/ 22 players who experienced training restriction due to groin pain. There was a strong association between the presence of of a T2 hyperintense line and groin pain (p=0.03), but no association between severe BME and groin pain (p=0.13).
Mens et al. (2006b)	Physical exam	44 athletes of various sports, mean duration of complaints 16.3 months	44 (38/6)	44 asymptomatic matched athletes	Symptomatic subjects have less adduction strength then healthy subjects (292N vs 350N). Symptomatic subjects had a median increase of 9.8% in adduction strength when wearing a pelvic belt. 39% had over 20% increase in strength. Controls had a median increase of 1.8%. An active straight leg raise was experienced as at least minimally difficult in 39% of the patients, whereas all controls were negative. Wearing a pelvic belt decreased difficulty in all patients.

Table 2: continued

First author[ref]	Investigation	Description of population with groin pain (GP)	N (♂/♀)	Controls	Main results
Harris & Murray (1974)	X-ray	26 soccer players (A), all history of GP; 11 other athletes (B), no data on duration of complaints	37 (?/?)	156 Asymptomatic young men (age between 17 and 18)	A: 9 had signs of instability, 19 irregularity, 17 sclerosis, 0 wide cleft, 17 abnormalities of the gracilis, 14 SI-joint abnormalities. B: 7 had signs of instability, 8 irregularity, 4 sclerosis, 2 wide cleft, 4 abnormalities of the gracilis, 6 SI-joint abnormalities. Controls: 70% abnormalities at pubic symphysis. The more athletic activity was performed, the more abnormalities were found.
Major & Helms (1997)	X-ray	Athletes of various sports, no data on duration of complaints	11 (9/2)	20 patients with other complaints	All patients demonstrated changes at the pubic symphysis. In 4 patients, abnormalities of the SI-joint showed abnormalities. In 6 (all >55 years old) out of 20 asymptomatic cases abnormalites were found at the pubic symphysis, but no abnormalities at the SI-joint.
Besjakov et al. (2003)	X-ray	20 athletes of various sports, at least 3 months complaints	20 (20/0)	20 age-matched athletes (A)/ 120 non-athletes (B)	9 athletes with groin pain slight, 9 intermediate, 2 advanced abnormalities, A: 3 none, 17 slight abnormalities, B: 42 (obs 1)/ 40 (obs 2) none, 64 (obs 1)/ 65 (obs 2) intermediate, 14 (obs 1)/ 15 (obs 2) intermediate abnormalities.
Smedberg et al. (1985)	Herniography	Athletes of various sports, mean duration of complaints 10 months	78 (78/0)	Asymptomatic side	In the symptomatic groins, a hernia was found in 84.2%. In the asymptomatic groins, hernias were found in 49.1%. Significantly more asymptomatic groin sides were normal (43.6% versus 8.9%).
Kesek et al. (2002)	Herniography	Mainly soccer players, mean duration 6 months	51 (51/0)	Asymptomatic side	In 51 patients, 16 pathological findings, of which 14 hernias were identified. One patiënt had bilateral hernias. Nine patients had a hernia in the symptomatic groin, 3 patients in the asymptomatic groin. Sportsman's hernia was found in 3 patients. Bone changes were found in 32 patients (21 advanced changes)

Table 2: continued

First author[ref]	Investigation	Description of population with groin pain (GP)	N (♂/♀)	Controls	Main results
Steele et al (2004)	Ultrasound/ bone scan	37 athletes of various sports, average duration of complaints 8 months	37 (37/0)	34 asymptomatic groin sides/ other features	Ultrasonography: On the symptomatic side, 14 ultrasound scans were normal, 26 were abnormal; on the asymptomatic side, 21 scans were normal, and 13 were abnormal. Bone scan: 22/ 29 were abnormal (pubic tubercle) on the symptomatic side, 13 abnormalities were found elsewhere in the groin (5 pubic tubercle, 3 pubic symphysis, 5 adductor origin).
Kalebo et al. (1992)	Ultrasound	36 athletes of various sports, mean duration of complaints 1,5 years	36 (28/8)	Asymptomatic side	In 28/36 patients, ultrasound examination showed abnormalities (focal hypoechoic areas and discontinuity of tendon fibres) in the region of the painful areas. Probe compression resulted in pain in the majority of the patients. No data are present about the asymptomatic side.
Orchard et al. (1998)	Ultrasound	14 athletes with a history or recent GP, hindered in sports during at least 1 month	14 (14/0)	21 asymptomatic matched athletes	A strong association was found between the presence of bilateral inguinal canal deficiency and the presence of groin pain(chi-square 7.78, $p<0.01$). No apparent correlation between side of the pain and side of the canal weakness. Significant association between age and increased risk for groin pain ($p<0.01$); **Weak and non-significant association between age and bilateral inguinal canal deficiency**.

Table 2: continued

First author[ref]	Investigation	Description of population with groin pain (GP)	N (♂/♀)	Controls	Main results
Lovell et al. (2006)	MRI	19 elite junior soccer players, no data on duration of complaints	19 (19/0)	Themselves during a 4 months training period	A total of 58 scans was taken during an intensive training period. If athletes were symptomatic, 3 grades 2, and 7 grades 3 BME were found. If athletes were asymptomatic, 11 grades 0, 6 grades 1, 16 grades 2 and 15 grades 3 BME were found.
Brennan et al. (2005)	MRI	15 soccer, 3 rugby players, mean duration 3 months	18 (18/0)	70 asymptomatic athletes	In 12/18 patients, a secondary cleft was identified at injection with X-ray, and corresponded with the symptomatic side. In the same 12/18 patients, a secondary cleft was identified at MRI. A secondary cleft was not identified in any of the 70 controls at MRI.
Cunning-ham et al. (2007)	MRI	Professional and amateur soccer players with complaints mean 3 months	100 (95/5)	50 asymptomatic volunteers, 37 with unexplained hip pain, 13 suspected sacroiliac dysfunction	Isolated adductor microtears in 47, isolated osteitis pubis in 9, both in 41 patients. Accessory cleft in 88 patients, all on side of symptoms , none in controls (chi square 188.34; $p<0.001$). 100 patients showed bone oedema, no controls (chi square 188.34; $p<0.001$). No significant difference with respect to fibrocartilaganious disk protrusion (chi square 2.32; $p=0.2$)
Verrall et al. (2005a)	**Etiological factors**	Australian football players without (CGP) or with (PBSI) pubic BME for at least 6 weeks	47 (47/0)	42 asymptomatic matched athletes	Comparing athletes with chronic groin injury with athletes without symptoms, a significant decrease in total hip internal ($p=0.03$) and total external ($p=0.01$) rotation was found. Increased age does not correlate with any of the ranges of motion.

Table 2: continued

First author[ref]	Investigation	Description of population with groin pain (GP)	N (♂/♀)	Controls	Main results
Delahaye et al. (2003)	**Etiological factors**	10 athletes of various sports, mean duration 19.8 months	10 (10/0)	Control values	Athletes with groin pain have significant more trunk range of motion ($p<0.01$); a trend for decrease in hip internal and external range of motion for both sides; significant decreases in hip muscle strength for all directions ($p<0.01$); significant decrease in knee extension strength ($p<0.01$); significant asymmetry for knee muscle power at higher movement speed (quadriceps $p<0.04$; hamstrings $p<0.005$).
Cowan et al. (2002)	**Etiological factors**	10 elite or subelite Australian Football players, complaints at least 6 weeks	10 (10/0)	12 asymptomatic matched athletes	Athletes with LGP have a delay in the recruiitment of the m. transversus abdominis compared with healthy subjects ($p< 0.05$) and a significant delay in movement onset
O'Connor (2004)	**Etiological factors**	Professional rugby players.	21 (21/0)	72 Asymptomatic matched athletes	Etiological factors identified as being related to injury of the groin musculotendinous unit included abduction and adduction-with-rotation peak torque, strength ratio of the hip muscles, bilateral difference in extension peak torque, femur diameter and body mass.
Tyler et al. (2001)	**Etiological factors**	Professional ice hockey players	8 (8/0)	39 asymptomatic matched athletes	Adduction strength was 95% of abduction strength in healthy subjects; Only 78% in injured athletes. A player is 17 times more at risk if the adductor strength was less then 80% of his abductor strength. Adductor flexibility has no influence.

Table 2: continued

First author[ref]	Investigation	Description of population with groin pain (GP)	N (♂/♀)	Controls	Main results
Emery & Meeuwisse (2001)	**Etiological factors**	52 professional ice hockey players	52 (52/0)	1240 Asymptomatic sport-matched athletes	Previous injury significantly increases relative risk for injury (RR 2.88, CI 1.33-6.26) Veterans had about 5 times more risk (RR 5.69; CI 2.05-15.85). Peak isometric adductor torque, abduction flexibility, skate blade hollow measurement were not predictive for injury. There is evidence of a dose response gradient as predicted probability of injury decreases with increasing levels of sport-specific training (< 18 sessions, RR 3.38, CI 1.45-7.92), but only at the start of the season.
Witvrouw et al. (2003)	**Etiological factors**	Professional ice hockey players	13 (13/0)	79 asymptomatic matched athletes	No differences were found for the number of injuries between the dominant and the non-dominant side (p=0.44). No significant differences were found for the flexibility of the adductor muscles between the injured and uninjured group (p=0.45).
Verrall et al. (2007)	**Etiological factors**	Australian Football players	4 (4/0)	25 healthy matched athletes	Lower body weight and reduced hip total hip joint range of motion were associated with the occurrence of chronic (> 6 weeks) groin pain.

BME: bone marrow edema

Given that the Active Straight Leg Raise test does not provoke the adductor muscle and a pelvic belt influences test performance, the results suggest that the pelvis does (also) play a role in chronic, adduction-related groin injury in terms of pubic symphysis stress. Tenderness of the pubic bone at palpation, which is also a normal part of the physical exam, is associated with groin pain, but is not associated with number of missed sports games (Slavotinek et al., 2005). Verrall et al. (2005b) also described the results of palpation. A combination of groin pain and tenderness of the pubic symphysis and/or superior pubic rami was found to be very common (47/48 cases with groin pain: sensitivity 98%). The combination of groin pain without tenderness was found in one subject; tenderness without groin pain was found in 13 of 42 asymptomatic subjects (specificity 69%). No specific findings were reported on clinical tests for the abdominal wall.

Imaging techniques
The results of X-ray, herniography and bone scan of the pelvis are discussed in six studies (Harris & Murray, 1974; Smedberg et al., 1985; Major & Helms, 1997; Kesek et al., 2002; Besjakov et al., 2003; Steele et al., 2004). After determining four grades of abnormality (none, slight, intermediate, advanced) on roentgen, Besjakov et al. (2003) found more slight, intermediate and advanced changes in a group of athletes with groin pain compared with agematched men. However, they also found an increase in abnormalities with increasing age in a second control group. Harris and Murray (1974) found abnormalities at radiography in over 76% of the athletes with (a history of) groin pain, and in 45% of the controls. On the other hand, a strong correlation between athletic activity and abnormalities was reported.

Degenerative changes at the sacroiliac joint (erosion, sclerosis, osteophytosis) were identified in 4/11 athletes by Major and Helms (1997), whereas in a group of 20 asymptomatic controls, this was identified in only six subjects, all 455 years old, suggestive of a role of the pelvic ring in LGP. Two studies were found describing the differences between the symptomatic and asymptomatic side seen at herniography (Smedberg et al., 1985; Kesek et al., 2002). At the asymptomatic side, a hernia was found at herniography in almost 50% of the population of athletes, whereas at the symptomatic side a hernia was identified in 84% of the cases (Smedberg et al., 1985). In contrast, Kesek et al. (2002) could only detect 14 hernias out of 51 cases (27%). Of these, three were found in the asymptomatic groin side. A bone scan of the pelvis showed more abnormalities of the pubic tubercle on the symptomatic side, compared with the asymptomatic side Steele et al. (2004). Three studies described findings using ultrasound (Kalebo et al., 1992; Orchard et al., 1998; Steele et al., 2004). Kalebo et al. (1992) found abnormalities of the adductor enthesis at the painful area in 28/36 patients. These authors concluded that ''normal findings are readily distinguished from pathologic ones,'' using the asymptomatic side as a reference. Orchard et al. (1998) compared ultrasound pictures of the abdominal wall at rest with pictures during various provoking maneuvers. A normal inguinal canal was diagnosed if, under stress, there was some kind of canal 'closure' ("a variable, sometimes only minimal, decrease in craniocaudal diameter and cross-sectional area") (Orchard et al., 1998). Abdominal wall deficiency was diagnosed if there was an increase in the cross-section. A strong association was found between the presence of bilateral canal deficiency and significant groin pain; however, no correlation was found between the side of groin pain and the side of inguinal canal weakness. A weak and non-significant association was found between age and abdominal wall deficiency. Steele et al. (2004) reported 22/40 abdominal wall deficiencies at the symptomatic side, and 10/34 at the asymptomatic side using ultrasound.

A total of seven studies described findings at MRI (Albers et al., 2001; Verrall et al., 2001; Robinson et al., 2004; Brennan et al., 2005; Slavotinek et al., 2005; Lovell et al., 2006; Cunningham et al., 2007). Robinson et al. (2004) found a weak but significant correlation (r=0.370) between the clinical side and abnormalities of the adductor enthesis on MRI. Albers et al. (2001) reported abnormalities of the adductor muscle group on MRI in 18/30 athletes having LGP. In 17/18 patients, these findings corresponded with the patients' primary symptoms. Brennan et al. (2005) studied the phenomenon called ''the secondary cleft'' visualized on MRI. According to these authors, this phenomenon can be interpreted as an adductor microtear at the symphyseal enthesis. MRI was able to identify a secondary cleft in 12/18 athletes with LGP, the same group in which a secondary cleft was seen on X-ray after a symphyseal cleft injection with contrast fluid. MRI did not identify a cleft in any of the control subjects, suggestive of the good validity of MRI for a secondary cleft sign. A later study by Cunningham et al. (2007) also studied this phenomenon and found the secondary cleft to be present in 88 out of 100 athletes with LGP, and in none of the 100 controls. Verrall et al. (2001) reported a very strong association (OR 25.8, P=0.01) between the presence of pubic bone marrow edema (BME) and symptoms of groin pain. The strength of the association increased when BME 42 cm was correlated with having symptoms (OR 46.5, P=0.01). In contrast, Slavotinek et al. (2005) reported no significant association between BME and groin pain. Similar results were found by Lovell et al. (2006), who reported the degrees of (abnormal) BME found in asymptomatic and symptomatic soccer players to be very similarly distributed over symptomatic and asymptomatic junior soccer players during a period of high-intensity training. Edema and enhancement of the anterior pubis correlated significantly with the clinical side, as reported by Robinson et al. (2004).

Only two studies specifically reported abnormalities of the abdominal wall on MRI (Albers et al.,2001; Robinson et al., 2004). Attenuation of the abdominal wall musculofascial layers was present in 27/30 patients. In 27/27, the side of the attenuation correlated with patients' side of symptoms (Albers et al., 2001). Abnormalities of the rectus abdominus were found in only very few patients in the study by Robinson et al. (2004), whereby agreement between the two MRI observers was poor.

Etiological factors

Three cross-sectional studies (Delahaye et al., 2003; Cowan et al., 2004; Verrall et al., 2005a) and five prospective cohort studies (Emery & Meeuwisse, 2001; Tyler et al., 2001; Witvrouw et al., 2003; O'Connor, 2004; Verrall et al., 2007) that could provide some relevant information for rehabilitation and/or prevention were identified. The cross-sectional studies reported on deficiencies in the kinetic chain hip–pelvis–lumbar spine. In the studies by Verrall et al. (2005a) and Delahaye et al. (2003), it was suggested that decreased hip rotation range of motion preceded groin injury, diagnosed with symptoms of groin pain and pubic bone edema on MRI. A later prospective study by Verrall et al. (2007) presented confirmative results; however, small numbers were used, and so the results have to be interpreted with caution. Using electromyography, Cowan et al. (2004) identified a significant delay in the recruitment of the m. transversus abdominis, an important muscle in stabilizing the pelvic ring (Richardson et al., 2002), in athletes with LGP during the performance of an Active Straight Leg Raise test after a visual cue. Increased lumbar spine range of motion and decreased hip muscle strength might also play a role in groin injury (Delahaye et al., 2003). However, no hard conclusions can be drawn from these cross-sectional studies. In the resulting prospective studies, dysfunction of the hip joint, lumbar spine or pelvis-stabilizing muscles was never mentioned: in the study by Emery and Meeuwisse (2001), it was concluded that o18 offseason sport-specific training sessions, a previous history of groin pain and increased age are important predictive factors in the occurrence of groin injury in ice hockey. Tyler et al. (2001) concluded that if hip adduction strength was below 80% of hip abduction strength, the risk for adductor strains increases significantly in a population of ice hockey players. Contradictive results were presented by O'Connor (2004), who stated that lower hip abduction peak torque (with/without hip external rotation for the non-dominant/dominant leg) and dominant femur diameter are the strongest predictors for the occurrence of a groin injury. Flexibility (limberness) of the adductor muscles does not seem to predict groin injury (Emery & Meeuwisse, 2001; Tyler et al., 2001; Witvrouw et al., 2003).

Because of poor injury description, it must be questioned whether the groin injuries that are mentioned in prospective studies truly relate to the chronic groin injuries discussed in this review.

Quality assessment

Methodological quality was assessed for 20 articles. For prospective studies, the criteria were not suitable. Two reviewers filled out the checklist. Before discussion, both reviewers agreed on 146 out of 180 (20 studies * 9) items. After discussion, a consensus concerning the other 34 items was reached. Methodo-

logical quality results after the consensus meeting are presented in Table 3.
In all but three articles (Besjakov et al., 2003; Delahaye et al., 2003; Steele et al., 2004), the method of investigation was described in sufficient detail to be reproduced. Besjakov et al. (2003) described only one position for radiography, but not the other positions that were used when necessary. Steele et al. (2004) and Delahaye et al. (2003) provide no details at all, and so their methods cannot be reproduced. Verrall et al. (2005a, 2007) counted ranges of hip internal and external motion and used these variables in statistics; whether this is a valid method is questionable.
Only four articles described clearly defined inclusion and exclusion criteria (Cowan et al., 2004; Robinson et al., 2004; Verrall et al., 2005a, b).
In all other articles, except for three (Harris & Murray, 1974; Kalebo et al., 1992; Kesek et al., 2002), a description of the population was given in terms of sports, age and gender. Information about the duration of complaints was given in all but four (Harris & Murray, 1974; Major & Helms, 1997; Albers et al., 2001; Lovell et al., 2006), but reading through also suggested populations having LGP in these four articles. The level of sports at which the subjects participated was described in 11 studies (Harris & Murray, 1974; Orchard et al., 1998; Verrall et al., 2001, 2005a, b, 2007; Richardson et al., 2002; Cowan et al., 2004; Slavotinek et al., 2005; Lovell et al., 2006; Mens et al., 2006). In addition, several articles also described some findings at physical exam (Verrall et al., 2001, 2005a, b; Slavotinek et al., 2005; Lovell et al., 2006; Mens et al., 2006).
In four articles, the subjects were waiting for surgical intervention and were therefore not representative for a population of athletes with LGP in general (Smedberg et al., 1985; Major & Helms, 1997; Albers et al., 2001; Steele et al., 2004). In the study by Smedberg et al. (1985), 53 out of 78 participants were operated, which is a rather high proportion.
In Albers et al. (2001), all patients were waiting for surgery and were surgically confirmed to have pubalgia caused by abdominal musculofascial abnormalities. In Robinson et al. (2004), 27 patients had undergone inguinal surgery, and therefore are not representative for the population as a whole. In Brennan et al. (2005), three of 18 patients had a history of symphyseal cleft injection.
Only six studies described results from <50 groins (Major & Helms, 1997; Orchard et al., 1998; Besjakov et al., 2003; Cowan et al., 2004; Lovell et al., 2006).
Eleven articles used a control group of athletes (Orchard et al., 1998; Verrall et al., 2001, 2005a, b; Cowan et al., 2004; Robinson et al., 2004; Brennan et al., 2005; Slavotinek et al., 2005; Lovell et al., 2006; Mens et al., 2006; Cunningham et al., 2007).

Table 3. Quality assessment of the 20 articles describing the characteristics of athletes with groin pain.

	Checklist items										
Study	A	B	C	D	E	F	G	H	I	total	% of max
Albers et al. (2001)	1	0	1	1	1	2	1	1	0	8	62
Besjakov et al. (2003)	1	1	1	0	0	0	0	1	0	4	31
Brennan et al. (2005)	1	0	1	1	1	0	1	0	2	7	54
Cunnigham et al. (2007)	1	1	1	1	1	2	0	0	1	8	62
Cowan et al. (2004)	1	2	1	2	0	2	*	*	1	9	82
Delahaye et al. (2003)	0	1	1	0	0	0	*	*	1	3	27
Harris & Murray (1974)	1	0	1	1	1	0	0	1	0	5	38
Kalebo et al. (1992)	1	0	1	1	1	0	0	1	0	5	38
Kesek et al.(2002)	1	0	0	1	1	0	0	1	0	4	31
Lovell et al. (2006)	1	1	1	2	0	2	1	1	1	10	77
Major & Helms (1997)	1	1	0	0	0	0	0	1	0	3	27
Mens et al. (2006)	1	1	1	2	1	0	*	*	1	7	64
Orchard et al. (1998)	1	1	1	2	0	2	0	1	1	9	69
Robinson et al. (2004)	1	2	1	1	1	2	1	1	1	11	85
Slavotinek et al. (2005)	1	1	1	2	1	2	0	1	1	10	77
Smedberg et al. (1985)	1	0	0	1	1	0	0	1	0	4	31
Steele et al. (2004)	0	1	0	1	1	0	1	0	0	4	31
Verrall et al. (2001)	1	1	1	2	1	2	0	1	1	10	77
Verrall et al. (2005a)	1	1	1	2	1	0	*	*	1	7	64
Verrall et al. (2005b)	1	1	1	2	1	2	0	1	2	10	77

* Not scored because no images were judged.

A maximum of 13 points could be obtained for studies describing imaging results; 11 points for other studies

The numbers of control subjects ranged from six (Robinson et al., 2004) up to 100 (Cunningham et al., 2007). Six articles described differences between the symptomatic and asymptomatic side (Smedberg et al., 1985; Kalebo et al., 1992; Albers et al., 2001; Kesek et al., 2002; Robinson et al., 2004; Steele et al., 2004). This is a major issue, because being active in sports can result in changes that can be judged as abnormal in a population of non-athletes (Harris & Murray, 1974). Only three studies did not report any relevant characteristics of the control subjects (Major & Helms, 1997; Besjakov et al., 2003; Delahaye et al., 2003).

Matching for kind of sport is important, because ''abnormalities'' may be sport-specific adaptations. In the studies by Brennan et al. (2005) and Cunningham et al. (2007) controls were mainly rowers, whereas patients were mainly soccer players.

In most retrospective studies, the asymptomatic side was taken as the control. Assessors or observers were blinded for (side of the) clinical symptoms in nine articles (Orchard et al., 1998; Albers et al., 2001; Verrall et al., 2001, 2005b; Cowan et al., 2004; Robinson et al., 2004; Slavotinek et al., 2005; Lovell et al., 2006; Cunningham et al., 2007). Verrall et al. (2005a) performed a physical exam before history, which might have biased the results. In all other studies, assessors or observers were aware of symptoms, or awareness was not reported. Although Cunningham et al. (2007) reported that radiologists were blinded for the side of symptoms in symptomatic cases, it was not mentioned whether they were blinded for cases (symptomatic/controls).

In reading images of radiological diagnostic procedures the experience of the assessor can be decisive. Unfortunately, only four of 16 studies describing the results of imaging techniques reported the level or years of experience of the radiologists (Robinson et al., 2004; Steele et al., 2004; Brennan et al., 2005; Lovell et al., 2006). When more than one observer was used, agreement between assessors is reported in one study (Robinson et al., 2004), which was, even for experienced radiologists, only poor to moderate (k=0.48 first reading, k=0.41 second reading).

In most articles describing findings at imaging, the abnormalities found during X-ray, MRI, CT or ultrasound scan were well documented. However, the phenomenon of ''secondary cleft'' is described poorly, making it hard to interpret the phenomenon for readers (Brennan et al., 2005; Cunningham et al., 2007).

Only two studies used statistics in terms of sensitivity, specificity or similar expressions (Brennan et al., 2005; Verrall et al. 2005b). Detailed information including data about sensitivity and specificity with respect to physical exam tests was presented by Verrall et al. (2005b), see Table 2. Brennan et al. (2005) reported a 100% sensitivity and specificity for MRI using symphyseal cleft injection as a reference test. Unfortunately, the symphyseal cleft could not be identified in all athletes with groin pain (12/18; 66%). In a later study, a secondary cleft was identified at MRI using the same procedure in a much higher proportion of athletes with LGP (88%; Cunningham et al., 2007) and none were found in healthy controls. However, the gold standard for identifying this phenomenon was not applied in the control subjects.

Discussion

Clinical tests aiming at provocation of adduction-related problems were studied in a high-quality publication (Verrall et al., 2005b). Hölmich et al. (2004) reported high reliability values for these tests. Therefore, these clinical tests can certainly be applied in the field to identify subgroups of patients with LGP, i.e. having adduction-related problems or not. Although a recent study reported one subgroup of groin pain to be adductor-related (Hölmich, 2007), this might not be 100% true. One moderate-quality study reported that if hip adduction is provocative, this does not have to be caused by adductor dysfunction only (Mens et al., 2006). Wearing a pelvic belt decreases adduction-related groin pain in a subgroup of athletes having LGP, indicating that the adductor is not the single cause for groin pain, but the pelvic ring/symphysis is also part of the problem. This is confirmed by Verrall et al. (2005b), who reported that tenderness of the pubic symphysis during palpation is very common in adduction-related groin pain. Therefore, the validity of provocation tests used for the identification of adductor dysfunction only is questionable. The combination of palpation and provocative tests can be helpful to identify subgroups in the population of athletes with LGP in general (Hölmich, 2007). Using palpation for the diagnosis of sportsman's hernia might not be indicated, because palpation for inguinal hernia is difficult and unreliable (Andrews et al., 1996).

The diagnostic value of imaging techniques was described in most studies. The usefulness of roentgen of the pelvis in the diagnostic process was evaluated in poor- to moderate-quality studies (Harris & Murray 1974; Major & Helms 1997; Besjakov et al., 2003; Steele et al., 2004). Furthermore, the results of these studies suggest poor validity for the pathologies mentioned. It is likely that changes of the pubic bone seen at roentgen are the result of high-load sports activities, instead of a pathology. Therefore, it is suggested that roentgen is useful to exclude pathologies such as osteoarthritis and similar diseases. Whether a bone scan is of any additional value cannot be judged, because this was only documented in one poor-quality study (Steele et al., 2004). Studies describing results of herniography are of poor quality, and the results are not convincing either (Smedberg et al., 1985; Kesek et al., 2002). Knowing this, and considering the impact of this technique on the patient, herniography might not be indicated in athletes having LGP.

In a moderate-quality study, Orchard et al. (1998) showed deficiencies of the abdominal wall under dynamic conditions in athletes with groin pain using ultrasound. Because ultrasound echography is easy to use, inexpensive, safe and can visualize anatomical structures under dynamic conditions, it can provide some relevant information in the diagnostic process, especially if the abdominal floor is thought to be the problem. However, only bilateral canal deficiency was correlated with complaints of groin pain. As suggested by Orchard et al. (1998), it might be possible that bilateral abdominal wall deficiency is a precursor for groin injury. More research is needed to make more definite conclusions.

Abnormalities of the adductor muscle, pubic bone/ symphysis and abdominal wall can also be visualized on MRI (Robinson et al., 2004). The so-called secondary cleft, described in moderate quality studies by Brennan et al. (2005) and Cunningham et al. (2007), is associated with adductor-related LGP: highly significant associations were found between MRI findings and complaints, suggestive of good validity. In these papers, it is suggested that a cleft originates from the adductor enthesis at the pubic symphysis and that symphysis problems are secondary (Brennan et al., 2005; Cunningham et al., 2007). Whether this is a valid explanation remains questionable. In a very recent study, abnormalities of adductor tendons on MRI were only found in subjects having LGP for 41 year. In athletes having groin pain of 1 year, no tendon abnormalities were found (Kunduracioglu et al., 2007). Verrall et al. (2001) found that 15 out of 51 patients had tenderness of the adductor muscle origin, and a hyperintense MR signal at the adductor origin in only six. Both studies suggest adductor abnormalities to be secondary. Unfortunately, abnormalities of the adductor on MRI were not reported in studies by Verrall et al. (2005a, b) and Slavotinek et al. (2005).

Considering pubic bone BME, one high-quality study showed that if hip adduction was provocative, the relation with pubic BME on MRI was strong (Verrall et al., 2005b). In an abstract by Brukner et al. (2004), a sensitivity for abnormalities on MRI of 78% and a specificity of 88% was reported. In another high-quality study, BME of the anterior pubis was also significantly correlated with LGP, although the correlation was low (Robinson et al., 2004). In contrast, in another high-quality study by Lovell et al. (2006), BME was also reported in 11/18 asymptomatic youth soccer players after a period of high-intensity training. Verrall et al. (2001) also reported BME in asymptomatic athletes, but severe BME was rarely seen in asymptomatic athletes. It is suggested that pubic bone BME on MRI is a marker of a highly loaded os pubis, whereas severe (>2 cm) BME may be a valid marker for LGP.

Abnormalities of the abdominal musculature can be visualized by MRI (Albers et al., 2001; Robinson et al., 2004). In the moderate-quality study by Albers et al. (2001), most patients showed abnormalities in the abdominal musculature on MRI, whereas Robinson et al. (2004) reported abnormalities to be present only in very few patients. Verrall et al. (2001) did not identify any changes there in their population. It is very likely that the populations described by Verrall et al. (2001), Robinson et al. (2004) and Albers et al. (2001) match different subgroups described by Hölmich (2007). However, as a result of suboptimal popu-

lation descriptions concerning clinical findings, this cannot be confirmed. If the population criteria had been more strict, the results might have been stronger. However, because several structures can be involved at the same time, this is not certain (Ekberg et al., 1988; Hölmich, 2007). A proper, detailed description of clinical findings in the populations under investigation is urgently required, for example in terms of the structure(s)/function(s) involved, as described by Hölmich (2007). The clinical findings, in combination with known validity of diagnostic tools, might aid clinical decision making.
Although it is a common practice in clinical tests, it was noticeable that only one study on imaging techniques evaluated findings under dynamic, provocative conditions (Orchard et al., 1998). This might be a subject of research on MRI in the future, given the fast development of the dynamic MRI technique. In studies on MRI, it was noticeable that different markers for LGP were used, for example: pubic bone BME, adductor enthesis enlargement and the secondary cleft sign. According to the literature, these signs correspond to different pathologies like pubic bone stress injury or adductor dysfunction. A recent cadaveric study has shown that there is a very intimate relation among musculotendinous aspects of the adductor, the symphysis and the abdominal muscles (Robinson et al., 2007). Therefore, it is suggested that interpretation of abnormalities of the adductor enthesis, pubic symphysis and rectus abdominus enthesis seen at MRI may refer to the same underlying problem. This might also explain the fact that ''multiple pathologies'' like osteitis pubis, adductor dysfunction and rectus abdominus dysfunction can co-exist (Ekberg et al., 1988; Hölmich,2007). Furthermore, it has been suggested that surgical intervention with placement of a mesh in treatment of osteitis pubis, or even in athletes without clear diagnosis for their groin pain, is successful (Paajanen et al., 2005; van Veen et al., 2007).
Besides the adductor, pubic symphysis and abdominal musculature, MRI can also used to visualize the hip joint, lumbar spine and abdominal organs. Therefore, it can be used to identify and specify other kinds of pathologies like femoroacetabular impingement, rupture of the labrum, osteoarthritis (Tanzer & Noiseux, 2004; Bohnsack et al., 2006; Burnett et al., 2006), prostatitis (Ekberg et al., 1988) and bursitis (Overdeck & Palmer, 2004), which are also causes of groin pain.
No studies describing comparative results of diagnostic laparoscopy in athletes with LGP were identified. Defects of abdominal muscles, but also lipomas adjacent to the spermatic cord, can be identified by laparoscopy (Paajanen et al., 2006). However, a recent study describing the results of laparoscopic intervention could only identify a possible cause for groin pain in 40% of athletes having LGP, unresponsive to conservative measures (van Veen et al., 2007). Because diagnostic laparoscopy does not appear to be highly sensitive in diagnosis and is invasive, it might only be indicated in the final stages of the diagnostic process. After excluding serious skeletal abnormalities by roentgen, it is therefore suggested that MRI should be the diagnostic tool of choice, purely based on the relevant information that can be gathered from MRI.

Because there is a lack of highly specific and sensitive diagnostic tools to select athletes who need surgery and those who do not, conservative treatment is generally the first option. Based on the crosssectional and prospective studies included in this review, exercises to strengthen the hip muscles are indicated. Furthermore, exercises aiming at stabilizing the pelvis should be performed. One RCT has already shown that such a training program can be effective (Hölmich et al., 1999). Recruitment of m. transversus abdominis might need some specific attention, and may even increase outcome success. Increasing hip range of motion may be applied, although evidence is only poor. Improving flexibility (limberness) of the adductor muscles might not be indicated.
Future research should describe the clinical features and imaging findings of athletes with LGP more extensively and correlate these features with treatment outcome. As a result, subgroups responding to specific interventions can be identified.

Perspectives

There is no high-quality evidence that chronic adductor dysfunction, osteitis pubis or abdominal wall weakness can be diagnosed with certainty as a single cause for long-standing groin pain. The lack of proper descriptions of populations makes it impossible to identify subgroups within the population of athletes with long-standing groin pain in general. Furthermore, multiple pathologies are regularly mentioned, suggesting that these diagnoses are different or multiple expressions of one underlying problem in the kinetic chain of adductor–pelvis–abdominals. Therefore, this should be targeted in
conservative rehabilitation. In clinical examination, the pelvic belt may be important to gain an insight into the role of the pelvis in the complaints. After excluding skeletal pathologies by roentgen, MRI should be the diagnostic tool of choice, because abnormalities of all structures can be visualized (under dynamic conditions). There is no consensus in the international literature about what markers are important in MRI, and how to interpret these findings. Furthermore, MRI should not be decisive for either conservative or surgical intervention. In future research, a detailed description of clinical features is needed, leading to subgroups within athletes having long-standing groin pain in general.

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CHAPTER 3

Treatment of longstanding groin pain in athletes

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Abstract

The aims of this study were to determine 1) the kinds of treatments applied for longstanding groin pain (LGP) in athletes; 2) the results; and 3) the levels of evidence for the interventions. Digital databases P were searched for articles describing the effects of interventions for LGP in athletes.Treatment of LGP in athletes can consist of conservative measures such as rest or restricted activity, active or passive physical therapy, steroid injections or dextrose prolotherapy. Studies describing surgery generally mention failure of conservative measures, although a description of these conservative measures is mostly lacking. During surgery, a reinforcement of the abdominal wall is applied in most cases, using an open or laparoscopic approach. There is level I evidence that physical therapy aiming at strengthening and coordinating the muscles stabilizing hip and pelvis has superior results compared with passive physical therapy. For patients with a positive herniography and/or positive ilioinguinal or iliohypogastric nerve block tests, there are indications (level II) that surgery results in earlier return to sport compared with exercise therapy. Possibly, laparoscopic intervention might result in an earlier return to sport compared with open approach surgery (level III). For different clinical diagnoses, the same or similar surgical interventions were performed.

Introduction

Groin pain is a common complaint in athletes. It occurs mostly in sports involving running, kicking, twisting and cutting like soccer, rugby, and (ice-) hockey (Bradshaw et al., 1997; Polglase et al., 2001). In professional soccer it comprises up to 10% of all the injuries (Hawkins et al. 2001). A large part of these injuries has a good prognosis and will heal over a short period of rest or restricted activity: in a study by Arnason et al. (2004), only 3 out of 22 players suffering a groin injury still had complaints three weeks after onset. In cases where the groin injury develops gradually, there is a broad differential diagnosis. Complaints may arise from (a combination of) systemic, gynecological, urogenital, gastrointestinal, neurological, and (musculo-) skeletal structures (Ekberg et al.,1988; Lynch & Renström, 1999; LeBlanc & LeBlanc, 2003). In sports medicine practice, sports-related, longstanding musculoskeletal complaints in the groin are diagnosed as pubalgia, chronic adductor tendinopathy, osteitis pubis, pubic instability, sports(-man's) hernia, hockey player syndrome, pubic symphysis syndrome etc. The difficulty in diagnosis is illustrated by Ekberg et al. (1988), who identified more than one diagnosis in 19 of 21 athletes with longstanding groin pain (LGP). Hölmich et al. (1999) found signs for osteitis pubis in over 60% of their athletic patients that were primarily diagnosed as suffering adductor complaints. Despite the diagnostic difficulties, athletes suffering LGP are treated in sports medicine practice and by physical therapists. The aims of this systematic review were to investigate the kinds of treatments described in the literature for this population, to document the results of these studies and then to review the levels of evidence and methodological quality.

Methods

Search

One reviewer (J. J.) searched the digital libraries of Pubmed, Cochrane, Scopus, Embase, Science Direct and doconline for articles on the treatment of sports-related LGP.

The following combination of keywords was used:

"("groin pain" OR "groin injury" OR "sportsman's hernia" OR "sports hernia" OR "osteitis pubis" OR "symphysis syndrome" OR "athletic pubalgia" OR "adductor tendinitis" OR "adduction-related") AND ("treatment" OR "surgery" OR "tenotomy" OR "physical therapy" OR "physiotherapy") AND (athletes OR sportsmen OR soccer OR hockey OR football)".

The database "doconline" was searched with the keyword "*lies*" which is the Dutch translation for groin. The electronic search was limited to official articles ranging from 1900 until 01 April 2007. If the study title was related to the treatment of athletes suffering groin pain, the article was selected. Reference

lists were also searched and additional relevant titles were retrieved. Titles referring to groin pain related to hip joint pathology were not selected. In a second selection round, studies were excluded if the articles were not written in English, German or Dutch; groin complaints were not longstanding (defined as > 6 weeks on average for the whole population); case reports with < 5 patients; publication type was review of literature, comment or letter; the article was not available in the Netherlands (Picarta library).
After the electronic search and the hand search, 141 relevant titles were identified. Based on the exclusion criteria, 96 studies were not included for review: 11 articles were comments or letters, 45 were reviews of literature, 26 were case reports with <5 patients, and 14 were not written in English, German or Dutch. As a result of the selection procedure, a total of 45 relevant publications remained.

Assessment of levels of evidence
The levels of evidence for included studies were determined using the method applied by the North American Spine Society (Table 1; http://www.spine.org/forms/LevelsofEvidenceFinal.pdf) and was performed by one author (J.J.). If the level of evidence was better than level IV, two reviewers (J.J. & N.K.), blinded for each others scores, applied the Delphi list by Verhagen et al. (1998) to determine the methodological quality of the studies (Table 2). After this procedure, consensus between both reviewers was reached by means of discussion.

Table 1. Levels of evidence

Levels of evidence	Therapeutic studies investigating the results of intervention
Level I	• High quality randomized trial with statistically significant difference, or no statistically significant difference but narrow confidence intervals • Systematic review[1] of Level I RCTs (and study results were homogenous[2])
Level II	• Lesser quality RCT (e.g. < 80% follow-up, no blinding, or improper randomization • Prospective[3] comparative study[4] • Systematic review of Level II studies or Level 1 studies with inconsistent results
Level III	• Case control study[5] • Retrospective comparative study[6] • Systematic review of Level III studies
Level IV	Case series[7]
Level V	Expert opinion

1) A combination of two or more results; 2) Studies provided consistent results; 3) Study was started before the first patient was enrolled; 4) Patients treated in one way compared with patients treated in another way at the same institution; 5) Patients identified for the study based on their outcome, called "cases"; 6) The study was started after the first patient was enrolled; 7) Patients treated in one way with no comparison group, or patients treated in another way. Source: http://www.spine.org/forms/LevelsofEvidenceFinal.pdf

Table 2. The Delphi items for randomized clinical trials (Verhagen et al., 1998): scored as yes (+), no (-) or don't know (±)

Delphi items
1)Treatment allocation
A Was a method of randomization performed?
B Was the treatment allocation concealed?
2) Were the groups similar at baseline regarding the most important prognostic indicators?
3) Were the eligibility criteria specified?
4) Was the outcome assessor blinded?
5) Was the care provider blinded?
6) Was the patient blinded?
7) Were point estimates and measures of variability presented for the primary outcome measures?
8) Did the analysis include an intention-to-treat analysis?

Results

Characteristics of the 45 studies included are given in Table 3. Twelve studies reported on the efficacy of various forms of conservative intervention. Eight studies reported on the effects of the conservative intervention alone (Fricker et al.,1991; Holt et al., 1995; Hölmich et al., 1999; McKim & Taunton, 2001; Rodriguez et al., 2001; O Connell et al., 2002;, Topol et al., 2005, Verrall et al., 2007); other studies (n =4) reported on conservative management compared with surgical intervention (Smedberg 1985a; Martens et al., 1987; Kalebo et al., 1992; Ekstrand & Ringborg, 2001).

Table 3. Study characteristics

Study	n	Diagnosis	Intervention	Follow up	Main results	Level of evidence
Hölmich et al. (1999)	59 M	Adductor tendinopathy	Gr 1 Active training during maximum 12 weeks (n=30) Gr.2 Passive therapy during maximum 12 weeks (n=29)	7 months after start intervention	Gr. 1 79% returned to same or higher level of sports without groin pain Gr. 2 14% returned to same or higher level of sports (p=0.006) without groin pain	I
Fricker et al. (1991)	50 M, 9 F	Osteitis pubis	NSAID's Stretching and strengthening, mobilizing, restricted activity, acupuncture	M: 2-92 months (mean 17.5) F: 1-20 months (mean 10.3)	F: Full recovery in 7 months (mean) M: Full recovery in 9.5 months (mean); 25% recurrence	IV
Holt et al. (1995)	10 M, 2 F	Osteitis pubis	Corticosteroids injection in pubic symphysis	6 months-4 years	8% was cured with rest; 25% had 1 injection and returned to full sports after 3 weeks; 25% had 2 injections and returned to full after 11-16 weeks after first injection. 8% had 3 injections, full participation after 2 weeks 1 athlete remains symptomatic after 2 injections.	IV
McKim & Taunton (2001)	9 M, 2 F	Osteitis pubis	Compression shorts	-	VAS and numeric rating scale show significant lower scores wearing compression shorts. No significant differences on functional tests	IV
O'Connell et al. (2002)	16 M	Osteitis pubis	Corticosteroids injection in symphyseal cleft	2 weeks, 3 and 6 months	87,5% immediate relief and able to resume sporting after 48hrs 12.5% only pain on provocation, but all less pain 2 months: 31% had persisting symptoms 6 months: 31% had persisting symptoms	IV

Table 3. continued

Study	n	Diagnosis	Intervention	Follow up	Main results	Level of evidence
Rodriguez et al. (2001)	35 M	Osteitis pubis	800mg Ibuprofen 3dd, 14 days, cryo- massage, laser, ultrasound r electric stimulation,14 days, + rehabilitation.		Symptom remission stage I* group 3-65 days (mean 3.8 weeks) Symptom remission stage II* group 9-83 days (mean 6.7 weeks) Symptom remission stage III* group 10 weeks	IV
Topol et al.(2005)	24 M	Osteitis pubis and adductor tendinopathy	Monthly injection in tender region (12.5% dextrose and 0.5% lidocaine) + rehabilitation	1 month and 6-32 months (mean 17.2)	1-2 treatments: returned to sports activity in 6 weeks > 2 treatments returned in 3 months Mean 2.8 treatments VAS pain improved from 6.3±1.4 to 1.0±2.4; Sport-related improved from 5.3±0.7 to 0.8±1.9 (NPPS-list), both at mean 17.2 months)	IV
Verrall et al. (2007)	27 M	Chronic groin injury	12 weeks rest from running, physiotherapy for pelvic/ core stability after 3-6 weeks	5, 7,12, 24 months	63%/ 78% playing at 5/ 7 months, 41% without symptoms at 5 months; 89%/ 100% playing at 12/ 24 months; 67%/ 81% playing without symptoms at 12/ 242 months; 74% at same level (24 months)	IV
Ekstrand & Ringborg (2001)	66 M	Chronic groin pain	Gr. 1 Bassini+neurotomy (n=17) Gr. 2 physiotherapy (n=14) Gr. 3 Abdominal training (n=18) Gr. 4 no treatment (n=17)	3 and 6 months	Gr. 1 significant decrease in symptoms at coughing & sit-ups. Gr. 2,3 and 4 did not change (3 months, p<0.05) Gr. 2,3,4 decrease of symptoms at jogging, kicking and sprinting at 3 months,. At 6 months only Gr. 1 decrease in symptoms. Cross-over (n=23) led to reduction of all symptoms (no further p-values)	II

Table 3. continued

Study	n	Diagnosis	Intervention	Follow up	Main results	Level of evidence
Smedberg et al. (1985a)	76 M	(Suspected) groin hernia	Gr 1. Hernia repair (53, all positive herniography) Gr. 2. Various conservative treatments (23)	11-100 months (mean 41)	Gr. 1 81.1% returned to full athletic activity, 16.9% reduced activity Gr. 2 34% cured,55% improved, 11% unchanged/ worse (contains both positive herniographs)	III
Martens et al. (1987)	102 M, 7 F	Adductor tendinitis and abdominis tendopathy	Gr. 1 (n=29): conservative management Gr. 2 (n=84): surgery; Adductor tenotomy (gracilis, adductor brevis (some) + some Bassini hernia repair	6 months- 5 years (mean 2 years)	Gr. 1 36% excellent or good results. 3 months to resume sports activity Gr. 2 Adductor tenotomy 53% excellent, 28% good results. Adductor tenotomy and/or Bassini 72% excellent, 22 % good results. No loss of power in adductor strength in most cases, group training after 10-14 weeks	III
Kalebo et al. (1992)	32 (M/F?)	Partial rupture of adductor/ abdominal tendons	Gr. 1 Conservative (n=22); Gr. 2 excision abnormal tissue (n=9); tenotomy(n=1)	12-36 months (mean 21)	Gr. 1 14 returned to sport activities at same level, 6 lower level, 2 unimproved. Gr.2 7 returned to sport activities at same level, 2 lower level, 1 worse	III
Ingoldby (1997)	28 M	Groin disruption	Gr. 1 Modified Bassini (n=3) and Lichtenstein (n=11) Gr. 2 Laparoscopic (n=14)	3 weeks and ?	Gr. 1 9/14 resumed training after 4 weeks; Full contact at median 5 (range1-6) weeks Gr. 2 13/14 resumed training after 4 weeks; Full contact at median 3 (range 1-9) weeks	III
Polglase et al. (1991)	46 M	PAWD*	Bassini repairs (n=51) or plications (n=30) neurotomy ilioinguinal nerve in 32 cases	> 8 months	62% returned to competitive sports 31.1% partially satisfied bur returned to sport	IV

Table 3. continued

Study	n	Diagnosis	Intervention	Follow up	Main results	Level of evidence
Taylor et al.(1991)	7 M, 2 F	2 pubalgia, 7 inguinal hernia	Modified Bassini	-	All returned to full activity within 3 months	IV
Malycha & Lovell (1992)	50	Sports hernia	Open technique repair posterior wall+training advice	6 months	n=44 93% returned to preinjury level; subjective score 75% good; 23% improved; pre-ok pain score 7.3(sd 1.4) ; post 1.2 (sd 1.6)	IV
Akermark & Johansson (1992)	16 M	Chronic groin pain	Adductor tenotomy	4-84 month (mean 34.8)	10 full athletic activity (14 weeks) 5 reduced level (14 weeks) 1 discontinued (other reasons) decrease in adduction strength	IV
Hackney (1993)	14 M, 1 F	Sports hernia	Repair conjoined tendon	18 months-5 years	12 returned to full competition; 1 other injury; 2 received adductor tenotomy and improved after	IV
Williams & Foster (1995)	6 M	Sports hernia	External oblique tear repair	6 weeks	All returned to full sports participation within 6 weeks; follow-up revealed no further pain.	IV
Simonet (1995)	10 M	PAWD*	direct Bassini (n=2) Modified Bassini (n=7)	6 months- 4 years	All returned to previous level All improved in symptoms	IV
Bradshaw et al. (1997)	31 M, 1 F	Obturator nerve entrapment	Gr. 1. obturator neurolysis (n=24) Gr. 2 obturator neurolysis & hernia repair (n=5) Gr. 3 removal of scar tissue (n=3)	Mean 23 months (sd 2.4)	Patients in gr. 1 & 3 resumed full sporting participation within 3-6 weeks. Gr. 2 resumed at 6-9 weeks. EMG of n. obturator returned to normal at 6 and 12 weeks after surgery.	IV
Gilmore (1998)	>1200 M	Sports hernia	Six layered suture repair + rehabilitation	-	Average return to play six weeks; 97% successful	IV

Table 3. continued

Study	n	Diagnosis	Intervention	Follow up	Main results	Level of evidence
Lacroix et al (1998)	11 M	Hockey player syndrome	Oblique aponeurosis repair neurectomy ilioinguinal nerve + rehabilitation	-	91% resumed careers within 8 weeks	IV
Orchard et al. (1998)	9 M	Canal insufficiency	Modified Bassini	At least 12 months	5 excellent results 2 had residual pain 2 fair results	IV
Evans (1998)	169 M	Sports hernia	Laparoscopic (bilateral) repair + supervised rehabilitation program	>2 months	Recuperation was quick, no difference in time till return to sports for single or bilateral repairs. 19 returned with persistent complaints	IV
Ziprin et al. (1999)	25 M	Nerve entrapment	Division of neurovascular bundles + open external oblique aponeurosis tear repair + rehabilitation program	7-56 months (mean20.6)	4-20 weeks to resumption sporting activities (mean 11.6 weeks) 20 out of 23 scored results as excellent (20.6 months)	IV
Williams et al. (2000)	7 M	Osteitis pubis and symphyseal instability	Arthrodesis and compression plate + rehabilitation	10 months-12 years (mean 52 months)	Resumed light training at mean 3.7 months (range 3.6 months) Time to return to match months range 5-9 months All compression plates remains in situ.	IV
Meyers et al. (2000)	137 M, 20 F	Athletic pubalgia	Rectus abdominus reattachment with/ without epimysial adductor release	25 month-12 years (mean 3.9 years)	89% no pain and full athletic activity (6 month) 6% less pain and similar (6 month) 3% less pain lower athletic activity (6 month) 2% no improvement	IV

Table 3. continued

Study	n	Diagnosis	Intervention	Follow up	Main results	Level of evidence
Brannigan et al. (2000)	85 M	Gilmore's groin	Modified Bassini	-	79 athletes returned to competitive sports (10 weeks) 3 athletes returned to competitive sports (15 weeks) 3 never returned	IV
Irshad et al. (2001)	22 M	Hockey groin syndrome	Oblique aponeurosis repair neurectomy ilioinguinal nerve (n=19 had a mesh)	2.5-139 months (mean 31.2)	82% had no pain, 4 mild intermittent pain All returned to competitive sports 86% resumed professional career	IV
Kumar et al. (2002)	26 M, 1 F	Sports hernia	Open repair of oblique tear (n=14) and prolene darn or Lichtenstein mesh (n=27)	6 months	93% returned to normal athletic activity to pre-injury level in average 14 weeks (range 6-24) Pain median VAS score improved from 8 (range 2-9) to 2 (range 0-6)	IV
Srinivasan (et al. (2002)	15 M	Sportsman's hernia	Laparoscopic preoperational hernia repair	6-80 months (mean 12.1)	all athletes resumed full unrestricted activity in 2-8 weeks; 87% full unrestricted athletic activity 4 weeks after surgery 100% return to activity at mean 12.1 months	IV
Van der Donckt et al. (2003)	41 M	Athletic pubalgia	Bassini repair + adductor tenotomy + rehabilitation	6 month after surgery	90% Sport activities at same level 10% Sport activities at lower level	IV
Biedert et al. (2003)	24 M	Chronic symphysis syndrome	Spreading shed rectus abdominus Adductor release	1.2-12.3 years (mean 6.6)	96% previous level of sports (3-4 months) 58 % full improvement on physical examination 88% Very content, 8% content, 4% no improvement (6.6 years)	IV

Table 3. continued

Study	n	Diagnosis	Intervention	Follow up	Main results	Level of evidence
Hemingway (2003)	16 M	PAWD*	Open procedure mesh repair and rehabilitation	6 weeks	No differences between legs and between controls and operated subjects in hip muscle strength. Pain of operated subjects improved (6 weeks)	IV
Susmallian et al. (2004)	35 M	Sports hernia	Laparoscopic exploration and repair	Mean 14.6 months	97.1% returned to normal activities 2.9% did not return in sports (no cause found)	IV
Genitsaris et al. (2004)	131 M	PIWD#	Bilateral Laparoscopic hernia repair (mesh)	4 months-5 years	All back to recreational sporting activities within 1 week and back to full sporting activities within 3 weeks	IV
Kluin et al. (2004)	14 M	Undiagnosed groin pain	4 transabdominal, 10 total extraperitoneal endoscopic exploration (+ repair)	3 months and 1 year	78% no symptoms 17% minor, 6% major (3 months) 89% no symptoms 6% minor, 6% major (1 year) 11 returned to full sports within 3 months	IV
Paajanen et al. (2004)	41 M	Sports hernia	total extraperitoneal endoscopic repair	1 month and 4.2±1.8 years	> 90% resumed full sporting activity (1 month) 95% painless, 5% symptoms in training (4.2±1.8 years)	IV
Steele et al. (2004)	47 M	PIWD#	Modified Bassini	18 groins < 1 year, 34 groins > 1 year	100% felt symptoms improved 40 of 52 groins repaired full returned to sports (1 month-1 year, average 4 months)	IV

Table 3. continued

Study	n	Diagnosis	Intervention	Follow up	Main results	Level of evidence
Paajanen et al. (2005)	5 M	Osteitis pubis	total extraperitoneal endoscopic hernia repair	1, 6 and 12 months	Full sporting activity gradually resumed after 4-8 weeks, no pain after 1, 6 and 12 months MRI decreased bone marrow edema (3)	IV
Ahumada et al. (2005)	11M, 1F	Athletic pubalgia	9x open approach mesh 4 x adductor tenotomy	2-13 month (mean 4)	6 months after surgery all returned to sports	IV
Diaco et al. (2005)	96 M	Athletic pubalgia	Rectus abdominus reattachment with/ without adductor release, modified Bassini, Lichtenstein, or laparoscopic repair	-	97% returned to preinjury level with little or no pain. 2 little or no relief 94% full activity within 6 weeks	IV
Edelman & Selesnick (2006)	10 M	Sports hernia	Laparoscopic placement of biological (resolvable) mesh	1 year	All returned to normal activities within one month, one athlete did not improve after surgery	IV
Van Veen et al. (2007)	53 M, 2 F	Undiagnosed chronic groin pain	total extraperitoneal endoscopic mesh placement	-	88% of all athletes returned to normal sports activities within 6-8 weeks; 9% was unable to participate at 12 weeks, but resolved with physiotherapy and rest	IV

The studies concerning results of conservative interventions (n=8) are described in the first part; studies concerning both conservative and surgical interventions (n=4) are described in the middle part; studies concerning only surgical intervention (n=33) are described in the latter part.
M: males; F; females;* PAWD: posterior abdominal wall deficiency; # PIWD: posterior inguinal wall deficiency

Conservative management interventions
Conservative management consisted overall of a period of restricted activity (n=12) sometimes in combination with NSAIDs (Smedberg et al., 1985a; Martens et al., 1987; Holt et al., 1995; Fricker, 1997) and/ or physical therapy (Smedberg et al., 1985a; Martens et al., 1987; Holt et al., 1995; Hölmich et al., 1999; Ekstrand & Ringborg, 2001; Rodriguez et al., 2001; Topol et al., 2005; Verrall et al., 2007).
A stretching and flexibility program (separate or as part of physical therapy) was mentioned in several studies (Smedberg et al., 1985a; Martens et al., 1987; Fricker, 1997; Hölmich et al., 1999; Rodriguez et al., 2001), as was a strengthening program for the adductor muscles and/or abdominal muscles (Hölmich et al., 1999; Ekstrand & Ringborg, 2001; Rodriguez et al., 2001). Other studies describe the effects of steroid injections separately (Holt et al., 1995; O'Connell et al., 2002), or in combination with other conservative measures (Smedberg et al., 1985a; Martens et al., 1987) or dextrose prolotherapy ("injection of growth factors or grow-factor-production stimulants to promote growth and repair of normal cells and tissue"; Topol et al., 2005). Injection therapies were started after various other kinds of conservative treatment (i.e. rest, physical therapy) failed (Holt et al., 1995; O'Connell et al., 2002; Topol et al., 2005).

Results of conservative treatments
Fricker et al. (1991), using (a combination of) NSAID's, stretching and strengthening, mobilizing, restricted activity, acupuncture showed full recovery after on average 7 months for females, and on average 9.5 months for males. Hölmich et al. (1999) reported that the results of an active physical therapy training program, aiming at the muscles stabilizing the pelvis, are significantly better than a program consisting of passive, local applications: At follow up (7 months after diagnosis), 79% of the patients treated with active therapy returned to sports at the same or higher level of sports as pre-injury, without residual symptoms clinically or subjectively, compared with only 14% of the patients in the passive therapy group. A rehabilitation program applied by Rodriguez et al. (2001), combined local passive applications (electric stimulation, ultrasound, cryomassage) and a gradual increased physical loading program for athletes with osteitis pubis. All athletes were symptom free after 10 weeks of treatment. Verrall et al. (2007) reported positive short-term results after a period of rest, physical therapy aiming at stability of the trunk, and a graded return to running activities: 89% of the athletes returned to sports in the subsequent season, although only 41% was without symptoms at that time. In the study by Ekstrand & Ringborg (2001), patients treated with strengthening exercises did experience some short-term positive effects, whereas the long-term effects were not significantly different compared with a control group that received no treatment. Kalebo et al. (1992) did not give specific information on their conservative treatment.
If non-invasive therapies did not result in any effects, injections were used in

several studies. Holt et al.(1995) injected steroids directly in the region of the pubic symphysis when a period of rest (> 16 weeks after onset of symptoms) and progressive exercise showed no results; in their study, all athletes returned to sports after maximum 16 weeks. In contrast with these results, O'Connell et al. (2002) reported persisting complaints in 31% of their population at 6 months after a steroid injection. Topol et al. (2005) started prolotherapy in athletes that did not respond to rest or various kinds of physical therapy; all athletes returned to sports within 3 months.
Wearing compression shorts only influenced subjective pain scores, but did not increase functional performance (McKim & Taunton, 2001).
Considering long-term effects, only few data were available. Topol et al. (2005) reported significant decreases in pain and increases in function at a mean of 17.2 months after intervention. Fricker et al. (1991) reported an average of over 25% recurrence after initial recovery in sportsmen at 7 months. Verrall et al. (2007) reported asymptomatic sport participation two years after treatment by 81%, and 74% was playing at the same level of competition.

Surgical management
In total, 37 publications reported on the results of various surgical interventions. In most studies, surgical groin exploration revealed a deficiency or tear of the posterior abdominal wall (abdominal wall deficiency; AWD), the aponeurosis of the m. obliquus externus, or the insertion of the tendon of the m. rectus abdominus. AWD was treated in most studies. A torn aponeurosis of the m. obliquus externus was treated in 5 articles (Williams & Foster, 1995; Lacroix et al., 1998; Ziprin et al., 1999; Irshad et al., 2001; Kumar et al., 2002).. A "thin" or damaged insertion of the tendon of the rectus abdominis onto the pubic crest was found and repaired by Meyers et al.(2000), Biedert et al.(2003) and Diaco et al.(2005). Surgical interventions were also applied in cases where no defects of the abdominal wall could be identified (Paajanen et al., 2005; van Veen et al., 2007). A neurectomy of the ilioinguinal nerve during surgical intervention was mentioned in 3 studies (Polglase et al., 1991; Lacroix et al., 1998; Ekstrand & Ringborg, 2001).
Several techniques to repair the defect can be applied. During open techniques like Bassini or Shouldice hernia repair (Smedberg et al., 1985a; Martens et al., 1987; Polglase et al., 1991; Malycha & Lovell, 1992; Hackney, 1993; Simonet et al., 1995; Gilmore, 1998; Ekstrand & Ringborg, 2001; van der Donckt et al., 2003), the inguinal canal floor is reconstructed by suturing the edges of a tear. In a modified Bassini or Shouldice with mesh repair (Taylor et al., 1991; Simonet et al., 1995; Ingoldby, 1997; Brannigan et al., 2000; Hemingway et al., 2003; Steele et al., 2004; Ahumada et al., 2005; Diaco et al., 2005) the reconstruction is reinforced by placement of a mesh. Other techniques for hernia surgery are tension free; the tear is not sutured together, but is totally covered with a mesh. This can be achieved by using an open technique (Ingoldby, 1997; Diaco

et al., 2005) or laparoscopically (Ingoldby, 1997; Evans, 1998; Srinivasan and Schuricht, 2002; Genitsaris et al., 2004; Kluin et al., 2004; Paajanen et al., 2004; Susmalian et al., 2004; Paajanen et al., 2005; van Veen et al., 2007).
During a laparoscopic hernia repair, a mesh is placed over the defect from the inside. Two variations are known: the transabdominal, preperitoneal approach (Ingoldby, 1997; Genitsaris et al., 2004;Kluin et al., 2004), and the total extraperitoneal approach (Srinivasan and Schuricht, 2002; Paajanen et al., 2004; Susmalian et al., 2004; Paajanen et al., 2005). Some authors recommend adductor tenotomy in selected cases (Martens et al., 1987; Akermark and Johansson, 1992; Kalebo et al., 1992; Meyers et al., 2000). Martens et al. (1987) and Meyers et al. (2000) propose this procedure during surgical intervention for the abdominal wall. Kalebo et al (1992) and Akermark and Johnsson (1992) performed this procedure as a single intervention.
A surgical neurolysis of the obturator nerve was performed in one study on subjects with adductor muscle weakness and paresthesia and electromyographic evidence for nerve denervation is present (Bradshaw et al., 1997) .

Results of surgical interventions
After open approach surgery for single adductor tenotomy, Akermark & Johansson (1992) reported that 10/16 patients returned to full athletic activity within 14 weeks. Martens et al.(1987) and Kalebo et al. (1992) do not report time till return to sports, but 53% had excellent results and 20/22 returned to the same or lower level of sports (Martens et al., 1987), and 7/10 returned to their previous level of sports at follow-up (Kalebo et al., 1992). If combinations of AWD and local adductor insertion pain coexist, abdominal wall repair and tenotomy can be combined in one surgical intervention (Martens et al., 1987; Meyers et al., 2000; Biedert et al., 2003; Van Der Donckt et al., 2003; Ahumada et al., 2005; Diaco et al., 2005). After open surgical techniques for AWD (and adductor tenotomy), returning to athletic activity varies from 4-6 weeks (Malycha and Lovell, 1992; Hackney, 1993; Williams and Foster, 1995; Ingoldby, 1997; Gilmore, 1998; Diaco et al., 2005) up to 3-6 months (Martens et al., 1987; Taylor et al., 1991; Ziprin et al., 1999; Brannigan et al., 2000; Meyers et al., 2000; Kumar et al., 2002; Steele et al., 2004; Ahumada et al., 2005). Ekstrand & Ringborg (2001) described the results of an open technique and neurotomy of the ilioinguinal nerve used for athletes with a positive herniogram and/or positive nerve block test. Operated patients had significantly better results at 3 and 6 months follow-up compared with athletes that were treated conservatively.
Laparoscopic (hernia) repair seems to require less recovery time compared with an open approach. Ingoldby et al. (1997) treated patients using both an open approach and laparoscopically: 13/14 patients from the laparoscopic group returned to sports after only 4 weeks. Similar results were obtained by Genitsaris et al. (2004) (all patients returned to full sporting activity in 3 weeks), Srinivasan & Schuricht (2002) (87% return at 4 weeks), Paajanen et al. (2004) (90% return

at 4 weeks), Paajanen et al. (2005) (gradual return at 4-8 weeks) and van Veen et al. (2007) (return to normal sports activities between in 6-8 weeks). If a severe instability of the pelvic ring is thought to be the underlying mechanism, arthrodesis can be an option, which has shown good short-term results (Williams et al., 2000). Results of surgical neurolysis show a return to sports within 3-6 weeks for most patients with signs of obturator neuropathy (Bradshaw et al., 1997). Reported long-term results of surgery (> 1 year) range from reasonable (27/30 no loss in power (Martens et al., 1987); 7/10 excellent (Kalebo et al., 1992); 80% returned to full competition (Hackney, 1993); 5/9 excellent (Orchard et al., 1998); 82% good/excellent (Kumar et al., 2002)) to good (88% content (Biedert et al., 2003); 20/23 excellent (Ziprin et al., 1999); 97% returned to normal activity (Susmalian et al., 2004); 155/160 performing better or the same than pre-injury (Meyers et al., 2000); 100% return to activity (Srinivasan and Schuricht, 2002); 95% painless (Paajanen et al., 2004); 89% no symptoms (Kluin et al., 2004)). Generally, very few recurrences and complications have been reported.

Levels of evidence

For all studies, the level of evidence was determined (Table 3, right-hand column). A total of 39 studies had level IV evidence. The number of subjects used in these studies was very low in most studies; only eight studies included more than 75 subjects (Smedberg et al., 1985a; Martens et al., 1987; Evans, 1998; Gilmore, 1998; Brannigan et al., 2000; Meyers et al., 2000; Genitsaris et al., 2004; Diaco et al., 2005)

Besides the study by Hölmich et al. (1999) and Verrall et al. (2007), inclusion (and exclusion) criteria were described poorly or not at all. A clear diagnosis prior to surgery was not reported in most articles, despite the use of extensive investigations using imaging techniques (X-ray, bone scan, MRI or herniography, CT scan). It must be noted that, in most studies concerning surgery, surgical exploration was only an option if patients did not respond to conservative measures (Akermark and Johansson, 1992;Gilmore, 1998; Lacroix et al., 1998; Ziprin et al., 1999; Brannigan et al., 2000;Williams et al., 2000; Irshad et al., 2001; Kumar et al., 2002; Srinivasan and Schuricht, 2002; Biedert et al., 2003; Van Der Donckt et al., 2003;Genitsaris et al., 2004; Kluin et al., 2004; Paajanen et al., 2004; Steele et al., 2004;Susmalian et al., 2004; Ahumada et al., 2005; Diaco et al., 2005; Edelman and Selesnick, 2006; van Veen et al., 2007). Furthermore, in surgical studies, a detailed description of the kind of physical therapy the patients had undergone, but failed to give positive results, was only reported in 3 studies describing surgery (Kumar et al., 2002; Biedert et al., 2003; Ahumada et al., 2005) . Therefore it is extremely difficult to judge whether populations under investigation are similar in both conservative and surgical intervention studies. Additionally, if imaging techniques were used to confirm diagnostics, the results of these techniques were not presented in most studies.

In treatment outcome parameters, "return to sports", "time till return to sports" and "level of sports" and "symptoms at playing sports" are considered to be relevant outcome parameters in sports medicine. Only two studies described results with respect to all these variables (Hölmich et al., 1999; Verrall et al., 2007). Some studies present the results of their intervention in terms of symptom relief or a subjective score by the investigator or patient (Martens et al., 1987; Gilmore, 1998; Orchard et al., 1998; Hemingway et al., 2003; Edelman and Selesnick, 2006). These parameters do not fulfill the criteria of determining sports-related restrictions. Subjective scores relating to sports function have better external validity than imaging techniques or physical exam parameters or measures of personal satisfaction. If a patient decided to quit athletic activity anyway, a higher level of satisfaction is easier achieved. Most studies used sports-related outcome parameters. Follow up as part of the recovery monitor process was mostly given 3-6 months after intervention. Long term results were reported in several studies, but only one study reported these consequently after a distinct period of time for each patient (Verrall et al., 2007) .
Regarding the designs used, only four studies were prospective (Hölmich et al., 1999; Ekstrand & Ringborg, 2001; Susmalian et al., 2004;Verrall et al., 2007). Most studies were retrospective and data were collected over longer periods of time, ranging from 1 up to 12 years; therefore, a patient selection bias seems obvious. Only one study has given any insight in the percentage of patients referred for surgery, since they did not respond to conservative measures. This was only 27% (n= 35) of all patients. Therefore, 73% of the patients suffering the same or similar complaints did respond to conservative measures (Susmalian et al., 2004).
The methodological quality of 7 studies (better than level IV) that described the results of some kind of control group was scored by the two reviewers using the Delphi criteria (Table 2). Before the consensus discussion, the percentage of agreement was 85%. The results of quality assessment after consensus are presented in Table 4.

A randomization process over > 1 intervention was only applied by Hölmich et al. (1999) and Ekstrand & Ringborg (2001). A detailed, reproducible description of all treatments applied was only given in one study (Hölmich et al., 1999). Several other studies present some results of an alternative treatment, but a proper description of these treatments is not available (Smedberg et al.,1985a; Martens et al., 1987;Kalebo et al., 1992) and therefore definite conclusions can not be drawn. Overall, the methodological quality of the selected studies is low.

Table 4. Methodological score on Delphi items for studies better than level IV after consensus discussion. + = yes; - = no; ± = don't know

Publication	Delphi items								
	1A	1B	2	3	4	5	6	7	8
Hölmich et al. (1999)	+	+	+	+	+	-	-	+	+
Ekstrand & Ringborg (2001)	+	±	+	+	±	-	-	-	-
Smedberg et al. (1985a)	-	-	-	-	±	-	-	-	-
Martens et al. (1987)	-	-	-	-	±	-	-	-	-
Kalebo et al. (1992)	-	-	-	+	±	-	-	-	-
Ingoldby (1997)	-	-	+	-	-	-	-	-	-

Discussion

The aims of this systematic review were 1) to investigate the treatments applied for athletes with LGP; 2) the results of these treatments; and 3) the levels of evidence for the studies describing these interventions. Despite the fact that, between studies, different pathologies are provided as an explanation, treatment strategies for pathologies like sportsman's hernia, osteitis pubis and hockey player syndrome tend to have many similarities.

In athletes with LGP, conservative measures are generally tried first. Conservative measures consist of rest, physical therapy, NSAIDs and steroid injections or prolotherapy. There is level I evidence for the positive effects of an active physical therapy program aiming at strengthening the muscles stabilizing the hip and pelvis, although this is based on only one RCT (Hölmich et al., 1999). The conservative measures applied in the study by Rodriguez et al. (2001) have strong similarities with the active training program by Hölmich et al. (1999) and also shows positive results, but the methodological quality of this study is poor. The studies describing the use of steroid injections reported a return to sports for all subjects; unfortunately, no single study concerning injections that had a control group could be identified. Return to sports within one year after intervention for osteitis pubis, as reported by Holt et al. (1995) is also mentioned in two case reports (Briggs et al., 1992; Batt et al., 1995). However, Lynch & Renström (1999) reported that, in most cases, osteitis pubis is a self-limiting disease that will heal normally over several months; therefore, there is no evidence for any additional effects for steroid injections. The use of dextrose prolotherapy, as described by Topol et al. (2005) may be an alternative for steroid injections, although the level of evidence is poor as well (level IV). This type of conserva-

tive injection treatment has to be investigated extensively in the future in randomized trials.
If conservative measures have failed, surgical exploration is described as a (final) option. In several case series studies, the argument that patients serve as their own controls is given. Generally, a patient will go through the process described in Figure 1. As a result of this process, conclusions of these studies are only valid for a very select population, i.e. those not responding to various conservative interventions.
It must be noted that the surgical interventions vary between studies, since the operative findings in studies focusing on surgical repair are not similar (Fredberg and Kissmeyer-Nielsen, 1996). However, generally some kind of deficit in the abdominal wall was identified at surgery. A (modified) Bassini hernia repair, or repair by placement of a mesh, is the method applied mostly during surgical exploration in patients with suspicion of sports hernia. Most studies describing surgery for the abdominal wall present good or even excellent results; however, levels of evidence for these studies are generally low (level IV). The lack of high quality RCTs might be caused by a relatively low prevalence of LGP in athletes, which may result in long study times of up to 12 years (Williams et al., 2000).

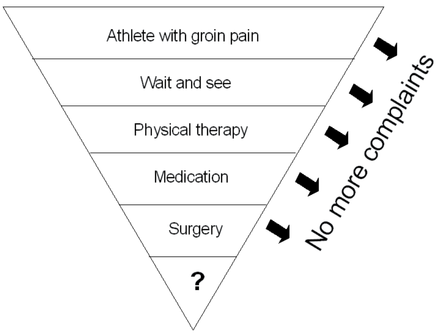

Figure 1. Patient selection in surgical case series studies. Since the diagnostic process does not give proper insight in the etiology of the complaints, an experience-based process will filter patients to the appropriate treatment. A group that will continue suffering from complaints cannot be overcome.

In one moderate quality RCT (level II), Ekstrand & Ringborg (2001) showed that surgical intervention by means of a Bassini hernia repair and neurotomy has better results than conservative treatment or no treatment in patients with LGP, and verified pathology in the form of incipient hernia at herniography and/or positive nerve block test of the ilioinguinal or iliohypogastric nerve. By adding these criteria, a patient selection takes place. Therefore, conclusions can not account for LGP in athletes in general. Nevertheless, this RCT does provide some information about the efficacy of surgery in this specific population, but high quality RCTs with detailed population description are needed.
Concerning the surgical approach, Ingoldby (1997) showed (in a level III study) that patients treated laparoscopically had earlier return to sports compared with patients who underwent an open approach surgical intervention. This sup-

ports a laparoscopic repair over open repair, which is in accordance with data having a high level of evidence, known for hernia repair in the non-athletic population (Bittner et al., 2005).
Hess (1980) stated, that in cases of an inguinal hernia, pain arises when the peritoneum moves into a gap as a result of high intra-abdominal pressure during sports activities. In a study by Smedberg et al. (1985b), a hernia was also identified at the asymptomatic side in 49% of the patients. Therefore, herniation does not have to be the (single) cause for complaints. Meyers et al.(2000) reattached the tendon of the rectus abdominus to stabilize the pubic symphysis. In other words, an imbalance of forces acting on the anterior pelvis was thought to be the cause of persisting symptoms, instead of an anatomical defect. Biedert et al. (2003), Diaco et al.(2005), Orchard et al.(1998) and Paajanen et al. (2005) also performed a hernia repair on patients who (also) had signs of osteitis pubis on physical examination, bone scan, MRI or X-ray. After placement of a mesh, complaints disappeared and MR images returned to normal. In literature, there are more indications that instability of the anterior pelvis might be a cause for groin complaints. In a recent study by Mens et al. (2006) 38% of the athletes with LGP had a highly significant increase in maximum adduction strength when wearing a pelvic belt, which can be applied to stabilize the pelvis. In the study by Hölmich et al. (1999), radiographic signs for osteitis pubis were present in over 60% of their population. By focusing the therapy on improving strength and coordination of the muscles stabilizing the hip and pelvis, 79% of the patients treated with this therapy had returned to the same or higher level of sports without symptoms at 4 months after treatment period. Case reports by Mc Carthy and Vicenzino (2003) and Wollin & Lovell (2006) reported even earlier return to athletic activity after a therapy for osteitis pubis, specifically aiming at strengthening the pelvic floor muscles and transverse abdominal muscle, who are known to be able to actively stabilize the pelvis (Richardson et al., 2002; Pool-Goudzwaard et al., 2004). On the other hand, Verrall et al. (2007), describing a similar exercise intervention, also reported good results on return to sports, but not all were able to participate without symptoms. The fact that a bulging of the abdominal wall, seen at ultrasound investigation in athletes with LGP during Valsalva maneuver, only slightly reduced after Bassini hernia repair, but with total disappearance of complaints, supports the theory that a restoration of balance might play an more important role than the bulging itself (Orchard et al., 1998). As stated by Biedert et al. (2003): "weakness or inability to stabilize the pelvis and the lumbo-sacral connection or false movement patterns are often the beginning of a negative story". Results described by Hölmich et al. (1999) support this theory. However, whether this theory is valid can only be determined in prospective cohort studies.

Perspectives

Longstanding groin pain in athletes is difficult to treat since signs and symptoms of different pathologies are very similar. Generally, conservative measures are tried first, consisting of an initial period of rest or restricted activity, followed by physical therapy aiming at the active stability of the pelvis and hip, which has shown good results in one high quality RCT. If this should not have the desired effects, steroid injection or prolotherapy can be used, although there is no scientific evidence for its efficacy. If this does not result in symptom remission, surgery might be indicated, since one moderate quality RCT shows that surgery seems to have better results at short and middle long term than further conservative therapy. Comparing the studies describing laparoscopic interventions to reinforce the abdominal wall with those describing an open approach, laparoscopic intervention may result in earlier return to sports. These surgical studies on sports-related groin pain are of poor quality, although the conclusion is supported by high quality research in the non-athletic population. There is no scientific evidence that an adductor tenotomy is of any additional value. There is need for more high quality RCTs investigating longstanding groin pain in athletes.

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CHAPTER 4

Longstanding adduction-related groin pain in athletes: Regular care by Dutch physical therapists

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Translated from: JACG Jansen, JMA Mens, FJG Backx, F Bous, C Kruiswijk, SL Schmikli, HJ Stam. Fysiotherapeutische behandeling van sporters met langdurige liesklachten. Sport en Geneeskunde 2008; 3: 6-12

Abstract

In the Netherlands, no guidelines are available for the treatment of longstanding groin pain by physical therapy. This study evaluated the current practice of physiotherapists in the treatment of longstanding groin pain among athletes. For this, a questionnaire describing a typical case was sent to physical therapists in the region of Utrecht.
All 36 physical therapists who responded had experience in treating this particular group. The majority (62%) often/always applied friction, stretching the adductor muscles (78%), mobilization of the hip (60%), strengthening exercises for hip and abdominal musculature (>60%), as well as stabilization exercises for hip and spine (>65%). Physiotechnical applications and manual therapy are applied by a minority (<40%).
The respondents' treatment is based on gaining optimum function of the kinetic chain. Only a part of the treatment provided by the respondents is evidence based. There is lack of high-quality research in the field of conservative treatment of longstanding athletic groin pain.

Introduction

Injuries as a result of sports are a major social concern. In the Netherlands, with about 420,000 injuries a year, soccer is held responsible for the largest contribution to the number of sports injuries per annum (Schmikli, 2005). About 10% of all injuries in soccer occur to the groin (Hawkins et al., 2001); moreover, once a groin injury has occurred, the risk for a subsequent injury to the same region is relatively high (Hägglund et al., 2006). About 10% of groin injuries do not recover within three weeks (Arnason et al., 2004). Because in chronic cases diagnosis is difficult (Jansen et al., 2008), the treatment of groin pain in athletes remains a challenge. Due to the lack of a guideline for the physiotherapeutic treatment of longstanding adduction-related groin pain (LAGP) in athletes, many treatment modalities can be applied. These modalities range from completely passive types, e.g. massage, ultrasound and transcutaneous electrical nerve stimulation (TENS), to completely active training programs, e.g. cardiovascular training and sport-specific exercises. To our knowledge, only one randomized controlled trial on physical therapy for longstanding groin pain has been published (Hölmich et al., 1999). The authors conclude that an active treatment consisting of strengthening and stabilizing exercises results in better outcome compared with a passive treatment consisting of stretching, friction, LASER treatment and TENS.
The main aim of the present study is to describe the regular care for LAGP provided by physical therapists (PTs) in the Utrecht region of the Netherlands. Secondly, to investigate whether any relation exists between the categories of interventions applied in the physiotherapeutic treatment of athletes with LAGP.

Methods

The group of PTs was recruited using the digital telephone directory searching for PTs in the Utrecht region (the Netherlands). In total, 220 PTs were asked via telephone about their experience with sports-related groin injury. Of these, only 36 PTs had treated athletes with groin pain on a regular basis. In October 2004, these 36 PTs were sent a questionnaire. No further selection criteria were used and all PTs who responded were included in the present study.
The questionnaire had two parts. The first part asked for details about personal characteristics and the practice setting; this section consisted of 19 variables.
The second part presented a hypothetical case of an athlete (resembling a soccer player) complaining of groin pain (see Table 1). Questions were asked about the usual care the PT would apply for a patient similar to the described soccer player. A total of 48 different modalities were presented divided over 10 main categories of treatment: mobilizing (3); stretching (8); strengthening (8); stabilizing (3); cardiovascular training (1); functional sport-specific training (1);

massage (6); physiotechnical applications (13); manual therapy (3); advice and information (2). The options per modality were "never", "sometimes", "often" and "always".

Table 1. Description of the hypothetical soccer player used in the ques

Type of sport	Soccer
Gender, age	Male, 32 years
Level of sports	First team, amateur level for several years
Practice/games	Training twice a week, competition once a week
Injury type	Longstanding, progressive
Injury duration	3 months
Injury location	Groin region
Physical examination	Pain at resisted adduction and palpation of the groin area
Imaging	X-ray
Therapy until now	Massage, adaptive training
Referred by	General practitioner
Likert pain score (0-10)	5

Statistical analyses

Descriptive statistics are used to describe the characteristics of the PTs and the practice setting. The use of treatment modalities is presented as percentages. Interventions that were often/always used by ≥ 60% of the participating PT's served as input for a model of physiotherapeutic care.

Furthermore, relations between categories of interventions were investigated. Data were prepared for analysis by obtaining a normal distribution using a data reduction procedure. The original score of four answers per item was reclassified into a bivariate score per main category ('0' for 'below average', and '1' for 'above average'). The following principles were used: if a PT's answers on every item within one main category are "never" at all times, then the main category is scored "0". If a PT's answers within one main category contained at least one "always", then the main category was scored "1". Approaching a fifty-fifty division for each main category was obtained by using cut-off point selection criteria. In order to find the optimum cut-off point, the scores "never",

“sometimes” and “often” were quantified using ‘0’, ’1’ and ‘2’, respectively. The sum of these scores on the items within one main category was the total categorical score per PT. A cut-off point was selected if the fifty-fifty division of all PTs over ‘0’ and ‘1’ was approached. If answers on items were missing, these items were scored ‘0’. Cardiovascular training, functional sport-specific training, and advice and information were not re-classified because these categories consisted of only one item each. In these latter categories, the answers ‘never’ and ‘sometimes’ were scored ‘0’, and scores ‘often’ and ‘always’ were scored ‘1’. A factor analysis was performed to find relations between categories of interventions. The strength of the relations are presented as odds ratios (OR) with confidence intervals (CI).
SPSS statistical software version 12.0.2 was used for data analysis. The level of significance was set at $p < 0.05$ bilaterally.

Results

Subjects and practice setting
All 36 PTs who received a questionnaire responded; 78% of the respondents were male. Mean age of the respondents was 42 (range 23-61) years. The working hours of the PTs were on average 35 (range 9-60) hours per week. The respondents had on average 16 (range 1-38) years of working experience as a PT after completing their PT education and (at the time they completed the questionnaire) 92% of the PT’s were a member of the national professional organisation for PT’s (Royal Dutch Society for Physical Therapy; KNGF). Of the 36 respondents, 86% currently attended at least one type of continuing education, and 14% did not. An education in sports physiotherapy had been completed by 14 PTs (40%), whether or not in combination with another type of additional education. Other types of relevant continuing education were manual therapy (55%) and academic education (17%). Of the respondents, 36% were self-employed, 17% were employed by others, and the employment status of the remaining 47% was unclear.
The average practice of the respondents contains: a practice room (83%), treadmill (69%), pulley (89%), cycle-ergometer (89%), row-ergometer (50%), cross-trainer (50%), therapy master (22%), squat-rack (47%), separate dumb bells (89%), dynaband (94%), and a Swiss ball (83%).
All 36 PTs had treated an athlete comparable to the hypothetical soccer player.

Soccer player case
Each year the PTs treated (on average) 6 (sd 4.0) patients resembling the hypothetical soccer player. The treatment consisted of (on average) 13 (sd 4.4) visits during 8.5 (sd 4.6) weeks; the average time per visit was 27 (sd 9.0) minutes. Table 2 lists the 48 different treatment modalities used by the PTs.

Table 2. The 48 different treatment modalities used by the 36 respondents. Respondents' answers over the 10 categories are given in percentages. Interventions often/always used by ^{3}60% of the respondents are reported in the right-hand column.

		Never (%)	Some-times (%)	Often (%)	Always (%)	Often/ always ^{3} 60%
Mobilizing	Hip	0	40	42	18	60%
(3)	Pelvis/Sacroiliac joints	0	47	39	14	
	Lumbar spine	0	45	39	16	
Stretching	Hip adductors	0	22	33	45	78%
(8)	Hip abductors	47	36	11	6	
	Hip extensors	25	44	20	11	
	Hip flexors	0	33	45	22	67%
	Quadriceps	6	49	31	14	
	Hamstrings	6	44	42	8	
	Abdominal musculature	56	33	3	8	
	Back musculature	39	39	14	8	
Strengthening	Hip adductors	8	19	26	47	73%
(8)	Hip abductors	3	33	39	25	64%
	Hip extensors	8	28	42	22	64%
	Hip flexors	17	31	22	30	
	Quadriceps	0	39	33	28	61%
	Hamstrings	11	36	31	22	
	Abdominal musculature	3	17	44	36	80%
	Back musculature	6	36	39	19	
Stabilizing	Hip	16	14	31	39	70%
(3)	Pelvis/Sacroiliac joints	14	28	31	27	
	Lumbar spine	11	22	42	25	67%
Cardiovascular (1)	Endurance	28	17	44	11	

Table 2 continued

		Never (%)	Some-times (%)	Often (%)	Always (%)	Often/ always [3] 60%
Sport-specific exercises (1)	Specific skills	3	16	22	59	81%
Massage	Friction	19	19	33	29	62%
(6)	Connective tissue	56	22	11	11	
	Lymph drainage	86	11	3	0	
	Relaxing	28	25	33	14	
	Toning	72	22	6	0	
	Mobilising	36	23	33	8	
Physio-technical	Coldpack	50	28	17	5	
applications	Hotpack	80	17	3	0	
(13)	Hydrotherapy	95	5	0	0	
	Ultrasound	56	25	17	3	
	Electrotherapy low frequencies	92	8	0	0	
	Electrotherapy middle frequencies	70	22	5	3	
	TENS	85	8	7	0	
	Shortwave therapy	78	19	3	0	
	Iontophoresis	89	8	3	0	
	Laser	94	6	0	0	
	Infrared	97	3	0	0	
	Vibration	94	3	3	0	
	Shockwave therapy	97	3	0	0	
Manual therapy	Hip	36	31	22	11	
(3)	Pelvis/Sacroiliac joints	31	31	28	10	
	Lumbar spine	25	29	29	17	
Advice and	Advice	0	0	0	100	100%
Information (2)	Information	0	0	0	100	100%

The interventions that scored often/always ≥ 60% and were subsequently used for the model for physiotherapeutic care are:

- Advice and information
- Friction of the proximal adductor insertion
- Mobilising of the hip
- Stretching of the hip adductors and flexors
- Strengthening of the hip, quadriceps and abdominal muscles
- Stabilizing (improving neuromuscular control)
- Sport-specific exercises.

After division into a bivariate score, significant associations emerged between "mobilizing" and "physiotechnical applications" (OR 5.2; CI 1.3-21.6), "stretching" and "strengthening" (OR 5.5; CI 1.7-237), "strengthening" and "massage" (OR 4.5; CI 1.1-19.0), "massage" and "stretching" (OR 9.1; CI 2.0-41.4), "stability" and "stretching" (OR 5.2; CI 1.3-21.6) and "strengthening" and "stability" (OR 44.8; CI 4.7-430.9). Since "manual therapy" has no association with any other treatment category, "manual therapy" was left out of the factor analysis. Advice and information were also omitted, because all PTs use these factors. Two main combinations of treatment categories were recognized in the factor analysis (Figure 1). Manual therapy had no significant association with the other categories and was not part of the factor analysis. Advice and information was used by all PTs and are, therefore, not included in Figure 1.

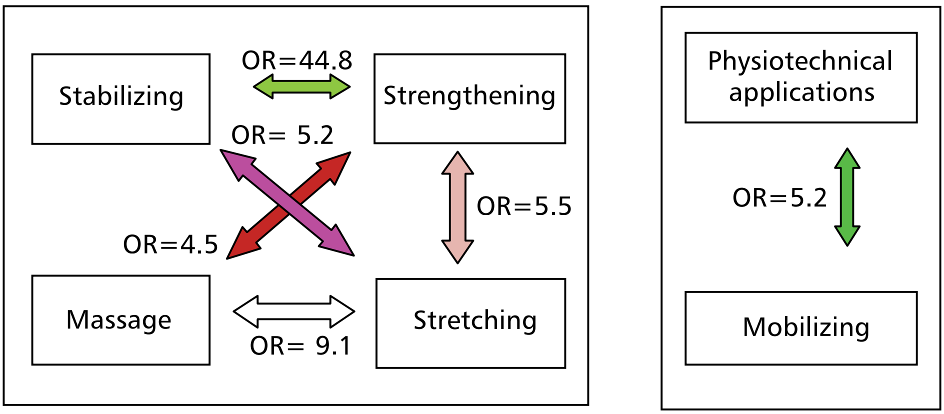

Figure 1. Combinations of treatment categories as a result of factor analysis. Associated significant odds ratios (ORs) ($p < 0.05$) are presented.

Discussion

LAGP is a problem that regularly occurs among soccer players. In the present study, the hypothetical soccer player might have one (or more) underlying pathologies that may cause his symptoms. These can range from problems at the origin of the adductor and osteitis pubis (or pubic bone stress injury), to sportsman's hernia. Based on history and physical examination alone, it is difficult to distinguish between these diagnoses; even use of advanced imaging techniques such as MRI are not able to unambiguously differentiate patients from controls (Slavotinek et al., 2006; Verrall et al., 2001). The hypothetical case presented here is a realistic example and commonly seen in physical therapy practice; all participating PTs reported that they treated similar cases about 6 times per year.

The present study investigated regular physiotherapeutic care (in the region of Utrecht) for patients suffering from LAGP, by means of a questionnaire. The respondent's answers were combined into a model. The model suggests that LAGP is approached as a problem of the kinetic chain. The hip seems to play a central role, since it receives considerable attention from most of the PTs with regard to mobilizing the hip, as well as stretching, strengthening and stabilizing exercises of the adjacent muscles. The active interventions used in the model correspond to a rehabilitation protocol described by Hölmich et al. (1999). In their high-quality RCT, the authors report significantly better effects after an active rehabilitation protocol for LAGP compared with a passive treatment consisting of LASER, stretching, friction and electrostimulation. In the active rehabilitation protocol, strengthening exercises for hip adductor and abductor, and abdominal and back extensor muscles, are described; exercises aimed at improving neuromuscular control are also included. Stretching exercises for the adductor muscles were not allowed in the active rehabilitation protocol described by Hölmich et al. (1999), whereas in the present study stretching was regularly applied by the respondents. According to Hölmich et al.(1999) stretching should not take place because of the potential adverse effects of tension on the insertion in prolonged position.

Amongst our PTs, mobilizing of the hip is regularly applied even though no high-quality studies have explored this specific intervention. Hölmich et al. (1999) also reported increased hip abduction range of motion after intervention. Prognostic studies have shown no association between decreased hip abduction range of motion and the risk for groin injury (Emery et al., 2001; Tyler et al., 2001; Witvrouw et al., 2003). Other cross-sectional and prognostic studies have reported an association between decreased hip rotation (especially internal rotation) range of motion and groin injury (Verrall et al., 2005; Verrall et al., 2007). To what extent mobilizing techniques have a therapeutic value remains unknown. Based on our questionnaire, it is unclear whether mobilizing techniques are aimed at rotation, or a range of motion in some other direction.

Friction massage was regularly applied by our PTs. In the study by Hölmich et al. (1999) friction massage was part of the less successful passive treatment. Nevertheless, the average estimated treatment period of our PTs was only 8.5 weeks with 13 treatment visits, whereas in the study by Hölmich et al. (1999) the intervention period was 8-12 weeks with 3 visits supervised by a PT per week, resulting in a median time till return to sports of 18.5 weeks. Results of the present study are suggestive of a better treatment outcome compared with those of Hölmich et al. (1999). However, in the present study it is unclear whether patients were able to return to sports after treatment. Another reason for fewer physiotherapeutic visits in our study might be insufficient coverage by health care insurance.

In the present study, mobilizing and stabilizing exercises for the pelvis were used often/always by 53% and 58% of the PTs, respectively, and were therefore not included in the model for regular care. A recent comparative study by Mens et al. (2006a) concluded that the pelvis can be an important factor in LAGP. They showed that tightening a pelvic belt around the pelvis can increase adduction strength and decrease adduction pain in patients with LAGP. Therefore there are indications that pelvic stability should receive more attention in the future. In clinical practice, however, it remains difficult to differentiate between exercises to improve stability of the hip, lumbar spine and pelvis. In total 80% of our respondents reported to often/always use strengthening exercises for the abdominals, and 72% often/always used strengthening exercises for the hip adductors. According to Hölmich et al. (1999) the combination of both is sufficient to stabilize the pelvis. In the present study, the percentage of PTs that never/sometimes use stabilizing exercises for hip, pelvis and low back is 31% to 43%, which is considered a high proportion given the scientific evidence (Hölmich et al., 1999).

There are indications that tensioning the abdominal muscles can contribute to the stability of the pelvis. Richardson et al.(2002) showed that abdominal bracing can increase pelvic stiffness threefold. However, during abdominal bracing, intra-abdominal pressure is increased. Applying abdominal bracing too much and too often might disadvantageously load the pelvis and might hinder recovery (Mens et al., 2006b). Based on this theoretical framework, selective recruitment of the pelvic floor and the m. transversus abdominis should be indicated, since intra-abdominal pressure is not increased to the same extent as during abdominal bracing, and pelvic stability is increased even more compared with abdominal bracing (Richardson et al., 2002). Moreover, it is reported that transversus abdominis recruitment is delayed in athletes with LAGP (Cowan et al., 2004). In Australia, exercises to improve transversus abdominis recruitment are implemented in rehabilitation (Hogan, 1998). Two prospective case series have described the results of such an intervention (McCarthy & Vicenzino, 2003; Wollin & Lovell, 2006); however, due to the lack of control groups the level of evidence is poor.

It is noteworthy that only 36 of the 220 PTs that we contacted had some experience with our hypothetical case. Therefore, it is doubtful whether the model of physiotherapeutic care is similar to the treatment that an 'average' PT would provide; therefore, generalization of these results requires some caution. However, the question arises whether an athlete with LAGP would go to an 'average' PT. Since only 36 of 220 PTs were experienced with treating LAGP, some selection made by the patients thermselves seems likely. Nowadays, patients are able to select their specialized PT using websites such as www.fysiotherapie.nl. Accordingly, 40% of our respondents had finished a continuing education as a sports PT's, which is considerably higher than the national average of 4% (Kenens & Hingstman, 2004).

A limitation of the present study is that the model of physiotherapeutic care is based on a hypothetical case. The respondent's answers are probably based on the association they make with this particular case. Which treatment a patient actually receives will probably depend on factors other than those described in the hypothetical case. For example, if the physical examination shows that hip range of motion is normal, interventions to increase hip range of motion will probably not be used. Individualized treatment therefore remains important.

Conclusion

In the present study, the physiotherapeutic treatment for longstanding adduction-related groin pain is based on a kinetic chain approach. It consists of advice and information, friction massage of the insertion of the adductor on the pubic bone, mobilizing of the hip, stretching of the hip adductors and flexors, strengthening of the quadriceps, hip and abdominal and muscles, stabilizing exercises for hip and low back, and sport-specific exercises. However, the scientific evidence for this type of treatment is currently somewhat limited.

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CHAPTER 5

Short and mid-term results of a comprehensive treatment program for longstanding adduction-related groin pain in athletes: a case series.

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Submitted at Physical Therapy in Sports

Abstract

Objective. To evaluate short and mid-term results of active physical therapy in athletes with longstanding groin pain.
Design. Case series
Setting. Primary care physical therapy practice.
Participants. A total of 44 athletes suffering longstanding adductor-related groin pain
Intervention. A combination of passive (joint mobilization) and active (exercises) physical therapy interventions.
Main outcome measurements. Return to (the same level of) sports, restriction in sports, and recurrence.
Results. Directly after treatment, return to the same level and type of sport was successful in 38 athletes (86%), and without symptoms in 34 athletes (77%). At 6.5 to 51 months follow- up, 10/38 (28%) of those that returned to sports had experienced a relapse; 22 (50%) athletes were able to participate in sports without any restrictions at the mid term follow-up.
Conclusion. For athletes with longstanding groin pain, short term results of physical therapy seem positive, whereas mid term results are moderately positive. The risk for recurrence is high.

Introduction

In soccer about 5-13% of all injuries per year occur to the groin (Arnason et al., 2004). In general acute groin injuries have a good prognosis and heal after a period of rest or restricted activity (Arnason et al., 2004). Some acute injuries and in cases with an insidious onset groin injury can often become a longstanding problem. A recent review found only one good quality study published on the treatment of longstanding adduction-related groin pain (LAGP) in athletes (Jansen et al., 2008). This study showed that an active physical training program aiming at stability of the hip and pelvis resulted in a return to sports in 79% of the patients after 18.5 weeks of training (Hölmich et al., 1999). Since the publication of this trial several new findings led to the development of a new treatment protocol for LAGP at the Royal Netherlands Football Association (KNVB). The program was based primarily on the active physical training program shown to be effective by Hölmich et al. (1999). In addition to the physical training specific motor control training for the transversus abdominis (TA) muscle function was given. This was included after reports that TA function is altered in patients with LAGP (Cowan et al., 2004) and that pelvic instability may play a role in LAGP (Mens et al., 2006). Recruiting the TA has been shown to improve stiffness of the pelvic ring (Richardson et al, 2002) and improved clinical outcome in women with pelvic girdle pain (Stuge et al., 2004).
The program also included manual therapy for the hip joint and Si-joints. It has long been known that reduced range of motion in the hip is often found in cases of athletic groin pain (Williams, 1978). Recent small prospective studies confirmed that the reduced range of motion preceded the onset of groin injury (Verrall et al., 2007; Ibrahim et al., 2008). Manual therapy for the SI-joint has been shown to improve the feed forward activation of the TA in cases where its activation is delayed (Marshall & Murphy, 2006).
This study reports the effectiveness of the treatment program in athletes undergoing treatment at the national treatment centre of the KNVB. The study also examined the number of recurrences as this has not been previously reported and all current published studies on treatment for LAGP have a short follow up. The number of treatments needed was also studied.

Methods

Subjects
Athletes with LAGP were included in the study. LAGP was diagnosed when there was pain at the proximal insertion of the adductor muscles on the pubic bone on palpation and this pain was felt on resisted adduction testing. The pain was said to be longstanding if it had lasted more than four weeks. Patients with pain felt above the conjoined tendon, hip joint pathology, concurrent lower

back pain, urinary tract infections, prostatitis, rheumatic disorders, clinical findings of a nerve entrapment syndrome or previous performance of a physical training program were excluded. Approval from the local Ethics Committee was acquired and all participants gave informed consent.

Outcome
For follow up, athletes were given a structured telephone interview to assess current sports participation and recurrence rate.

Treatment program
The treatment program is outlined in Table 1. In the first phase the athletes were informed about the potential mechanisms of the injury, and the treatment program was outlined. They were instructed to cease competitive sports for a minimum of three weeks. In contrast with Hölmich et al. (1999), the program's criteria to move on to the next phase were not based solely on time but on the achievement of clinical milestones. Mobilization techniques for the hip were used if there was decreased hip range of motion on the symptomatic side compared with the asymptomatic side. For the sacroiliac joint and lumbar spine the overtake phenomenon during the Gillet test (Levangie, 1999), and decreased spinal flexion and rotation range of motion during inspection were used to determine the need for manipulations. These were performed at each treatment session until the physical findings were normal. Exercises were started with the basic TA motor control exercises (abdominal hollowing) using palpation medial to the anterior superior iliac spine and observation of the abdomen as bio-feedback. Abdominal bracing with Valsalva maneuver was not allowed. Progressing to phase two of stabilizing exercises was allowed when the athlete was able to selectively contract the TA without bracing and maintaining a normal breathing pattern.
In the second phase, TA tension had to be integrated in common core stability exercises like prone bridge, lateral bridge, oblique and straight sit-up exercises. The subject's exercise performance was evaluated using endurance tests described by McGill et al. (1999) for the core stability exercises. Low load exercises for the adductor muscles using the seated fitness machine or the one leg pulley exercise in stance were also performed in phase two. Performance level was considered sufficient to progress to phase three if endurance times of bridging exercises exceed average values plus one standard deviation described by McGill et al. (1999) and low load adductor exercises could be executed without pain.
In phase three, general stabilizing exercises for the whole kinetic chain, using the wobble board or Swiss ball as a support surface were added. Numbers of repetitions and load were modified to the individual's capacity to perform the exercises without pain and started with three sets of 15 repetitions with a decreasing number of repetitions and increasing load over time. Before athletes could progress to the next phase, groin pain had to be absent during the

squeeze test, the modified Thomas test, and the Bent Knee Fall Out test (Hogan &Lovell, 2002) had to be normal. Progression to running was allowed in phase three when swimming or biking could be performed without pain or stiffness the next day. The first run lasted 5 minutes, increasing with 1 minute per run. If the athlete was able to run for 15 minutes without pain, progression to the next phase was allowedIn phase four, agility drills and sport-specific exercises were initiated under supervision by the physical therapists. These exercises were started at a low intensity: jumping at 30% of maximal capacity; sprinting, cutting and turning at a subjectively estimated 30% of maximum running speed, kicking a ball at 30% of maximum force. An increase in sports specific exercise intensity was always initiated under supervision of the treating physical therapist using the athletes (lack of) pain and/ or fatigue response as a marker to increase intensity by a maximum of 10%-20%. If a subjectively estimated 80% of the athlete's maximum capacity was reached without symptoms, the athlete was allowed to return to sports at the own club in phase 5. A gradual progression from training to match was stipulated. Furthermore, subjects were encouraged to continue exercises from phase three and four at home.

During phases 1-4, athletes attended the physiotherapist once a week and performed exercises twice a week without supervision. Each exercise session lasted about 90 minutes.

Table 1. Treatment program

Phase 1	Advice and information Mobilization for hip, sacroiliac joints and lumbar spine Basic TA recruitment
Milestone	Normal physical findings on hip range of motion and sacroiliac joint dunction (Gillet test) Selective TA recruitment without abdominal bracing
Phase 2	TA recruitment combined with core stability exercises Low load hip adduction exercises
Milestone	Normative values for core stability endurance exercises Low load hip adduction exercise without pain
Phase 3	General whole body stabilizing exercises. Increase in hip adduction strength exercise intensity with decreased number of repetitions while experiencing no adduction pain Start running
Milestone	No pain during the squeeze test and modified Thomas test and Bent Knee fall out test Running for 15 minutes without pain
Phase 4	Agility drills and sport-specific exercises
Milestone	80% of subjectively estimated performance capacity
Phase 5	Return to sports

Statistical Analysis

Descriptive statistics were used to describe short- and mid-term results. (Non-) parametric tests (independent t-test and Mann-Whitney U test) were used to compare risk factors in athletes with and without recurrence. SPSS software (SPSS Inc, Chicago, Ill version 15.0) was used for analysis. A p-value <0.05 (two-sided) was considered significant.

Results

In total 44 patients were included in the study and all consented to give a telephone interview for the mid-term follow up assessment. The characteristics are shown in Table 2.

Table 2: Baseline characteristics of the athletes

Total	n=44
Gender	37 ♂; 7 ♀
Age (mean; sd)	27 (10.8)
Sports	
Soccer	31
Running	3
Field hockey	3
Tennis	2
Other sports	5
Duration of complaints	
>4 ≤10 weeks	11
>10 - ≤26 weeks	11
>26 - ≤52 weeks	9
> 52 weeks	13

Short term follow up

In total, 40 athletes returned to their preferred sports directly after treatment. 34 returned to their pre-injury level without any symptoms at the time of return to sports. Four returned to their pre-injury level but still had some mild symptoms. Two athletes had to reduce their level of sporting activities and in 4 cases persisting groin complaints prevented return to their preferred sports. The 38 athletes who successfully returned to the same level of sports did so in median (IQR) 142 (70-221) days.

The athletes' median (IQR) score for treatment satisfaction was 8 out of 10 (7-9). The athletes underwent a median (IQR) of 21 (13-31) treatments during their rehabilitation.

Mid term follow up

Median time to mid term follow-up was 22 (range 6.5-51) months. After completing the treatment and returning to sports, 33 athletes had continued to perform the home exercises for a median (IQR) period of 9.5 (4.5-23.5) months. Of the 38 athletes who had returned to the same level of sport at short term follow up, 11 experienced a recurrence after median (IQR) 8 (3.5-13) months. Six athletes had attended physical therapy for a second time. The median (IQR) recurrent episode of symptoms lasted 2.5 (1-17) months.

At mid term follow up, 77% (34/44) of athletes still participated in their preferred sport. A total of 23 athletes were active at their previous level of sports; 5 were active at a higher level and 7 at a lower level (but only 3 in this latter group because of persisting groin complaints). Six athletes had switched to another type of sport, but mostly because of personal reasons (e.g. their work, birth of a child). Three ceased sporting activities due to persisting groin complaints. On average, sports intensity was 5.25 (range 0-16) hours/week.

Risk factors

Age, duration of complaints, duration of treatment period/number of treatment visits, and time to follow-up were considered as possible risk factors for recurrence (Table 3). No significant differences were found ($p \geq 0.27$).

Table 3. Differences between patients that did and did not experience a recurrence

	Recurrence	n=41*	Mean (sd)	p- value
Age (years)	Yes	10	29.9 (13.4)	
	No	31	25.0 (9.3)	0.271
Treatment visits (n)	Yes	10	27.7 (20.2)	
	No	31	23.9 (17.5)	0.571
Duration of treatment (days)	Yes	10	186.7 (159.7)	
	No	31	149.7 (96.3)	0.378
Time to follow-up (months)	Yes	10	20.3 (7.7)	
	No	31	23.1 (10.5)	0.444

* Three subjects were never entirely free of symptoms and were considered not to experience a relapse; therefore, they were excluded from the analysis

Discussion

After completing the comprehensive treatment program, 34/44 (77%) of the athletes returned to the pre-injury level of sports without symptoms. The athletes who returned to sports activities did so in an average of 20 weeks. At mid-term follow up, 26% (10/38) athletes had experienced a recurrence of their groin pain. At mid-term follow up 70% of the athletes were still competing in their preferred sports at the original or a higher level than before the injury.

The 77% success after the treatment is comparable with the 74% effectiveness reported by Hölmich et al. (1999) The median time to return top sports of 20 weeks in this study is also similar to the 18.5 weeks reported by Hölmich et al. (1999). This shows that recovery from LAGP is a long process and in this study the time to return to sport was not reduced by including the treatments other than active physical therapy.

Although the short-term results are positive in the study by Hölmich et al. (1999) and in the present study, Verrall et al. (2007) found different results; 63% of their patients returned to sports but only 41% was able to participate at the pre-injury level 7 months after start of treatment. A possible explanation for the latter result is that most of their subjects were professional Australian football players, whereas all the subjects in the other two studies were amateur athletes. Professional athletes generally have a higher intensity of sports participation compared with amateur athletes, making their return to the pre-injury level more complex. The addition of specific motor control training for the TA was based on the study of Cowan et al. (2004) showing a significant delay of TA recruitment in athletes suffering longstanding groin pain. It may be that the motor control training for the TA has no additional benefit when compared to non-specific trunk muscle exercises. This was found to be the case in a recent RCT comparing general exercise with general exercise *plus* additional TA exercises in subjects with recurrent low back pain in which both programs were equally effective (Koumantakis et al., 2005). It would be interesting to measure if the TA function improved after treatment for LAGP and if this improvement would be associated with recovery.

The use of manipulations and mobilizations for the hip was due to the fact that decreased hip range of motion may be a relevant factor in groin injury (Williams, 1978), which was later confirmed in small prospective studies (Ibrahim et al., 2007; Verrall et al., 2007). Mobilizing techniques for the Si-joint and lumbar spine were used because of its relation with TA function (Marshall & Murphy, 2006; Gill et al., 2007) and hip range of motion (Cibulka et al., 1998).

It was hoped that the treatment of the hip, Si joint and lumber spine alongside the specific transversus abdominis training would improve outcome and decrease the risk of recurrence. In the present study, the risk for developing a recurrence of the groin injury within the period of 6.5 to 51 months was 27%

(10/38). It would thus seem that the treatment was not highly effective at preventing re-injury. Previous groin injury is known to be a risk factor for developing groin injury. Arnason et al. (2004) reported that the risk for developing groin injury after previous groin injury was 9%(10/109) compared with a risk of only 2%(7/414) in subjects without previous groin injury (Arnason et al., 2004). In the other studies, the reported risk for recurrent injury ranged from 31-50% (Hagglund et al., 2005; Hawkins & Fuller, 1999). It may well be that there are other factors that are important in the development of groin injuries that were not addressed during the treatment and a recent review noted the lack of good prospective studies on this subject (Maffey & Emery 2007).
The mid-term results reported in present study are fairly positive and despite the high recurrence rate, 79% of the athletes still participated in their pre-injury sport. Only three who were still active had been forced to a lower level of competition by their groin injuries. In our study, adherence to home exercises during a specific period of time did not influence mid-term outcome, in contrast to what is suggested in the review by Maffey and Emery (2007). It should be noted that the duration of the preventative exercises was not standardized.
Age has been suggested to be an independent predictor of injury in general (Arnason et al., 2004). In the present study, although athletes that suffered a recurrence were slightly older, age was not a significant risk factor for recurrent groin injury. A similar lack of association between age and groin injury has been reported by others (Hölmich et al., 2009).

Study limitations
Firstly, data were collected retrospectively whereby accuracy of the information tends to be decreased compared with data collected prospectively (Hallquist & Jansson, 2005). This means that, for some subjects, recall bias is a significant factor that might have influenced the results by underestimating or overestimating some of the parameters. Secondly, because there was no control group, no definite conclusions can be drawn as to whether our results are solely related to the intervention described. Third, because only subjective data were collected and no physical function tests were performed, no objective data on physical functioning in sports are available.

In conclusion, the present study shows that the short-term results of a comprehensive physical therapy intervention for LAGP are positive. The mid-term results are fairly positive but there was a 27% chance of recurrence.

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CHAPTER 6

Resting thickness of transversus abdominis is decreased in athletes with longstanding adduction-related groin pain

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Abstract

Purpose. To compare thickness of the transversus abdominis (TA) and obliquus internus (OI) muscles between athletes with and without longstanding adduction-related groin pain (LAGP).

Methods. 42 athletes with LAGP and 23 controls were included. Thickness of TA and OI were measured with ultrasound imaging on the right side of the body during rest. Relative muscle thickness (compared to rest) was measured during the Active Straight Leg Raise (ASLR) left and right, and during isometric hip adduction.

Results. TA resting thickness was significantly smaller in injured subjects with left-sided (4.0± 0.82mm; $P<0.001$) or right-sided (4.3±0.64 mm; $P=0.015$) groin complaints compared with controls (4.9±0.90 mm). No significant differences between patients and controls in TA or OI relative thickness during the ASLR and isometric hip adduction were found (all cases $P \geq 0.15$).

Conclusion. TA resting thickness is smaller in athletes with LAGP and may thus be a risk factor for (recurrent) groin injury. This may have implications for therapy and prevention of LAGP.

Introduction

Injuries to the groin region are a common problem in sports characterized by quick accelerations and decelerations and sudden directional changes such as soccer, field hockey and tennis. The differential diagnosis can cover a broad area of possibilities such as adductor strain or tendinitis, osteitis pubis and sports hernia. When isometric hip adduction is painful, groin pain is often referred to as adductor tendinitis, which implies pathology of the adductor muscles. Mens et al. (2006c) evaluated the hypothesis that longstanding adduction-related groin pain (LAGP) in athletes on isometric hip adduction may not be caused by adductor pathology. When comparing isometric hip adduction with and without wearing a pelvic belt, force increased significantly in 39% and pain decreased in 68% of the injured athletes while wearing the belt. Studies on patients with posterior pelvic pain have also shown that pain decreased significantly while wearing a pelvic belt (Ostgaard et al., 1994; Damen et al., 2002). This latter response to a pelvic belt suggests instability of the pelvic ring (Damen et al., 2002; Mens et al., 2006a).

Anatomically, the transversus abdominis (TA) and obliquus internus (OI) may function as a internal pelvic belt since their fibers are perpendicular to the sacroiliac joint (Snijders et al., 1998; Hoek van Dijke et al., 1999). TA recruitment, performed by abdominal hollowing, resulted in a significant decrease of sacroiliac joint laxity, even when compared with abdominal muscle co-contraction (Richardson et al., 2002). A recent study using electromyography (EMG) investigated the differences in TA recruitment between healthy athletes and athletes with LAGP (Cowan et al., 2004). A significant delay (10 msec) in TA recruitment in athletes with groin pain was found, although the delay was not similar to the responses found in the population of back pain patients (>50 msec, Hodges et al., 1998; Hodges and Richardson, 1999a & 1999b). Ferreira et al. (2004) also studied TA recruitment in persons with low back pain. Using ultrasound imaging, they found significantly smaller relative TA thickness compared to a control group when performing isometric lower extremity tasks. Relative thickness of TA and OI measured by ultrasound imaging has shown to be a valid method to measure low level muscle activity (Hodges et al., 2003; McMeeken et al., 2004). This method is used by paramedical professionals to visualize the abdominal muscles, particularly when specific training of TA is emphasized (McCarthy and Vicenzino, 2003; Wollin and Lovell, 2006). However, it is not known whether ultrasound can be used to identify abnormal abdominal muscle behavior in athletes with LAGP.

The purpose of the present study was to compare the resting thickness and thickness relative to rest of TA and OI during lower extremity tasks, between athletes with LAGP and controls using ultrasound imaging.

Materials and Methods

Subjects

Patients were recruited from the Sports Medical Center of the Royal Netherlands Football Association (KNVB, Zeist, the Netherlands) and the Sports Medicine Department of the The Hague Medical Centre (The Hague, the Netherlands). Male subjects were included if they were aged 18-55 years and restricted in sports participation for at least 6 weeks as a result of adduction-related groin pain. This was defined as experiencing unilateral groin pain during bilateral isometric hip adduction in supine hook lying position (i.e. the squeeze test, Verrall et al., 2005). Subjects were excluded if the pain was bilateral; started after a high-impact trauma; if symptoms were suggestive for fracture of the pelvis or hip, for osteoarthritis of the hip, tear of the labrum of the hip, inguinal or femoral hernia, radicular syndrome, nerve entrapment, bursitis, malignant diseases, vascular pathologies, prostatitis, urinary tract pathology; anatomical abnormalities; systemic diseases; obvious psychopathology, or if subjects were unable to fill in forms. Controls were healthy male athletes with no restriction in sports and were recruited using verbal communication and flyers. Controls were excluded if they experienced groin pain on performing isometric hip adduction. Subjects were checked on inclusion and exclusion criteria by an experienced sports medicine physician using medical history and a complete active and passive physical examination of the hip, pelvis and lumbar spine, after which they were referred to the researcher. After this physical examination, informed consent was signed and measurements were started.

Prior to study start, approval of the local Research Ethics Committee was acquired. The present study was conducted in compliance with the Declaration of Helsinki.

Characteristics

A structured questionnaire was used to record the following information: age, height, weight, type of sports, sports intensity (hours/week), level of sports, side of complaints, duration of complaints, medical history and the presence of pain at isometric hip adduction. Restriction in sports participation (*"To what extent are you restricted in sports participation?"*) was measured using a numeric Likert scale ranging from 0 (*"I can participate at my own level of sports"*) to 10 (*"I can not participate in sports at all"*). To measure impaired load transfer through the lumbo-pelvic area, the active straight leg raise (ASLR) test was performed according to Mens et al. (1999, 2001, 2002). The ASLR test was performed in a supine position with straight legs. The test was performed after the instruction: *''Try to raise your leg above the couch 20 cm while keeping your leg straight''.* The left leg was always tested first, followed by the right leg. The patient was asked to score impairment for each leg on a 6-point scale: not difficult at all

= 0; minimally difficult = 1; somewhat difficult = 2; fairly difficult = 3; very difficult = 4; unable to lift the leg= 5. The scores of both sides were added, so the summed score ranged from 0 to 10. Score 0 was defined as negative, and scores 1 to 10 as positive.
Maximum adduction force was measured in Newtons with a hand-held dynamometer (Microfet, Biometrics BV, the Netherlands) in supine hook-lying position. The researcher's hand and the dynamometer were placed between the knees of the subject. The subject was asked to squeeze the knees together with maximum effort. Subjects performed a minimum of three attempts. If the score of the last attempt was the highest of the series, another attempt was allowed. Subjects were verbally encouraged to perform at their utmost. Maximum force was measured within 5 seconds. In these force measurements, the score of the highest attempt was used for analysis. Immediately after the final attempt, severity of the groin pain was measured using a numeric Likert scale ranging from 0 (no pain) to 10 (unbearable pain).

Ultrasound measurements
Ultrasound imaging (5 cm linear transducer 7.5 Mhz, B-mode, Honda Electronics, HS-2000, Dynamic BV, the Netherlands) was used to measure the thickness of the two abdominal muscles TA and OI. The transducer was placed in the transverse plane on the right side of the subject on the mid-axillary line midway between the inferior angle of the rib cage and the iliac crest. The position of the transducer was adjusted until the medial junction of the TA with OI was visualized in the far left of the screen. Thickness of TA and OI was measured from the point where the superficial fascial line of the muscle crosses the midline of the ultrasound image, perpendicular on the superficial fascial line, to the deeper fascial line. Measurements were made using the on-screen calipers. Firstly, the thickness of the abdominal muscles was measured during rest with the subject in supine hook lying position.
Secondly, thickness of TA and OI was measured during ASLR left and right. The subject was asked to perform an ASLR test as described above.
The fourth and final measurements were performed during maximum isometric hip adduction. Again, the subject was positioned in a supine position with the hips flexed 45 degrees and knees flexed to 90 degrees. A soft rubber soccer ball was placed between the knees of the subject. The ankles were placed together. The subject was verbally encouraged to squeeze the ball with maximum effort. All measurements were taken at the end of expiration as determined by visual inspection of the abdominal wall. This was done in order to standardize the influence of respiration (Hodges et al., 1997; Teyhen et al., 2005). The average of three repetitions per task and condition was used for analysis.

Statistical Analysis

The number of subjects needed for this study was based on the study of Ferreira et al. (2004), investigating TA function in a population of patients suffering low back pain. Given an effect size of 28% and $p<0.05$, a power of 80% was reached by using a number of at least 10 subjects per group. However, given the smaller difference in abdominal muscle recruitment found by Cowan et al. (2004) compared with studies on subjects with low back pain, this was considered too low; therefore, at least 15 subjects per group were included.

Patients were divided into subgroups based on complaints laterality (left or right). ANOVA or the non-parametric alternative (Chi-square or Kruskall Willis test) were used to evaluate differences between groups on population characteristics.

Intra-rater reliability of ultrasound imaging measurements per task was analyzed using intraclass correlation coefficient (ICC_{intra} model 3,1) for single measures. ANOVA was used to evaluate differences between patients and controls in abdominal muscle resting thickness and relative thickness during the tasks, calculated as percentage increase (or decrease) relative to rest. Scheffé was used for post-hoc testing between groups. $P<0.05$ was considered statistically significant. All statistical analyses were performed using SPSS statistical software (version 15.0. SPSS Inc. Chicago, USA)

Results

Characteristics

A total of 53 patients were referred for inclusion and 28 controls were contacted. All subjects were competitive amateur athletes. Four controls experienced adduction pain during testing and were excluded; one female control was also excluded. Of the 53 patients, six patients did not experience adduction-related groin pain and four patients had bilateral complaints during testing by the researcher and were also excluded from analysis. One female was also excluded. A total of 18 athletes had left-sided and 24 right-sided groin complaints.

Table 1 presents the characteristics of the study population.

There were no significant differences between groups for most of the variables assessed, except for clinical characteristics (*i.e.* pain and restriction in sports). For adduction force, post-hoc testing revealed a significant difference between controls and subjects with left-sided complaints ($P=0.01$) and no difference between subjects with right-sided complaints and controls ($P=0.73$), or between subjects with left or right-sided complaints ($P=0.06$).

Table 1. Characteristics of the study population.

	Controls (n=23)	Patients' complaints left (n=18)	Patients' complaints right (n=24)	*P*-value
Age in years; mean (SD)	23.9 (4.7)	28.2 (10.4)	24.8 (6.9)	*P*=0.18
Weight in kg; mean SD)	78.9 (6.8)	76.4 (11.8)	80.0 (9.2)	*P*=0.45
Height in cm; mean (SD)	183.7 (6.7)	181.4 (6.5)	184.4 (6.8)	*P*=0.36
Usual sports participation before injury in hours/week; mean (SD)	5.9 (2.3)	5.5 (1.8)	6.1 (2.8)	*P*=0.67
Sports				
Soccer	15	11	20	
Running	3	4	1	
Field hockey	2	0	0	
Cycling	1	0	1	
Korfball	1	0	0	
Fitness	1	0	1	
Rugby	0	1	0	
Swimming	0	1	0	
Speed skating	0	1	1	
Duration of complaints in weeks; mean (SD)	0	37 (32)	45 (58)	*P*<0.001*
Force isometric adduction in Newton; mean (SD)	355 (45)	290 (60)#	340 (80)	*P* =0.07
Restriction in sports participation (Likert 0-10); median (range)	0 (0-0)	6 (3-10) #	7 (2-10) #	*P*<0.001*
ASLR score sum of left and right; median (range)	0 (0-0)	0 (0-4) #	0 (0-3)#	*P*<0.001*
Adduction pain (Likert 0-10); median (range)	0 (0-0)	4 (2-8)#	5 (1-9)#	*P*<0.001*

p-values according to simple ANOVA unless indicated otherwise.
* According to the Kruskall-Wallis test
 # Significant difference compared with controls using the post-hoc Scheffé or Mann-Whitney U test

Ultrasound measurements

Intra-rater reliability for single measures of TA and OI thickness measurements ranged from moderate to good over the conditions (ICC 0.77-0.97; SEM 0.15-0.51 mm).

Right-sided TA resting thickness was significantly smaller in injured subjects with left-sided (4.0± 0.82mm; $P<0.001$) or right-sided (4.3±0.64 mm; $P=0.015$) complaints compared with controls (4.9± 0.90 mm). There were no significant differences ($P=0.54$) between subjects with left-sided complaints and subjects with right-sided complaints. For right-sided OI, resting thicknesses were 11.8 (1.3 mm) for controls, 12.6 (1.8) mm for subjects with right-sided complaints, and 10.9 (2.3) mm for subjects with left-sided complaints. A significant difference was found only between subjects suffering right-sided and left-sided complaints ($P=0.02$).

There was no significant difference between controls and subjects with right or left-sided groin complaints on right-sided TA or OI relative thickness during the tasks evaluated (Figure 1; in all cases $P\geq0.15$).

Discussion

The transversely-oriented abdominal muscles and especially TA are considered to play an important role in contributing to active stability of the pelvis (Richardson et al., 2004). Since pain provocation in LAGP during adduction is associated with pubic symphysis-related abnormalities seen on MRI (Verrall et al., 2005), it was suggested that a dysfunction might exist in the pelvic stabilizing muscles in athletes with LAGP. The aims of the present study were to compare the resting thicknesses of TA and OI between athletes with and without LAGP, and to compare TA and OI relative thickness during simple lower extremity tasks. For both aims, ultrasound imaging was used. Our results showed a significantly smaller right TA resting thickness in patients with LAGP. No significant differences between patients and controls in OI resting thickness or relative thickness of both muscles during ASLR and isometric hip adduction were found.

The reliability of ultrasound imaging ranged from moderate to good (ICC =0.76 to 0.97), which is consistent with reported values (Hides et al., 2007; Teyhen et al., 2005; Teyhen et al., 2007). The small variations in measurements are probably due to the variability within subjects, since intra-rater reliability of measuring the same image is high (ICC>0.97; Hides et al., 2007). TA and OI resting thicknesses in healthy controls were slightly higher than average values reported in a study on reference values for healthy subjects (4.5 ±0.13 mm, Rankin et al., 2006) but comparable with values measured on an active military population (4.7±0.16 mm, Teyhen et al., 2008), suggesting that our measurements are valid. A significantly smaller right-sided TA resting thickness was found in patients with LAGP, independent of the side of complaints. Physical characteristics such as height, weight, and (pre-injury) sports intensity were similar between all groups. A less active lifestyle due to the injury could theoretically lead to decreased muscle thickness, but a smaller resting thickness was not found for OI. The smaller right-sided TA resting thickness and similar OI resting thickness might also be the result of inhibitory reflexes and muscle substitution patterns.

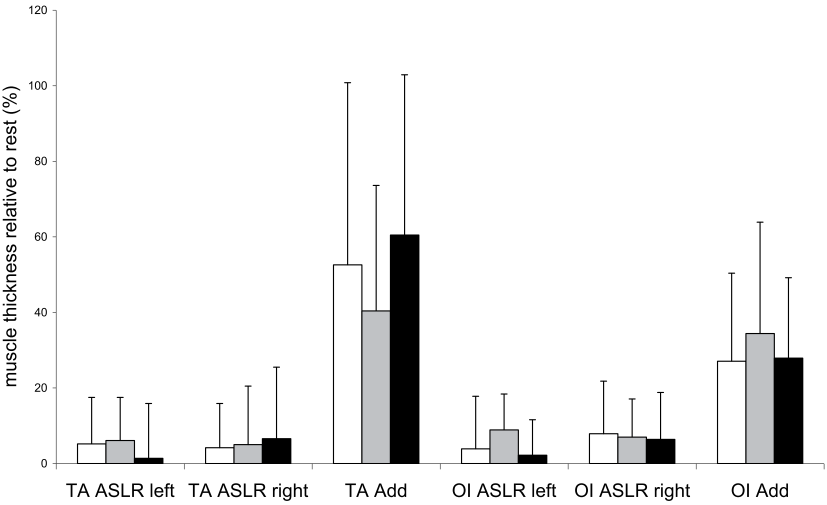

Figure 1. Relative thickness of the transversus abdominis (TA) and obliquus internus (OI) during Active Straight Leg Raise (ASLR) left and right, and hip adduction (Add). White bars represent controls; grey bars subjects with left-sided complaints, and black bars subjects with right-sided complaints.

In back pain patients more superficial abdominal muscle activity is observed when compared with healthy controls (van Dieen et al., 2003). A similar mechanism might explain the present findings in patients with LAGP. However, women with pregnancy-related pelvic girdle pain, who are thought to have a similar underlying pathological mechanism, appear not to have a smaller TA resting thickness compared with matched controls (Stuge et al., 2006), and neither do back pain patients (Critchley and Coutts, 2002; Ferreira et al., 2004; Hides et al., 2008). Localized muscle atrophy (due to physical inactivity and/or inhibitory reflexes and muscle substitution patterns) may be more pronounced in subjects who are more active than average, such as the athletic population described in the present study. Consequently, the smaller right-sided TA resting thickness found in our patients might be a predisposing factor for recurrent groin injury for athletes, and might require attention in terms of strength and/or recruitment training in rehabilitation and prevention (McCarthy and Vicenzino, 2003; Wollin and Lovell, 2006; Maffey and Emery, 2007). Previous groin injury is known to be a significant predictor for developing a new groin injury (Arnason et al., 2004; Hagglund et al., 2006).

For therapists active in the field of rehabilitation or prevention of LAGP, ultrasound imaging of the deep abdominal muscles could be considered when designing individual training programs; lower values of TA resting thickness might require specific preventative or rehabilitative exercises. Our research group recently showed (Jansen et al., 2009) that a program aiming at 'core stability' can improve TA resting thickness in patients with LAGP.

Patients and controls showed no difference in the relative thickness of the right TA during the lower extremity tasks. This was unexpected because Ferreira et al. (2004) showed decreased TA relative thickness on ultrasound in subjects with back pain known to have delayed TA recruitment on EMG, similar to groin pain patients (Cowan et al., 2004). Several explanations for this finding can be proposed. Instead of timing, thickness (change) of abdominal muscles is measured by ultrasound. It is possible that only the onset of TA is different, and not the relative thickness. In the study by Cowan et al. (2004), the subjects were only measured on the symptomatic side of the body. The side of measurements (symptomatic or not) has been shown to influence data on abdominal muscle recruitment on EMG (Hungerford et al., 2003). However, in the present study, a comparison of subjects with right-sided complaints with healthy subjects also showed no significant differences. Furthermore, relative thickness of TA is similar independent of the lower extremity task laterality (Hides et al., 2007). This was confirmed since our further analysis showed that TA relative thickness in healthy subjects was similar during ALSR left and right. Several studies have shown no significant side-to-side-differences in TA resting thickness (Stuge et al., 2006; Hides et al., 2008) or relative thickness during lower extremity tasks (Hides et al.,2007; Teyhen et al., 2009). This suggests that any possible difference in TA resting or relative thickness between our patients and controls should also be found on one side. On the other hand, research has shown that considerable side-to-side differences in resting muscle thickness can exist within individuals. These intra-individual differences can be masked when comparing group means (Rankin et al., 2006; Mannion et al., 2008). Therefore, the possibility that the thicker side was measured in controls whereas the thinner side was measured in patients can not be excluded. Future research should measure thickness at both sides.

The low ASLR scores in the symptomatic group might also be an explanation for the present findings. The ASLR score is positively associated with mobility of the pelvic joints (Mens et al., 1999) and disease severity in pregnancy-related pelvic girdle pain (Mens et al., 2002). De Groot et al. (2008) showed increased external oblique (OE) activity in post-partum women suffering pelvis-related complaints who had an average ASLR score of 3.9 (2.0), whereas controls had a score of 0.9 (1.1).This latter value is similar to that found in patients in the present study. Activity of OE was not measured in the present study given the lack of association between OE relative thickness and EMG activity (Hodges et al., 2003). It is plausible that patients try to stabilize their pelvis using more superficial abdominal muscle contraction (Richardson et al., 2002). Decreased TA function is associated with increased superficial abdominal muscle activity to maintain task performance (Moseley and Hodges, 2005). However, generalized superficial abdominal co-contraction raises intra-abdominal pressure, which may be disadvantageous for pelvic ligaments and predispose for (recurrent) pelvis-related complaints (Mens et al., 2006b). Unfortunately this theory could not be verified in the present study and should be tested prospectively.

In the present study, right-sided OI resting thickness and relative thickness during the tasks were not significantly different between patients and controls. This is in line with other ultrasound studies on abdominal muscle thickness in back and pelvic pain patients (Ferreira et al., 2004; Stuge et al., 2006). A significantly smaller OI resting thickness was found for patients with left-sided complaints compared with subjects with right-sided complaints. The side of dominance may serve as an explanatory variable (Hides et al., 2008), but this was not controlled for.

Limitations

Results reported in present study have to be interpreted in the light of several limitations.

The ultrasound probe was placed between the iliac crest and anterior iliac spine; a place commonly used in ultrasound studies on abdominal muscle recruitment.(Ferreira et al., 2004; Teyhen et al., 2005; Stuge et al., 2006). Cowan et al. (2004) placed needle electrodes below the level of the anterior iliac spine. Research has shown that activity of TA varies between regions of TA (Urquhart and Hodges, 2005; Urquhart et al., 2005). Consequently, these regional differences might explain the different findings. It was suggested that ultrasound can be used as a valid measure of TA and OI activity during low-level contractions (Hodges et al., 2003). However, ultrasound's sensitivity to change might not be sufficient to detect small differences in activity (Hodges et al., 2003). It might therefore be possible that stabilizing activity of TA and OI is slightly higher in patients than in controls, as illustrated by significantly higher ASLR score in patients. This indicates that the ultrasound data should be interpreted with caution with respect to muscle activity. Because measurements were made in a clinical setting, blinding of ultrasound image judging was not performed. Theoretically, this might have influenced the reliability of the ultrasound data. Given that the reliability results found in this study correspond with values reported in the literature (Hides et al., 2007; Teyhen et al., 2005), it is suggested that this methodological flaw will not have influenced the results. Another limitation was that force was not standardized and controlled for during the ultrasound measurements in the isometric hip adduction task. Possibly, patients and controls might have behaved differently during this task and this may have confounded results.

Conclusions

In this study, patients with LAGP pain had a smaller right-sided TA resting thickness compared with healthy athletes. No differences between patients and controls were found for TA and OI relative thickness during ASLR or isometric hip adduction. This information can be useful in rehabilitation and prevention programs for athletes with LAGP.

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CHAPTER 7

Changes in abdominal muscle thickness measured by ultrasound are not associated with recovery in athletes with longstanding adduction-related groin pain

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Abstract

Study design: Longitudinal single-cohort study.
Background: Athletes with longstanding adduction-related groin pain (LAGP) have been shown to have abnormal activation of the transversus abdominis (TA). Therefore, exercises targeting the TA to help stabilize the lumbopelvic area are generally used in the rehabilitation of these athletes.
Objectives: To investigate if (1) changes in abdominal muscle resting thickness and changes in relative thickness during lower extremity tasks after 14 weeks of intervention are related to changes in clinical status and (2) the changes in abdominal muscle resting/relative thickness are significant postintervention.
Methods: In 21 athletes with LAGP, ultrasound imaging of the abdominal musculature on the right side was performed at rest, during the active straight-leg raise (left and right), and during bilateral isometric hip adduction. Athletes then followed a 14-week rehabilitation protocol. Clinical outcome measured by self-reported sports restriction and change in abdominal muscle resting and relative thickness during lower extremity tasks were evaluated.
Results: There was an overall significant decrease in self-reported sports restriction after intervention for this group of athletes. Apart from a significant negative correlation for changes in TA resting thickness, no significant association between changes in abdominal muscle thickness and change in self-reported sports restriction were found. Postintervention, TA resting thickness was significantly increased but relative thickness during the lower extremity tasks was found not to be statistically different for all muscles, except for a decreased relative thickness of obliquus externus abdominus (OE) during the active straight-leg raise for the left lower extremity.
Conclusions: There was no association between changes in abdominal muscle resting thickness and relative thickness during lower extremity tasks, and change in self-reported sports restriction after a period of physical therapy in athletes with LAGP. Although this study was designed as a single-cohort longitudinal study, the data suggest that the intervention described can change TA resting thickness. The intervention did not influence abdominal muscle relative thickness during lower extremity tasks.

Introduction

Groin injuries are a common occurrence in sports that require frequent cutting and turning, such as soccer, rugby, and tennis. Generally, the prognosis is good and recovery is within 3 weeks (Arnason et al., 2004). For a small subgroup of these athletes, however, a groin injury may result in a long-lasting problem. Athletes with chronic groin pain are regularly seen in sports medicine clinics. Because of a lack of valid diagnostic tools (Jansen et al., 2008a), diagnosis for this specific population is often speculative. Consequently, treatment is often applied in a nonspecific manner (Jansen et al., 2008b). Physical therapy interventions aimed at strengthening and improving the coordination of the muscles stabilizing the hip and pelvis are noninvasive, safe, and often chosen as the initial treatment approach (Jansen et al., 2008b). These interventions generally result in a positive outcome for a majority of athletes with longstanding adduction-related groin pain (LAGP) (Hölmich et al., 1999).
Researchers have recently shown that wearing a pelvic belt can increase hip adduction strength and decrease pain during resisted hip adduction in athletes with LAGP (Mens et al., 2006). A pelvic belt increases stability of the pelvis by force closure (Damen et al., 2002); Mens et al., 2006b) Consequently, it is unclear whether or not groin pain associated with resisted hip adduction is solely caused by a lesion of the adductor tendon or muscle. Furthermore, athletes with LAGP who experienced difficulty lifting 1 lower extremity off the supporting surface when in supine (positive outcome on the active straight leg raise (ASLR) test) showed improvement when wearing a pelvic belt (Mens et al., 2006a). The performance on ASLR is associated with mobility of the pelvic joints (Mens et al., 1999), which further suggests that the pelvis plays an important role in longstanding groin pain associated with resisted hip adduction.
Findings on the effects of a pelvic belt in athletes with LAGP were the motive for the sports medical center of the Royal Netherlands Football Association (KNVB, Zeist, The Netherlands) to have specific attention for pelvic stabilization during rehabilitation of this population. Richardson et al. (2002) showed that bilateral activation of the transversus abdominis (TA) muscle increases stiffness of the pelvis. Furthermore, a cross-sectional study by Cowan et al. (2004) has shown that TA recruitment during ASLR is delayed in athletes with longstanding groin pain associated with resisted hip adduction compared with matched healthy athletes. As a result, in addition to the general exercises aiming at strengthening and stabilizing the hip and lumbopelvic area described by Hölmich et al, (1999) rehabilitation of these individuals in the Netherlands also focuses on activation of TA.
A delay in TA recruitment similar to that reported by Cowan et al. (2004) was also found in studies that included patients with back pain (Ferreira et al., 2004; Hodges et al., 1998, 1999, 2001) Interventions with a specific focus on TA activation have been reported to be effective in populations with back pain (Goldby

et al., 2006; Moseley 2002; O'Sullivan et al., 1997) or pelvic pain (Stuge et al., 2004a, 2004b) and some small case series on athletes with groin pain (McCathy & Vicenzino 2003; Wollin & Lovell 2006). Although this specific activation of TA is considered important in the rehabilitation for athletes with longstanding groin pain associated with resisted hip adduction, only 1 cross-sectional study of athletes with groin pain found an association between clinical status (controls versus patient) and TA recruitment (Cowan et al., 2004). Prospective data on this topic for this specific population are lacking, making it unclear if any noted deficits are present prior to or as a result of the injury. Consequently, it is unclear if there is a link between TA behavior and sports restriction prospectively.

In this study the primary objective was to investigate if changes in abdominal muscle resting thickness and behavior during lower extremity tasks would be associated with recovery of athletes with LAGP. The secondary objective was to investigate if abdominal muscle resting thickness and behavior would change significantly after a 14-week intervention. Results may help support or refute the inclusion of exercises specifically aimed at deep abdominal muscle activation, as an adjunct to general stabilizing and strengthening exercises, in the rehabilitation of these athletes.

Methods

Approval to conduct this study was granted by the Human Research Ethics Committee of the University Medical Centre Utrecht, the Netherlands. All subjects gave written informed consent and rights of the subjects were protected.

Participants

Patients attending treatment for groin pain at the sports medical center of the Royal Netherlands Football Association were approached for participation in the study. Patients were included if they were athletes aged 18 to 45 years, suffered groin pain that restricted them from sports participation for at least 4 weeks, and were motivated to return to sports. Furthermore, the groin pain needed to be provoked during a squeeze test (Verrall et al., 2005). Exclusion criteria consisted of the following: the pain started after an acute trauma, indications of fracture, hip arthritis, inguinal and/or femoral hernia, bursitis, referred pain, organ-related symptoms, psychopathology, systemic disease, earlier surgery in the groin region, visually abnormal anatomy of the hip, back, or pelvis, any other injury that prevented the subject from participating in the rehabilitation program, or inability to understand the Dutch language. Potential participants were evaluated for inclusion and exclusion criteria using a combination of a medical history intake and a complete assessment of active and passive movement of the hip, pelvis, and lumbar spine.

The calculation of sample size was based on 2 relevant studies (Cowan et al., 2004; Ferreira et al., 2004). Ferreira et al. (2004) reported decreased relative thickness of TA of about 27% (estimated SD, 22%) during a lower extremity task in a group of 10 patients with low back pain. Based on a sample of 10 athletes with longstanding groin pain associated with resisted hip adduction, Cowan et al. (2004) concluded that those patients also have a delayed TA recruitment, although the delay was smaller than that measured for those with back pain (Ferreira et al., 2004). Given the association between delayed TA recruitment and decreased relative thickness of TA during a lower extremity task,8 we estimated the decrease in TA relative thickness to be smaller (about 15%) in patients with groin pain. Using Java applets for power and sample size calculation for paired *t* tests (R.V. Lenth [2006-2009], http://www.stat.uiowa.edu/~rlenth/power), the required sample size to find a significant change in muscle recruitment with a power of 80% was estimated at a minimum of 20 subjects.

Intervention

All patients underwent a rehabilitation program consisting of 14 weeks of treatment supervised by a physical therapist. The patients attended physical therapy twice a week during the first 4 to 6 weeks, and 1 to 2 times a week during the remaining 8 to 10 weeks, depending on necessity, insurance coverage, and willingness of the individual patients to cover the costs of treatment themselves.

The program was initiated with individual treatment sessions, in which specific exercises for recruitment of the TA using palpatory feedback medial to the anterior superior iliac spines (ultrasound biofeedback was not used to avoid association with research methodology) were used. Passive joint mobilization/manipulation techniques to increase hip/sacroiliac joint/lumbar spine range of motion were applied when considered necessary by the treating physical therapist.

If patients were able to recruit the TA, exercises were given to integrate selective TA activation and respiratory activity of abdominal muscles. In the following phase, activation of the TA was integrated in simple exercises in 4-point kneeling, whereby the other abdominal and back muscles are also recruited, such as extending/bending a lower extremity and/or an upper extremity. In the next phase, exercises like the prone bridge, lateral bridge, and back bridge (Ekstrom et al., 2007) were performed.

Intensity of the exercises was gradually raised by increasing the number of repetitions, and with the use of a Swiss ball or wobble board as support surface. More functional exercises (such as squat and lunge) were also integrated in the rehabilitation program, keeping the focus on continuous TA activation for integration in functional movement patterns. In these weight-bearing exercises, avoiding knee valgus was also considered important, and therefore instructions for proper lower extremity control were provided as well. In the final stages of rehabilitation, sport-specific exercises were used, during which specific TA activation was no longer the center of attention.

Exercises to strengthen the hip adductor muscles, as described by Hölmich et al. (1999) were also used as part of treatment. Increasing the load and/or the number of repetitions was used to progress the exercises.
In addition to supervised treatment and exercise, all patients were instructed to perform home exercises. Patients were given written instructions to take home and were instructed to perform home exercises at least twice a week.

Measurements
After assessing for inclusion and exclusion criteria, the baseline measurements were performed. A questionnaire was completed with information on age, height, body mass, practiced sports, total amount of sports participation (hours per week), level of sports, laterality of complaints (if bilateral, the side with most severe pain was ascertained), and duration of complaints. Restriction in sports participation was measured using an 11-point Likert scale, ranging from 0 ("I can participate at my own level of sports") to 10 ("I can not participate in sports at all").
To estimate the amount of pelvis-related pain, the influence of a pelvic belt on the performance on the ASLR test and squeeze tests (Verrall et al.,2005) was evaluated. The ASLR test was performed in a supine position, with both lower extremities flat on the support surface and feet approximately 20 cm apart, as controlled by visual inspection. The patient was instructed to "try to raise your leg above the table to approximately 20 cm without bending the knee." Lifting the left lower extremity was tested first, followed by the right lower extremity. The patient was asked to score impairment for each leg on a 6-point scale: 0, not difficult at all; 1, minimally difficult; 2, somewhat difficult; 3, fairly difficult; 4, very difficult; 5, unable to do. The scores for both sides were added, so the summed score ranged from 0 to 10. Score 0 was defined as a negative test and scores 1 to 10 as a positive test.
Groin pain was measured during the performance of a squeeze test using an 11-point Likert scale ranging from 0 ("no pain") to 10 ("unbearable pain"). The subject was positioned in a supine hook-lying position, with the hips flexed approximately 45°, and knees flexed approximately 90°. A soft rubber soccer ball was placed between the knees of the patient. The ankles were placed together; the subjects were verbally encouraged to squeeze both knees together with maximum effort.
Then the ASLR test and the squeeze tests were repeated with the subject wearing a pelvic belt. The belt consisted of nonelastic material (model 3221/3300; Rafys, Hengelo, The Netherlands) and was positioned just below the anterior superior iliac spines, and just above the greater trochanters in an attempt to provide maximum support to the sacroiliac region (Damen et al., 2002; Mens et al., 2006). The belt was maximally tightened by hand in an effort to exceed the minimum tension of 50 N, which has been shown to be needed to influence sacroiliac joint stability (Damen et al., 2002).

Then, measurements of abdominal muscle thickness were performed. A 7.5-MHz ultrasound imaging unit (HS-2000; Honda Electronics Co, Ltd, Oiwa-cho, Toyohashi City, Aichi, Japan) was used to measure the thickness of the abdominal muscles (TA, obliquus internus [OI], and obliquus externus [OE]). The ultrasound transducer was placed in the transverse plane on the right side of the subject on the mid-axillary line, midway between the inferior angle of the rib cage and the iliac crest. The transducer's position was adjusted until the medial enthesis of the TA with OI was visualized in the far left portion of the screen. Thickness of TA, OI, and OE was measured perpendicularly from the point where the superficial fascial line of the muscle crosses the vertical midline of the ultrasound image to the deeper fascial line (Figure 1).
First, the thickness of the abdominal muscles was measured during rest. For this measurement, the subject was positioned in a supine hook-lying position with the hips flexed approximately 45° and knees flexed approximately 90°. Second, thickness of the abdominal muscles was measured during ASLR performed with the left, then the right, lower extremity, as described earlier for the ASLR test. In the third condition, ultrasound measurements were performed during maximum isometric hip adduction in the same position, as described earlier for the squeeze test. Images were captured at the end of expiration, as judged by visual inspection of the abdominal wall. Thicknesses were not measured blinded but using the on-screen calipers. All ultrasound measurements were repeated 3 times for each task. The average of these 3 measurements was used for statistical analyses (Springer et al., 2006). All ultrasound measurements were performed by the same observer (J.J.). The order of all tests was standardized as described above. Baseline measurements were made in the week before the start of the intervention. Baseline measurements on self-reported restriction in sports participation, pain with isometric hip adduction, and abdominal muscle thickness were repeated within 1 week after the end of the 14 weeks intervention.

Analyses
Intrarater reliability for single ultrasound measurements of the TA, OI, and OE was calculated by intraclass correlation coefficient (ICC 3,1). Values at baseline and follow-up were pooled for analysis of reliability. Relative thickness during the tasks was calculated for TA, OI, and OE as ([mean thickness_{task} – mean thickness_{rest}]/mean thickness_{rest}) *100% (Ferreira et al., 2004; Hides et al., 2007). The change in relative thickness after the intervention period was calculated by subtraction. Muscle thickness values at rest and relative muscle thickness during tasks were used for analysis. An independent *t* test was used to compare abdominal muscle thickness and relative thickness during the functional tasks between groups with left- versus rightsided groin pain. A Spearman rho was used to determine the level of association between change of muscle resting thickness or relative thickness during the tasks with the change in self-reported

sports restriction. A negative association would indicate that an increase in (relative) muscle thickness following the intervention is associated with decreased sports restriction. Changes on self-reported sports restriction and pain with the squeeze test were evaluated using Wilcoxon signed rank test. Consistency of changes in ultrasound measures, from baseline to follow-up, across subjects, was analyzed with paired *t* tests. If data were distributed normally (Kolmogorov-Smirnov test, $P<0.05$, combined with skewness and kurtosis values of less than (–)1), parametric tests (paired Student *t* test) were used for comparison of baseline with follow-up; otherwise, the nonparametric alternative (Wilcoxon signed rank test) was performed. Level of significance was set at $P<0.05$.
Statistical analyses were performed using SPSS software Version 15.0 (SPSS Inc, Chicago, IL).

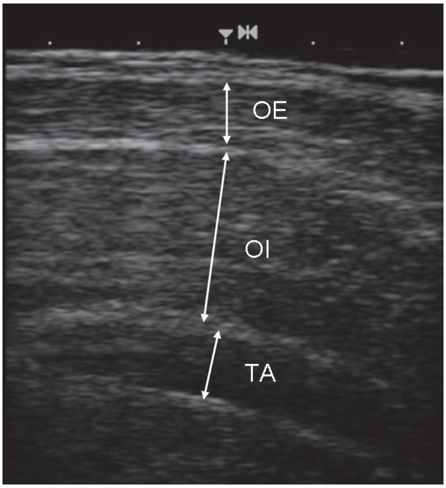

Figure 1. Measurement methodology for ultrasound imaging of the abdominal muscles. TA, transversus abdominis; OI, obliquus internus; OE, obliquus externus.

Results

Population characteristics
A total of 21 competitive amateur athletes (20 males, 1 female) fulfilled the criteria for participation in the study (Table 1). In cases with bilateral complaints (n = 6), the right side was more severe in 5 cases. Before the intervention, 7 subjects had a positive ASLR test. For these 7 subjects, median ASLR score was 2 (range, 1-4) without the belt and 1 (range, 0-3), while wearing the belt ($z = -1.9$, $P = .06$).

Characteristics	
Age (years)	24.8 (7.4)
Body mass (kg)	76.1 (10.5)
Height (cm)	183 (7.4)
Previous groin injury	9: yes; 12: no
Laterality of complaints	7left; 8 right; bilateral: 6
Median duration of complaints (weeks)	37 (range 4-104)
Sports	fitness (1), running (2), soccer (16), speed skating (1), rugby (1)
Pre-injury sports intensity (hours/week)	6.5 (2.5)

Table 1. Patients characteristics (n=21)*.
*Data represent mean (sd) unless indicated otherwise

Also before the intervention, 10 subjects experienced a decrease in pain during the squeeze test when wearing a pelvic belt. For the group (n = 21), the median (range) amount of pain during the squeeze test decreased from 6 (1-9) without a belt to 4 (0-8) when wearing a pelvic belt ($z = -2.95$, $P = .003$).

Self-reported measures
After intervention, 16 patients reported improvement on sports restriction, 3 reported to have an increase in sports restriction, 2 maintained the same level of sports restriction. Following the intervention, pain during the squeeze test was decreased in 19 subjects, increased for 1 subject, and stayed the same for the remaining subject. When considering the entire group of 21 patients, the median self-reported sports restriction and pain during the squeeze test were significantly decreased following the intervention (Table 2).

Table 2. Changes in pain and sports restriction.

	Before intervention	After intervention
Pain during the squeeze test# (median, range)	6 (1 – 9)	1 (0 – 7)*
Self-reported restriction in playing sports# (median, range)	8 (2 – 10)	2 (0 – 9)*

Likert (0-10)
* $P<0.05$ based on Wilcoxon Signed Rank test

Ultrasound measurements
The intrarater reliability of ultrasound measurements was considered to be good, with ICCs for TA, OI, and OE thickness measurements of 0.86, 0.85, and 0.80, respectively. There were no significant differences in abdominal muscle resting thickness or relative thickness during the tasks when comparing subjects with right-sided groin pain compared to those with left-sided groin pain (all $P > 0.11$). Table 3 provides the Spearman correlation coefficients between change in muscle resting thicknesses and change in relative thickness during the tasks and change in self-reported restriction in sports participation. A significant association between ultrasound measures and self-reported sports restriction was only found for TA resting thickness.
Figure 2 shows a scatter plot of the change in relative thickness of the TA during the ASLR test, lifting the right lower extremity, and change in self-reported sports restriction. This scatter plot is representative for most muscles and tasks. For changes in relative thickness of the abdominal muscles, no significant associations were found with change in self-reported sports restriction (all $P>0.12$). Compared with baseline, TA resting thickness was significantly increased after the 14-week intervention session; no significant changes were found for resting thicknesses of OI and OE (Table 4). Changes in abdominal muscle relative thickness during the tasks evaluated are shown in Table 4. Among subjects, positive but also negative changes were noticed (Figure 2) (x-axis). The only significant inding was the decrease in relative thickness of the OE during performance of the ASLR with the left lower extremity ($P = 0.039$).

Table 3. Spearman correlation coefficients [rho (*P*-value)] of changes (Δ) in muscle resting thickness or relative thickness during tasks (% thickness relative to rest), and changes (Δ) in sports restriction. Positive correlations indicate that an increase of (relative) thickness is associated with recovery.

	Δ sports restriction
Δ TA resting thickness	-0.52 (0.017)
Δ OI resting thickness	0.025 (0.91)
Δ OE resting thickness	0.126 (0.58)
Δ % TA ASLR left	0.35 (0.12)
Δ % TA ASLR right	0.09 (0.69)
Δ % TA squeeze test	0.351 (0.12)
Δ % OI ASLR left	0.13 (0.57)
Δ % OI ASLR right	0.34 (0.13)
Δ % OI squeeze test	0.34 (0.13)
Δ % OE ASLR left	0.21 (0.37)
Δ % OE ASLR right	-0.26 (0.26)
Δ % OE squeeze test	-0.27 (0.25)

Abbreviations: TA, transversus abdominis; OI, obliquus internus; OE, obliquus externus.

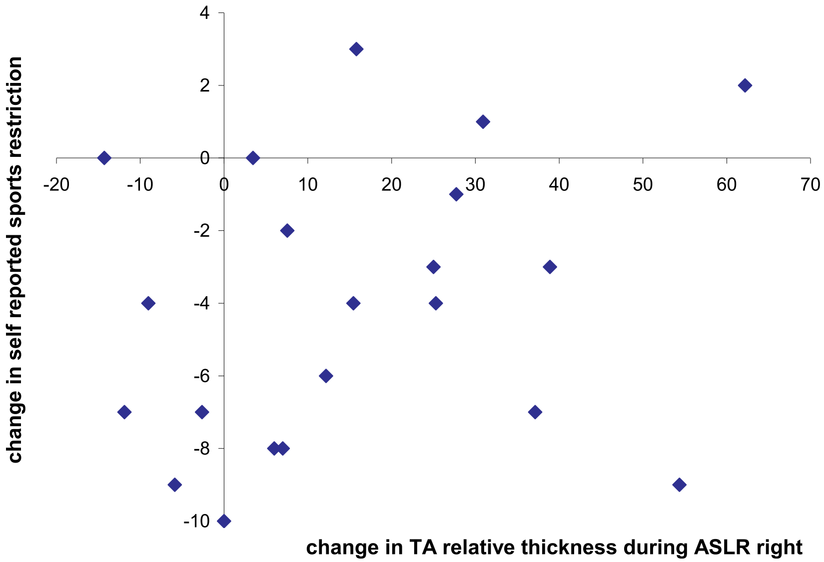

Figure 2. Representative data of change in transversus abdominus (TA) relative thickness (%) during a lower extremity task, and change in self reported sports restriction, over the intervention period. Each dot represents a subject (n=21). Notice the large variation in changes in both self-reported sports restriction and relative muscle thickness.

Table 4. Abdominal muscle resting thickness and muscle thickness relative to rest during the tasks evaluated.

	Before intervention	After intervention	*P-value**
resting thickness (mm)			
TA	4.0 (0.74) [2.9-5.5]	4.5 (0.80) [3.3–6.5]	*P*=0.006
OI	11.5 (1.3) [8.0-14.0]	12.0 (1.8) [8.6- 15.2]	*P*=0.22
OE	7.4 (1.5) [5.1-10.3]	7.8 (1.7) [5.5-12.5]	*P*= 0.15*
ASLR left			
% TA	3.4 (15.2) [-18.4-32.8]	2.8 (14.3) [-26.7-31.4]	*P*=0.86
% OI	6.2 (11.1) [-13.3–28.2]	5.3 (9.5) [-12.1-21.0]	*P*=0.77
% OE	31.5 (31.4) [-28.6-110.3]	23.0 (25.0) [-25.4-94.0]	P=0.039*
ASLR right			
%TA	4.8 (17.5) [-15.8-62.2]	7.7 (18.1) [-13.1-68.2]	*P*=0.69*
% OI	6.0 (8.6) [-4.4-25.4]	6.1 (11.5) [-10.6-37.6]	P=0.87*
% OE	-1.9 (15.3) [-22.1-44.9]	-5.9 (10.2) [-20.2-20.1]	P=0.24*
Hip Adduction			
% TA	55.8 (40.1) [-8.6-158.2]	66.4 (45.8) [0,0-188.2]	*P*=0.32
% OI	29.5 (23.7) [-8.4-84.5]	34.7 (20.5) [9.2-8.7]	P=0.41
% OE	-3.7 (25.9) [-45.6-55.9]	1.9 (26.7) [-50.0-59.5]	P=0.24

Data are mean (standard deviation) and [range].
*Based on paired t-test except for those indicated by a * which were based on a Wilcoxon signed rank test. %=percentage change relative to resting thickness

Discussion

Previous studies show that TA recruitment is significantly delayed in individuals with low back pain (Ferreira et al., 2004; Hodges et al., 1998, 1999, 2001) as well as in athletes with LAGP (Cowan et al., 2004). Therefore, exercises aiming at improving abdominal muscle behavior are commonly used in rehabilitation of individuals with longstanding groin injury.24,42 In the present study, 16 of 21 subjects reported less sports restriction after the treatment period, suggesting that the intervention described may be effective for LAGP.
In a previous study, Ferreira et al. (2004), using ultrasound, reported smaller relative thickness of the TA during lower extremity tasks in subjects, with

smaller and delayed electromyographic signal of the TA on EMG (delayed recruitment and lower EMG). We therefore hypothesized that an increase in TA relative thickness during selective tasks would be associated with a decrease in sports restriction after an intervention focusing on the TA. This hypothesis was rejected. A possible explanation may be that the delay in TA recruitment for athletes with a groin injury is less than for individuals with back pain (10 versus 50 milliseconds) (Cowan et al., 2004; Ferreira et al., 2004; Hodges et al., 1998, 1999, 2001); the similarities between these 2 groups might not be as clear as previously thought.

A significant negative association between TA resting thickness and change in sports restriction was found. Because of the significant increase in TA resting thickness and significant improvement in sports restriction, this was initially unexpected. However, a similar association between decreased TA resting thickness and decreased pain was earlier noticed in small studies of patients with back pain (Gill et al., 2007; Raney et al., 2007). It can be speculated that in those studies a decrease in pain leads to a decrease in "resting" muscle tone. It is suggested that the current increase in TA resting thickness can be the result of the 14-week intervention, but what exactly causes this change should be the focus of future research.

Several randomized controlled trials have shown that interventions using a similar approach to what we used can be effective for treating chronic low back (Goldby et al., 2006; Moseley 2002; O'Sullivan et al., 1997) or pelvic pain (Stuge et al., 2004a, 2004b). However, a study on subjects with recurrent low back pain has shown that if changes in abdominal muscle recruitment occur, these changes have no significant association with recovery (Tsao et al., 2008). In a population of women with long-lasting pelvic girdle pain, Stuge et al. (2006) also found no difference between relative thickness of TA during an abdominal-hollowing task between women with pelvic girdle pain and women who recovered from pelvic girdle pain. However, abdominal hollowing does not represent a potentially provocative task. Because behavior of muscles is very task and condition-specific, this could be the reason why no differences were found by Stuge et al. (2006). But, in agreement with the results reported by Stuge et al, (2006), no significant associations between changes in abdominal muscle relative thickness measured by ultrasound, and changes in sports restriction were found in the current study.

The efficacy of similar interventions as described in this study for patients with chronic lumbopelvic pain (Goldby et al., 2006; Moseley 2002; O'Sullivan et al., 1997; Stuge et al., 2004a, 2004b) or longstanding groin pain (McCarthy & Vicenzino 2003; Wollin & Lovell 2006) seems unlikely to be related to changes in abdominal muscle behavior. An explanation may be that the association between different domains of testing (muscle behavior and clinical status) is expected to be low (WHO 2001). A gradual increase in exercise intensity, as described in most studies on exercise interventions for longstanding groin pain and lumbopelvic pain, could also explain the intervention effect. The outcome of the intervention described in our study is very similar to the outcome of a strengthening and stabilizing intervention without specific TA attention, as described by Hölmich et al. (1999) In addition, studies on patients with back pain have shown that there seems to be no additional effect of these specific exercises to an active exercise intervention program in functional outcome (Cairns et al., 2006; Koumantakis., 2005).

Relative thickness of the TA as well as the OI during ASLR left or right and isometric resisted hip adduction (squeeze test) was not significantly changed after 14 weeks of exercises. Tsao and Hodges (2007) reported immediate changes in TA onset in a population of patients with low back pain after instructions on TA recruitment using ultrasound biofeedback, suggesting that changes in abdominal muscle behavior can be obtained without changing the clinical status (ie, level of disability). Another report by the same authors even suggests long-term preservation of changed motor control after such an intervention (Tsao & Hodges 2008). Because the exercises aiming at TA activation in the current study are similar to the exercises described by Tsao and Hodges (2007, 2008) our results were unexpected. The fact that the subjects were not provided ultrasound feedback in the present study and that TA recruitment was not emphasized in the final phases of rehabilitation in our study might explain the different results. It is also possible that ultrasound may not be sufficiently sensitive to detect small differences in abdominal muscle behavior. In fact, Hodges et al. (2003) noticed that a difference of 17% of maximum voluntary contraction of the TA, measured by electromyography, can reliably be detected using ultrasound, which is a considerable change.

Furthermore, the association between relative thickness of the TA and the activity measured by electromyography is not well established. One study showed moderate correlation only at low levels of contraction (Hodges et al., 2003); another study reported a very strong association, even at higher levels of contraction (McMeeken et al., 2004). Similar conflicting results on the validity of ultrasound for quantifying the activity of the OE are presented in the literature (Hodges et al., 2003; John & Beith, 2007). Consequently, the present results on relative abdominal muscle thickness should be interpreted with caution in terms of abdominal muscle activity.

It is questionable if the population under investigation had impaired load transfer over the lumbopelvic region. The pelvic belt significantly reduced pain during the squeeze test, but this reduction was only evident in 10 patients. Furthermore, the ASLR test was positive in only 7 of 21 subjects and the pelvic belt improved ASLR performance in only 4 of these 7. In addition, the ASLR scores found in our population were low (average ASLR score for the whole population was 0.71), but they were comparable with the scores reported by Mens et al. (2006). It is possible that ASLR scores need to be higher to be able to identify changes in muscle behavior. For example, OE activity during ASLR was significantly increased in women with pelvic girdle pain having an ASLR score of 3.9, compared with a healthy control group whose average ASLR score was 0.9 (de Groot et al., 2008), a value comparable to the subjects in the current study.

Post hoc analyses on the association of changes in relative thickness with recovery and changes in abdominal muscle relative thickness over time in the subgroup of patients responding to a pelvic belt in terms of a decrease in pain during the squeeze test (n = 10) did not show any significant association or change as well. Only 4 subjects had decreased ASLR score after a pelvic belt, and this was considered insufficient for further subgroup analysis. It is suggested that future studies only include patients responding to a pelvic belt in terms of decrease in ASLR score or decrease in pain with the squeeze test. In the present study only 2 subjects fulfilled both criteria. Whether subjects described by Cowan et al. (2004) would have responded to a pelvic belt is unknown. Therefore, it is unsure if a positive response to a pelvic belt is associated with TA dysfunction.

This study had some limitations. Although we attempted to make ultrasound measurements at the end of expiration, we probably did not succeed on every occasion. During the squeeze test, several subjects held their breath or respiration was irregular. Therefore, measuring at the end of expiration was difficult. Despite this limitation, the ICCs obtained in this study were moderate to high and are consistent with earlier reports (Hides et al., 2007; Teyhen et al., 2007). Therefore, we assume that this issue has no influence on the results.

Because measurements were made in a clinical context, the observer was not blinded to the subject's clinical status and task when performing ultrasound measurements. However, the observer and patient were unaware of the baseline values of sports restriction and abdominal muscle thickness scores at the moment of follow-up measurements. Therefore, we believe that possible bias due to lack of blinding was minimized.

Ultrasound measurements were only made on the right side of the body. Because exercises for TA were aimed at bilateral activation, an effect was expected on both sides. Furthermore, research has shown that relative thickness of the TA is very similar bilaterally during a unilateral lower extremity task in healthy subjects (Hides et al., 2007) and in subjects with back pain (Hides et al., 2009). In addition, despite the possibility of asymmetrical onset of TA as reported by Allison et al. (2008), electromyographic activity of TA after movement start seems similar between both sides. Therefore, we again believe that the measurements being performed only for the right side did not influence the results.

The lack of a control group, randomization, and blinding limits the strength of the conclusions from this study. In addition, confounding factors like improvements in hip range of motion, sacroiliac joint mobility, abdominal and lower extremity muscle strength and stability, all of which were also targeted in the rehabilitation protocol, might be associated with abdominal muscle behavior (Marshall & Murphy 2006) and/ or recovery (Hölmich et al., 1999; Verrall et al., 2006).

Conclusion

In athletes with LAGP, there was no association between changes in abdominal muscle resting thickness and relative thickness during selected lower extremity tasks, and change in self-reported sports restriction after 14 weeks of physical therapy focusing on strengthening of the deep abdominal musculature.

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CHAPTER 8

No relation between pelvic belt tests and abdominal muscle thickness behavior in athletes with longstanding groin pain. Measurements with ultrasound.

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Abstract

Objective: To investigate whether abdominal muscle thickness in athletes with longstanding adduction-related groin pain (LAGP) differs between subgroups with a positive or no response to a pelvic belt. The response to a pelvic belt is defined positive in case of a decrease ≥ 1 on a Likert pain scale (0-10) during the squeeze test (SQT), or a decrease ≥ 1 on the ASLR test score (0-10).
Design: Cross-sectional study
Setting: Physical therapy practice
Patients: 50 athletes with LAGP
Independent variables: SQT and ASLR test
Main outcome measures: First, the effect of a pelvic belt on pain during the SQT and the ASLR test score was evaluated. Then, thickness of m. transversus abdominis (TA) and m. obliquus internus (OI) was measured using ultrasound during rest, ASLR left and right, and SQT.
Results: Of the 50 subjects, 25 (50%) experienced a decrease in pain during the SQT when wearing a pelvic belt and10 subjects (20%) improved in ASLR performance with a pelvic belt. Thickness of TA and OI at rest (both cases $p>0.08$) and relative thickness compared to rest during tasks (in all cases $p>0.12$) revealed no significant difference when comparing the two sub-groups based on the belt response during the SQT or ASLR.
Conclusions: Using these methods, abdominal muscle thickness behavior in athletes with LAGP did not differ between the subgroups based on a positive or no response to a pelvic belt. However, the ultrasound method used may not have been sensitive enough to reveal differences between groups.

Introduction

In sports that require lots of twisting and turning, groin pain is a common complaint. In professional soccer, injuries to the hip/ groin represent about 16% of all injuries. However, of all injuries (besides knee injuries), groin injuries are the most responsible for long-lasting loss of playing time (Walden et al., 2001).
A common test used in the diagnostic work-up for groin pain is the so-called squeeze test (SQT). The subject is in supine crook-lying position and is asked to squeeze both knees with maximum effort (Verrall et al., 2005). Pain is then scored as present or absent. The reliability of this test is high (Holmich et al., 2004) and highly sensitive to show pubic symphysis bone marrow oedema in athletes with longstanding adduction-related groin pain (LAGP) (Verrall et al., 2005).
The SQT is also used for pain provocation in women suffering pregnancy-related posterior pelvic girdle pain (PPPGP) (Mens et al., 2002). In this female population, insufficient stability of the lumbo-pelvic region is thought to be the underlying problem. In accordance, bone marrow oedema found in the pubic symphysis on MRI in athletes with LAGP could also indicate pelvic dysfunction in this population (Verrall et al., 2005). Furthermore, Mens et al. (2006) reported decreased Active Straight Leg Raise (ASLR) test performance in patients with LAGP. The ASLR is a valid and reliable measure of the ability of load transfer over the lumbo-pelvic region (Mens et al., 2001). For all patients with LAGP and decreased ASLR test performance, wearing a pelvic belt decreased difficulty in raising the leg (Mens et al., 2006), which is a similar finding in women with PPPGP (Mens et al., 1999, 2001). In addition, the majority athletes with LAGP experiences decreased pain during the SQT, and increased adduction strength when wearing a pelvic belt (Mens et al., 2006). Given that a significant group of athletes with LAGP has a positive ASLR test, and a positive response to wearing a pelvic belt during the SQT and/or ASLR test, some form of lumbo-pelvic instability might also be present in athletes with LAGP.
Richardson et al. (2002) have shown that contraction of m. transversus abdominis (TA) and pelvic floor muscles can increase the stability of the pelvic ring. A later study by Cowan et al. (2004) reported a delay in recruitment of TA using electromyography (EMG) in athletes with longstanding groin pain during the ASLR. In the Netherlands, these findings have led to the implementation of specific pelvis-stabilizing exercises in rehabilitation protocols for athletes with LAGP to normalize deep abdominal motor control.
Although there is a positive correlation between delayed TA recruitment using EMG and decreased TA thickness using ultrasound (Ferreira et al., 2004), a later study by Jansen and colleagues using ultrasound did not report significant differences in abdominal muscle relative thickness during ASLR in athletes with LAGP (unpublished data, 2008). These results are in contrast to Cowan et al. (2004), which raises doubts about the need for implementation of specific

pelvis-stabilizing exercises in athletes with LAGP. However, it may be plausible that the subjects identified by Cowan et al. (2004) belonged to the subgroup with a positive response to a pelvic belt during the ASLR test. For this subgroup, specific pelvis-stabilizing exercises might be indicated.
The present study investigated, whether deep abdominal muscle behavior in athletes with LAGP differs between subgroups based on a positive or no response to a pelvic belt. If differences are found, this will allow physical therapists to make a more evidence-based decision as to whether or not to apply specific pelvis-stabilizing exercises.

Materials and methods

Data were collected during two earlier studies from our study group, both using the same inclusion and exclusion criteria. For both studies, approval of the local Ethics Committee was obtained before inclusion. A total of 68 experienced physical therapist (>5 years working experience) in the region of Utrecht, the Netherlands, were instructed to screen their patients for potential participants using the inclusion criteria. Subjects (male and female) were included if they were aged 18-55 years and restricted in sports participation during a period of at least four weeks as a result of LAGP. Women were only included when nulliparous. Subjects were excluded if adduction pain was absent during the squeeze test at the moment of testing. Subjects were also excluded if the pain started after a high-impact trauma; if symptoms were suggestive for fracture of the pelvis or hip, for osteoarthritis of the hip, rupture of the labrum of the hip, inguinal or femoral hernia, radicular syndrome, nerve entrapment, bursitis, malignant diseases, vascular pathologies, prostatitis, urinary tract pathology; anatomical abnormalities; systemic diseases; obvious psycho-pathology or if subjects were unable to fill in forms. A full history and physical examination were performed by the physical therapist to check on the inclusion and exclusion criteria before referring to the researcher.

Characteristics
First, a structured questionnaire was completed with information about age, height, weight, kind of sports, sports intensity (hours/week), laterality of complaints, and duration of complaints. Restriction in sports participation ("How restricted are you in sports participation?") was measured using an 11-point numeric Likert scale ranging from 0 ("I can participate at my own level of sports") to 10 ("I can not participate in sports at all").
To measure impaired load transfer through the lumbo-pelvic area, the ASLR test was performed according to Mens et al. secondly (Mens et al., 2001; Mens et al., 2006). Briefly, the ASLR test was performed in a supine position with straight legs and feet approximately 20 cm apart. The test was performed after

the instruction, ‘‘Try to raise your leg above the treatment couch for approximately 20 cm without bending the knee.’’ The left leg was always tested first. The patient was asked to score impairment for each leg on a 6-point scale: not difficult at all = 0; minimally difficult = 1; somewhat difficult = 2; fairly difficult = 3; very difficult = 4; unable to do = 5. The scores of both sides were added, so that the summed score ranged from 0 to 10. Score 0 was defined as negative and score 1 to 10 as positive. The test was repeated with the subject wearing a pelvic belt. The belt consisted of non-elastic material (Rafys, model 3221/3300) (Rafys, Hengelo, the Netherlands) and was positioned just caudally to the anterior superior iliac spines, and just cranially to the greater trochanter to obtain a maximum decrease in sacroiliac (SI) joint laxity (Damen et al., 2002; Mens et al., 2006). The belt was maximally tightened by hand to guarantee that the minimum tension to influence SI-joint laxity (≥ 50 Newton (Damen et al., 2002)) was reached. A decrease in the ASLR-score of at least 1 point on the ASLR score after wearing a pelvic belt was used as a criterion to create two subgroups among the athletes with LAGP, *i.e.* BeltASLR+ or BeltASLR-.

Third, the severity of isometric hip adduction pain was measured using an 11-point numeric Likert scale ranging from 0 (“no pain”) to 10 (“unbearable pain”) during the performance of a SQT according to Verrall et al. (2005) Again, the test was repeated with the subject wearing the pelvic belt. The response to a pelvic belt in terms of pain decrease of at least 1 point on the Likert scale during isometric hip adduction was used as an independent factor to create two subgroups within the group of athletes with LAGP, *i.e.* Beltadd+ or Beltadd-.

Ultrasound measurements

After collecting data on the population characteristics, ultrasound echography (Honda Electronics, HS-2000) (Dynamics, Almelo, the Netherlands) was used to measure the thickness of TA and *m obliquus internus* (OI). Two trained observers performed all the ultrasound measurements. The transducer (B-Mode, 5 MHz, linear) was placed in the transverse plane on the right side of the subject on the mid-axillary line midway between the inferior angle of the rib cage and the iliac crest. The transducer’s position was adjusted until the medial enthesis of the TA with OI was visualized in the far left portion of the screen. Thickness of TA and OI was measured from the point where the superficial fascial line of the muscle crosses the midline of the ultrasound image, perpendicular on the superficial fascial line, to the more deep fascial line. Measurements were made using the on-screen calipers.

First, the thickness of the abdominal muscles was measured during rest. The subject was positioned in a supine crook-lying position with the hips flexed about 45 degrees and knees flexed approximately 90 degrees and a pillow under the head.

Second, thickness of TA and OI was measured during ASLR. The ASLR test was performed in a supine position with straight legs and feet approximately 20 cm

apart. The test was performed after the instruction: ''Try to raise your leg above the couch for about 20 cm without bending the knee.'' The left leg was always tested first, followed by the right leg. The last condition measured was the SQT. The subject was again positioned in a supine crook-lying position with the hips flexed about approximately 45 degrees, and knees flexed approximately 90 degrees. A soft rubber football was placed between the knees of the subject. Ankles were placed together. The subject was asked to squeeze both knees with maximum effort.
All measurements were made at the end of expiration, as determined by visual inspection of the abdominal wall. This was done in order to standardize the influence of respiration (Hodges et al., 1997; Teyhen et al., 2005). The average of three repetitions per task and condition were used as input for analysis.

Statistical analyses
For both abdominal muscles (TA and OI), relative thickness compared to rest during each task was calculated according to Ferreira et al. (2004) as $[(\text{thickness}_{\text{-task}}-\text{thickness}_{\text{-rest}})/\text{thickness}_{\text{-rest}}] * 100\%$.
Independent t-tests were used to compare abdominal muscle thicknesses using Beltadd and BeltASLR as independent factors. The sum of TA and OI relative thickness during the tasks was also analyzed.
The level of significance was set at $p<0,05$ bilateral. All statistical analyses were performed using SPSS statistical software version 15.0 (SPSS Inc. Chicago, USA).

Results

In total, 56 injured athletes with LAGP were included. Six subjects were excluded because adduction pain was absent at the moment of testing. Table 1 presents the characteristics of the study population. Of the 20 patients with a positive ASLR, 10 (8 male, 2 female) subjects experienced decreased difficulty in raising the leg after wearing a pelvic belt (-1: n=7; -2: n=3) (BeltASLR+). Consequently, 40 subjects had no pelvic belt response on ASLR (BeltASLR-); the median ASLR score for these 10 subjects was 1.5 (range 1-4).

Table 1. Characteristics of the study population

Gender	46 males; 4 females
Age in years (mean, sd)	25,8 (8,3)
Weight in kg(mean, sd)	76.7 (10,8)
Height in cm (mean, sd)	182 (7.3)
Sports	• Soccer n=37 • Running n=5 • Fitness n=1 • Speed skating n=1 • Swimming n=1 • Dancing n=2 • Cycling n=1 • Gymnastics n=1 • Rugby n=1
Sports intensity in hours/week (mean, sd)	6.1 (2.8)
Sports restriction: Likert scale 0-10 (mean, sd)	6.7 (2.2)
Duration of complaints in weeks (median, range)	30 (4-290)
Laterality of complaints	Left n=20 Right n=26 Bilateral n=4

There was no significant difference in mean adduction pain between the two subgroups [BeltASLR+: 5.1(2.4) and BeltASLR-: 4.5 (2.4); $p=0.50$]

In total, 25 (24 male, 1 female) subjects experienced a decrease in pain during the SQT of at least 1 point on the Likert scale when wearing a pelvic belt (-1: n=10; -2: n=11; -3: n=2; -4: n=2) (Beltadd+); the remaining 25 had no decrease in adduction pain during the SQT (Beltadd-). Again, no significant difference in adduction pain was found between the two subgroups [Beltadd+: 4.8 (2.2) and Beltadd-: 4.5 (2.6); $p=0.73$]
For both divisions (i.e. based on ASLR or hip adduction), no significant differences in characteristics were found between the groups (in all cases $p>0.08$).

ASLR

The resting thickness of TA and OI showed no significant difference between the subgroup with a positive effect of a pelvic belt on ASLR compared with the subgroup with no response to a pelvic belt on ASLR (Table 2). Similarly, in these two subgroups (BeltALSR+ and BeltASLR-), no significant difference was found in the relative thickness of TA or OI during ASLR and isometric hip adduction (Table 2). Also, for all tasks, the sum of the relative thickness of TA and OI showed no significant difference between the two subgroups (all *p*-values ≥0.36).

Table 2. Absolute and relative muscle thickness (% to rest) of TA and OI during tasks evaluated for groups based on BeltASLR.

TASK	Muscle	BeltASLR - (n=40)	BeltASLR+ (n=10)	95% CI of the difference	p-value
Rest	TA	4.1 (0.84) mm	4.3 (0.83) mm	-.83 - 0.35 mm	0.42
ASLR left	TA	3.1 (13.3)%	8.5 (12.3)%	-14.77% - 3.87%	0.25
ASLR right	TA	4.8 (18.4)%	6.7 (7.5)%	-13.90% - 10.15%	0.76
Hip adduction	TA	49.8 (41.8)%	43.3 (25.5)%	-21.48% - 34.38%	0.65
Rest	OI	11.6 (2.5) mm	11.4 (2.4) mm	-.1.9 - 1.49 mm	0.81
ASLR left	OI	5.1 (11.5)%	5.5 (9.7)%	-8.33% - 7.55%	0.92
ASLR right	OI	6.3 (12.2)%	10.1 (10.3)%	-12.24% - 4.68%	0.37
Hip adduction	OI	26.8 (24.7)%	32.7 (22.8)%	-23.24% - 11.38%	0.49

Data are presented as mean (SD). TA=*m. transversus abdominis*; OI=*m. obliquus internus*; ASLR= Active Straight Leg Raise

Hip adduction

There was no significant difference in the resting thickness of TA and OI did between the subgroup with a positive effect of a pelvic belt compared with the subgroup with no response to a pelvic belt regarding isometric hip adduction pain (Table 3).

Table 3 also presents the relative thickness of TA and OI during ASLR and isometric hip adduction in subjects with a positive and a negative pelvic belt test regarding isometric hip adduction pain. Similar to ASLR, no combination of muscle and task showed a significant difference between both subgroups (in all cases $p \geq 0.12$; see Table 3).Also, for all tasks, the sum of the relative thickness of TA and OI showed no significant difference between the two subgroups (all p-values ≥0.14).

Table 3 Absolute (mm) and relative (% to rest) muscle thickness of TA and OI during tasks evaluated for groups based on the Beltadd-score.

TASK	Muscle	Beltadd – (n=25)	Beltadd + (n=25)	95% CI of the difference	p-value
Rest	TA	3.9 (0.86) mm	4.3 (0.76) mm	-.87 - 0.05 mm	0.08
ASLR left	TA	6.2 (13.6)	2.2 (12.6)	-3.49 - 11.46	0.29
ASLR right	TA	7.5 (16.3)	2.8 (17.2)	-4.8 - 14.23	0.33
Hip adduction	TA	50.5 (38.6)	46.5 (40.0)	-18.4 - 26.32	0.72
Rest	OI	11.8 (2.7) mm	11.0(2.0) mm	-.63 - 2.06 mm	0.29
ASLR left	OI	6.5 (11.7)	3.8 (10.4)	-3.68 - 8.92	0.41
ASLR right	OI	9.6 (10.1)	4.4 (13.1)	-1.37 - 11.94	0.12
Hip adduction	OI	29.7 (19.7)	26.3 (28.1)	-10.41 - 17.34	0.62

Data are presented as mean (SD). TA=*m. transversus abdominis*; OI=*m. obliquus internus*; ASLR= Active Straight Leg Raise

Discussion

The present study investigated whether abdominal muscle thickness behavior in athletes with LAGP was different in subgroups based on a positive or no response to a pelvic belt.

Comparing subjects with LAGP with and without a response to a pelvic belt during ASLR or hip adduction showed similar deep abdominal muscle thickness behavior during different tasks of the lower extremity. Consequently, a patient's response to a pelvic belt can not be used to identify abnormal deep abdominal muscle thickness behavior in athletes with LAGP.

A clear correlation has been shown between impairment of ASLR and mobility of the pelvic joints in women with PPPGP (Mens et al., 1999) and abnormal movement of iliac bones in subjects with SI joint pain (Hungerford et al., 2004). Therefore it was suggested that subjects with LAGP who are positive on ASLR *(i.e.* who experience difficulty raising at least one leg) may have increased pelvic mobility. However, other reasons for a positive ASLR are possible as well. For example, the presence of groin pain itself, muscle weakness or concurrent hip flexor irritation might hinder raising one leg (Hölmich et al., 2007). In the present study, this was confirmed by the finding that only 10 out of 20 subjects had a decreased ASLR score after wearing a pelvic belt. Consequently, only subjects with a positive response to a pelvic belt on ASLR were hypothesized to have a deficiency in pelvic stability. For these subjects, the average ASLR score was 2.3. This is on average 1.7 points less compared with the average ASLR scores of subjects with PPPGP as described by De Groot et al. (2008), who reported increased EMG activity of the *m. obliquus externus* (OE) in their specific population. Another difference between women with PPPGP and the current population is that in male and nulliparous women with LAGP, hormonal weakening of the pelvic ring is absent. Instead of a decreased intrinsic pelvic stability, an external overload is suggested to cause LAGP in athletes. It is therefore suggested that in athletes with LAGP, the relation between the ASLR score and mobility of the pelvic joints, *i.e.* pelvic instability (Mens et al., 1999), is not similar to the situation of women with PPPGP. An alternative explanation for the effects of a pelvic belt on ASLR performance in athletes with LAGP is that a pelvic belt might decrease normal physiological pelvic motion (Damen et al., 2002). The provocation of sensitized pelvic ligaments strained during ASLR might affect proprioception and/ or reflex inhibition of adjacent muscles, causing difficulty raising the leg. A similar explanation can be given for the effects of the belt on hip adduction pain. The normal physiological motion can be painful during hip adduction due to pubic bone stress (Verrall et al., 2005; Mens et al., 2006). Pelvic compression by means of a pelvic belt might decrease movement and, consequently, decrease adduction pain. However, an alternative explanation like improved proprioception of the hip muscles when wearing a belt is also possible.

There are indications that lumbo-pelvic stiffness can increase by generalized abdominal muscle activation (Richardson et al., 2002). As noted earlier, de Groot et al. (2008) reported increased EMG activity of OE in women with PPPGP.

Thickness of OE was not measured in the present study due to the lack of a relation between ultrasound measurements and OE EMG activity (Hodges et al., 2003). Nevertheless, it is possible that subjects with no response to a pelvic belt during ASLR or hip adduction have additional active stabilization of the pelvis by OE recruitment, whereas non-responders do not. It is reported that increased activation of OE is associated with altered recruitment of TA (Moseley et al., 2005), which could explain the findings by Cowan et al. (2004) Thus, it can also be hypothesized that subjects with no response to a pelvic belt on ASLR suffer from pelvic instability, but manage to compensate by increased superficial abdominal muscle activity. This needs to be investigated in future studies using EMG.

It was noticeable that only four of our subjects had a positive response to a pelvic belt on SQT pain and ASLR test performance. Both isometric hip adduction and ASLR are used to evaluate load transfer of the pelvis in PPPGP. However, both tests involve different loading of the pelvis. The torque induced by ASLR may lead to anterior rotation of the ipsilateral ilium, whereas hip adduction forces lead to distraction of the pubic symphysis. Mens et al. (2001) also reported that injured subjects with a positive response to a pelvic belt during ASLR were equally divided over the partition based on increased adduction force. It is possible that two different anatomic structures are provoked during ASLR and hip adduction, which can be sensitized alone, combined or neither of these.

Study limitations

Although no differences in abdominal muscle thickness behavior were found, this does not mean that differences were totally absent. For example, Hodges et al. (2003) reported that when using ultrasound, differences in activity of OI can only be found if the EMG difference is about 22% of maximum voluntary contraction. Our group recently found no significant differences in relative thickness of OI on the right side when comparing ASLR left and right in healthy subjects (unpublished data). In contrast, Beales et al. (2009) showed significantly greater activation (estimated 15% normalized EMG) of OI on the ipsilateral side compared with the contralateral side during ASLR. Because ultrasound measurements may not be sufficiently sensitive to detect potential differences in the present population, the hypothesis should be tested using a more sensitive measurement tool.

A second limitation could be that data were pooled from two different observers. However, both observers were trained in ultrasound imaging of the abdominal wall muscles and the subjects measured by different observers were equally divided over the subgroups. Furthermore, the inter-rater reliability of the average of three images is reported to be very high (Springer et al., 2006).

A third limitation could be that ultrasound images were measured using the on-screen calipers. However, since the average of three repeated measures was used, it is very unlikely that this method has influenced results. However, future research should apply blinding for subject and condition when possible.

A final limitation could be that the order of the tasks was not randomized. Especially for the pelvic belt test, this might have influenced results. Subjects that experienced adduction pain, might, have decreased adduction force to avoid pain, despite of encouragement for maximum performance. However, because an earlier study (Mens et al., 2006) also found no decrease in adduction force when wearing a pelvic belt, we think that this is unlikely to have occurred. Furthermore, if provocation of groin complaints during testing without a pelvic belt had occurred, it is more likely that an increase in pain would occur during the second performance rather than a decrease. Therefore we believe that the standardized order has not influenced results.

Conclusion

Subjects with LAGP experiencing decreased difficulty during ASLR or decreased pain during hip adduction after wearing a pelvic belt, have similar deep abdominal muscle thickness behavior as measured with ultrasound, compared with subjects with LAGP that have no response to a pelvic belt.

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CHAPTER 9

The effects of experimental groin pain on abdominal muscle thickness

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Abstract

Objectives: It is not clear whether abnormal abdominal muscle behavior in athletes with longstanding groin pain is a risk factor for groin pain or is caused by groin pain itself. Therefore, this study investigated whether anticipation of experimental groin pain influences abdominal muscle behavior.
Methods: In 14 healthy athletes, abdominal muscle thickness was measured using ultrasound under conditions of anticipated groin pain and acute groin pain. Groin pain was induced using superficial electrical skin stimulation. Tasks evaluated were isometric hip adduction and active straight leg raise (ASLR) left.
Results: The m. transversus abdominis and m. obliquus internus showed a significant decrease in thickness during ''anticipation of pain'' compared with ''no pain'' and ''pain'' during both hip adduction and ASLR (P values <0.04). For m. obliquus externus, a significant increase in thickness was found only during ''pain'' compared with ''no pain'' and ''anticipation of pain'' for ASLR ($P<0.004$).
Discussion: If ASLR or hip adduction is associated with anticipated groin pain, abdominal muscle behavior is different from a pain-free situation and from a painful situation. These results suggest that abnormal abdominal muscle behavior found in athletes with longstanding groin pain may be caused by a pain anticipatory motor strategy. This may have implications for rehabilitation.

Introduction

Groin injury is a common problem in sports characterized by a lot of twisting and turning or accelerations and decelerations. In outdoor soccer, 2% to 5% of all injuries occur to the groin (Morelli & Smith, 2001). Groin pain covers a broad variety of diagnoses like adductor tendinitis, osteitis pubis, abdominal wall deficiency, hip lesions, and urogenital disorders. Most groin strains are of short duration: only 14% of all groin injuries have duration of >3 weeks (Arnason et al., 2004). For the participants whose complaints are of longer duration, a proper diagnosis and treatment are indicated. However, due to the poor validity of diagnostic tools, treatment is often experience based (Jansen et al., 2008). A period of rest and physical therapy are generally the first options. Hölmich et al. (1999) showed that an active rehabilitation program, consisting of strengthening exercises for abdominal and hip muscles combined with stabilizing exercises, is more effective compared with passive physical therapy interventions for athletes with longstanding adductor-related groin pain.

Since then, other studies have provided more insight into factors associated with longstanding groin pain. Mens et al. (2006a) have shown that wearing a pelvic belt facilitates active straight leg raise (ASLR) in a subgroup of athletes with longstanding adduction-related groin pain (LAGP). The ASLR is known to be associated with mobility of the pelvic joints in women suffering pregnancy-related pelvic girdle pain (Mens et al., 2002; 2006b). As a pelvic belt contributes to force closure of the pelvis (Damen et al., 2002; Mens et al.,2006b), these findings are suggestive for pelvic dysfunction in athletes with LAGP. In accordance, pubic symphysis bone marrow edema found on MRI in athletes with LAGP could also indicate pelvic dysfunction in this population (Verrall et al., 2005). Since Cowan et al. (2004) reported a significant delay of m. transversus abdominis (TA) recruitment in athletes with LAGP during the performance of an ASLR, specific exercises aiming at normalization of TA recruitment are also regularly applied in treatment of athletic groin pain (Wollin & Lovell 2006; McCarthy & Vicenzino, 2003). However, whether the delay in TA recruitment is causally associated with groin injury is not known. Several studies reported that experimentally induced back pain also significantly delayed TA recruitment (Hodges & Richardson 1998, 1999). A similar delay in TA recruitment was also found if healthy participants were anticipating experimental back pain (Moseley et al., 2004). In those studies it was suggested that delayed recruitment of TA is part of a protective motor strategy to avoid nociceptive input from an injured anatomic substrate (Moseley et al., 2004; van Dieen et al., 2003). Consequently, the delay in TA recruitment in athletes with LAGP reported by Cowan et al. (2004) might also be a characteristic of a protective motor strategy to avoid nociceptive input. Abdominal bracing, whereby TA recruitment can be delayed (Hodges et al., 1997), is known to stabilize the lumbo-pelvic area (Richardson et al, 2002; Grenier & McGill 2007). Besides a delayed TA recruitment,

altered recruitment of m. obliquus internus (OI) (Hodges & Richardson 1999) and increased activity of m. obliquus externus (OE) (Silfies et al., 2005) are also associated with a lumbo-pelvic pain avoidance motor strategy.
In the current study, it was hypothesized that anticipation of experimentally induced groin pain and groin pain itself can affect the behavior of the abdominal muscles.

Materials and Methods

Population
Healthy male and female participants were included if they were active in sports and aged between 18 and 45 years. Exclusion criteria were injuries at the musculoskeletal system, fear of electricity, abnormal anatomy, earlier surgery or physical therapy treatment for back, hip or groin pain, systemic disease, psychopathology, or inability to fill out forms. Females were also excluded if they were pregnant or had a history of pregnancy.

Ultrasound Imaging
To avoid influence of electro-stimulation on measurements of abdominal muscle activity, ultrasound imaging (5 MHz, B-mode, Honda HS 2000, Dynamics BV, Almelo, the Netherlands) was chosen. Ultrasound has shown to be a reliable method in measuring abdominal muscle thickness (Teyhen et al., 2007; Hides et al., 2007). After application of ultrasound gel, the transducer was placed in the transverse plane just superior to the iliac crest along the axillary line on the right side of the body. To ensure measurements were taken at similar points along the TA, the transducer was adjusted until the medial junction of the TA with OI was visualized in the far left portion of the screen.
Thickness of TA, OI, and OE were measured by drawing a line from the point where the superficial fascial line of the muscle crosses the midline of the ultrasound image, perpendicularly to the deeper fascial line (Figure 1). For all images, an attempt was made to capture images at the end of expiration when possible. All measurements were repeated three times to increase reliability (Springer et al., 2006). Time between each image was 1 minute. All images were captured by the same observer (J.J.). Images were digitally stored and exported to a personal computer. To guarantee blinding for condition, task, and participant, all images were given a 3-letter code generated by a random letter generator. All images were then judged in alphabetic order, each by 2 independent observers (J.J. and B.P.). MB Ruler 3.5 was used to digitally measure abdominal muscle thicknesses.
If images were of poor quality and thickness could not be determined, missing thicknesses were inputted using the mean of the other 2 images belonging to the same participant, task, and condition (see Protocol).

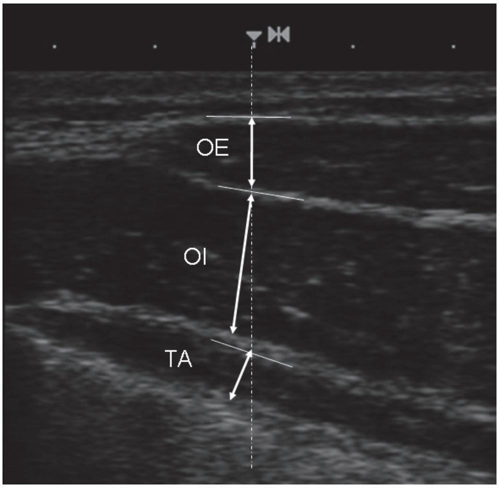

FIGURE 1. Method for determining abdominal muscle thickness. TA: m. transversus abdominis; OI: m. obliquus internus; OE: m. obliquus externus.

Protocol

The protocol was approved by the local Ethics Committee and in agreement with the Helsinki Declaration. After signing informed consent, height, weight, and type and frequency of sports were noted.

First, ultrasound images were made at rest. The participant was positioned supine with knees flexed 90 degrees and feet on the bench, and arms besides the body on the bench.

Second, ultrasound images were made during the performance of an ASLR with the left leg. The participant was in supine position with both legs extended. The participant was asked to lift and hold the extended left leg approximately 20 cm above the bench for 15 seconds. Images were made when the leg was in the correct position.

Third, ultrasound images were captured during the performance of maximal isometric hip adduction. The participant was positioned supine with hips flexed about 45 degrees and knees flexed approximately 90 degrees and feet on the bench, and arms sideways on the bench. A rubber football was placed between both knees. Participants were instructed to perform a maximal isometric hip adduction and squeeze for about 15 seconds. The measurements without painful stimulation were used as reference.

Then the individual pain level was determined using electro-stimulation. One pair of surface electrodes was placed on the inner, upper left thigh (the groin region). Painful electro-stimulation (Faradic current, phase 100 ms; interval 20 ms) was applied by the Sonopuls 692 (Enraf Nonius BV, Rotterdam, the Netherlands). This method is noninvasive and pain can be switched on and off at any moment at a reproducible intensity.25 Level of pain was measured using a 100-mm visual analog scale (VAS), where 0mm represents no pain and 100mm represents unbearable pain. The VAS is a reliable and valid method to measure acute pain intensity (Gallagher et al., 2002; Bijur et al., 2001). The electrical current was increased until the participant scored the pain experience to be at least 80mm on the VAS. When the level of electrical current was determined, the ASLR and hip adduction tasks were both repeated in the same order as reference.

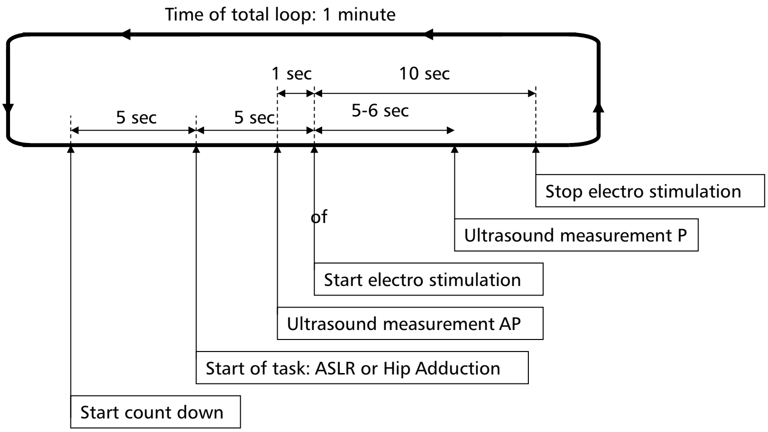

Figure 2. Timeline for measurements during the conditions ''anticipated pain'' (AP) and ''pain'' (P).

For each task, 1 researcher (B.P.) counted down out loud from 10 to 0 out loud before the beginning of the stimulation. The start of the task (ASLR or hip adduction) was initiated 5 seconds before the electrical stimulation was started. The electrical stimulation was present during 10 seconds. After these 10 seconds, a 50-second break was inserted and the subject was instructed to relax. One second before the electrical stimulation was started, an image of abdominal muscles was captured and this represented the condition ''anticipated pain.'' About 5 to 6 seconds after starting the painful stimulus, another image was captured, representing the condition ''pain'' (Fig. 2). For reliability, 3 images were made for each condition and task (Springer et al., 2006). This resulted in 21 images per participant (resting thicknesses, ASLR and hip adduction under reference, anticipated pain, and pain conditions). All ultrasound images were captured by the same observer (J.J.). The participants were denied feedback and were not allowed to view the ultrasound images.

Statistical analyses

Sample size calculations were based on a cross-sectional study by Ferreira et al. (2004) who reported a significant decrease in TA activity in a population of low back pain patients. Given a power of 0.80 and $P<0.05$ tested bilaterally, sample size was estimated at a minimum of 12 participants.

Muscle thicknesses were averaged over the 3 images belonging to the same task and condition. The behavior of abdominal muscles (TA, OI, and OE) was quantified as percentage increase in thickness relative to rest [(mean thickness$_{task}$- mean thickness$_{rest}$)/mean thickness$_{rest}$]*100%.

To check reliability of the data, interrater reliability for absolute muscle thickness per image was analysed using intraclass correlation (model 2,1; ICC_{br}). Intrarater consistency was analyzed for recruitment for each muscle using ICC as well (model 3,1; ICC_{ir}). Calculation of ICC for interrater reliability of the mean value of 3 images was not possible, and was adopted from literature ($ICC_{av}=0.98$; Springer et al., 2006). Standard error of measurement (SEM) per muscle was calculated according to the formula: $SEM=SD*\sqrt{(1-ICC_{av})}$ (de Vet et al., 2006). Pooled standard deviation per muscle was used as input. Smallest detectable difference (SDD) was calculated according to the formula $SDD= 1.96*\sqrt{(2*SEM)}$ (Knols et al., 2002).

The Kolmogorov-Smirnov test was used to check data on normal distribution. Post hoc analysis of repeated measures analysis of variance was used to evaluate the within-participant effects of pain anticipation and pain on abdominal muscle behavior per task (ASLR and hip adduction). All statistical analyses were performed using SPSS statistical software 15.0 (SPSS Inc., Chicago, IL).

Results

Fourteen participants (7 males; 7 females) volunteered to participate. Mean weight (SD) and height (SD) were 72.6 (11.2) kg and 1.80 (0.10) m, respectively. Participants participated in fitness (N=3), horse riding (N=2), soccer (N=2), running (N=2), tennis, badminton, korfball, jujitsu, and speed skating. Sports frequency varied from 1 to 5 times/ week.

Reliability

Results on reliability are presented in Table 1. Values reported are consistent with values in literature (Tehen et al., 2007; Hides et al., 2007).

Table 1. Reliability of ultrasound measurements

Muscle	ICC_{br}	ICC_{ir}	SD (% relative to rest)	SEM (% relative to rest)*	SDD (%)
OE	0.98	0.90	30.4	4.3	± 11.9
OI	0.98	0.74	16.1	2.3	± 6.3
TA	0.91	0.67	27.8	3.9	± 10.9

ICC_{br}= ICC between raters per image for absolute muscle thickness; ICC_{ir}=ICC within one rater for muscle recruitment during tasks; SEM*=Standard Error of measurement, calculated with ICC_{av}; SDD=Smallest Detectable Difference.

Anticipated Pain Effects

Mean (SD) electrical current values were 39.3 (8.1) mA resulting in a mean pain score of 89.4 (5.0) mm measured by the 100-mm VAS. Kolmogorov-Smirnov showed all data on abdominal muscle behavior to be normally distributed. The result of experimental conditions was that TA and OI relative thickness during ASLR and hip adduction were significantly decreased compared with both the reference and pain condition (P values <0.05; Figs. 3A, B). For both TA and OI during ASLR and hip adduction, no significant differences were found between the reference and pain condition (P values ≥ 0.44). For OE during ASLR, a significantly increased relative thickness was found for the pain condition compared with the reference and pain anticipation conditions (P values ≤ 0.05; Fig. 3C). No significant differences for OE were found between conditions during hip adduction.

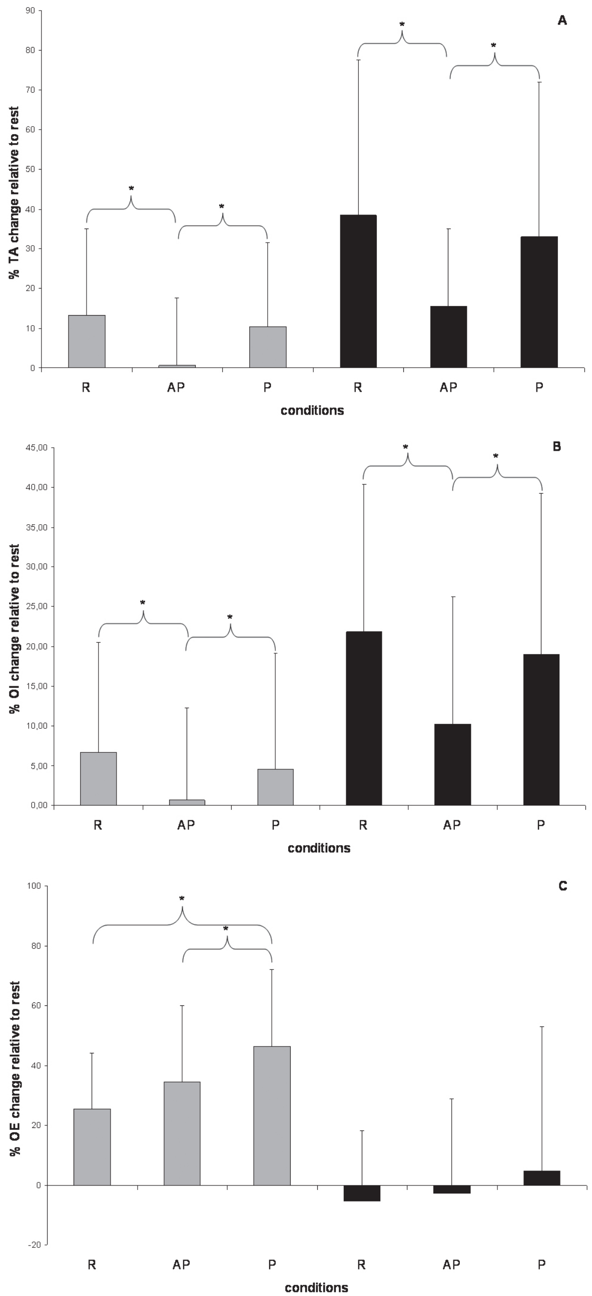

Figure 3. Changes in abdominal muscle relative thickness under experimental conditions 3A: m. transversus abdominis; 3B m. obliquus internus; 2C m. obliquus internus. Gray columns represent active straight leg raise; black columns represent hip adduction. R = reference condition; AP = anticipation of pain; P = groin pain. * indicates significant difference at the P<0.05 level.

Discussion

In the present study it was hypothesized that anticipating experimental groin pain, and experiencing pain would affect abdominal muscle behavior. The current study using ultrasound showed that there is a decrease in relative thickness of TA in anticipation of acute groin pain during both ASLR and hip adduction in healthy participants (Fig. 3A). Many studies also report a decreased relative thickness of TA with ultrasound and delayed and/or decreased electromyographic activity in participants with recurrent low back pain (Hodges & Richardson 1998, 1999, Ferreira et al., 2004). It has been suggested that the delayed recruitment of TA found in athletes with LAGP would leave the pelvic ring unprotected (Cowan et al., 2004). Consequently this would result in excessive pelvic movement and therefore increase the risk for athletic LAGP. The present study indicates that changes in abdominal muscle behavior can also be the consequence of pain anticipation, instead of the cause.

Parallel with TA, OI relative thickness during groin pain anticipation was also decreased (Fig. 3B). This pattern is in correspondence with other studies using electromyography (Hodges & Richardson 1998) or ultrasound (Ainscough-Potts et al., 2006). In the study of Ferreira et al, (2004) the activity of OI had the same tendency as TA but did not reach statistical significance. Despite the fact that relative thickness of TA and OI decreased under condition of groin pain anticipation during ASLR, the raised leg remained in the same position. The pain adaptation model by Lund et al. (1991) stipulates that in case of acute pain, muscles are recruited in such a manner that range and velocity of motion in relevant joints are limited. Crisco and Panjabi (1991) suggested that larger and more superficial muscles can contribute more to joint stiffness than deeper and smaller muscles. This could implicate that decreased relative thickness of TA and OI (being the deep muscles) are a characteristic of a compensatory alternative motor strategy. Although not significant, relative thickness of the more superficial OE was increased in anticipation of groin pain during ASLR ($P=0.13$). But, in line with present findings, significant increase of OE activity has been reported during ASLR in pregnancy-related pelvic girdle pain (de Groot et al., 2008), and in participants with experimental back pain (Hodges et al., 2003). Furthermore, relative thickness of OE did increase significantly during the pain condition. As power calculation for this study was based on previous studies on the TA, it might be possible that this study was underpowered to find statistical significant differences for OE during groin pain anticipation. It is therefore suggested that the non-significant increase in OE relative thickness during ASLR in pain anticipation can be a part of a compensatory motor strategy. However, similar studies including more participants are required to validate this hypothesis.

The fact that no differences in relative thickness of OE during hip adduction were found could be explained by the task evaluated. John and Beith (2007) reported that activity of OE can be measured validly during isometric trunk rotation tasks whereas Hodges et al. (2003b) concluded that activity of OE can not be measured using ultrasound during an isometric abdominal co-contraction task. This is illustrated in our results, showing more OE relative thickness during ASLR compared with hip adduction, although activity of OE is likely to be higher during a maximum hip adduction task. Consequently, ultrasound might not have been valid for OE activity during hip adduction.

Although a decrease in relative thickness was found for TA and OI, the difference was not statistically significant during the groin pain condition. The only significant change in relative thickness was found for OE during ASLR. We found no change in TA and OI behavior during the groin pain condition. This is in contrast with previous studies (Moseley et al., 2004; Hodges et al., 2003a). The main difference between studies on experimental back pain and present study on groin pain is the location of painful stimulation. The presence of pain may affect proprioceptive input into the central nervous system (Matre et al., 1999). Studies have shown that the presence of pain on a certain movement segment may lead to a reorganization of motor control (Brumange et al., 200, 2004). If proprioceptive input from the groin is affected by the presence of pain, the hip and anterior pelvis might be controlled in a generalized, non-specific stiffening manner activating all adjacent muscles. Due to the lack of research in this field, this explanation remains suggestive and requires further investigation.

The results of the present study may have consequences for the rehabilitation of athletes with LAGP. Although it would seem obvious that compensatory abdominal muscle behavior returns to normal if the (anticipated) acute noxious sensation disappears (Hodges et al., 2003a; Moseley & Hodges 2005), a learning effect might hinder a return to normal motor strategy in cases with longstanding pain. A longstanding pattern of postural adjustments that relies on superficial trunk muscle activity (OE) at the expense of deep trunk muscle activity (TA and OI) may lead to improper athletic movements, which in turn can lead to a vicious cycle of (new) pain and persistent motor dysfunction (Hodges & Richardson 1996, 1998; Hides et al., 1996). If such a learning effect also exists in athletes with LAGP, a return to normal motor control is not obvious, and might even lead to deconditioning of stabilizing muscles (Hides et al., 1996; Vlaeyen & Linton, 2000). Therefore it is reasonable to suggest that treatment for LAGP could also be focused on reduction of pain and/or fear of pain combined with exercises to improve abdominal muscle recruitment (Wollin & Lovell 2006; McCarthy & Vicenzino, 2003). Whether the addition of such interventions to general stabilizing and strengthening exercises described by Hölmich et al. (1999) is more effective in the treatment or relapse prevention of athletes with longstanding groin pain must be evaluated prospectively.

In general, interrater reliability per image and intrarater reliability over 3 images for measuring absolute abdominal muscle thickness was considered good. It was noticeable though that intrarater reliability for TA recruitment was only moderate. However, values reported are in line with those reported in literature

(Teyhen et al., 2007; Hides et al., 2007). Within-participant variability in muscle recruitment during tasks is suggested as a plausible explanation (Moseley & Hodges, 2006). Analysis of differences using this ICC_{av} showed most statistical differences to be bigger than the SDD.

Present study has several limitations. First, acute pain was induced by superficial electrical skin stimulation. Because multiple trials per task and condition were evaluated, the technique used in the present study was considered to be optimal. Deep electro-stimulation was not performed because of the possible influence of muscle contraction. Second, the kind of acute induced pain is not similar to real, chronic injury-related musculoskeletal pain. However, studies on experimental back pain using superficial electrical stimulation (Moseley et al., 2004) and muscle pain through saline injection (Hodges et al., 2003a) both resulted in the same adapted motor pattern seen in chronic and recurrent back pain patients. Whether activity of the abdominal muscles can be measured validly by ultrasound is a topic for discussion. McMeeken et al. (2004) showed good correlation of TA thickness changes and electromyographic activity, whereas Hodges et al. (2003b) reported ultrasound to be valid only at low levels of contraction. In addition, as was stated earlier, there is conflicting evidence whether activity of OE can be measured with ultrasound (Hodges et al.,2003b; John & Beith, 2007). Consequently, it is suggested that the interpretation of changes in relative thickness in terms of muscle activity should be with caution. Nevertheless, the changes in overall abdominal relative thickness associated with anticipated groin pain and groin pain were clear.

Force level during hip adduction was not controlled for. Participants were instructed to hold maximum adduction force during 15 seconds. Adduction force and corresponding abdominal muscle activity may have been different during the anticipated pain or pain conditions. On the other hand, task performance is standardized during the performance of an isometric ASLR. As the effects of anticipated pain and pain on abdominal muscle behavior are very similar for all abdominal muscles during both tasks, it is suggested that the effect was real. The influence of respiratory activity could only be controlled during the reference conditions. Research has shown that abdominal muscle activity is modulated by respiration (Hodges et al., 1997). It was noticed that respiration was often ceased during ''groin pain anticipation'' and ''groin pain'' conditions which might have confounded the results. Alternatively, ceasing respiratory activity of the abdominal muscles might have increased the opportunity for these muscles to contribute to postural control (Hodges & Gandevia, 2000). Therefore, it is suggested that ceasing respiration for a short duration is part of an active postural motor strategy.

Conclusion

Anticipation of experimental groin pain results in decreased relative thickness of TA and OI during ASLR and hip adduction. Relative thickness of OE is increased during experimental groin pain during ASLR. These findings may have implications for groin injury management.

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CHAPTER 10

General discussion and conclusions

Introduction

A groin injury is a common health problem in sports (Schmikli et al., 2004). Although the majority of subjects with groin injuries can return to sports within a relatively short period, some patients require more time (Arnason et al., 2004). Furthermore, subjects with previous groin injuries are at increased risk for recurrent groin injury Maffey & Emery, 2007). In this thesis, longstanding adduction-related groin pain (LAGP) was studied from several perspectives: the etiological factors and diagnosis (Chapter 2), the treatment of LAGP (Chapters 3-5 and 7), and from a fundamental point of view by exploring the relation between abdominal muscle behavior and groin pain (Chapter 6-9).
In this final chapter, the results of the studies are discussed in a broader context. In addition, implications for clinical practice are addressed and recommendations are made for future research.

Longstanding adduction-related groin pain: care for athletes

Diagnosis

A groin injury is commonly seen in sports medical care, and establishing a correct diagnosis for the injury is generally the first step towards treatment and return to sports. For patients with LAGP, multiple diagnoses are available. **Chapter 2** presents a systematic literature review on the validity of the tools used in the diagnostic work-up of athletes with LAGP was performed. Only the most commonly applied diagnoses were included, *i.e.* chronic adductor dysfunction; osteitis pubis (also known as pelvic ring overload or pubic bone stress injury) and abdominal wall deficiency. In the diagnostic studies explored in **Chapter 2**, a diagnosis was often based on the combination of findings resulting from history and physical examination together with a radiological investigation performed. The findings from the physical examination are not always given the same value by researchers. For example, Hölmich et al. (2004) suggest that palpation is the key to identifying the pathological structure and thereby leading to a diagnosis. Others state that palpation may not be of additional value since most structures in the groin will be sensitized in case of an injury and consequently, diagnosis is non-specific (Orchard, 1999). In the articles dealing with the diagnostic value of imaging techniques, considerable variability was found with regard to the type of technique used (*e.g.* X-ray, bone scan, ultrasound echography, herniography or MRI), as well as in the interpretation of the images was noticeable. Ekberg et al. (1988) noted that a certain diagnosis for longstanding groin pain originates from the specific medical specialty of the diagnostic or treating investigator and/ or from the pathomechanism that the investigator tends to prefer. This lack of uniformity in diagnostic tools and corresponding diagnoses may lead to miscommunication between the clinicians involved in treating LAGP, and will certainly confuse the athlete. Well-defined and comparable diagnostic protocols have been published by two different research groups (Hölmich, 2007; Verrall et al., 2005b), however, the final diagnoses are illustratively given names, *i.e.*: "adductor-related pain" (Hölmich, 2007) versus "chronic groin pain" (Verrall et al., 2005b). This latter diagnosis seems to be non-specific, but appears to reflect the newest insights related to the groin anatomy. A strict division between the anterior capsule of the pubic symphysis and adductor and abdominal muscles insertions on the pubic rami does not represent the *in vivo* situation. Cadaveric MRI studies have shown a very close relation between the capsule of the pubic symphysis and adductor insertions and abdominal muscles insertions (Robinson et al., 2007; Strauss et al., 2007). Furthermore in **Chapter 2** it was concluded that the suggested overload mechanism of the adductor tendon and/or pubic bone and/or pubic symphysis and/or abdominal muscles insertions can produce co-existing symptoms and abnormalities found during physical examination or imaging. This suggests that further differentiation between the diagnoses is not required since the treatment for all these pathologies will be basically the same *i.e.* improving the function of the kinetic chain adductor-pelvis-abdominals.

Treatment

Interventions for the diagnoses adductor dysfunction, osteitis pubis and abdominal wall deficiency are commonly applied in clinical practice. The treatments may consist of active exercise interventions, as well as passive interventions such as friction, electrotherapy and joint mobilizing techniques. Furthermore, extraperitoneal placement of a mesh to reinforce the abdominal wall in patients that are resistant to conservative management is a popular intervention (van Veen et al., 2007). In **Chapter 3**, the results and the levels of evidence for these treatments were evaluated by means of a systematic review of literature. In addition, in **Chapter 4** the content and outcome of physical therapy treatment in the region of Utrecht, the Netherlands was investigated using a questionnaire among physical therapists familiar with treating LAGP in athletes.
In **Chapter 5**, the outcome of physical therapy was evaluated using a telephone interview among ex-groin pain patients.
Chapter 7 presents the results of an extensive physical therapy treatment program that was investigated in a prospective study.

Conservative treatment
In **Chapter 2** it was suggested that different musculoskeletal pathologies in the groin could be different expressions of one unifying problem (i.e. a disorder in

the kinetic chain adductor-pelvis-abdominals) that may result in instability and consequently overload of one of these components. The hypothesis of pelvic instability was supported by the positive effects of a pelvic belt on the Active Straight Leg Raise (ASLR) test score and on adduction pain in athletes with LAGP reported by Mens et al. (2006). Exercise interventions for hips and abdominals can possibly improve function of the adductor-pelvis-abdominals kinetic chain and consequently improve pelvic stability. Accordingly, our systematic review on the treatment of LAGP (**Chapter 3**) included one case series and one high-quality randomized clinical trial on the treatment of LAGP (Hölmich et al., 1999; Verrall et al., 2007). These studies reported successful outcome after active physical therapy consisting of strengthening and stabilizing exercises for hips and pelvis. The model for physical therapy treatment that was extracted from the 36 physical therapists' answers to the questionnaire (**Chapter 4**) consisted of friction of the proximal adductor insertion, mobilising of the hip, stretching of the hip adductors and flexors, strengthening of the hip, quadriceps and abdominal muscles, improving neuromuscular control and sport-specific exercises. According to the physical therapists, a treatment consisting of these interventions should be successful, and might require only 13 (sd 4.4) treatment visits over a period of 8.5 (sd 4.8) weeks. However, **Chapter 4** shows that there is considerable discrepancy between both the number of treatment visits and length of the treatment period reported by the physical therapists compared with the number of visits and treatment duration of a very similar rehabilitation program reported in **Chapter 5** (*i.e.* a median (IQR) of 20 (23) treatments during a median of (IQR) 140 (158) days). It is suggested that the discrepancy between the hypothetical case as described in **Chapter 4** and the real ex-patients in **Chapter 5** can be attributed to differences in populations (physical therapists versus patients) and in the research design. Some ex-patients (in **Chapter 5**) indeed required only 13 or less treatment visits as reported by physical therapists in **Chapter 4**. However, this was a small minority. Comparing data from both studies is difficult due to the lack of strictly defined criteria used to define a treatment outcome as "successful": Criteria such as "no more complaints during activities of daily living", "running without pain" or "symptom-free return to the same level of sports" can all be used to define treatment success, but may also result in unjustifiable comparison of treatment results.

In the rehabilitation programs described in **Chapters 4**, **5** and **7**, also passive interventions aimed at mobility of the hip were described. Several cross-sectional and prospective studies have shown that decreased hip rotation range of motion is associated with groin injury (Ibrahim et al., 2007; Verrall et al., 2005a; 2007). Using a manual therapy intervention, Hoeksma et al. (2004) showed that manual therapy can increase hip range of motion, and therefore interventions aiming to improve hip range of motion in athletes with LAGP may well be indicated. Verrall et al. (2005) demonstrated that hip range of motion is similar in athletes with previous groin injury compared with matched healthy controls, and suggested that mobilizing techniques might have been important. However, based on the results in **Chapters 5** and **7** of this thesis, there is no indication that an intervention aimed at improving hip range of motion can improve outcome in athletes with LAGP, compared with the study results reported by Hölmich et al. (1999).

Besides passive interventions, another discrepancy exists between the interventions described in **Chapter 5** and **7** compared with the program by Hölmich et al. (1999), namely the specific attention paid to m. transversus abdominis (TA). Earlier research showed delayed recruitment of TA when compared with matched healthy controls (Cowan et al., 2004). Given the stabilizing effects of specific TA contraction on the pelvis (Richardson et al., 2002), it was expected that our retrospective study (**Chapter 5**) and prospective study (**Chapter 7**) would indicate that the addition of these exercises would result in better treatment outcome. However, this assumption was not substantiated. In **Chapters 5** and **Chapter 7**, the inclusion and exclusion criteria for study participation were very similar to those applied by Hölmich et al. (1999). Ioannidis et al. (2001) showed that results from non-randomized or controlled studies have a strong correlation with findings in similar populations, although the effects tend to be overestimated in uncontrolled studies. Furthermore, Samson & Aronson (2001) suggested that evidence from case series may be sufficient to draw conclusions the effectiveness of interventions, on the condition of homogeneous patient population, a well-defined natural history, consistent results, and an effect size large enough to exceed the effects of bias. In our opinion, we fulfilled most of these criteria, and therefore suggest that specific stabilizing exercises may not have additional value in the treatment of LAGP in athletes in the short term.

In the randomized controlled trial by Hölmich et al. (1999), the successful exercise therapy was also aimed at increasing hip adduction strength. This supports the idea to focus on improving the adduction strength during rehabilitation. Accordingly, Mens et al. (2006) and Malliaras et al. (2009) also showed decrease hip adduction force in patients with LAGP compared with healthy controls. It should be noted however, that the presence of pain itself can result in decreased force production due to pain inhibition (i.e. pain-contingent behavior). This could mean that decreasing the level of pain would consequently increase adduction force level. On the other hand, patients with right-sided LAGP in our study described in **Chapter 6** were shown to have a similar adduction force level when compared with healthy athletes. This could indicate that they did not have pain contingent behavior, or that the maximum adduction force level was even higher.

<u>Mechanism of improvement</u>

It remains debatable whether the proclaimed success of conservative treatment is solely due to the effect of exercise in terms of increased stability due to increased strength of the adductor-pelvis-abdominals kinetic chain. Recovery might also be the result of natural healing due to the decrease in physical load

during initial phases of rehabilitation, which is then followed by a gradual increase in physical loading. Initial rest and/ or low load might indeed give injured structures a chance to heal. Verrall et al. (2008) have recently shown that new bone formation at the pubic symphysis takes place in subjects with chronic groin pain and oedema seen on MRI. The initial instruction to refrain from all weight-bearing activities during 12 weeks as noted by Verrall et al. (2007), or the low-load exercises in the first weeks of rehabilitation reported by Hölmich et al. (1999) and in the present **Chapter 7** also makes it possible for the pubic bone and/ or pubic symphysis cartilage and/ or the adductor enthesis to heal. The subsequent gradual increase in exercise intensity derived from Verrall et al. (2007), is also applied in the active rehabilitation program described by Hölmich et al. (1999), and in the intervention described in **Chapter 7** of this thesis. Although a gradual increase in activity was also allowed in the passive therapy group described by Hölmich et al. (1999), these subjects were also instructed to stretch the adductor muscles, which was not the case in the active therapy group (Hölmich et al., 1999). It was hypothesized that stretching of the adductor muscle and thereby pulling on the insertions at the pubic bone and pubic symphysis capsule, might worsen the injury and conflict with the gradual load increase (Hölmich et al., 1999). On the other hand, a recent case series by Weir et al. (2008) described positive results of a manual stretching technique after pre-warming the adductor muscles, followed by two weeks of intensive home stretch exercises and hot baths. Weir and colleagues suggested that a decrease in thixotropy (muscle resistance to movement) was potentially decreased after manual therapy. During the subsequent two weeks of stretching, muscle tone is suggested to remain low so there is a decrease in permanent pulling of the insertion on the pubic bone, giving the sensitized area an opportunity to heal. The main difference between the stretching protocol applied by Hölmich et al. (1999) and the intervention described by Weir et al. (2008) is the manual therapy technique and hot bathing; This might explain the different results reported in both studies. In conclusion, there is conflicting evidence with respect to stretching as part of rehabilitation in the case of LAGP.
If physical therapy treatment fails, injection with corticosteroids or dextrose prolotherapy may be an alternative. Although described in poor-quality studies, the results are promising for athletes with LAGP who do not respond well to physical therapy (Schilders et al., 2007; Topol et al., 2005). It remains unknown whether the same results would be obtained for injured athletes that did not undergo previous physical therapy treatment.

Operative interventions
In the field of operative treatment, our systematic review in **Chapter 3** identified only one randomized controlled study on surgical interventions (Ekstrand & Ringborg, 2001). In that study, although the population was well defined, the clinical tests used (herniogram and/ or nerve block test) are seldom applied

in clinical practice, which complicates the transferability of these study results to the clinical practice. The fact that surgical interventions to reinforce the abdominal wall (*i.e.* placement of a mesh) appears to be successful in patients with conservative therapy-resistant adduction-related groin pain without clinical symptoms of abdominal wall dysfunction (Paajanen et al., 2005), suggests that some components that may contribute to sports-related groin pain cannot be influenced by exercise or other conservative interventions. A generalized reinforcement of the conjoined tendon is suggested as a possible explanatory factor (Paajanen et al., 2005).

Prevention

In **Chapter 2**, the literature on etiological factors and diagnostics in athletes with LAGP pain was systematically evaluated.
Several potential modifiable factors that may contribute to the occurrence of a groin injury were identified.
First there is evidence from one prospective study that decreased hip adduction force is a risk factor for groin injury (Tyler et al. 2001). In addition, a recent large-scale Danish intervention study evaluated the effects of an exercise program consisting of strengthening and stabilizing exercises for muscles related to the pelvis, with special emphasis on the adductor muscles (Hölmich et al., 2009). They reported a 31%reduction in the number of groin injuries; however, this decreasedid not reach statistical significance due to the small number of participants (Hölmich et al., 2009).
Second, there is limited evidence that delayed TA recruitment can cause groin injury (Cowan et al., 2004). Cowan and colleagues (2004) hypothesized that this could cause pelvic instability due to lack of force closure of the pelvis (van Wingerden et al., 2004). In our cross-sectional study (**Chapter 6**), we also found decreased TA thickness in patients compared with matched controls. These factors could, in turn, increase the risk for groin injury. The single randomised clinical trial exploring the prevention of groin injuries also included exercises for the abdominals, and showed positive effects (Hölmich et al., 1999). Whether or not any change in the abnormal recruitment/thickness of the TA is explanatory for the preventive effects of the program described by Hölmich et al. (1999) remains a topic of discussion. In **Chapter 9** the effect of experimentally induced groin pain on abdominal muscle thicknesses was studied. It was shown that if subjects anticipated on groin pain, abdominal muscle behavior changed significantly. Therefore it is suggested that altered TA recruitment is more likely to be the result of pain rather than the cause of pain.
Third there are indications that hip rotation range of motion is important, although it was only concluded in only two small studies (Ibrahim et al., 2007; Verrall et al., 2007). Weir et al. (2009) found radiological signs of femoro-

acetabular impingement in 94% of the athletes with adductor-related groin injury which may explain the decreased hip range of motion and which may also be considered as a risk factor. However, because no comparison was made with healthy matched subjects, this finding needs further investigation.

Similarities between athletes with LAGP and women with pregnancy related pelvic girdle pain?

A key-article by Mens et al. (2006) showed that many athletes with LAGP experienced a decrease in adduction pain and an increase in adduction strength when wearing a pelvic belt. Similarly, in subjects that experienced difficulty raising one leg, an increase in the ASLR test performance was observed when wearing a pelvic belt (Mens et al., 2006). A totally different category of patients, namely women with pregnancy-related posterior pelvic girdle pain (PPPGP), also respond positively to a pelvic belt. Since pelvic instability is thought to cause PPPGP, the suggestion that some kind of pelvic instability also exists in athletes with LAGP was proposed. The finding of altered recruitment of TA (Cowan et al., 2004), an important muscle for active pelvic stability (Richardson et al., 2002), served to strengthen this hypothesis. Although there is some evidence for an association between abnormal abdominal muscle recruitment and groin pain, this evidence is only based on a single study using electromyography (EMG) (Cowan et al., 2004).
In **Chapter 6** we investigated the association between injury status and the resting thickness and behavior of the deep abdominal muscles using ultrasound. The results of patients with LAGP were compared with those of healthy athletes. TA resting thickness was found to be significantly smaller in patients with LAGP when compared with controls, independent of the side of the complaints. No significant differences in abdominal muscle behavior were found between patients and controls. This was unexpected since a study on low back pain patients showing delayed TA recruitment on EMG, reported a significant change in TA behavior when measured with ultrasound (Ferreira et al., 2004). This finding conflicted with the hypothesis of pelvic instability in athletes with LAGP.
Earlier research on women with PPPGP showed beneficial effects of an active exercise intervention aimed at the deep abdominal muscles (Stuge et al., 2004a & 2004b). This suggested that in those women with PPPGP an increase in abdominal muscle recruitment can be associated with recovery, hypothetically due to improved force closure. Given the similarities between patients with LAGP and women with PPPGP, we expected to see this relation in our population of athletes.
In **Chapter 7**, the association between clinical status and abdominal muscle thickness behavior was studied prospectively. A total of 21 patients with LAGP underwent 14 weeks of physical therapy treatment including exercises to im-

prove abdominal muscle behavior in order to stabilize the pelvis. This study was the first to investigate the association between different levels of the International Classification of Functioning, Disability and Health (ICF), *i.e.* a disorder (an abnormality at the level of physiological function) combined with dysfunction (a problem with (functional) task performance) prospectively in patients with LAGP. Results showed that TA resting thickness was significantly increased after 14 weeks of intervention, but this increase was negatively associated with recovery. Behavior of the deep abdominal muscles during lower extremity tasks showed no significant change at the group level, and individual changes were not associated with recovery. Neither of these findings corresponded with the previous suggestion of a relation between clinical status and abdominal muscle behavior in athletes with LAGP. Consequently these findings shed doubt on the suggestion that pelvic instability exists in athletes with LAGP.

Nevertheless, Mens et al. (2006) noted that among athletes suffering LAGP subgroups can be made based on their response to a pelvic belt. Similar to women with PPPGP, a positive response to a pelvic belt does not have to be present in all cases of PPPGP (Mens et al., 1999), and therefore instability does not have to be present in all patients with LAGP. It can be hypothesized that only subjects that respond to a pelvic belt have insufficient pelvic stability, possibly due to insufficient force closure. Thus, the subjects that were included by Cowan et al. (2004) might have responded to a pelvic belt because these subjects had altered recruitment of TA, which is an important stabilizer of the pelvis (Richardson et al., 2002). In **Chapter 8**, a comparison was made between patients with LAGP that do or do not respond to a pelvic belt in terms of a decrease in adduction pain or ASLR score. Again, no significant difference in deep abdominal muscle behavior was found between the two subgroups.

To gain more insight in the cause and effect relation between the presence of groin pain and altered abdominal muscle recruitment as reported by Cowan et al.(2004), in **Chapter 9** we studied the effects of groin pain on abdominal muscle behavior. Pain was induced in 14 healthy athletes using electrostimulation, and the behavior of the abdominal muscles during ASLR and adduction was measured. Using this method we observed that a threat of experimental groin pain causes a change in abdominal muscle behavior. This might explain the changes in abdominal muscle behavior as reported by Cowan et al. (2004). These findings were in accordance with other EMG-studies investigating the effect of anticipation to experimental pain (Hodges et al., 2003; Moseley et al., 2004; Moseley & Hodges 2005). Kiesel et al. (2008) also reported significant changes in TA relative thickness during experimental low back pain measured with ultrasound. Therefore it seems that a change in abdominal muscle behavior is a consequence of the threat of pain, rather than the cause. The fact that no results corresponding with the theory of an overlap between LAGP and women with PPPGP were found in the ultrasound studies presented in this thesis, led to the development of a new theoretical model. This model is discussed below.

A model for the effects of a pelvic belt in athletes with LAGP and women with PPPGP.

Despite the similarities, there is a fundamental difference between male athletes with LAGP responding to a pelvic belt, and women with PPPGP responding positively to a pelvic belt. Although signs of pelvic involvement in athletes with LAGP in terms of pubic bone edema are present in most subjects with adduction pain (Verrall et al., 2005b; Verrall et al., 2007), athletes with LAGP have not experienced a major birth trauma or hormonal weakening of the pelvic ligaments, as is the case in women with PPPGP. This discrepancy was also confirmed by the low ASLR-scores in subjects positive on ASLR test when compared with ASLR test scores in women with PPPGP. For example, median (range) ASLR scores reported in **Chapter 6** were 0 (0-4), whereas ASLR-scores in women with PPPGP reached values of on average 3.1 (0,5) (Beales et al., 2009a), 3.9 (2,0) (de Groot et al., 2008), and 3.72 (2.6) (Mens et al., 2001). Furthermore, the ASLR score was positively influenced by a pelvic belt in the minority of patients with LAGP, whereas ASLR performance increased in 95% of the women with PPPGP (Mens et al., 1999). The effect of a pelvic belt in athletes with LAGP might be attributed to a decrease in normal physiologic mobility in the sacroiliac joints. It is known that applying extra force closure to the pelvis with a minimum of 50 N decreases normal sacroiliac mobility in healthy subjects (Damen et al., 2002). In some athletes with LAGP, sensitivity of the pubic symphysis ligaments will be increased, and therefore the effect of a belt can be more pronounced. Therefore, it is hypothesized that a positive ASLR test score (combined with the response to a pelvic belt) in male athletes is not associated with mobility of the pelvic joint, which is opposite to women with PPPGP (Mens et al., 1999). In contrast to women with PPPGP, who are assumed to have decreased intrinsic pelvic load capacity due to structural changes, in athletes a gradual overload of the pelvis and adjacent structures (*i.e.* the adductor and abdominal wall) is assumed to cause LAGP. This pathomechanism is therefore fundamentally different to that of women with PPPGP. The normal behavior of the abdominal muscles as found in **Chapter 6** can be the result of the lack of pelvic instability, although another explanation might be the lack of (severe) pain during ASLR combined with ultrasound's poor sensitivity to change (see below: *Limitations*) can serve as explanations as well. De Groot et al. (2008) reported changes in abdominal muscle behavior in women with PPPGP. It is suggested that an adaptation in motor strategy is prompted by the central nervous system when considered necessary, whereby "experienced difficulty" or "pain threat" are used as input variables. In patients with higher levels of injury severity, pain will be more pronounced, which can lead to changes in abdominal muscle behavior as well, as has been shown in **Chapter 9**.

Study Limitations

Population

In our population of athletes with LAGP the ASLR test scores were low, indicating that the level of difficulty in raising one leg was low. Consequently, it can be expected that differences in abdominal muscle behavior will be hard to find during ASLR. In addition, in **Chapter 6** it was unexpected to see that adduction force was not decreased in one group of patients compared with controls. This could indicate that adduction pain and adduction force are not associated in athletes. As suggested earlier, athletes with LAGP might not show pain-contingent behavior. Also it is generally accepted that men and women differ in their pain coping style (Fillingim et al., 2009). In addition, the athletes with LAGP included in our studies may be "familiar" with pain; most of them had continued participating in sports despite their pain. Furthermore, median (range) pain levels during maximum isometric hip adduction in these patients were 4 (2-8) for patients with left-sided complaints, and 5 (1-9) for patients with right-sided complaints (**Chapter 6**), which is slightly less compared with the pain levels reported by Mens et al. (2006) Perhaps the pain level has to be higher in order to change the adduction force scores.

Design

In this thesis, three chapters of this thesis are related to the treatment of LAGP. In **Chapter 4**, physical therapists were asked about the content of their treatment, as well as for details on the number of treatment visits and duration of treatment for athletes with LAGP. In **Chapter 5**, ex-patients were retrospectively evaluated.

In **Chapter 7**, a group of 21 athletes with LAGP was followed prospectively. Due to the lack of a control group it can not be concluded that the improvements in clinical status was soley due to the intervention described. It has been suggested that results from non-randomized or controlled studies have a strong correlation with findings in similar populations (Ioannidis et al., 2002). However, even then it remains unsure which part of the intervention contributed to recovery due to the large variety of interventions applied (ranging from passive hip and lumbar spine mobilization/ manipulation to lumbo-pelvic stabilization exercises).

Physical performance was not measured in either the cross-sectional study (**Chapter 6**) or the prospective study (**Chapter 7**). Restriction in sports is likely to be associated with physical capacity. In our studies, sports restriction was measured using a numeric Likert scale. Although most athletes were competitive athletes, sports restriction can be considered higher in elite amateur ath-

letes compared with the more recreational competitive athlete, assuming the same physical characteristics. Untill now, no valid methods are available to measure disability due to groin pain in younger subjects (Thorborg et al., 2009).
In our studies on abdominal muscle behavior, ultrasound echography was used. Ultrasound is commonly used for biofeedback in rehabilitation (Tsao & Hodges 2008). Compared with EMG, the ultrasound modality is more patient-friendly. For example, to measure TA activity with EMG, fine wire needle electrodes have to be inserted through the skin. Ultrasound is also user-friendly, allowing data collection on abdominal muscle thickness in a relatively quick and easy way.
Despite these advantages, ultrasound may not have been the optimum method in the present studies. First, as stated before, the association between EMG-activity and relative thickness of abdominal muscles remains a topic of discussion (Hodges et al., 2003; McMeeken et al., 2004). This makes interpretation of ultrasound data in terms of electromyographic muscle activity rather difficult. Second, the sensitivity to change in activity is relatively poor; Hodges et al. (2003) noted that a change of 17% maximum voluntary contraction on EMG can be reliably detected by ultrasound. In addition, Kiesel et al. (2007) reported that a minimally detectable difference of relative thickness would be 17.34% and Teyhen et al. (2009) reported 19.6%. This lack of sensitivity to change is further illustrated by a recent EMG-study by Beales et al. (2009b) showing significant differences in m. obliquus internus muscle activity between ASLR left and right in healthy subjects whereas we failed to demonstrate such differences in our healthy population using ultrasound (**Chapter 6**). The reliability of *differences* of ultrasound has not been extensively studied (Costa et al., 2009).
In our studies, we measured abdominal muscle thickness (changes) only at the right side of the body. Intra-individual differences in muscle resting thickness may exist, but on a group level these are generally not found (Mannion et al., 2008). Potential differences will more likely be found when measurements are taken at the (most) symptomatic side. In fact, Beales et al. (2009a) showed that the side of measurement did make a difference using EMG in subjects with unilateral pelvic girdle pain. In contrast, Teyhen et al. (2009) found no side-to-side differences in TA relative thickness during ASLR when measured with ultrasound on the symptomatic or asymptomatic side. Again the poor sensitivity ultrasound to detect change might have played a role in that latter study.
Besides ASLR, we used maximum isometric adduction as a potential provocative task. Despite the presence of adduction pain, no differences in abdominal muscle thickness were found between patients and controls. The instruction to give one's maximum performance might have motivated the athletes to ignore any pain and "give their all".
The timing of recruitment could not be measured with ultrasound, although this was the only deviant finding using EMG as reported by Cowan et al. (2004)
Finally, a common problem in ultrasound studies is the existence of high between subjects variability (Misuri et al., 1997) which was also encountered in

our studies. This makes it very difficult to find significant differences between groups. Perhaps, the instructions for task performance had to be more standardized to deal with this phenomenon. Further, in all studies, ultrasound measurements were made at the end of an expiration, except for the study on experimental groin pain. It has been shown that respiration is modified during painful situations (O'Sullivan et al., 2002). Although abdominal bracing using a Valsalva-like action was probably stronger in the group with groin pain than in healthy subjects, this effect may not have been revealed because all measurements were made at the end of expiration. Since all abdominal muscles, especially TA, play an important role in the creation of intra-abdominal pressure and respiration, the moment of measurement might have adversely influenced the results (Grenier & McGill, 2008).

In all studies we positioned the ultrasound probe at the height of the umbilicus. This position was chosen because it visualizes all abdominal muscles in one image and is commonly used in ultrasound studies on the abdominal muscles. However, Urquhart et al. (2005b) have shown that TA,activation is different dependent on the selected region. A position at the height of the superior anterior iliac spine might have been yielded different results. On the other hand, at the height of the superior anterior iliac spine, no fibers of the m. obliquus externus are present (Urquhart et al., 2005a), meaning that additional measures would be needed to acquire data on this muscle. Furthermore, results in **Chapter 9** show that differences in muscle behavior at the height of the umbilicus can be found in relation to groin pain.

Implications for clinical practice

Based on the findings presented in this thesis, some recommendations can be made.

Diagnosis

Firstly, it is important that specific and unambiguous terminology related to groin pain is used among clinicians and in their communication with patients. To improve this communication it is suggested that patients with groin pain are characterized by generally understandable symptoms and painful functions. For example, adduction-related groin pain combined with painful palpation of the adductor enthesis, pubis ramus and pubic symphysis. Based on the findings reported in **Chapter 8**, a pelvic belt in the diagnostic work-up seems to be of no additional value, whereas examination of the hip, sacroiliac joints and lumbar spine function is recommended given their relation with the anterior pelvis.

Due to the large differential diagnoses for groin pain, it is considered very difficult to state when imaging techniques are (or are not) of any additional value in the diagnostic process. It is suggested that the use of imaging techniques should be based on the findings in history and physical examination, and only if potential abnormalities would result in different clinical goals and interventions. In **Chapter 2**, the use of X-ray was recommended only to exclude pathology related to the skeletal system. MRI was recommended to visualize pubic bone marrow edema and abnormalities related to the pubic symphysis and adductor insertion. MRI is also recommended to exclude other pathologies unrelated to the bony system. It is suggested that MRI is not required before active physical therapy has been applied. Given its relatively inexpensive costs, ultrasound imaging to visualize the abdominal wall under dynamic conditions can be recommended at the same time as MRI, but only if abdominal wall deficiency is considered a possibility. In view of the lack of sound scientific evidence in favour of one type of methodology over another, the individual investigator's experience is considered to be very important.

Treatment

For clinicians it remains difficult to select the most appropriate intervention since characteristics of subgroups of subjects that do (or do not) respond to different kinds of interventions are not yet known. Therefore, it is recommended that an extensive active physical therapy to stabilize the anterior pelvis combined with interventions to optimize hip and lumbo-pelvic function should be the first option. Results from **Chapters 5 and 7** indicate that the addition of specific exercises to the deep abdominal muscles has no additional short term effect to a generalized exercise intervention. Despite these findings the implementation of specific exercises is recommended. There are indications that specific exercises can alter TA recruitment in a more generalized manner compared with regular sit-up training (Tsao & Hodges, 2007), and specific exercises may give better results in the long term (Hides et al., 2001). The use of ultrasound is recommended as a tool for biofeedback. Specific hip adduction training to improve strength in the initial phases is not recommended during rehabilitation. Such exercises might aggravate the pain and delay the return to sports. In the latter phases, when hip adduction is pain free, adduction strength exercises can be implemented, although any increase in exercise load should be carefully considered. Besides increasing strength, decreased adduction-related fear of movement may also be a therapeutic goal. In addition to the active exercise program, passive interventions aiming at improving hip, sacroiliac and lumbar spine function are also recommended. It should be noted, however, that the efficacy of the interventions described is not well supported by high-quality intervention studies or even case series. The clinical milestones described in **Chapter 5** are based on best practice rather than being evidence based. Finally, realistic expectations about the intervention effects should be communicated by providing appropriate information about the expected treatment duration, exercise frequency and intensity and compliance. This might avoid disappointments among both physical therapists and patients. Whether or not all exercise sessions should be supervised during the whole rehabilitation period is not known. Weir and colleagues (unpublished data) described poorer results after the unsupervised active exercise program described by Hölmich et al. (1999). Whether this difference can be explained by differences in supervision is also unknown.

The clinical decision about when to stop conservative treatment and progress to injections or surgery, or to even quit sports, is difficult in the absence of consensus concerning clinical milestones. Currently, it is unclear which criteria are used to define treatment outcome as *not* being successful, and it is unknown what happens to those patients who do not recover during the intervention period. Verrall et al. (2007) reported that a minority of patients can return to professional sports within the same season of the injury, but the remaining injured athletes that did not succeed were *not* operated on. It is recommended that a minimum intervention period of 12-14 weeks with conservative exercise therapy should be implemented, to establish whether any progress is made. If no progress is made and no clinical signs for abdominal wall deficiency are found on MRI or ultrasound, injection therapy (dextrose prolotherapy or steroid injection) can be considered. When signs of abdominal wall deficiency are present, preperitoneal placement of a mesh can be considered if the patient agrees to undergo surgery. When injections do not achieve the desired effects, explorative surgery and placement of a mesh can be considered; however, the patient's own preferences are very important in this phase. According to Paajanen et al. (2005), athletes with LAGP without signs of abdominal wall deficiency generally show good prognosis after extraperitoneal placement of a mesh. The patient's preferences and the clinician's experience can be decisive in such cases. The process of clinical decision-making is shown in Figure 1.

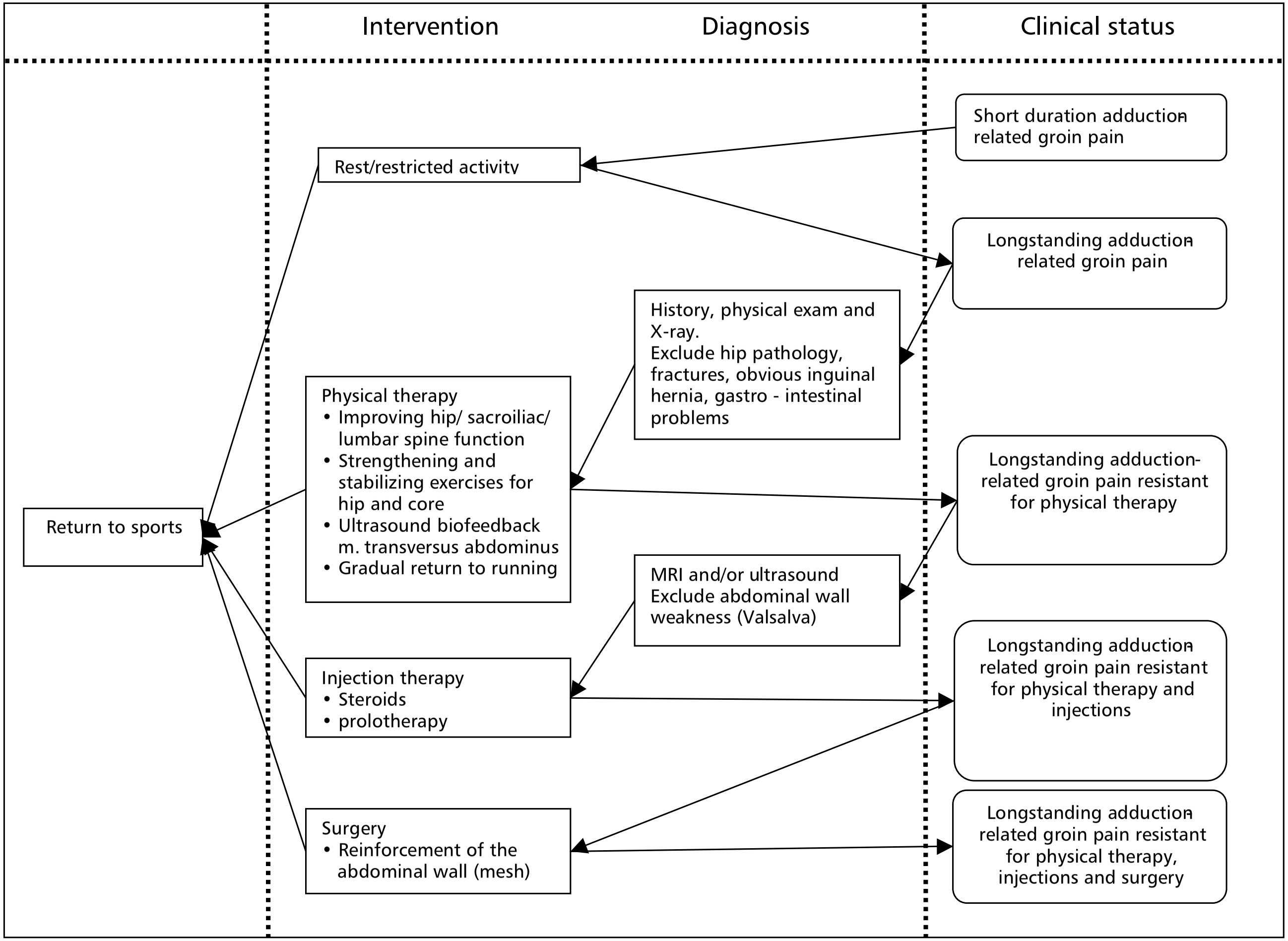

Figure 1. Guideline for clinical decision-making in athletes with adduction-related groin pain. The patient's preferences are considered important at each step, but especially in the final stages leading toward surgery.

Prevention
With regard to prevention, adduction strength can be monitored. The isometric hip adduction-to-abduction ratio of <80% mentioned by Tyler et al. (2001) can provide sound indications for setting goals in prevention as well as in rehabilitation.
Improving core stability using specific exercises is also recommended. Both core stability and hip adduction exercises have recently been evaluated in a large-scale randomized controlled trial and showed relevant but (unfortunately) non-significant effects (Hölmich et al., 2009). Furthermore, hip rotation range of motion seems to be important (Verrall et al., 2005a, 2007). If hip range of motion is unilaterally decreased on the symptomatic side, interventions aimed at improving flexibility are probably indicated. However, there is no sound evidence to support this specific intervention.
As for all preventive programs, the compliance of athletes, their trainers and coaches remains a challenge. This is nicely illustrated in the preventive study by Hölmich et al. (2009) in which of the 120 eligible football clubs, 42 declined to participate and an additional 34 clubs withdrew their participation during the course of the trial.

Recommendations for future research

Although this thesis has provided some important new insights in LAGP, there is still much to be explained and discovered in the field of LAGP.
Although most groin injuries are of short duration, what causes some groin injuries to develop in longstanding problems. For some athletes peer pressure from team mates and/or trainer as well as the level of sports and the individual coping style are important factors to be taken in consideration.
For the diagnosis of longstanding groin pain, strict and clearly defined criteria are required. Research on agreement and reliability on interpretation of clinical tests and the various imaging techniques is considered important. This will help to identify subgroups that may require different types of interventions, and may improve communication between clinicians dealing with this specific population with LAGP.
Reliable and valid methods to measure an individual's disability due to groin pain are required in order to properly evaluate injury severity, and to measure progress during the rehabilitation period.
In addition, insight is needed into the prognosis of subjects presenting with different types of clinical characteristics. Future studies should aim to match successful treatment outcome to reliable and specific clinical patient characteristics (such as hip muscle strength, and imaging results), to enable treatment to be more tailored the the individual's need. Furthermore, follow up measurements are required to establish which changes in the various parameters are associ-

ated with recovery. This will provide more insight into the relation between different domains of testing of the ICF. A relevant example is given by Schilders et al. (2007) who showed that athletes with groin pain without radiological signs of adductor enthesopathy had a better prognosis than subjects who had these radiological signs.
Since specific pelvic stabilizing exercises are recommended, we need to establish whether the addition of these exercises would results in better treatment outcome when compared with regular physiotherapeutic care. Especially long-term results are required, given the known increased risk after previous groin injury, reported in literature (Maffey & Emery, 2007).
The Internet also provides information on some promising conservative treatments for longstanding groin pain (www.liesblessure.nl; www.liesblessures.nl). Using manual massage and friction techniques to decrease the tone of muscles of the hip-pelvis-lower back kinetic chain, return to sports within a few weeks may be possible. These latter interventions should be compared with exercise interventions described in literature. When considering treatments other than physical therapy, the effects of injections (dextrose prolotherapy or steroids) should be investigated in comparison with physical therapy in a randomized controlled trial setting.
To test the hypothesis of pelvic instability in athletes with LAGP, research on motor control and mobility of the pelvic joints is required. For example, using X-ray we need to establish whether or not athletes with a positive response to a pelvic belt have increased range of motion of the pelvis.
To gain more insight in the motor control patterns and core stability of athletes with LAGP, EMG is recommended rather than ultrasound. Recent developments in wireless EMG recording allow measurements to be made during functional tasks, which may yield data with greater differentiation between motor patterns.

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SUMMARY

Groin injuries are a common problem in sports, especially in soccer. In general, most groin problems resolve with a period of rest/restricted activity and patients are able to return to sports. However, a minority of the groin injuries do not resolve; these are generally characterized by insidious onset and do not recover with rest/restricted activity. Athletes with this chronic type of injury often present themselves to (para-)medical care in order to be able to return to sports. Although interest in sports injuries is increasing, the number of basic or clinical studies in the field of chronic groin injury remains limited.
The aim of the work presented in this thesis is to contribute to the knowledge on longstanding adduction-related groin pain (LAGP) and to potentially improve (para-)medical care for subjects with this specific type of injury.

Chapter 1 presents some background information, introduces the topics of research and explains the terminology used in this thesis.
Thereafter, chapters 2 to 9 describe the research projects conducted during the period 2005 to 2009. For this, collaboration was initiated between the Erasmus Medical Center Rotterdam, the Royal Netherlands Football Association Zeist and the University Medical Center Utrecht to form a research group to study the specific topics. In addition, 68 physical therapists cooperated in order to recruit the subjects required for the data collection. For each study, approval was obtained for data collection from the appropriate local Ethics Committee, and all participating subjects provided informed consent before any measurements were made.
Chapter 2 presents the results of a systematic literature review on the validity of diagnostic tools used in LAGP. This chapter also includes a literature study on the etiological factors of LAGP. The methodological quality of the studies included in the review was evaluated using pre-defined criteria; there proved to be a wide range in the methodological quality of these studies. It is concluded that most tests, whether based on physical examination or on radiological imaging, cannot unambiguously reveal the pathological structure(s). Abnormalities seen using imaging techniques (such as roentgen, bone scan and MRI) in athletes with LAGP can also be present in healthy subjects matched for gender, sports participation and intensity. Moreover, the acquired images are multi-interpretable. Thus, the knowledge as to which factors can contribute to the occurrence of a groin injury remains limited. However, there is strong evidence that previous groin injury increases the risk for a new groin injury. Furthermore, the adduction-to-abduction hip strength ratio and the hip rotation range of motion are considered relevant, even though the strength of the evidence for these factors is limited.
Chapter 3 focuses on the results of a systematic literature review on the effectiveness of interventions for LAGP. Similar to the study in chapter 2, the methodological quality of the included studies was evaluated using pre-defined criteria for the levels of evidence. Conservative treatment generally consists of

active exercise therapy aimed at strengthening the hip and abdominal muscles combined with stabilizing exercises. In one randomized controlled trial there was strong evidence that such an intervention can result in superior treatment outcome after a supervised exercise period of about 8-12 weeks, compared with passive treatment. Surgical interventions, which generally are only applied when conservative measures have failed, mostly consist of placement of a mesh to reinforce the abdominal wall, or adductor tenotomy (i.e. surgical release of the tendon from the bone). It is noteworthy that placement of a mesh also seems to be effective in subjects without clinical signs of abdominal wall weakness. Generally speaking, the methodological quality of these surgical studies is poor due to the lack of a control group.
In **Chapter 4**, the regular physiotherapeutic care for LAGP provided in the region of Utrecht is evaluated by means of a written questionnaire. A hypothetical case of sports injury is described and the questionnaire asks about which treatment would be applied. From a total of 220 physical therapists, 36 had experience with this specific subgroup of athletes. Treatment mainly consists of advice and information, mobilizing techniques aimed at the hip, stretching of the hip adductors and flexors, friction of the adductor insertion, and strengthening and stabilizing exercises for the hip and lumbo-pelvic area, followed by sport-specific exercises. The average duration of treatment is estimated at 8.5 weeks with about 13 treatment visits. Physio-technical applications are uncommon. It is concluded that physiotherapists approach LAGP as a problem of the kinetic chain. However, due to the lack of high-quality research the described treatment is not supported by sound scientific evidence.
Chapter 5 explores the effectiveness of an extensive physiotherapeutic rehabilitation protocol. The intervention consisted of passive interventions for hip, sacroiliac and lumbar spine function, strengthening and stabilizing exercises for the hip and pelvic muscles focusing on the m. transversus abdominus, and sport-specific exercises. This study describes the results of a telephone interview among 44 ex-patients with LAGP treated at the medical center of the Royal Netherlands Football Association (KNVB). In general, satisfaction with the treatment was good. Of the 44 patients, 34 (77%) were able to return to the same level of sports without complaints. The median time until return to sports was 20 weeks and about 50% of the original 44 athletes had remained symptom-free at follow-up of 22 (range 6.5-51) months after the start of treatment. However, 26% of the athletes that returned to sports reported a recurrence of the groin injury. This observation of a higher prevalence of recurrent groin injury in those with a previous injury, compared with subjects with no previous groin injury, is in accordance with others and with our own studies (see Chapter 2).

There are indications that pelvic instability plays a role in athletes with LAGP. Through contraction, the abdominal muscles can increase pelvic stability and might therefore play an important role in rehabilitation. In **Chapters 6, 7, 8 and**

9 the association between abdominal muscles and groin pain is studied from various perspectives. Using ultrasound, the abdominal muscles (m. transversus abdominis, TA; m. obliquus internus, OI; and m. obliquus externus, OE) on the right side of the body are visualized. Measurements are made during rest as well as during tasks of the lower extremity, e.g. Active Straight Leg Raise (ASLR) left and right, and isometric hip adduction. During the lower extremity tasks, abdominal muscle behavior is expressed as percentage thickness relative to rest.
In **Chapter 6**, the abdominal muscle resting thickness and behavior during the lower extremity tasks is compared between patients with LAGP and matched controls. It was hypothesized that resting thickness and behavior during lower extremity tasks would be decreased in patients with LAGP. This study included 18 male patients with left-sided LAGP, 24 male patients with right-sided LAGP and 23 asymptomatic matched controls. TA resting thickness was found to be significantly smaller in both patient groups compared with controls. Relative thickness of TA and OI was found to be similar in all groups during the tasks evaluated. It was suggested that selective atrophy can lead to changes in TA resting thickness.
In **Chapter 7**, a prospective study is made of the association between abdominal muscle resting thickness and relative thickness during lower extremity tasks on the one hand, and sports restriction on the other. A total of 21 athletes with LAGP were included. They were treated for 14 weeks by specially trained physical therapists using interventions aiming at mobility of the hip sacroiliac joints and lumbar spine, combined with strengthening exercises for hip and abdominal muscles. Emphasis was placed on optimized recruitment of TA. There were indications that changes in abdominal muscle resting thickness and behavior during lower extremity tasks were associated with changes in sports restriction. After 14 weeks, sports restriction was significantly decreased, and TA resting thickness was significantly increased. However, no associations between changes in muscle thicknesses and changes in sports restriction were found. Large inter-individual differences were noted. These results indicate that emphasizing recruitment of TA does not contribute to the short-term results. In this study, due to the lack of a control group it is not possible to conclude whether (or not) the reported changes are the result of the intervention.
In **Chapter 8**, the hypothesis was tested that differences in abdominal muscle thicknesses can be found between subgroups of patients based on a positive or negative response to wearing a pelvic belt. One subgroup division was made based on a decrease in difficulty during ASLR after wearing a pelvic belt; another division was based on a decrease in pain during isometric adduction when wearing a pelvic belt. A total of 50 patients with LAGP were included. Between the subgroups, no significant differences in abdominal muscle resting thickness or behavior of TA and OI were found. These results suggest that the use of a pelvic belt in patients with LAGP can not differentiate between normal and abnormal abdominal muscle thickness and muscle behavior.

In **Chapter 9** the cause-and-effect relation between the presence of groin pain and abdominal muscle thickness is investigated. In 14 healthy subjects with no previous groin pain, experimental groin pain was induced using electrostimulation. The relative thickness of TA, OI and OE during ASLR and isometric hip adduction was compared under normal conditions, under a condition of pain anticipation, and during groin pain.
In both ASLR and isometric hip adduction, relative thickness of the TA and OI was significantly smaller in the pain anticipation condition compared with both the normal and the painful condition. OE showed a gradual increase in relative thickness from the normal condition to the pain anticipation condition to the painful condition, whereby relative thickness during the painful condition was significantly increased compared with the other two conditions. These results indicate that selective atrophy of TA (and OI) is possible as a result of pain anticipation, and increasing thickness might be indicated to decrease the risk of recurrent groin injury.

Chapter 10 discusses the overall results and conclusions of these studies. Recommendations are made for possible changes in clinical practice and theoretical models. Finally, a guideline for the clinical care of athletes with LAGP is presented.

SAMENVATTING

Een liesblessure is een veel voorkomend probleem bij sporters, en in het bijzonder bij voetballers. Gelukkig gaan de meeste liesblessures na een korte periode van rust vanzelf over, en is sportdeelname weer mogelijk. Er zijn echter ook liesblessures die niet vanzelf over gaan. Meestal zijn dit ook de blessures die geleidelijk zijn ontstaan. Sporters met een dergelijke blessure komen vroeg of laat in het (para-)medische circuit terecht op zoek naar duidelijkheid betreffende hun probleem, om uiteindelijk te komen tot een oplossing, opdat zij hun sportactiviteiten weer kunnen hervatten. Hoewel onderzoek op het gebied van sportblessures steeds meer aandacht lijkt te krijgen, en klinische beslissingen steeds meer op evidentie berusten, blijft wetenschappelijk onderzoek bij chronische liesklachten slechts beperkt.
Dit proefschrift is geschreven om een bijdrage te leveren aan de kennis betreffende langdurige adductie-gerelateerde liesklachten (overal in het proefschrift afgekort als LAGP) om de zorg te verbeteren.
In **hoofdstuk 1** wordt de aanleiding en achtergrondinformatie gegeven over liesblessures, worden de verschillende hoofdstukken geïntroduceerd, en worden belangrijke begrippen, die centraal staan in dit proefschrift, verhelderd.
In hoofdstuk 2 t/m 9 worden de onderzoeken beschreven die zijn uitgevoerd in de periode 2005-2009. Voorafgaand was er een samenwerkingsverband vastgelegd tussen het Erasmus Medisch Centrum Rotterdam, de Koninklijke Nederlandse Voetbal Bond (KNVB) en het Universitair Medisch Centrum Utrecht, om deze onderzoeken gezamenlijk uit te voeren. Daarnaast hebben 68 (sport-) fysiotherapeuten uit de regio Utrecht meegeholpen om de noodzakelijke proefpersonen te verzamelen. Voor iedere studie was toestemming verkregen van de Medische Ethische Toetsingscommissie, en alle deelnemers hebben mondeling danwel schriftelijk toestemming gegeven voor het gebruik van hun gegevens voor wetenschappelijke doeleinden.
In **hoofdstuk 2** worden de resultaten van een systematische literatuurstudie naar de waarde van diagnostische testen, toegepast bij sporters met LAGP, beschreven. Daarnaast worden de mogelijke oorzakelijke factoren uitgediept. Van de geselecteerde studies is de methodologische kwaliteit beoordeeld aan de hand van een scorelijst. Er wordt geconcludeerd dat de meeste testen die in het lichamelijk onderzoek worden toegepast geen eenduidigheid kunnen geven over de aangedane structu(u)r(en). Ook afwijkingen gezien op aanvullende beeldvormende technieken zoals röntgen, botscan en MRI, geven geen eenduidige afwijkingen te zien die bij gezonde sporters van hetzelfde geslacht, leeftijd, sport en sportintensiteit niet te zien zouden zijn. Daarnaast is het opmerkelijk dat bij MRI-toepassingen verschillende interpretaties van soortgelijke beelden mogelijk zijn. Kortom, duidelijke normen en standaarden ontbreken.
De methodologische kwaliteit varieerde erg tussen de verschillende studies. Wat betreft mogelijke oorzakelijke factoren zijn er slechts weinig harde feiten. Er bestaan concrete aanwijzingen dat een eerdere liesblessure het risico op een nieuwe liesblessure vergroot. Daarnaast lijkt een verminderde heupadductie-

tot abductiekracht ratio een belangrijke voorspeller te zijn, evenals een verminderde heup rotatie beweeglijkheid. Het bewijs voor deze bevindingen is echter niet sterk.

In **hoofdstuk 3** worden de resultaten besproken van een systematische literatuurstudie naar de effectiviteit van verschillende behandelmogelijkheden voor LAGP. Daarnaast is de methodologische kwaliteit van de studies beoordeeld aan de hand van een criterialijst voor interventiestudies. Er bestaan uiteenlopende vormen van conservatieve behandeling en operatieve behandeling. Conservatieve fysiotherapeutische behandeling bestaat meestal uit stabiliserende en spierversterkende oefentherapie. Er bestaat sterk bewijs dat een periode van 8-12 weken intensieve begeleide oefentherapie, gericht op het verbeteren van kracht van heup- en lage rug spieren (zowel extensoren als flexoren), een effectievere behandelmethode is voor LAGP vergeleken met een passieve behandeling. De operatieve interventies, die meestal worden toegepast als conservatieve behandelingen mislukt zijn, zijn gericht op het versterken van de binnenste buikwand door middel van het plaatsen van een kunststof matje ("mesh"), of het doorklieven van een deel van de adductoren ter hoogte van de aanhechting aan het schaambeen. Opvallend is dat het plaatsen van een mesh ook effectief lijkt te zijn bij sporters bij wie geen aanwijzingen zijn dat de buikwand oorzaak van het probleem is. Het wetenschappelijk niveau van deze operatieve studies is bij afwezigheid van een controlegroep over het algemeen mager.

In **hoofdstuk 4** wordt gefocust op de gangbare fysiotherapeutische behandelmethode van sporters met LAGP in de regio Utrecht. Door middel van een vragenlijst is geïnventariseerd welke middelen worden ingezet. Aan de ondervraagden is een hypothetische casus met LAGP voorgelegd, waarna de fysiotherapeutische behandeling wordt uitgevraagd. Van de 220 aangeschreven fysiotherapeuten bleken 36 (sport-)fysiotherapeuten ervaring met de specifieke doelgroep te hebben. De behandeling blijkt te bestaan uit advies en informatie, mobiliserende technieken gericht op de heup, rekken van de heupadductoren en -flexoren, spierversterkende en coördinatie-verbeterende oefeningen voor de heup en romp gevolgd door sportspecifieke oefeningen. De geschatte gemiddelde duur van behandeling is ongeveer 8.5 weken waarin 13 behandelingen worden gegeven. Fysiotechnische applicaties worden nauwelijks meer toegepast. In de praktijk blijkt dat LAGP benaderd wordt als een probleem van de bewegingsketen. Bij gebrek aan goede studies is de maat waarin de behandeling wetenschappelijk wordt ondersteund slechts beperkt.

In **hoofdstuk 5** worden de resultaten van een interventie bestaande uit mobiliserende technieken gericht op de heup, het bekken en lage rug, aangevuld met spierversterkende en stabiliserende oefeningen voor heup en bekken beschreven. Aan de hand van een telefonische enquete onder (ex-)patiënten met een LAGP, behandeld op het sport medisch centrum van de KNVB, zijn zowel de korte als de lange termijn resultaten in kaart gebracht. Over het algemeen zijn sporters direct na de behandeling zeer tevreden over het resultaat van hun behandeling. 77% van de ondervraagden gaf aan na 20 weken weer terug op het oude niveau van hun sport terug te keren. De lange termijn effecten zijn gematigd positief. Ongeveer 50% had geen klachten meer na het einde van de behandeling tot het moment van navraag (22 (range 6.5-51) maanden na start van de behandeling), maar 26% van de sporters die waren teruggekeerd naar hun sport hebben een terugval gehad. Er zijn dus aanwijzingen dat het risico op een terugval is toegenomen als men eenmaal een liesblessure heeft gehad, vergeleken met sporters die nooit een liesblessure hebben gehad. Dit sluit aan bij andere literatuur (hoofdstuk 2).

In de wetenschappelijke literatuur zijn er aanwijzingen dat bekkeninstabiliteit een rol zou kunnen spelen bij sporters met LAGP. De buikspieren kunnen door contractie een bijdrage leveren aan bekkenstabiliteit, en zouden daarom belangrijk kunnen zijn in de behandeling. In **hoofstuk 6, 7, 8 en 9** wordt de relatie tussen de rustdikte en het gedrag (percentage diktetoename tijdens een taak ten opzichte van rust) van de buikspieren en LAGP bestudeerd. Aan de hand van echografie worden opnamen van de buikspieren (m. transversus abdominus (TA) en m. obliquus internus (OI) en m. obliquus externus (OE)) aan de rechter lichaamszijde gemaakt tijdens rust, het uitvoeren van een "Active Straight Leg Raise" (ASLR) links en rechts, en het uitvoeren van een maximale isometrische heupadductie.

In **hoofdstuk 6** wordt de dikte en het gedrag van de buikspieren vergeleken tussen sporters met LAGP en gezonde sporters. De hypothese was dat rustdikte en gedrag bij sporters met LAGP afwijkend zou zijn. 18 sporters met LAGP links en 24 sporters met LAGP rechts en 23 gematchte, gezonde sporters werden geincludeerd. De rustdikte van TA bleek significant kleiner bij patiënten met LAGP vergeleken met gezonde sporters. In het algemeen bleek het gedrag tijdens de geëvalueerde taken niet verschillend tussen de groepen. Dit was in tegenstelling met eerdere resultaten uit de wetenschappelijke literatuur. Als mogelijke verklaring voor de verminderde TA rustdikte wordt selectieve atrofie gesuggereerd.

In **hoofdstuk 7** wordt de relatie tussen dikte en gedrag van de buikspieren en ervaren sportbeperking prospectief onderzocht. Bij 21 sporters met LAGP zijn echografiemetingen voor en na een fysiotherapeutische interventie, gericht op het verbeteren van de beweeglijkheid van de heup, sacro-iliacale gewrichten en lage rug, het versterken van de rompspieren en het verbeteren van het gedrag van de buikspieren, uitgevoerd. De patiënten werden behandeld door een speciaal geïnstrueerde fysiotherapeut gedurende 14 weken. Er werd onderzocht in hoeverre er na de interventie veranderingen in het gedrag van de buikspieren meetbaar waren, en in hoeverre deze veranderingen gerelateerd waren aan veranderingen in ervaren sportbeperking. Na 14 weken was de sportbeperking gemiddeld significant afgenomen, maar waren er geen significante veranderingen in het gedrag van de buikspieren. De rustdikte van TA was wel significant toegenomen. Het bleek dat er grote inter-individuele verschillen bestonden tussen de veranderingen in het gebruik van de buikspieren. Er bleek tevens geen significante relatie te bestaan tussen veranderingen in het gebruik van de buikspieren en veranderingen op het gebied van sportbeperking. Dit suggereert dat het veranderen van het gebruik van de buikspieren niet direct relevant is voor verminderde sportbeperking. Dat de veranderingen (bij een deel van de proefpersonen) toe te schrijven is aan de interventie kan, bij gebrek aan een controlegroep, niet hard gemaakt worden.

In **hoofdstuk 8** is onderzocht in hoeverre er subgroepen binnen de categorie van sporters met LAGP bestaan. Gegevens van 50 sporters met LAGP zijn gebruikt om te onderzoeken in hoeverre sporters die minder adductiepijn krijgen na het omsnoeren van een bekkenband een ander gebruik van de buikspieren hebben dan sporters die niet reageren op een bekkenband. Een soortgelijke test werd gedaan voor de subgroepen gebaseerd op een positieve of geen reactie op een bekkenband tijdens ASLR. Er werden geen significante verschillen gevonden in het gebruik van de buikspieren tussen subgroepen, ongeacht welke indeling is gekozen. Deze resultaten wekken de indruk dat een bekkenband test niet gebruikt kan worden om te differentiëren in het gedrag van de buikspieren bij sporters met LAGP.

In **hoofdstuk 9** wordt de oorzaak-gevolg relatie tussen een afwijkend gedrag van de buikspieren en de (dreigende) aanwezigheid van liespijn onderzocht. Bij 14 gezonde sporters werd het gedrag van de buikspieren gemeten tijdens ASLR en heup adductie onder normale omstandigheden, tijdens dreigende liespijn, en tijdens echte liespijn. De liespijn werd opgewekt door middel van elektrostimulatie. Zowel bij ASLR alsook bij adductie blijken de dieper gelegen buikspieren, TA en OI, minder ingezet worden, terwijl er aanwijzingen zijn dat de meer oppervlakkige buikspier, OE, meer ingezet wordt. Tijdens de conditie liespijn was de relatieve dikte van OE toegenomen, terwijl de relatieve diktes van TA en OI weer normaliseerden. Deze resultaten sluiten aan bij de gedachtegang dat atrofie van de diepe buikspieren kan optreden bij persisterende dreiging van liesklachten. Het vergroten van de dikte van TA zou daarom van belang kunnen zijn, om, op de lange termijn, de kans op recidiefklachten te verminderen.

In **hoofdstuk 10** worden de gevonden resultaten beschouwd en algemene conclusies getrokken. Ook worden aanbevelingen voor de (para-)medische praktijk, aanpassingen op bestaande theorieën en vervolgonderzoek gegeven. Daarnaast wordt er een richtlijn beschreven die zou kunnen dienen voor de klinische zorg van sporters met LAGP.

DANKWOORD

"De lies, de lies, en anders niets" is een toepasselijke verbastering van een boekje van Gert-Jan Theunisse getiteld "De fiets, de fiets en anders niets". De afgelopen 4,5 jaar heb ik mij met dit kleine onderwerp bezig gehouden. Gelukkig heb ik vanuit verschillende hoeken hulp en ondersteuning hierbij gehad. Op deze plaats wil ik alle betrokken bedanken voor hun bijdrage die uiteindelijk tot dit proefschrift heeft geleid.

Mijn eerste promotor, prof. dr. Frank Backx, De derde (?) professor in de klinische sportgeneeskunde in het UMC Utrecht. De laatste jaren zijn belangrijk geweest om dit horizontale specialisme een plaats te geven in het UMC Utrecht. Mede dankzij jouw inzet lijkt dit steeds meer te lukken! Dank voor je tactische inzichten en voor de vele handtekeningen die gezet zijn voor METC. Daarnaast heb je een goed gevoel voor de stijl, de flow van de geschreven manuscripten. Jouw bijdragen hebben zeker aan de leesbaarheid van de manuscripten bijgedragen!

Mijn tweede promotor, prof. dr. Henk Stam. Goed om je erbij te hebben, al was het vaak op een afstand. Deze letterlijke maar zeker ook figuurlijke afstand heeft er echter wel voor gezorgd dat er een geheel objectieve blik op de manuscripten werd geworpen. De rust en structuur waarmee jij regelmatige overleggen leidde, resulteerde in daadwerkelijk stappen voorwaarts.

Dr. Jan Mens. Vele inhoudelijke discussies, veelal over de mail, over de biomechanica van het bekken, de ASLR test en de adductietest, intra-abdominale druk en de invloed van een bekkenband. Jij was de man van de inhoud en biomechanica, en was de vraag hoe de inhoud gepresenteerd werd iets minder relevant! Gedurende de tijd hebben wij onze hypothesen over het gebruik van de buikspieren bij bekken-gerelateerde problemen iets moeten bijstellen. Uiteindelijk zijn wij toch weer een stapje dichterbij gekomen.

Adam Weir, mijn klinische paranimf. Je had een fantastisch bereidschap om te helpen mijn projecten tot een goed einde te brengen. Daarnaast heb je mij ontzettend geholpen met het schrijven van een discussie met een boodschap voor de kliniek! Super dat jouw RCT tot een goed einde is gekomen! Heel veel succes in je komende carrières als onderzoeker, sportarts en vader!

Drs. Sandór Schmikli, mijn methodologische paranimf. Hoe sommige dingen op het gebied van statistiek, die mij een halve dag kosten, in 5 minuten opgelost kunnen worden. Ben ik nou zo dom of ben jij nou zo slim? Ik zal onze lunchwandelingen zeker gaan missen.

Dr. Ingrid van de Port; mijn ex-kamergenoot. Super bedankt voor je goede adviezen op wetenschappelijk gebied. Je hebt mij ook bij fysiotherapiewetenschappen betrokken wat een leuke ervaring voor mij was!

Professoren Bart Koes, Ron Diercks en Jan Verhaar, hartelijk dank voor de kritische beoordeling van mijn proefschrift!

Sportartsen bij de KNVB te Zeist, Gert-Jan Goudzwaard, maar met name Han Inklaar. Mede dankzij jouw initiatief en ideëen is dit onderzoek van de grond gekomen. Ik hoop dat het nog lukt je ambitie om de "Inklaar disease" te ontdekken waar te maken! Jammer dat je met pensioen bent. Toch een icoon dat afscheid heeft genomen.

Alle deelnemende fysiotherapeuten die bereid waren de benodigde proefpersonen te verzamelen. In het bijzonder de fysiotherapeuten van het sport medisch centrum van de KNVB te Zeist, waar ik vaak over de vloer ben gekomen.

Irma Hennevelt, Marion Jansen, Justine Herzog en de andere telefonisten/receptionisten van de KNVB. Bedankt dat jullie mij bij iedere aanmelding van een liespatiënt op de hoogte hebben gehouden.

Alle patiënten die bereid waren om de metingen te ondergaan. De meeste patiënten met een liesblessure hadden op het moment van testen ook pijn bij de weerstand test adductie. Ik ben erg blij dat jullie deze vervelende beweging meerdere keren voor mij wilde herhalen!

Geert Aufdemkampe. Betrouwbaarheid van data bestaat niet alleen uit een ICC! Dit heeft ertoe geleid dat ik me nogmaals flink in de betrouwbaarheidsstatistiek heb verdiept en dit heeft uiteindelijk een grote toegevoegde waarde gehad. Bedankt voor deze eye-openers!

Elmar Hulstijn. Bedankt dat je samen met mij de website over het onderzoek hebt ontwikkeld. We waren een van de eerste die een dergelijke subsite wilden opzetten. Opeens bleken er erg veel groepen invloed te hebben op een dergelijke subsite. Zo leer je een grote organisatie als het UMC kennen.

Laraine Visser-Isles. Thanks for your corrections on my English writing.

Selma May. Bedankt voor je geduld en alle andere belangrijke dingen die het leven zo aangenaam maken…..Voortaan staat de auto hopelijk wel tot je beschikking en zal ik geen metingen meer plannen. Ook zal het echo-apparaat geen prominente plaats meer in de woonkamer innemen! Gelukkig hebben we genoeg speelgoed die na de komst van onze Teun deze leegte kan opvullen!

Onze Teun. Onze fantastische aanwinst van 12 december 2008. Altijd (nou ja, tenminste meestal) een blij gezicht als ik je op kwam halen bij de blauwe kikker. Door jou was de reis van de Uithof naar huis al een pleziertje op zich!

De stagiaires die in de loop der jaren aan de verscheidene deelprojecten hebben meegewerkt! In chronologische volgorde:
Nikki Kolfschoten. Een grote meerwaarde voor de systematische review naar de effectiviteit van verschillende behandelvormen. Nu heb ik je ook nog op TV gezien. Waar gaat dat heen! Een mooie toekomst toegewenst.
Renee Dénis. Een fantastische hulp bij het verzamelen van de gegevens voor de vergelijkende studie en de eerste analyses. Het was super dat je bereid was om na je stage nog een aantal keer terug te komen om wat toegevoegde metingen uit te voeren. Helaas is de wetenschap wat dat betreft streng, dat als je ergens aan begint je het ook tot het einde moet afmaken. Heel veel succes in je fysiotherapeutische carrière!
Joyce van Keulen. Super dat je bereid was de data te verzamelen met betrekking tot de lange-termijn follow up bij sporters met liesklachten. Een zware dobber, maar uiteindelijk beloond met een mooi co-auteurschap in hoofdstuk 6.
Bart Poot. "Experimental groin pain"; klinkt als een klok. En wat waren wij een mietjes wat betreft de liespijn vergeleken met de anderen! De studie is een mooie scriptie geworden, beloond met de Jaco den Dekker-scriptieprijs, en uiteindelijk een mooie internationale publicatie. Veel succes met de afronding van bewegingswetenschappen!

Ons pap en ons mam. In eerste instantie mogelijk niet zo enthousiast over nog meer studie ("Zou je onderhand niet eens echt gaan werken; dat levert wat meer op?"). Gelukkig heb ik de afgelopen jaren van mijn hobby mijn werk gemaakt, en in die zin heb ik nog steeds niet gewerkt, en hoop ik in de toekomst ook niet aan echt werken toe te komen. Bedankt dat jullie ons zo fantastisch geholpen hebben met het huis (slopen, schilderen, vloertje leggen, badkamertje maken etcetera).

Onze Wouter. Ik was en ben erg blij met je telefoontjes uit het verre buitenland. Bij het verschijnen van de naam "Wouter" in de telefoon kon ik me voorbereiden op een paar minuten nonsens, kraaien, koekoeks en gestoord doen. Heerlijke nonsens als afwisseling op een vrij serieuze dagtaak. De zeldene avonden in het Menneke in Boekel blijven erg leuk, en hoop dat deze zullen blijven volgen, al vermoed ik dat ik ook een huispapa zal moeten zijn….

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Jaap

CURRICULUM VITAE

Johannes Antonius Cornelis Gerardus (Jaap) Jansen was born on 23 April 1977 in Veghel, the Netherlands. After attending the VWO at the Kruisheren Kollege in Uden, he studied Physical Therapy at the University of Applied Sciences (1997-2002) in Utrecht, the Netherlands. After graduating he worked for one year as a physical therapist in Rorschach, Switzerland and then returned to the Netherlands to study Human Movement sciences at the Free University, Amsterdam. He obtained his Master of Science degree in 2005. As part of his traineeship two projects were initiated. His first project was conducted at the department of Human Movement science and focused on the effects of repetitive shear loading on porcine lumbar vertebrae, under the supervision of prof. Jaap van Dieën, PhD and Idsart Kingma, PhD. The second project was performed at the Swiss Federal Institute of technology (ETH) in Zurich, Switzerland and explored the relation between body composition and physical performance in Swiss elderly, under the supervision of Eling de Bruin, PhD and prof. dr Jaap van Dieën, PhD. In August 2005 he started the PhD research project described in this thesis at the department of Rehabilitation and Sports Medicine of the University Medical Center Utrecht, the Netherlands under the supervision of prof. Frank Backx, MD, PhD University Medical Center Utrecht, Jan Mens, MD, PhD and prof. Henk Stam, MD, PhD (both Erasmus Medical Center Rotterdam). He started working as a tutor and lecturer at the faculty of Applied Sciences Utrecht at the master education of Sports Physical Therapy in 2007 till now.

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PHD PORTFOLIO SUMMARY

ERASMUS UNIVERSITEIT ROTTERDAM

Summary of PhD training and techning activities

Name PhD student: Jaap Jansen Erasmus MC Department: Rehabilitation Medicine Research School: MUSC	PhD period: 15/8/2005 – 23/4/2010 Promotors: Prof. dr. H.J. Stam & Prof. dr. F.J.G. Backx Co-promotor. Dr. J.M.A. Mens	

1. PhD training

	Year	Workload (hours/fte)
Academic skills		
English writing for academic purposes, James Boswell Institute Utrecht	2008	30 hours
Presenting in English, James Boswell Institute Utrecht	2008	30 hours
Presentations		
Oral presentation: The groin injury. Scientific congress Vereniging voor SportGeneeskunde, Noorwijkerhout	2005	10 hours
Oral presentation: Exercise and chronic disease. Scientific congress Vereniging voor SportGeneeskunde, Noorwijkerhout	2006	10 hours
Oral presentation: Stabilizing exercises for athletes with longstanding adduction-related groin pain. Scientific congress Koninklijk Nederlands Genootschap voor Fysiotherapie, Amsterdam	2006	10 hours
Oral presentation: Stabilizing exercises for athletes with groin pain. Symposium Vereniging van Fysiotherapeuten binnen Betaald Voetbal, Amersfoort	2007	10 hours
Oral presentation: Treatment of longstanding groin pain in athletes. World congress Society for Tennis Medicine and Science, Antwerpen.	2007	10 hours

	Year	Workload (hours/fte)
Oral presentation: Adduction-related groin pain Sports medical congresss Koninklijke Nederlandse Hockey Bond, Soestduinen.	2007	10 hours
Oral presentation: Abdominal muscle recruitment in athletes with longstanding adduction-related groin pain. Scientific congress Vereniging voor SportGeneeskunde, Noorwijkerhout	2007	10 hours
Oral presentation: The application of "clinical prediction rules" in low back pain. symposium Koninklijk Nederlands Genootschap voor Fysiotherapie, Den Dolder	2008	20 hours
Oral presentation: The association between recovery and changes in abdominal muscle thickness. Scientific congress Vereniging voor SportGeneeskunde, Noorwijkerhout	2008	10 hours
Oral presentation: The effects of experimental groin pain on abdominal muscle thickness. Congresss of the American College of Sports Medicine, Seattle, USA	2009	20 hours
Oral presentation: Athletes with groin pain have decreased thickness of m. transversus abdominus. Scientific congress Koninklijk Nederlands Genootschap voor Fysiotherapie, Amsterdam	2009	10 hours
Oral presentation: Treatment of longstanding groin pain. An update. Sports therapists Jeugdplan Nederland, Breda	2010	10 hours
Seminars and workshops		
Workshop treatment of longstanding adduction-related groin pain. University Medical Center Utrecht, Utrecht	2006	70 hours
National conferences		
Scientific congress Vereniging voor SportGeneeskunde, Noorwijkerhout	2005	8 hours
Scientific congress Vereniging voor SportGeneeskunde, Noorwijkerhout	2006	8 hours
Scientific congress Koninklijk Nederlands Genootschap voor Fysiotherapie, Amsterdam	2006	8 hours
Symposium Vereniging van Fysiotherapeuten binnen Betaald Voetbal, Amersfoort	2007	8 hours
Sports medical congresss Koninklijke Nederlandse Hockey Bond, Soestduinen	2007	8 hours
Scientific congress Vereniging voor SportGeneeskunde, Noorwijkerhout	2007	8 hours

	Year	Workload (hours/fte)
Scientific congress Vereniging voor SportGeneeskunde, Noorwijkerhout	2008	8 hours
Scientific congress Koninklijk Nederlands Genootschap voor Fysiotherapie, Amsterdam.	2009	8 hours
International conferences		
5th Interdisciplinary world congress on low back pain, Papendal	2005	8 hours
World congresss Society for Tennis Medicine and Science, Antwerpen	2007	16 hours
World Congresss of the American College of Sports Medicine. Seattle, USA	2009	30 hours
2. Teaching activities		
Lecturer professional master physical therapy. University of applied sciences Utrecht	2006 -	0.1 fte
Tutor professional master sports physical therapy. University of applied sciences Utrecht	2006 -	0.3 fte
Tutor scientific master in physical therapy. University Utrecht.	2008	30 hours
Supervising research of students faculty of medicine, University Medical Center Utrecht	2006 - 2007	30 hours
Supervising bachelor theses students physical therapy University of applied sciences Utrecht	2008 -	200 hours

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