Clinical examination for athletes with inguinal-related groin pain: interexaminer reliability and prevalence of positive tests

Willem M P Heijboer 1,2,3, Zarko Vuckovic,1 Adam Weir 1,4, Johannes L Tol1,2,3 Per Hölmich,5 Andreas Serner 1,6

ABSTRACT

Objectives To evaluate the interexaminer reliability of abdominal palpation and resistance tests in athletes with longstanding groin pain, and to identify the prevalence of positive clinical tests in athletes classified with inguinal-related groin pain.

Methods Male athletes (18–40 years) with longstanding groin pain were prospectively recruited between March 2019 and October 2020 at a sports medicine hospital. Two examiners performed history taking and standardised clinical examination (including abdominal palpation, scrotal invagination and abdominal resistance tests) blinded to each other’s findings. Interexaminer reliability was calculated using Cohen’s Kappa statistic (κ). Examiners classified groin pain using the Dohia agreement meeting terminology. A differentiation was made between ‘defined inguinal-related groin pain’ (according to recommended definition criteria) and ‘likely inguinal-related groin pain’ (expert-based application of the Dohia agreement classification when not all recommended criteria were present).

Results Overall, 44 athletes were included (61 symptomatic sides). Interexaminer reliability of inguinal palpation pain provocation tests varied from fair to moderate (κ=0.35–0.49). Reliability of posterior wall structure palpation (firm/soft) was slight (κ=0.01), and posterior wall bulging (yes/no) fair (κ=0.29). Reliability for abdominal resistance tests varied from fair to substantial (κ=0.35–0.72). In athletes classified with defined inguinal-related groin pain, recognisable injury pain on palpation during scrotal invagination when athletes performed a Valsalva manoeuvre was the most prevalent positive palpation test (79%). Abdominal resistance tests were positive in 21%–49% of these cases.

Conclusion The interexaminer reliability for clinical examination tests used to classify inguinal-related groin pain in athletes varies from slight to substantial. There is no single perfect clinical examination test.

Trial registration number NCT03842826.

INTRODUCTION

Groin pain in the inguinal region without an inguinal hernia is a common diagnostic and therapeutic challenge in sports medicine.1 Unclear aetiology and heterogenous terminology, such as sports(man)’s hernia, Gilmore’s groin and incipient hernia, cause confusion.2,3 Two consensus meetings, the Dohia agreement meeting (involving groin pain experts from multiple disciplines)4 and the British Hernia Society’s meeting (involving primarily general surgeons),5 addressed the terminology and proposed the terms inguinal-related groin pain and inguinal disruption, respectively. A recent e-survey found that the term inguinal-related groin pain is most often used by clinicians, and this term is used in our study.6

Classifying inguinal-related groin pain is done using history and clinical examination findings. The main symptom is activity-related pain in the inguinal canal region and also recognisable pain on palpation of the inguinal canal.4 It is more likely when symptoms are aggravated by resisted abdominal testing, during Valsalva, coughing or sneezing.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The classification of inguinal-related groin pain is based on injury history and clinical examination findings (palpation/resistance test pain). Scientific support for any specific clinical examination test is limited.

WHAT THIS STUDY ADDS

⇒ This is the first study evaluating the interexaminer reliability of commonly performed abdominal palpation and resistance tests for classifying inguinal-related groin pain in athletes.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ There is no single perfect test for classifying athletes with inguinal-related groin pain.

⇒ After history taking, we recommend performing abdominal palpation including scrotal invagination, and abdominal resistance as pain provocation tests to obtain a complete overview of all potentially relevant clinical examination findings.

⇒ Further research is needed to evaluate if specific clinical examination findings influence management (conservative and/or surgical) or prognosis.
Despite the importance of clinical examination in classifying inguinal-related groin pain, the reliability of these physical tests is unknown. It is also unknown how often athletes with inguinal-related groin pain report recognisable injury pain during each specific clinical examination test. For example, the Doha agreement classification states that inguinal-related groin pain is more likely when symptoms are aggravated with resisted abdominal testing, but this has never been quantified.

The primary aim of our study was to evaluate the interexaminer reliability of abdominal palpation and resistance tests for classifying inguinal-related groin pain in athletes with longstanding groin pain. The secondary aim was to identify the prevalence of positive clinical tests in athletes with inguinal-related groin pain.

**METHODS**

This study was part of a larger interexaminer reliability study on clinical examination findings in athletes with longstanding groin pain and was registered on ClinicalTrials.gov (NCT03842826) prior to participant inclusion. Some participants in this study were also part of a previous study examining the interexaminer reliability of the Doha agreement meeting classification system (ClinicalTrials.gov: NCT03590145).

**Protocol deviation**

We deviated from the original protocol for the secondary aim. We additionally differentiated inguinal-related groin pain as: (1) ‘defined inguinal-related groin pain’ (according to the recommended definition criteria) and (2) ‘likely inguinal-related groin pain’ (expert-based application of the Doha agreement classification when not all recommended criteria were present). This was done to ensure a more complete and transparent reporting of the findings.

**Setting**

The study was performed at Aspetar Orthopaedic and Sports Medicine Hospital in Doha, Qatar.

**Participants**

Participants were prospectively assessed for eligibility between March 2019 and October 2020 if they were: (1) a male athlete (performing sports ≥1 time/week), (2) 18–40 years old and (3) experiencing sports-related groin pain of ≥4 weeks duration. Exclusion criteria were: (1) prior assessment/treatment by one of the two examiners (<6 months) for the same complaint, (2) any prior surgery in the hip and groin area, (3) clinical signs of prostatitis or urinary tract infections, (4) more than 7 days between the two examiners' assessment.

**Procedures**

A general surgeon (ZV, 24 years of clinical experience) and a physiotherapist (AS, 11 years of clinical experience) with specific clinical interest/experience in groin injuries performed a standardised clinical examination (online supplemental appendix A). Both examiners were trained in the standardised clinical examination by the same orthopaedic surgeon (PH, with >35 years of clinical experience) specialised in groin injuries. Additionally, 10 practice sessions were performed to make sure both examiners performed the clinical examination tests in a comparable way. Both examiners were blinded to any imaging findings. Study participants were instructed not to share any information from the first examination with the second examiner. The order of examiners was decided by the clinic from which the participant was recruited; if the participant was recruited in the general surgeon’s clinic, the general surgeon performed the first clinical assessment. If the participant was recruited from a sports medicine clinic within the hospital, the physiotherapist performed the first clinical assessment. Both examiners performed a semi-structured history taking prior to the clinical examination. Both examiners were blinded to each other’s history taking, clinical examination findings and classifications.

**Participant characteristics**

Participant characteristics were registered and included: age, weight, height, sport participation including level (elite, subelite, amateur) and frequency/duration, and a detailed injury history. Additionally, participant-reported function was registered using two validated questionnaires: (1) the Copenhagen Hip and Groin Outcome Score (HAGOS) and (2) the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire modified to focus on groin problems only. The HAGOS is a valid Patient-Reported Outcome Questionnaire with six separate subscales: for the assessment of symptoms, activity limitations, participation restrictions and QOL in physically active, young to middle-aged patients with longstanding hip and/or groin pain. Each subscale is scored from 0 to 100, where 100 indicates no hip and/or groin symptoms and 0 indicates extreme symptoms. The OSTRC overuse injury questionnaire is a validated 4-item questionnaire for monitoring acute injuries, overuse injuries and/or illness in elite athletes. A severity score (0–100) is then derived with 0 indicating no problems and 100 maximum problems. Both questionnaires were available in English or Arabic, based on athlete preference.

**Standardised clinical examination**

The standardised clinical examination of the inguinal area consisted of palpation tests of the lower abdominal/inguinal region (with and without scrotal invagination of the inguinal canal), and resisted abdominal testing (figure 1). These tests were part of a more extensive standardised clinical examination of the groin (online supplemental appendix A). Participants were instructed to report any pain during palpation or resisted abdominal tests (yes/no). They were then asked if this pain corresponded to their recognisable injury pain (yes/no). If the participant reported recognisable injury pain, a score on an 11-point Numeric Pain Rating Scale (NPRS)

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### Abdominal palpation tests:

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus abdominis muscle/insertion</td>
<td>The rectus abdominis muscle is palpated slightly lateral to the umbilicus and followed distally to the pubic insertion. Score: pain (yes/no)</td>
</tr>
<tr>
<td>Pubic tubercle (image 1a)</td>
<td>Examiner palpates the lateral/craniolateral border of the pubic tubercle at the insertions of the inguinal ligament and conjoint tendon. Score: pain (yes/no)</td>
</tr>
<tr>
<td>Ingual ligament (image 1b)</td>
<td>Examiner palpates the medial 0.5-3cm of the inguinal ligament. Score: pain (yes/no)</td>
</tr>
<tr>
<td>External ring (medial border)</td>
<td>Examiner palpates the medial border of the external ring at the lateral border of the rectus abdominis (superolateral of the pubic tubercle). The examiner palpates an area of 0.5-3cm. Score: pain (yes/no)</td>
</tr>
</tbody>
</table>

### Palpation tests during scrotal invagination of the inguinal canal (image 1c):

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>External ring</td>
<td>Examiner inverts the scrotum with the index finger and palpates the external inguinal ring approximately 1 cm cranial to the pubic tubercle. Score: size (L/M/S), and pain (yes/no)</td>
</tr>
<tr>
<td>Conjoint tendon</td>
<td>Examiner palpates the conjoint tendon during invagination of the inguinal canal, directly medial after passing the external inguinal ring. Score: pain (yes/no)</td>
</tr>
<tr>
<td>Posterior wall palpation</td>
<td>Examiner palpates the posterior wall of the inguinal canal during invagination. Score: structure (soft/firm)</td>
</tr>
<tr>
<td>Bulging/Valsalva</td>
<td>Examiner palpates the posterior wall and asks the participant to perform a Valsalva maneuver by inhaling deeply first and then to exhale forcefully against the backside of his hand. Pain is recorded and bulging scored positive if the examiner feels “ballooning” of the posterior wall during Valsalva. Score: bulging (yes/no), and pain (yes/no)</td>
</tr>
</tbody>
</table>

### Abdominal resistance tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight sit-up 0° hip flexion (Figure 1d)</td>
<td>The participant performs a sit-up movement, lifting head and scapulae from the couch, while the examiner resists the movement by holding one arm on the participant’s knees and the other arm on the participant’s chest (isometric test). Score: pain (yes/no)</td>
</tr>
<tr>
<td>Cross test 0° hip flexion (Figure 1e)</td>
<td>The participant performs an oblique sit up where the opposite hip is simultaneously flexed with an extended knee. The examiner resists the movement by fixating the shoulder and the opposite hip just above the knee cap. This isometric test is also performed on the opposite side. Score: pain (yes/no)</td>
</tr>
<tr>
<td>Straight sit-up 45° hip flexion (Figure 1f)</td>
<td>The participant performs a sit-up movement, lifting head and scapulae from the couch, while the examiner resists the movement by holding one arm on the patient’s knees and the other arm on the patient’s chest (isometric test). Score: pain (yes/no)</td>
</tr>
<tr>
<td>Oblique sit-up 45° hip flexion (Figure 1g)</td>
<td>The participant performs an oblique sit up. The examiner resists the movement by fixating the shoulder and the opposite leg just above the knee cap. This isometric test is also performed on the opposite side. Score: pain (yes/no)</td>
</tr>
</tbody>
</table>

Figure 1: Summary of abdominal palpation and resistance tests performed as part of the standardised clinical examination protocol (online supplemental appendix A). Pain provocation tests were scored positive if the participant reported recognisable injury pain (in his inguinal area). L, large (> fingertip); M, medium (~fingertip); S, small (< fingertip). * Picture reproduced with permission from Serner et al.13.
was elicited, where 0 indicated ‘no (injury) pain’ and 10 indicated ‘worst possible pain’. All NPRS scores from 1 to 10 were registered as a positive test. When participants reported recognisable injury pain during resisted abdominal testing, an NPRS Score (0–10) and the participant reported pain location(s) were registered by the examiner as: adductor, iliopsoas, inguinal, pubic and/or other. An abdominal resistance test was scored positive if the participant reported recognisable injury pain in his inguinal area.

Clinical entity classification

Inguinal-related groin pain is defined in the Doha agreement meeting classification system as: pain in the inguinal canal region that worsened with exercise (history) and tenderness of the inguinal canal (clinical examination). Inguinal-related groin pain was also suggested to be more likely if the pain is aggravated during abdominal resistance testing or on Valsalva, cough or sneeze. An additional classification (likely inguinal-related groin pain) was used to include patients, not completely fulfilling the criteria of the Doha classification, although it was the overall impression by the experienced clinician that inguinal-related pain was a main factor in the patient’s problem. The two separate classifications were:

1. Defined inguinal-related groin pain (according to the defined criteria).

Inguinal-related groin pain was classified based on the criteria defined in the Doha agreement meeting classification system: As a minimum, the athlete had to report pain in the inguinal canal region that worsened with exercise, and recognisable tenderness (injury pain) of the inguinal canal during palpation (with or without scrotal invagination). This was determined by the specific findings reported by each examiner.

2. Likely inguinal-related groin pain.

As a minimum, the athlete had to report pain in the inguinal canal region that worsened with exercise. If recognisable tenderness was absent during palpation, and only history suggested inguinal-related groin pain and/or other clinical examination tests (such as abdominal resistance testing) provoked recognisable injury pain in the inguinal canal region, the classification ‘likely inguinal-related groin pain’ could be made at the discretion of the examiner. This clinical decision also took the other findings from the complete examination into account.

Statistical plan

Participant characteristics were reported using descriptive statistics according to measurement scale and distribution. Reliability of clinical examination tests with a dichotomous outcome were analysed using Cohen’s Kappa statistic (κ). Clinical examination tests for athletes with bilateral groin pain were analysed per side. The size of the inguinal external ring was analysed as an ordinal variable using linear weighted κ. Agreement was considered almost perfect if κ=0.81–1.00, substantial κ=0.61–0.80, moderate κ=0.41–0.60, fair κ=0.21–0.40, slight κ=0.20 and poor if κ<0.10. Additionally, the prevalence, prevalence index, overall agreement, positive agreement, negative agreement and bias index were calculated. The mean prevalence of positive clinical tests (ie, the average between both examiners) was calculated for defined and for likely inguinal-related groin pain.

Sample size calculation

A prevalence between 30% and 60% was expected for the main three clinical entities of groin pain (adductor-related, inguinal-related and iliopsoas-related) in our research population. Assuming that approximately 4 out of every five tests (80%) targeting each entity were positive, we expected a prevalence of positive tests of approximately 24%–48% in the whole sample. With an expected Kappa of at least 0.8 with a 95% CI lower limit of 0.4, using a 2-tailed test and assuming no bias between examiners, at least 60 symptomatic sides were needed for this study. No dropouts were expected due to the cross-sectional character of the study. We continued participant inclusions until we had at least 60 symptomatic sides.

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Patient and/or public involvement
Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

RESULTS
Forty-four athletes with groin pain were included. Overall, 17 athletes reported bilateral symptoms, thus 61 symptomatic and 27 asymptomatic sides were examined by both examiners. Table 1 presents the participants characteristics. One participant refused scrotal invagination during the second clinical examination. Some of the examination findings during scrotal invagination (conjoint tendon, bulging and posterior wall; figure 1C) were not assessable by one or both of the examiners (specified in tables 2–3), mainly because of a smaller external ring size.

Table 2 presents the reliability and agreement values of all abdominal pain provocation tests. The interexaminer reliability of inguinal palpation and abdominal resistance as pain provocation tests varied from fair to substantial (κ=0.35–0.72). The reliability of rectus abdominis palpation was slight to substantial depending on the location (κ=0.17 for the insertion, κ=0.66 for the muscle/tendon). Following the criteria for defined inguinal-related groin pain (pain in the inguinal canal region AND tenderness during palpation), examiner A classified inguinal-related groin pain in 41/61 (67%) symptomatic sides, and examiner B in 37/61 (61%) symptomatic sides. Examiner A classified ‘likely inguinal-related groin pain’ in 11/61 (18%) symptomatic sides and examiner B in 5/61 (8%) symptomatic sides. The interexaminer reliability of other clinical palpation findings during invagination of the inguinal canal not focusing on pain (external ring size, bulging and the posterior wall structure) was found slight to moderate (κ=0.01–0.56) (table 3).

Figure 2 presents the associations between positive clinical examination findings (mean prevalence between the two examiners) and ‘defined’, ‘likely’ and ‘all’ (‘defined’+‘likely’) inguinal-related groin pain. Figure 3 presents the mean prevalence of palpation pain locations in athletes classified with ‘defined inguinal-related groin pain’. Online supplemental appendix B presents overviews of: (1) participant reported pain locations during abdominal resistance tests, (2) participant reported pain during palpation tests that was not related to the groin pain experienced during sports (as reported by the athlete) and (3) the mean prevalence of positive clinical examination tests in athletes classified with ‘all’ (defined+likely) inguinal-related groin pain.

DISCUSSION
This is the first study evaluating the interexaminer reliability of commonly performed abdominal palpation and resistance tests for classifying inguinal-related groin pain in athletes. The interexaminer reliability of palpation pain provocation tests varied from fair to moderate (κ=0.35–0.49). The reliability of posterior wall structure palpation was slight (κ=0.01), posterior wall bulging fair (κ=0.29) and external ring size moderate (κ=0.56). The interexaminer reliability for abdominal resistance tests

Table 1 Participant characteristics (n=44)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>28.5±5.7</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>76.1±11.3</td>
</tr>
<tr>
<td>Height, cm</td>
<td>176.1±8.5</td>
</tr>
<tr>
<td>Main sports</td>
<td></td>
</tr>
<tr>
<td>Soccer</td>
<td>31 (70%)</td>
</tr>
<tr>
<td>Fitness/running</td>
<td>3 (7%)</td>
</tr>
<tr>
<td>Futsal</td>
<td>3 (7%)</td>
</tr>
<tr>
<td>Running</td>
<td>3 (7%)</td>
</tr>
<tr>
<td>Basketball</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>Swimming</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>Body building</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>Volleyball</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>Level</td>
<td></td>
</tr>
<tr>
<td>Elite</td>
<td>16 (36%)</td>
</tr>
<tr>
<td>Subelite</td>
<td>8 (18%)</td>
</tr>
<tr>
<td>Amateur</td>
<td>20 (45%)</td>
</tr>
<tr>
<td>Onset of injury</td>
<td></td>
</tr>
<tr>
<td>Sudden</td>
<td>12 (27%)</td>
</tr>
<tr>
<td>Gradual</td>
<td>32 (73%)</td>
</tr>
<tr>
<td>Duration of symptoms, months</td>
<td>4.5 (2–9)</td>
</tr>
<tr>
<td>Pain on cough/sneeze, yes</td>
<td>16 (36%)</td>
</tr>
<tr>
<td>Time between examinations</td>
<td></td>
</tr>
<tr>
<td>0 days</td>
<td>29 (66%)</td>
</tr>
<tr>
<td>1–2 days</td>
<td>6 (14%)</td>
</tr>
<tr>
<td>3–5 days</td>
<td>7 (16%)</td>
</tr>
<tr>
<td>6–7 days</td>
<td>2 (5%)</td>
</tr>
<tr>
<td>HAGOS</td>
<td></td>
</tr>
<tr>
<td>Symptoms (0–100)</td>
<td>61 (50–79)</td>
</tr>
<tr>
<td>Pain (0–100)</td>
<td>73 (59–80)</td>
</tr>
<tr>
<td>ADL (0–100)</td>
<td>70 (60–85)</td>
</tr>
<tr>
<td>Sport/rec (0–100)</td>
<td>53 (35–72)</td>
</tr>
<tr>
<td>PA (0–100)</td>
<td>50 (25–63)</td>
</tr>
<tr>
<td>QOL (0–100)</td>
<td>45 (35–60)</td>
</tr>
<tr>
<td>OSTRC</td>
<td></td>
</tr>
<tr>
<td>Participation (0–25)</td>
<td>17 (17–25)</td>
</tr>
<tr>
<td>Volume (0–25)</td>
<td>19 (13–25)</td>
</tr>
<tr>
<td>Performance (0–25)</td>
<td>13 (11–25)</td>
</tr>
<tr>
<td>QOL (0–25)</td>
<td>17 (17–25)</td>
</tr>
<tr>
<td>Severity score (0–100)</td>
<td>66 (50–92)</td>
</tr>
</tbody>
</table>

Data reported as mean ± SD, median (IQR), number (%). For the HAGOS, a score of 100 indicates no symptoms and a score of 0 indicates extreme symptoms. For the severity score of the OSTRC, this scoring is inverse. ADL, activities of daily living; HAGOS, Hip and Groin Outcome Score; OSTRC, Oslo Sports Trauma Research Centre; PA, participation in physical activities; QOL, quality of life; Sports/rec, function in sport and recreation.
Table 2  Interexaminer reliability of abdominal pain provocation tests including palpation and resistance (n=61)

<table>
<thead>
<tr>
<th></th>
<th>Kappa (95% CI)</th>
<th>Kappa interpretation</th>
<th>Overall agreement</th>
<th>Positive agreement</th>
<th>Negative agreement</th>
<th>Bias index</th>
<th>Prevalence [PI]</th>
<th>Mean prevalence of positive tests in IRGP*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abdominal palpation pain</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pubic tubercle</td>
<td>0.41 (0.18 to 0.64)</td>
<td>Moderate</td>
<td>71%</td>
<td>68%</td>
<td>73%</td>
<td>0.10</td>
<td>46% (−0.08)</td>
<td>66%</td>
</tr>
<tr>
<td>Inguinal ligament</td>
<td>0.39 (0.16 to 0.62)</td>
<td>Fair</td>
<td>69%</td>
<td>62%</td>
<td>74%</td>
<td>0.25</td>
<td>40% (−0.20)</td>
<td>58%</td>
</tr>
<tr>
<td>External ring (medial border)</td>
<td>0.49 (0.26 to 0.72)</td>
<td>Moderate</td>
<td>75%</td>
<td>68%</td>
<td>80%</td>
<td>0.11</td>
<td>39% (−0.23)</td>
<td>59%</td>
</tr>
<tr>
<td>External ring</td>
<td>0.35 (0.10 to 0.61)</td>
<td>Fair</td>
<td>70%</td>
<td>59%</td>
<td>76%</td>
<td>0.03</td>
<td>37% (−0.27)</td>
<td>55%</td>
</tr>
<tr>
<td>Conjoint tendon</td>
<td>0.42 (0.18 to 0.65)</td>
<td>Moderate</td>
<td>70%</td>
<td>62%</td>
<td>75%</td>
<td>0.26</td>
<td>39% (−0.21)</td>
<td>54%</td>
</tr>
<tr>
<td>Posterior wall (during Valsalva)*</td>
<td>0.40 (0.17 to 0.64)</td>
<td>Fair</td>
<td>70%</td>
<td>73%</td>
<td>67%</td>
<td>0.13</td>
<td>55% (0.10)</td>
<td>79%</td>
</tr>
<tr>
<td>Any inguinal palpation pain without invagination†</td>
<td>0.61 (0.41 to 0.81)</td>
<td>Substantial</td>
<td>80%</td>
<td>81%</td>
<td>80%</td>
<td>0.07</td>
<td>51% (0.02)</td>
<td>77%</td>
</tr>
<tr>
<td>Any inguinal palpation pain during invagination‡</td>
<td>0.54 (0.31 to 0.76)</td>
<td>Moderate</td>
<td>78%</td>
<td>83%</td>
<td>70%</td>
<td>0.12</td>
<td>64% (0.28)</td>
<td>94%</td>
</tr>
<tr>
<td>Any inguinal palpation pain without or during invagination*</td>
<td>0.65 (0.44 to 0.87)</td>
<td>Substantial</td>
<td>85%</td>
<td>89%</td>
<td>76%</td>
<td>0.08</td>
<td>69% (0.38)</td>
<td>100%</td>
</tr>
<tr>
<td>Rectus abdominis insertion</td>
<td>0.17 (-0.16 to 0.50)</td>
<td>Slight</td>
<td>71%</td>
<td>36%</td>
<td>81%</td>
<td>0.07</td>
<td>23% (−0.54)</td>
<td>–</td>
</tr>
<tr>
<td>Rectus abdominis muscle/tendon</td>
<td>0.66 (0.37 to 0.95)</td>
<td>Substantial</td>
<td>92%</td>
<td>71%</td>
<td>95%</td>
<td>0.02</td>
<td>14% (0.72)</td>
<td>–</td>
</tr>
<tr>
<td><strong>Abdominal resistance pain</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight sit-up 0°</td>
<td>0.63 (0.39 to 0.87)</td>
<td>Substantial</td>
<td>87%</td>
<td>71%</td>
<td>92%</td>
<td>0.03</td>
<td>23% (−0.54)</td>
<td>30%</td>
</tr>
<tr>
<td>Cross test 0°—shoulder affected side</td>
<td>0.67 (0.44 to 0.91)</td>
<td>Substantial</td>
<td>89%</td>
<td>74%</td>
<td>93%</td>
<td>0.08</td>
<td>22% (−0.56)</td>
<td>27%</td>
</tr>
<tr>
<td>Cross test 0°—shoulder contralateral side§</td>
<td>0.61 (0.40 to 0.82)</td>
<td>Substantial</td>
<td>82%</td>
<td>76%</td>
<td>86%</td>
<td>−0.02</td>
<td>37% (−0.26)</td>
<td>49%</td>
</tr>
<tr>
<td>Straight sit-up 45°</td>
<td>0.72 (0.52 to 0.92)</td>
<td>Substantial</td>
<td>89%</td>
<td>80%</td>
<td>92%</td>
<td>0.02</td>
<td>29% (−0.43)</td>
<td>38%</td>
</tr>
<tr>
<td>Oblique sit-up 45°—shoulder affected side</td>
<td>0.35 (-0.03 to 0.73)</td>
<td>Fair</td>
<td>84%</td>
<td>44%</td>
<td>90%</td>
<td>−0.03</td>
<td>15% (−0.70)</td>
<td>21%</td>
</tr>
<tr>
<td>Oblique sit-up 45°—shoulder contralateral side§</td>
<td>0.56 (0.32 to 0.80)</td>
<td>Moderate</td>
<td>82%</td>
<td>69%</td>
<td>87%</td>
<td>−0.08</td>
<td>29% (−0.43)</td>
<td>39%</td>
</tr>
<tr>
<td>Pain during any abdominal resistance test</td>
<td>0.54 (0.32 to 0.75)</td>
<td>Moderate</td>
<td>77%</td>
<td>74%</td>
<td>79%</td>
<td>0.03</td>
<td>44% (−0.11)</td>
<td>58%</td>
</tr>
</tbody>
</table>

*1 participant with unilateral groin pain refused a second inguinal invagination and was therefore excluded from this specific analyses. The conjoint tendon (three sides) and posterior wall (one side) were not assessable during scrotal invagination by at least one of the examiners.
†If any of the above three tests (pubic tubercle, inguinal ligament, external ring (medial border)) were scored positive.
‡If any of the above three tests (external ring, conjoint tendon during invagination, posterior wall) were scored positive.
§Pain reported on the contralateral side (eg, patient reported recognisable injury pain in the left inguinal canal region during an oblique sit-up with resistance on the right shoulder).
IRGP, inguinal-related groin pain according to the defined clinical entity; PI, prevalence index.
varied from fair to substantial ($\kappa=0.35\text{–}0.72$). Abdominal resistance tests were positive in 21%–49% of athletes classified with defined inguinal-related groin pain.

No previous studies have been published on the interexaminer reliability of clinical examination tests to classify inguinal-related groin pain, or the presence of an inguinal hernia. Only one study investigated the reliability of rectus abdominis palpation and resistance tests. This study included nine athletes with and nine athletes without groin pain who were assessed by four blinded examiners. The interexaminer reliability values for abdominal resistance tests found in that study ($\kappa=0.41\text{–}0.57$) are in line with our findings ($\kappa=0.35\text{–}0.72$). Contrarily, rectus abdominis palpation as pain provocation test was found less reliable in our study: $\kappa=0.17\text{–}0.66$ compared with $\kappa=0.83$ reported by Holmich.15 The wide confidence intervals around the kappa values for rectus abdominis palpations tests in our study indicate a higher uncertainty around our estimated reliability. Additionally, the prevalence index in our study was relatively high.

<table>
<thead>
<tr>
<th></th>
<th>Kappa (95% CI)</th>
<th>Kappa interpretation</th>
<th>OA</th>
<th>PA</th>
<th>NA</th>
<th>Bias index</th>
<th>Prevalence (PI)</th>
<th>Mean prevalence in defined IRGP*</th>
<th>Mean prevalence in non-IRGP†</th>
</tr>
</thead>
<tbody>
<tr>
<td>External ring size (S/M/L) (n=86)‡</td>
<td>0.56 (0.43 to 0.70)</td>
<td>Moderate</td>
<td>70%</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>S: 15%</td>
<td>M: 18%</td>
<td>L: 67%</td>
</tr>
<tr>
<td>Bulging (y/n) (n=67)§</td>
<td>0.29 (0.05 to 0.52)</td>
<td>Fair</td>
<td>64%</td>
<td>64%</td>
<td>65%</td>
<td>0.06</td>
<td>49% (−0.01)</td>
<td>Yes: 54%</td>
<td>No: 31%</td>
</tr>
<tr>
<td>Posterior wall structure (firm/soft) (n=59)¶</td>
<td>0.01 (−0.38 to 0.40)</td>
<td>Slight</td>
<td>70%</td>
<td>18%</td>
<td>81%</td>
<td>−0.10</td>
<td>19% (−0.63)</td>
<td>Soft: 68%</td>
<td>Firm: 10%</td>
</tr>
</tbody>
</table>

*Based on the average prevalence in defined inguinal-related groin pain between examiner A (n=41) and B (n=37).
†Based on the average prevalence in non-inguinal-related groin pain (ie no likely or defined inguinal-related groin pain classified by the examiner OR fully asymptomatic side) between examiner A (n=36) and B (n=44). One participant refused inguinal examination of the second examiner and no classification was made for this participant by examiner B. Cases classified with likely inguinal-related groin pain were not separately described due to the small sample size.
§1 Participant refused inguinal examination of the second examiner.
¶1 Participant refused inguinal examination of the second examiner, 19 inguinal canals were not assessable for bulging by at least one of the examiners.
*Palpation test performed on scrotal invagination. Picture modified with permission from Vuckovic et al.3

**Not applicable; IRGP, inguinal-related groin pain; L, large (>fingertip); M, medium (~fingertip); NA, negative agreement; n/a, not assessable by the examiner; OA, overall agreement; PA, positive agreement; PI, prevalence index; S, small (<fingertip).
κ = 0.10–1.00), medial tibial stress syndrome example: kappa values for classifying subacromial pain musculoskeletal clinical examination tests vary a lot. For practice. Interexaminer reliability values of widely used needed before recommending a test in clinical prac- sion in the classification/diagnosis.

There is no consensus on what level of reliability is needed before recommending a test in clinical prac- tice. Interexaminer reliability values of widely used musculoskeletal clinical examination tests vary a lot. For example: kappa values for classifying subacromial pain syndrome (κ = 0.10–1.00),17 medial tibial stress syndrome or concurrent lower leg injury (κ = 0.73–0.89),18 or sacroiliac joint, disc and facet joint pain (κ = 0.20) vary from poor to perfect reliability. Using a combination of clinical examination tests is recommended by the Dutch guideline for the diagnosis and treatment of subacromial pain syndrome to improve the diagnostic accuracy based on level 2 evidence.19 In our study, the interexaminer reliability of the individual inguinal palpation pain prov- ocation tests was fair to moderate (κ = 0.35–0.49), while for the clustered palpation tests (ie, ‘any’ inguinal palpa- tion pain) moderate to substantial (κ = 0.54–0.65). The interexaminer reliability of the majority of abdominal resistance tests was higher than those of the palpation tests.

In athletes classified with defined inguinal-related groin pain, palpation pain was almost always present during scrotal invagination (94%). Four out of every five of these athletes also reported pain during at least one of the transabdominal palpation tests. Scrotal invagination is not part of standard training for some musculoskel- etal health professionals (such as physiotherapists). The combination of transabdominal palpation tests and abdominal resistance tests will be sufficient to classify ~90% of the cases with inguinal-related groin pain. Not performing scrotal invagination may lead to missing the classification in 1 in 10 cases (figure 2).

Abdominal resistance tests were positive in approxi- mately half of the athletes classified with inguinal-related groin pain. The most prevalent positive abdominal resistance test (49%) was the cross-test with shoulder resistance on the contralateral side and resisted hip flexion on the ipsilateral side. A recent study20 investigated the diag- nostic accuracy of four different clinical examination tests for the diagnosis of ‘core muscle injury’, which is a different term used for groin pain in the inguinal canal region.8 This study found a sensitivity of 100% and specific- ificity of 3% for both a ‘resisted cross-body sit up’ test (which has similarities with the cross test in our study) and an adductor contracture test. These sensitivity values may be overestimated due to incorporation bias, since the index tests were part of the reference standard.

Overclassification, or overdiagnosis, may be a pitfall after performing clinical examination in the inguinal canal area. We found that several palpation tests caused pain that was not recognisable injury pain, according to the athletes (6%–24%). To prevent overdiagnosis and potentially unnecessary treatment, it is important to always ask the athlete if pain during palpation tests replicates the injury pain and to elicit the pain location during abdominal resistance tests. On the contrary, some athletes report recognisable injury pain in the inguinal canal region during sports and/or during abdominal resistance testing, but are pain free on inguinal palpa- tion. According to the Doha agreement definitions, these cases would not be classified as inguinal-related groin pain. In our study, examiners could classify these cases as ‘likely inguinal-related groin pain’, to provide a full overview of potentially involved clinical examination findings in inguinal-related groin pain. Future research should investigate if the specific presence of palpation pain is required to guide prognosis and/or treatment.

There is no gold standard for the classification of inguinal-related groin pain, nor an accepted reference standard. We believe it would be inappropriate to analyse and report our data for diagnostic accuracy purposes (sensitivity, specificity etc). For clinical implications, however, we reported the mean prevalence of positive test findings in athletes classified with inguinal-related groin pain. When a test is highly prevalent (such as recogn- isible injury pain during scrotal invagination), it should be included as part of the diagnostic work-up for the target condition (inguinal-related groin pain). In these instances, a negative test can potentially assist in ruling out the target condition.

Imaging is regularly used as part of the diagnostic process in athletes with groin pain in the inguinal region. Ultrasound is often the imaging modality of choice in these instances.21 There is, however, no sound evidence that specific ultrasound findings can differentiate between athletes with and without inguinal-related groin pain.22 For example, posterior wall bulging on ultrasound is suggested to be related to the pathoaeiology of ‘poste- rior wall weakness’,23 but is also found commonly (~65%) in asymptomatic athletes.24 The interobserver reliability of assessing the posterior wall for bulging on ultrasound is unknown. Clinically, we found that bulging was present in 26% of sides without inguinal-related groin, and a soft posterior wall in 54% of these sides. The interexaminer
reliability adds uncertainty to this with κ=0.29 and κ=0.01, respectively. The unknown interexaminer or intraexaminer reliability of ultrasound findings and the presence of bulging and soft posterior walls without pain make interpretation complex. We recommend interpreting ultrasound findings with caution, and only using them as an adjunct to injury history and clinical examination findings, and not as a standalone diagnostic modality.

Our study showed that there is no single perfect test for classifying athletes with inguinal-related groin pain. Knowing the benefits and limitations of specific clinical examination tests can assist clinicians in their diagnostic work and ultimately in providing an optimal treatment plan. After history taking, we recommend performing abdominal palpation including scrotal invagination, and abdominal resistance as pain provocation tests to obtain a complete overview of all potentially relevant clinical examination findings. Further research is needed to evaluate if specific clinical examination findings influence management (conservative and/or surgical) or prognosis.

Limitations
This is the first study evaluating the interexaminer reliability of standardised clinical examination tests that clinicians use to classify athletes with inguinal-related groin pain. Our study has some limitations. First, the examiners were experienced clinicians that both worked in a specialised groin clinic and our results may therefore not be generalisable to less experienced clinicians. We tried to compensate for this by standardising and describing each test in detail (online supplemental appendix A), prior to commencement of our study. Second, there is no gold (reference) standard available for inguinal-related groin pain. For the overview of the prevalence of positive tests, examiners used the Doha agreement terminology, but were also allowed to classify likely inguinal-related groin pain when not all criteria were present. This approach potentially decreases the reproducibility due to a higher level of subjectivity. On the other hand, it might reflect clinical practice and increase external generalisability as not all diagnostic findings are always present during physical examination. Thirdly, the percentage of inguinal-related groin pain was higher than reported in the literature and probably reflects selection bias in a tertiary clinic with predominantly male athletes. Lastly, our study only included male athletes, which limits generalisability to female or transgender athletes. Inguinal-related groin pain is less prevalent in female athletes, potentially due to the different anatomy of the inguinal canal (the spermatic cord runs through the inguinal canal in men, while in women this is the round ligament of the uterus).

CONCLUSION
The interexaminer reliability for clinical examination tests used to classify inguinal-related groin pain in athletes varies from slight to substantial. There is no single perfect clinical examination test. We recommend using full abdominal palpation, including scrotal invagination and abdominal resistance testing as pain provocation tests for classifying athletes with inguinal-related groin pain.

REFERENCES


Clinical Examination

Aspetar Sports Groin Pain Centre
Willem Heijboer
Zarko Vuckovic
Adam Weir
Hans Tol
Per Hölmich
Andreas Serner
• This protocol is a description of the clinical examination tests included in our research study on the diagnosis of groin pain in athletes. All clinical examination tests include bilateral comparison.

• Palpation pain provocation tests are only scored positive when the athlete recognizes his specific injury pain.

• Stretch and resistance pain provocation tests are only scored positive when the athlete reports recognizable injury pain in the tested region (for example: the adductor stretch test has to reproduce the athlete’s recognizable injury pain in the adductor region).

• When dealing with athletes with acute groin pain, there may be other relevant tests to perform.
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Adductor palpation

The patient lies supine on the examination bed with the tested leg placed in a relaxed position with the knee on the examiner’s thigh. The hip of the tested leg is flexed, slightly abducted and externally rotated.

Adductor Longus

The examiner palpates the adductor longus insertion on the pubic bone just inferior to the pubic tubercle and follows the adductor longus tendon and muscle distally. Score: pain (yes/no)

Gracilis

The examiner palpates the gracilis muscle a few cm. distal to the pubic insertion, just posterior of the adductor longus insertion, to distinguish the gracilis from the adductor longus. The gracilis is then palpated proximally to the insertion. Score: pain (yes/no)

Adductor Magnus

The examiner palpates the adductor magnus insertion on the ischiopubic ramus, just posterior of the gracilis insertion, and then continuous more posterior to the ischial tuberosity. Score: pain (yes/no)

Pectineus

The examiner palpates the pubic tubercle and follows the superior pubic ramus a few cm. laterally. Palpation is then performed a few cm. distal from this point within the femoral triangle, lateral to the adductor longus, and medial to the femoral vein, artery and nerve. While the examiner palpates the pectineus with a firm pressure with one hand, the patient is asked to push against the examiner’s other arm which is placed medially on the knee of the tested leg. The examiner should then be able to feel a contraction of the pectineus. Score: pain (yes/no)
Assessment of groin injuries

Adductor longus palpation

Adductor magnus palpation

Gracilis palpation

Pectineus palpation

RF=rectus femoris, S=sartorius, IL=iliopsoas, P=pectineus, AL=adductor longus, G=gracilis
PAIN PROVOCATION TESTS
ADDUCTOR STRETCH & RESISTANCE

Adductor stretch
The patient lies supine on the examination bed.

Hip abduction
The examiner abducts the tested leg, holding it with one hand to ensure the foot points straight up. With the other hand, the contralateral leg is supported to stabilize the testing position. The tested leg is then moved into maximal abduction. Score: pain (yes/no)

Adductor resistance
The patient lies supine on the examination bed.

Adduction in maximal abduction
The patient-examiner position for this test is similar to the hip abduction test: the tested leg is maximally abducted and in this position the patient is asked to push the leg towards the examiners body. Score: pain (yes/no)

Mid-range adduction — cross-over sign
The examiner places the tested leg outside of the examination bed (the thigh is on the bed, and the lower leg is “hanging” next to the bed). The other leg is positioned in approximately 45° hip abduction. The patient is asked to give a maximal isometric adduction. This test is positive, if the patients reports the recognizable injury pain at the proximal adductor region of the contralateral leg (the “hanging” leg). Score: pain (yes/no)
Assessment of groin injuries

Hip abduction

Outer-range adduction

Outer-range adduction
Cross-over sign
PAIN PROVOCATION TESTS
ADDUCTOR RESISTANCE

Squeeze 0°
The patient lies supine on the examination bed with the hips and knees in neutral position. The examiner stands at the end of the examination bed holding the lower legs of the patient (arms crossed) just above the medial malleoli. The patient is asked to perform a maximum hip adduction. Score: pain (yes/no)

Squeeze 45°
The patient lies supine on the examination bed. One leg is flexed until the medial malleolus is positioned at the level of the contralateral medial knee joint line. The other leg is then flexed similarly, so both medial malleoli are next to each other and the feet flat on the bed. The hips will then be approximately 45 degrees flexed and the knees approximately 90 degrees flexed. The examiner then positions a clenched fist between the patient’s knees, and the patient is asked to press the knees together with maximal force. Score: pain (yes/no)

Squeeze 90°
The patient lies supine on the examination bed. Both hips and knees are flexed in 90 degrees. The legs are not supported by the examiner. The patient is allowed to hold the sides of the examination table. The examiner then positions a clenched fist between the patient’s knees, and the patient is asked to press the knees together with maximal force. Score: pain (yes/no)
Assessment of groin injuries

Knees

Mid-Shins

Ankles

Floor

Stretching Pain

Squeeze 0°

Squeeze 45°

Squeeze 90°
PAIN PROVOCATION TESTS
ABDOMINAL WALL & PUBIC PALPATION

**Abdominal wall palpation**
The patient lies supine on the examination bed.

*Rectus abdominis*
The rectus abdominis muscle is palpated slightly lateral to the umbilicus and followed distally to the pubic insertion. *Score: pain (yes/no)*

**Pubic palpation**
The patient lies supine on the examination bed.

*Pubic symphysis*
The examiner palpates the pubic symphysis on the proximal side with one finger. *Score: pain (yes/no)*

*Adjacent bone*
Remaining with one finger on the symphysis, the adjacent bone is palpated on the lateral borders. (The adjacent bone is comparable with the knuckles of the hand, where the pubic symphysis is the “gap” in between). *Score: pain (yes/no)*
Assessment of groin injuries

- Rectus abdominis palpation
- Pubic symphysis joint palpation & Adjacent bone palpation
PAIN PROVOCATION TESTS

INGUINAL PALPATION
(without invagination)

Inguinal palpation (without invagination)
The patient lies supine on the examination bed.

Pubic tubercle
The examiner palpates the lateral/craniolateral border of the pubic tubercle at the insertions of the inguinal ligament and conjoint tendon. Score: pain (yes/no)

Inguinal ligament
The inguinal ligament is a firm structure between the pubic tubercle and the spina iliaca anterior superior (SIAS). The examiner palpates the medial 0.5-3cm of the inguinal ligament. Score: pain (yes/no)

External ring (medial border)
The examiner palpates the medial border of the external ring at the lateral border of the rectus abdominis (superolateral of the pubic tubercle). The examiner palpates an area of 0.5-3cm. Score: pain (yes/no)
Assessment of groin injuries

Knees
Mid-Shins
Ankles
Floor

Stretching

Pubic tubercle

External ring (medial border)

Inguinal ligament
Inguinal invagination

The patient lies supine on the examination bed.

External ring

The examiner inverts the scrotum with the index finger and the external inguinal ring can be palpated approximately 1 cm craniolateral to the pubic tubercle. The examiner then gently attempts to move the tip of the finger through the external inguinal ring into the inguinal canal. **Score: pain (yes/no), size of the “entrance” of the inguinal canal (S: no entry, M: fingertip, L: >fingertip)**

Conjoint tendon

The examiner palpates the conjoint tendon during invagination of the inguinal canal, directly medial after passing the external inguinal ring. **Score: pain (yes/no)**

Posterior wall

The examiner palpates the posterior wall of the inguinal canal during invagination and follows the inguinal canal proximolateral. **Score: structure (soft/firm)**

Bulging/Valsalva

Examiner palpates the posterior wall and asks the patient to perform a Valsalva maneuver by inhaling deeply first and then to exhale forcefully against the backside of his hand (without letting the air escape). **Score: pain (yes/no), bulging is defined as the subjective feeling of “ballooning” of the posterior wall during Valsalva (yes/no)**
Invagination of the inguinal canal
PAIN PROVOCATION TESTS
ABDOMINAL RESISTANCE

Abdominal resistance tests
The patient lies supine on the examination bed.

Straight sit-up 0° hip flexion
The patient lies in supine on the examination bed with knees and hips extended (0° hip flexion). The patient crosses his arms in front of the chest. The patient then performs a sit-up movement, lifting head and scapulae from the couch, while the examiner resists the movement (isometric test) by holding one arm on the patient’s knees and the other arm on the patient’s chest. Score: pain (yes/no)

“Cross test” 0° hip flexion
The patient lies in supine on the examination bed with knees and hips extended (0°). The patient crosses his arms in front of the chest. The patient then performs an oblique sit up where the opposite hip is simultaneously flexed with an extended knee. The examiner resists the movement by fixating the right shoulder and the left leg just above the knee cap. This isometric test is also performed on the opposite site. Score: pain (yes/no)
Assessment of acute adductor injuries

Knees
Mid-shins
Ankles
Floor
Stretching
Pain
Straight sit-up 0° hip flexion

Cross-test 0° hip flexion
PAIN PROVOCATION TESTS
ABDOMINAL RESISTANCE

Straight sit-up 45° hip flexion
The patient lies in supine on the examination bed with the hips in approximately 45° flexion and the knees in 90° flexion. The patient crosses his arms in front of the chest. The patient then performs a sit-up movement, lifting head and scapulae from the couch, while the examiner resists the movement by holding one arm on the patient’s knees and the other arm on the patient’s chest (isometric test). Score: pain (yes/no)

Oblique sit-up 45° hip flexion
The patient lies in supine on the examination bed with the hips in approximately 45° flexion and the knees in 90° flexion. The patient then performs an oblique sit up (right shoulder to left knee), while the examiner resists the movement by fixating the right shoulder and the left knee just above the knee cap. This isometric test is also performed on the opposite site. Score: pain (yes/no)
Assessment of groin injuries

Knees
Mid-Shins
Ankles
Floor

Stretching Pain

Straight sit-up 45° hip flexion

Oblique sit-up 45° hip flexion
PAIN PROVOCATION TESTS
HIP FLEXOR PALPATION

**Psoas palpation (supra-inguinal)**
The patient lies supine on the examination bed. The examiner locates the lateral edge of the rectus abdominis muscle at the level of the anterior superior iliac spine. Palpation is performed laterally to this. The fingers are gently pressed posteromedial while pushing the intra-abdominal structures away to reach the psoas muscle. The patient must be relaxed (let the patient exhale). When the hands are as “deep” as possible, the patient is told to elevate the foot slightly on the side being tested. The psoas muscle is now palpated firmly over an area as large as possible. *Score: pain (yes/no)*

**Iliopsoas palpation (infra-inguinal)**
The patient lies supine on the examination bed with the tested leg placed in a flexed, slightly abducted and externally rotated position. The patient is asked to push against the examiners hand which is placed on the medial malleolus of the tested leg. This will make the sartorius appear clearly, and the examiner can locate the distal iliopsoas in the femoral triangle just medial to the sartorius below the inguinal ligament. If the examiner cannot clearly distinguish the iliopsoas a resisted hip flexion can be performed while the examiner palpates. *Score: pain (yes/no)*

**Proximal sartorius palpation**
The patient lies supine on the examination bed with the tested leg placed in a relaxed position with the knee on the examiners thigh, which is supported by the examination bed. The hip of the tested leg is flexed, slightly abducted and externally rotated. The patient is asked to push against the examiners hand which is placed on the medial malleolus of the tested leg. This will make the sartorius appear clearly, and the muscle can be differentiated from the surrounding muscles proximally near the insertion on the Anterior Superior Iliac Spine. *Score: pain (yes/no)*

**Proximal rectus femoris palpation**
The patient lies supine on the examination bed. The rectus femoris is localized by asking the patient to push against the examiners hand, which is placed anteriorly on the distal tibia. The leg is then relaxed again and the knee is slightly flexed by the examiner. The rectus femoris is then palpated proximally towards the insertion on the anterior inferior iliac spine in the small triangle between the sartorius medially and the tensor fascia latae laterally. *Score: pain (yes/no)*
Assessment of groin injuries

Psoas palpation

Iliopsoas palpation

Sartorius palpation

Rectus femoris palpation

S=Sartorius, IL=iliopsoas, P=pectineus, AL=Adductor longus, G=Gracilis
**PAIN PROVOCATION TESTS**

**HIP FLEXOR RESISTANCE**

**Hip flexion 0°**
The patient lies supine on the examination bed. The patient is asked to flex the hip keeping the leg straight, while the examiner applies resistance slightly proximal to the ankle of the tested leg (isometric test). *Score: pain (yes/no)*

**Hip flexion 90°/90°**
The patient lies supine on the examination bed. Both hip and knee are flexed approximately 90 degrees. The examiner tries to extend the flexed hip by pulling it with one arm wrapped around the thigh just proximal to the knee (isometric test). *Score: pain (yes/no)*
Assessment of groin injuries

Hip flexion 0°

Hip flexion 90°
**PAIN PROVOCATION TESTS**

**HIP FLEXOR RESISTANCE & STRETCH**

**Modified Thomas test**

(A) Hip extension stretch and (B) Hip flexion resistance (isometric) and (C) Hip flexion-adduction resistance (isometric)

(A) The examiner places one hand on the thigh of the hanging leg just above the knee, and presses the leg down applying a hip extension stretch. (B) The patient is then asked to push the knee against the examiner’s hand, while the examiner resists the hip flexion movement. (C) Similar to test B, but now the patient is asked to perform a combined hip flexion and adduction movement (“try to move the knee in the direction of the contralateral shoulder”).
Modified Thomas Test
**PAIN PROVOCATION TESTS**

**HIP TESTS**

**Hip tests**
The patient lies supine on the examination bed.

**FADIR**
The examiner moves the tested hip to maximal flexion, adduction and internal rotation (FADIR), with compression on the hip joint. This test is scored positive when the patient feels recognizable injury pain. *Score: pain (yes/no)*

**FABER**
The hip and knee of the tested leg is flexed, abducted and externally rotated, as the foot of the tested leg is placed on the contralateral thigh just proximal to the knee. While stabilizing the pelvis on the contralateral side, a gentle pressure is applied downwards on the knee of the tested leg. This test is scored positive when the patient feels recognizable injury pain. *Score: pain (yes/no)*

**Internal rotation 90°/90°**
The examiner moves the tested leg to 90 degrees flexion of both hip and knee, and then internal rotates the hip. This test is scored positive when the patient feels recognizable injury pain. *Score: pain (yes/no)*

**External rotation 90°/90°**
The examiner moves the tested leg to 90 degrees flexion of both hip and knee, and then external rotates the hip. This test is scored positive when the patient feels recognizable injury pain. *Score: pain (yes/no)*
Assessment of groin injuries

Knees
Mid-Shins
Ankles
Floor

Stretching
Pain

FABER

Internal rotation 90°/90°

External rotation 90°/90°
Optional tests
The following tests are optional and can be used when there is clinical suspicion on a certain pathology: e.g. when a femoral stress fracture is in the examiner's differential diagnosis, the fulcrum test should be performed.

Prone internal rotation
The examiner lies prone on the examination bed. The examiner flexes the knee to approximately 90 degrees and then internal rotates the hip. The test is positive when the athlete reports recognizable injury pain (yes/no).

Internal snapping hip
The patient lies supine on the examination bed. The examiner flexes and external rotates the hip to the end range. The patient is then asked to extend and internal rotate the hip. If a recognizable “click/clunk” is heard/felt by the patient, this test is positive for an internal snapping hip. Pain (yes/no) is also recorded.

Fulcrum test
The patient sits on the examination bed, with both thighs fully supported on the bed. The examiner places his arm under the tested thigh and puts his hand on the other thigh. The examiner then gives a firm pressure downwards with his other hand on the knee of the tested leg. If the patient reports recognizable injury pain, this can be suggestive for a femoral stress fracture.

Posterior hip impingement
The examiner lies prone on the side of the examination bed. The examiner then places the hip in extension, abduction and external rotation on the side of the examination bed. The test is positive when the athlete reports recognizable injury pain (yes/no).

Prone knee flexion
The patient lies prone on the examination bed. The examiner then flexes the knee. The test is positive when the athlete reports recognizable injury pain (yes/no).
Assessment of groin injuries

- Internal snapping hip
- Prone internal rotation
- Fulcrum test
- Posterior hip impingement
- Prone knee flexion
Appendix B - Additional clinical examination findings

Participant reported pain locations during abdominal resistance tests for n=61 symptomatic sides (average of both examiners).

<table>
<thead>
<tr>
<th>Resistance tests (n=61)</th>
<th>Pain in the inguinal canal region</th>
<th>Pain in region of other entities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adductor</td>
<td>Iliopsoas</td>
</tr>
<tr>
<td>Straight sit-up 0°</td>
<td>23%</td>
<td>8%</td>
</tr>
<tr>
<td>Cross test - shoulder affected side</td>
<td>21%</td>
<td>3%</td>
</tr>
<tr>
<td>Cross test - shoulder contralateral side</td>
<td>38%</td>
<td>18%</td>
</tr>
<tr>
<td>Straight sit-up 45°</td>
<td>30%</td>
<td>7%</td>
</tr>
<tr>
<td>Oblique sit-up - shoulder affected side</td>
<td>15%</td>
<td>3%</td>
</tr>
<tr>
<td>Oblique sit-up - shoulder contralateral side</td>
<td>30%</td>
<td>8%</td>
</tr>
</tbody>
</table>

Average prevalence of participant-reported palpation pain NOT related to their injury in symptomatic and asymptomatic sides (n=88).

<table>
<thead>
<tr>
<th>Abdominal palpation tests</th>
<th>Pain NOT related to injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus abdominis insertion</td>
<td>11%</td>
</tr>
<tr>
<td>Rectus abdominis muscle/tendon</td>
<td>2%</td>
</tr>
<tr>
<td>Pubic tubercle</td>
<td>9%</td>
</tr>
<tr>
<td>Inguinal ligament</td>
<td>6%</td>
</tr>
<tr>
<td>External ring (medial border)</td>
<td>11%</td>
</tr>
<tr>
<td>External ring *</td>
<td>16%</td>
</tr>
<tr>
<td>Conjoint tendon *</td>
<td>16%</td>
</tr>
<tr>
<td>Posterior wall (Valsalva) *</td>
<td>23%</td>
</tr>
</tbody>
</table>

*Palpation tests during scrotal invagination
If any of the above 3 tests (pubic tubercle, inguinal ligament, external ring (medial border)) were scored positive

If any of the above 3 test (external ring, conjoint tendon, posterior wall) were scored positive

Pain reported on the contralateral side (e.g. patient reported recognizable injury pain in the left inguinal canal region during an oblique sit-up with resistance on the right shoulder)

<table>
<thead>
<tr>
<th>Abdominal palpation</th>
<th>Mean prevalence of positive tests in defined inguinal-related groin pain</th>
<th>Mean prevalence of positive tests in “all” (defined+likely) inguinal-related groin pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pubic tubercle</td>
<td>66%</td>
<td>56%</td>
</tr>
<tr>
<td>Inguinal ligament</td>
<td>58%</td>
<td>49%</td>
</tr>
<tr>
<td>External ring</td>
<td>59%</td>
<td>49%</td>
</tr>
<tr>
<td>External ring (medial border)</td>
<td>55%</td>
<td>46%</td>
</tr>
<tr>
<td>Conjoint tendon</td>
<td>54%</td>
<td>45%</td>
</tr>
<tr>
<td>Posterior wall (during Valsalva)</td>
<td>79%</td>
<td>66%</td>
</tr>
<tr>
<td>Any inguinal palpation pain without invagination a</td>
<td>77%</td>
<td>64%</td>
</tr>
<tr>
<td>Any inguinal palpation pain DURING invagination b</td>
<td>94%</td>
<td>78%</td>
</tr>
<tr>
<td>Any inguinal palpation pain (without/during) invagination</td>
<td>100%</td>
<td>83%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abdominal resistance</th>
<th>Mean prevalence of positive tests in IRGP</th>
<th>Mean prevalence of positive tests in IRGP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight sit-up 0°</td>
<td>30%</td>
<td>34%</td>
</tr>
<tr>
<td>Cross test - shoulder affected side</td>
<td>27%</td>
<td>28%</td>
</tr>
<tr>
<td>Cross test - shoulder contralateral side</td>
<td>49%</td>
<td>48%</td>
</tr>
<tr>
<td>Straight sit-up 45°</td>
<td>38%</td>
<td>38%</td>
</tr>
<tr>
<td>Oblique sit-up - shoulder affected side</td>
<td>21%</td>
<td>20%</td>
</tr>
<tr>
<td>Oblique sit-up - shoulder contralateral side</td>
<td>39%</td>
<td>38%</td>
</tr>
<tr>
<td>Pain during any abdominal resistance test</td>
<td>58%</td>
<td>57%</td>
</tr>
</tbody>
</table>

a If any of the above 3 tests (pubic tubercle, inguinal ligament, external ring (medial border)) were scored positive
b If any of the above 3 test (external ring, conjoint tendon, posterior wall) were scored positive
c Pain reported on the contralateral side (e.g. patient reported recognizable injury pain in the left inguinal canal region during an oblique sit-up with resistance on the right shoulder)