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Review

Diagnostics in athletes with long-standing groin pain

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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 OKE. 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.

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 ''ultra sound'' 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 and the QUADAS-tool by Whiting et al., 2003)

Items	Possible points
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 the results of a 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 etiology. 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).

Table 2. description of the selected articles

Study	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). Sensitivities to detect CGP were 30% (SA), 40% SQ and 55% (BA); to detect positive MRI, they were 30% (SA), 43% SQ and 54% (BA); and to detect PBSI, they were 32% (SA), 49% SQ and 65% (BA). Specificities 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 who experienced groin pain during/after a 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 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. (2006)	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 a 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
Harris and 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 the athletic activity performed, the more the abnormalities found
Major and 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, abnormalities were found at the pubic symphysis, but with no abnormalities at the SI-joint
Besjakov et al. (2003)	X-ray	20 athletes of various sports, duration of complaints of at least 3 months	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% vs 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 patient had bilateral hernias. Nine patients had a hernia in the symptomatic groin, and 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)

Study	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 fibers) 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 the side of the pain and the 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*
Albers et al (2001)	MRI	Mainly soccer players and football players, no data on duration of complaints	30 (29/1)	Asymptomatic side	In 27/30 patients, attenuation of the musculofascial layers was demonstrated, and 100% correlated with the clinical side. In 20/21 patients, increased signal was found in the pubic symphysis, corresponding with the surgical site. In 6/6 patients increased signal, found in the rectus abdominus, corresponded with the patients' more symptomatic side. In 17/21 patients, irregularity of the rectus abdominus corresponded with the side of predominant complaints. In 17/18 patients, abnormalities found in the adductors corresponded with the primary symptoms. In 9/11 patients, irregularity of the adductor group corresponded with the more symptomatic side. In 6/6 patients, abnormalities found in the pectineus corresponded with the patients' symptoms
Lovell et al. (2006)	MRI	19 elite junior soccer players, no data on duration of complaints	19 (19/0)	Themselves during a 4-month training period	A total of 58 scans were 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
Cunningham et al. (2007)	MRI	Professional and amateur soccer players with a mean duration of complaints of 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 edema, no controls (chi square = 188.34; $P<0.001$). No significant difference with respect to fibrocartilaganious disk protrusion (chi square = 2.32; $P=0.2$)

Table 2. (continued)

Study	Investigation	Description of population with groin pain (GP)	*N* (♂/♀)	Controls	Main results
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.
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 significantly 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 ($P<0.01$); a significant decrease in knee extension strength ($P<0.01$); significant asymmetry for knee muscle power at a higher movement speed (quadriceps $P<0.04$; hamstrings $P<0.005$)
Cowan et al. (2004)	Etiological factors	10 elite or subelite Australian Football players, duration of complaints of at least 6 weeks	10 (10/0)	12 asymptomatic matched athletes	Athletes with LGP have a delay in the recruitment of the m. transversus abdominus 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
Emery and Meeuwisse (2001)	Etiological factors	52 professional ice hockey players	52 (52/0)	1240 Asymptomatic sport-matched athletes	Previous injury significantly increases the 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 and skate blade hollow measurement were not predictive for injury. There is evidence of a dose–response gradient as the 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 the 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.

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 90°, 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 30°, and knees extended; manual resistance to hip adduction) and the bilateral adductor test (55%; patient is supine, both hips flexed 30°, 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). 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 age-matched 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 >55 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 >2 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 abdominus, 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 the 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 <18 off-season 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. Methodological 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). 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.

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

Study	Checklist items									Total	% of max
	A	B	C	D	E	F	G	H	I		
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
Cunningham 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 and 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 and 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.

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 >1 year. In athletes having groin pain <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 population 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 cross-sectional 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 abdominus 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.

Key words: groin, athletes, diagnosis, validity, sports medicine.

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