Hip and groin pain in athletes
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CHAPTER 5

Is lower hip range of motion a risk factor for groin pain in athletes? A systematic review with clinical applications

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Gino Kerkhoffs
Rob Langhout
Janine Stubbe
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Abstract

Background: Whether hip range of motion (ROM) is a risk factor for groin pain in athletes is unknown. A systematic review is required to synthesise the available evidence and provide clinical interpretations.

Objectives: To systematically review the relationship between hip ROM and groin pain in athletes.

Study design: Systematic review, prospectively registered (PROSPERO) according PRISMA guidelines.

Methods: PubMed, Embase, CINAHL and SPORTDiscus were systematically searched to December 2015. Two authors performed study selection, data extraction/analysis, quality assessment (Critical Appraisal Skills Program) and strength of evidence synthesis.

Results: We identified 7 prospective and 4 case-control studies. The total quality score ranged 29-92%. Heterogeneity in groin pain classification, injury definitions and physical assessment precluded data-pooling. There was strong evidence that lower total rotation of both hips below 85° measured at the pre-season screening was a risk factor for groin pain development. Strong evidence suggested internal rotation, abduction and extension were neither associated with the risk nor the presence of groin pain.

Conclusion: Total hip ROM is the factor most consistently related to groin pain in athletes. Screening for hip ROM is unlikely to correctly identify an athlete at risk because of the small ROM differences found and the poor measurement properties.
Introduction

Groin pain is common in sports involving explosive movements, directional changes, repeated kicking and body contact\textsuperscript{250}. The aetiology of groin pain is unclear and probably multifactorial\textsuperscript{58}. Seven systematic reviews\textsuperscript{48,99,140,157,202,258} have focused on factors associated with groin pain in athletes. Lower hip range of motion (ROM) was found to be a risk factor in four studies\textsuperscript{48,98,99,202}, but not in two reviews\textsuperscript{140,258}. Mosler et al.\textsuperscript{157} studied factors that differentiated athletes with and without hip and groin pain and found lower hip ROM to be associated with its presence.

A recent international agreement reported that the hip can be an important cause of groin pain in athletes\textsuperscript{250}. The interference of hip related pathology, hip ROM and groin pain was not addressed in these reviews. Additionally, no clear understanding of the paradigm of decreased hip ROM in relation to groin pain exists\textsuperscript{22,260}.

No published prevention or treatment programs for groin pain in athletes focus specifically on hip ROM\textsuperscript{250,258}. A recent meta-analysis of 7 randomized trials on preventing groin injuries in athletes showed a lack of efficacy\textsuperscript{62}. These prevention programs mainly consisted of active exercise and did not address hip range of motion at base line or follow-up. A review appraising existing literature on hip ROM measures and their relation to groin pain assist planning new preventative strategies and making adequate choices in study designs.

The primary aim of this review was to collect and synthesize all available evidence on the relationship between hip ROM and groin pain in athletes. The secondary aim was to guide clinicians and researchers to interpret the findings on the relationship between hip ROM and groin pain. The key research question was: is there a relationship between hip range of motion and the presence of groin pain in athletes.

Methods

This systematic review was conducted in accordance with the PRISMA guidelines. The protocol for this review was registered at the PROSPERO register (website; http://www.crd.york.ac.uk/PROSPERO) for systematic reviews under registration number CRD42015017666.

Search strategy

Prior to this systematic review the Cochrane Database of Systematic Reviews, MEDLINE and PEDro were searched for systematic reviews on groin pain in athletes involving hip ROM as to ensure that a similar study had not already been conducted. There were no date restrictions applied thus all databases were searched in full up to August 1\textsuperscript{st} 2015 when this review process commenced.
To identify studies that meet the inclusion criteria, a search was conducted on December 1st 2015 in the electronic databases PubMed, Embase, CINAHL and SPORTDiscus without any date restriction. A combination of the following keywords and their synonyms were used: *groin pain, hip range of motion, risk factors* (see Appendix 1 for the full search strategy). Cross-references from the previous reviews and all retained articles that fulfilled the inclusion criteria were screened for possible relevance. Additionally three experts in the field were asked whether they had any relevant references available from books or other sources. All results were entered in Reference Manager (Thomson Reuters, Philadelphia, USA). Double citations were removed.

**Eligibility criteria**

Studies were considered eligible for this review if data were presented on hip ROM in athletes in a study evaluating risk of developing groin pain (prospective longitudinal study), OR when comparing athletes with and without groin pain (cross-sectional/case series study). Groin pain could be described according to the numerous past different definitions known to be present in literature ^2^.

**Inclusion and exclusion criteria**

A study was included when it was:

(a) an original study, published in English, German, French or Dutch;
(b) an observational (prospective) cohort, cross-sectional or case-control study;
(c) studying athletes as the population of interest;
(d) studying groin pain as a variable;
(e) studying hip ROM as a variable;
(f) presenting statistical data analyses of the relationship between dependent and independent variables (groin pain and hip ROM).

Only studies meeting all criteria were included.

This review aimed to assist clinicians working with athletes who may be at risk for or have already developed groin pain. Studies on hip and/or groin pain caused by known hip conditions were excluded as being outside the scope of this review. Intervention studies were excluded, as were studies on cadavers or animals.

**Selection of studies**

Two reviewers (LE and IT) independently reviewed all obtained titles and abstracts to determine possible eligibility. They checked full-text versions of all of the retained articles and screened reference lists of both these studies and the systematic reviews already identified, for other relevant citations. Full-text screening was then performed according to the inclusion and exclusion criteria. The selection status of each retained
article was discussed and disagreements were resolved by consensus. A third reviewer (AW) was available to discuss on-going disagreement. A final list of articles for further detailed analysis was created.

Data extraction, synthesis and analysis
Two reviewers (LE and IT) extracted the following data, using a standardized form:

- Definitions of groin pain and the accompanying injury criteria (used terms, specifications of groin pain and (physical) examination criteria)
- Onset of pain
- Time of existing complaints
- Time-loss
- Study setting (sports type and level, gender, country)
- Study design
- Details on ROM assessment (movement directions, body position, measurement device, reporting of data in appropriate Système International units\textsuperscript{226}, definition of end ROM and the number and qualification of assessors)

Regarding the study results and outcomes, the number of participants, injuries and (injured) hips including percentage are presented. It was reported whether injured players or injured hips were used for analyses and which data were provided (per side, for all hips or bilateral as sum scores). As a previous injury increases the risk for a re-injury, any reporting on re-injuries and methodological/statistical considerations (whether correction was needed or not) are presented. Data were analysed descriptively. For the studies that supplied adequate continuous data, means and standard deviations or standard error of means are presented, specified to one decimal point. For dichotomous data, odd ratios/relative risk (OR/RR) with matching 95\% confidence interval (CI) are presented. Mean differences (MD) for each ROM movement are calculated and presented, rounded off to whole numbers as most measurement tools have 1° increments.

Methodological quality assessment
The checklist assessing the methodological quality of cross-sectional, case-control and prospective cohort studies according to the Critical Appraisal Skills Program (CASP, 2014, www.casp-uk.net), as used by Van der Windt\textsuperscript{261} was used. This was specifically adapted\textsuperscript{25,268} (LE, IT, MB) for the purposes of this study. The criteria list contains items on information, validity and/or precision in the following categories: study objective, study population, exposure measurement and assessment of the outcome and analysis of the outcome and data presentation.

Two independent reviewers (LE and IT) rated each study as “positive” (+) if it included an item, “negative” (-) if it did not include an item, “non applicable” (NA) if that item
was not applicable to that particular study. When no clear information was present on this item a “negative” (-) was scored. The reviewers compared their results and in case of disagreement, consensus upon each item was reached in a meeting. Absolute and level of agreement (Cohen’s κ) are presented. A total quality score for each study was calculated and presented by counting the number of items that were rated positively divided by the total achievable (applicable items only) score. The studies were ranked as a percentage of the maximum achievable score, and, relative to this total score, categorized as scoring high or low according to the CASP criteria. A high score, thus a low risk of bias study, was a study that scored positively for >50% of the validity/precision items on the methodological quality list. A low-score, referring to high risk of bias study, was one that scored positively for ≤50% of the validity/precision items. Quality scores were performed per study type and over-all. All studies were checked for reporting on conflicts of interest.

**Item assessment**

Item assessment was performed by calculating the ratio of positively scored items / negatively scored items per CASP item over all studies. When no negative score was obtained a ‘maximum’ score was assigned and when no positive score was obtained a ‘minimum’ score was assigned. This was done in order to give insight into which items in general scored low or high among the studies included.

**Strength-of-evidence assessment**

The strength of evidence for hip ROM as a potential risk-factor for, or in association with groin pain was assessed by defining four levels of evidence (see Table 1). A relationship was rated as positive when the risk estimate was increased. No relationship was identified when the effect estimate indicated no increased or decreased risk for hip ROM or when it was reported to be statistically non-significant (P>0.05) without reporting the risk estimate. Significant differences were based on means with standard deviations (SD) and/or matching 95% CI. If a study provided neither of these two, any information on significant differences (P<0.05) between the groups was used.

**RESULTS**

**Search results of this study**

The database search resulted in 784 studies of which 208 duplicates were removed. Screening of titles and abstracts was performed on the 576 remaining references for possible eligibility and 29 potentially relevant studies were screened in full text. After checking cross-references, 2 additional studies were considered potentially relevant.
**Table 1.** Strength of evidence assessment.

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Strong evidence Consistent findings in multiple high-quality cohort and/or case-control studies.</td>
</tr>
<tr>
<td>2</td>
<td>Moderate evidence Consistent findings in multiple cohort and/or case-control studies, of which only one is a high-quality study.</td>
</tr>
<tr>
<td>3</td>
<td>Some evidence Findings of one cohort or case-control study or consistent findings in multiple cross-sectional studies, of which at least one study is a high-quality study.</td>
</tr>
<tr>
<td>4</td>
<td>Inconclusive evidence Concerns all other cases: i.e., consistent findings in multiple low-quality, cross-sectional studies or inconsistent findings in multiple studies. The evidence is considered to be inconclusive if only one cross-sectional study is available, regardless of the quality of this study.</td>
</tr>
</tbody>
</table>

Note: Findings are consistent when the results of at least 75% of the studies have similar outcomes.

**Figure 1.** PRISMA Flow Diagram of the study search and selection procedure. Abbreviations: DSR=Database of systematic reviews; ROM=range of motion.
and included 60,16. All citations (410 in total) from the 7 relevant reviews 48,98,99,140,157,202,258 were manually screened for potentially relevant references which resulted in 2 additional references 58,149. The experts did not provide additional references. Finally, 11 of these 33 studies assessed in full text fulfilled the criteria and were included for data extraction (see Figure 1).

**Study characteristics**

There were 7 prospective cohort and 4 case control studies included. Heterogeneity of definitions of groin pain and ROM was found (see Table 2).

**Table 2. Definitions of groin pain and eligibility criteria.**

<table>
<thead>
<tr>
<th>Groin pain definition Authors (type of study)</th>
<th>Groin pain specified as</th>
<th>Pain onset (PC/CC)/ Pain duration (CC)</th>
<th>Injury time reference criterion</th>
<th>Exclusion of athletes at baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Groin strain</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Arnason et al.14 (PC)</td>
<td>Groin strain specified as</td>
<td>a. NR</td>
<td>a. Miss one training/match</td>
<td>a. NR</td>
</tr>
<tr>
<td>b. Engebretsen et al.60 (PC)</td>
<td></td>
<td>b. Pain on inner side of thigh</td>
<td>b. 1. Miss part of training/match</td>
<td>b. NR</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>b. 2. No time-loss</td>
<td></td>
</tr>
<tr>
<td><strong>Groin muscle strain injury</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emery et al.59 (PC)</td>
<td>Muscle injury in the hip flexor or hip adductor muscle groups</td>
<td>A+NoA</td>
<td>Stop training/match or missed next day training/match</td>
<td>Groin contact injury / contusions</td>
</tr>
<tr>
<td><strong>Adductor (muscle) strain</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Ibrahim et al.100 (PC)</td>
<td>a+b:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Pain on palpation of the adductor tendons or their insertion on the pubic bone or both AND 2. Groin pain during adduction against resistance</td>
<td>a. NR</td>
<td>a. Miss training/match &gt;1 week</td>
<td>a. NR</td>
</tr>
<tr>
<td>b. Tyler et al.241 (PC)</td>
<td></td>
<td></td>
<td>b. Miss training/match or medical attention</td>
<td>b. Athletic pubalgia, osteitis pubis, hernia, hip osteoarthritis, rectal or testicular referred pain, piriformis syndrome, pelvic or lower extremity fracture</td>
</tr>
<tr>
<td><strong>Adductor muscle injury</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Witvrouw et al.263 (PC)</td>
<td>First time adductor muscle injury</td>
<td>A+NoA</td>
<td>Miss one training/match</td>
<td>Previous lower extremity muscle injury from 2 years</td>
</tr>
</tbody>
</table>
### Table 2. Continued

<table>
<thead>
<tr>
<th>Chronic groin injury</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Verrall et al. (2007)²⁴⁴ (PC)</td>
<td>a. Pain in adductor and/or lower abdominal and/or pubic bone region AND 2. Pain for at least 6 weeks</td>
<td>a. NR</td>
<td>a. Pain &gt;6 weeks and miss one match</td>
</tr>
<tr>
<td>b. Verrall et al. (2005)²⁴³ (CC)</td>
<td>b. 1. Pain in the groin region; 2. Tenderness of the pubic symphysis and/or superior pubic rami</td>
<td>b. NR/NR</td>
<td>b. Pain &gt;6 weeks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Longstanding groin pain</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Nevin et al.¹⁶⁷(CC)</td>
<td>a. 1. Pain of palpation of the adductor tendons, their insertion onto the pubic rami of pubic symphysis 2. Presence of pain during resisted adduction</td>
<td>a. NR/NR</td>
<td>a. Pain &gt;6 weeks</td>
</tr>
<tr>
<td>b. Malliaras et al.¹⁴¹(CC)</td>
<td>b. 1. Pain while running of performing rapid agility movements AND at least one of the following 1. Groin pain standing on one leg 2. Groin pain or stiffness in morning 3. Groin pain at night 4. Groin pain when coughing or sneezing</td>
<td>b. NR/≥4 weeks</td>
<td>b. NR</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Groin pain: sports hernia</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rambani¹⁸⁵(CC)</td>
<td>Unilateral groin pain</td>
<td>NR/NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

Abbreviations: A=acute; NoA=non-acute; NR=not reported; PC=prospective cohort study; CC=case-control study. Pain onset is presented as acute or non-acute for PC and CC. Duration of pain only presented for CC.
Table 3 presents the descriptives of the 11 studies included in this review.

**Table 3. Descriptives of included studies.**

<table>
<thead>
<tr>
<th>Authors, Study type</th>
<th>Setting</th>
<th>Groin pain</th>
<th>Hip ROM</th>
<th>Assessment procedure</th>
<th>Number of assessors/ Qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groin strain</td>
<td>Soccer / M / Prof / Iceland</td>
<td>92%</td>
<td>1. ABD 2. EXT</td>
<td>1. Supine, hip neutral EXT 2. Supine, hip neutral ABD (Thomas test)</td>
<td>Standard goniometer in degrees (˚) 1 experienced PT</td>
</tr>
<tr>
<td>Verrall et al. (2007).94 PC</td>
<td>ARF / M / Prof / Australia</td>
<td>92%</td>
<td>1. IR 2. ER 3. TR</td>
<td>1, 2 and 3: Supine, hip and knee FL 90˚</td>
<td>Standard goniometer in degrees (˚) Maximum range of rotation Not further specified 1 NR</td>
</tr>
<tr>
<td>Emery et al.15 PC</td>
<td>Ice hockey / M / Prof / Canada</td>
<td>67%</td>
<td>1. Bilateral ABD (active)</td>
<td>1. Supine, hip neutral EXT, ABD performed bilaterally at once</td>
<td>Standard goniometer in degrees (˚) Maximum active abduction Not further specified 23 PTs / physicians</td>
</tr>
<tr>
<td>Ibrahim et al.160 PC</td>
<td>Soccer / M / Prof / Australia</td>
<td>58%</td>
<td>1. TR</td>
<td>1. Supine, hip and knee FL 90˚</td>
<td>Standard goniometer in degrees (˚) Move to end range Not further specified 1 NR</td>
</tr>
<tr>
<td>Tyler et al.241 PC</td>
<td>Ice hockey / M / Prof / USA</td>
<td>58%</td>
<td>1. ABD</td>
<td>1. Supine, hip neutral EXT</td>
<td>Standard goniometer in degrees (˚) Start of leg to externally rotate Not further specified 1 NR</td>
</tr>
<tr>
<td>Witvrouw et al.253 PC</td>
<td>Soccer / M / Prof / Belgium</td>
<td>58%</td>
<td>1. ABD</td>
<td>1. Supine, hip neutral EXT</td>
<td>Standard goniometer in degrees (˚) Start of leg to externally rotate Not further specified 2 PT</td>
</tr>
</tbody>
</table>
### Table 3. Continued

<table>
<thead>
<tr>
<th>Study</th>
<th>Sport</th>
<th>Injury Type</th>
<th>HIP ROM Methodology</th>
<th>Abbreviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verrall et al. (2005) 243 CC</td>
<td>ARF / M / Prof / Australia</td>
<td>Chronic groin injury</td>
<td>1. Bilateral IR&lt;br&gt;2. Bilateral ER&lt;br&gt;3. Bilateral TR&lt;br&gt;1,2,3 Supine, hip and knee FL 90°</td>
<td>1. Gentle overpressure 1. Inclinometer in degrees° 1,2,3. Maximum range of rotation, not further specified</td>
</tr>
<tr>
<td>Malliaras et al. 141 CC</td>
<td>ARF+soccer / M / Elite junior / Australia</td>
<td>Groin pain</td>
<td>1. IR&lt;br&gt;2. ER&lt;br&gt;3. Bilateral IR&lt;br&gt;4. Bilateral ER&lt;br&gt;5. BKFO&lt;br&gt;1. Prone, hip neutral EXT, knees FL 90°&lt;br&gt;2. Supine, hip neutral EXT, knees FL 90°&lt;br&gt;3. as per 1&lt;br&gt;4. as per 2&lt;br&gt;5. Crook-lying, hips FL 45°, knee FL 90° feet together</td>
<td>1. Gentle overpressure 1. Inclinometer in degrees° 1. Gentle overpressure 2. End range of motion OR pelvic movement 5. Gentle over pressure for BKFO</td>
</tr>
<tr>
<td>Rambani et al. 185 CC</td>
<td>NR / M+F / NR / UK</td>
<td>Sports Hernia</td>
<td>1. IR&lt;br&gt;2. ER&lt;br&gt;3. FL&lt;br&gt;4. ABD&lt;br&gt;5. ADD&lt;br&gt;1.2, Supine, hip and knee FL 90°&lt;br&gt;3. Prone&lt;br&gt;4.5. Prone, hip neutral EXT</td>
<td>1. Gentle overpressure 1. Inclinometer in degrees° 2. Rigid tape measure; distance fibula-head to plinth (cm)</td>
</tr>
</tbody>
</table>

Abbreviations: PC=prospective study; CC=case-control study; HIP ROM refers to passive measures unless stated otherwise. M=male; F=female; NR=not reported; IR=internal rotation; ER=external rotation; TR=total rotation (IR+ER) per hip; FL=flexion; EXT=extension; ABD=abduction; ADD=adduction; BKFO=bent knee fall out; ARF=Australian rules football; Prof=professional; Am=amateur; PT=physical therapist.
The prospective cohort studies lasted for one or two consecutive playing seasons. The duration of the playing seasons depended on the sport and ranged from 4 months (Australian Rules Football/Gaelic Football), to 6 months (ice hockey) or 9 months (soccer). The results of the included studies are presented in Table 4.

**Methodological quality**

There were 35/146 (24%) disagreements (See Appendix 4) on the quality assessment, resulting in a moderate level of agreement of 0.43 (Cohen's \( \kappa \))\(^{145} \). The scores of the studies on the methodological-quality-assessment list are presented for prospective cohort and case-control designs (Table 5A).

All but two\(^{141,185} \) included studies had a high score. The total quality score ranged 29-92%. The total score of the 7 prospective studies ranged 58-92% and that of the 4 case control studies range 29-71%. There were 3 studies that did not report on a possible conflict of interest\(^{100,185,243} \), 4 studies that reported a possible conflict\(^{14,59,60,141} \) and 4 studies that reported no conflict of interest\(^{167,241,244,263} \) to be present.

The item scores per study type are presented in Table 5B. Scores <1 represent items with more negative than positive scores. These are considered scoring relatively low.
Table 4. Results of included studies. Hip ROM refers to passive measures unless stated otherwise. Re-injury: a re-injury of one player during the study; Age presented as mean (standard deviation).

<table>
<thead>
<tr>
<th>Authors, Study type, CASP score (%)</th>
<th>Population</th>
<th>Groin injuries</th>
<th>Hip ROM</th>
<th>Injury analysis</th>
<th>Re-injury</th>
<th>Outcomes</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non injured players</td>
<td>Injured players</td>
<td>Injuries</td>
<td>Per hip/ per player</td>
<td>Data presented PS, AH or BH</td>
<td>Reported/ Statistical check or correction</td>
<td>Mean (SD) values for injured/non-injured hip ROM of hips (of players), p-value and odd’s ratio (OR), relative risk [95%CI] with p-value</td>
</tr>
<tr>
<td>Arnason et al. (1994) PC, 92%</td>
<td>294</td>
<td>17/6</td>
<td>32</td>
<td>1. ABD</td>
<td>AH</td>
<td>Y / Y</td>
<td>1. 40.9(1.1)/43.4(0.2), p=0.08. OR 0.90 [95% CI 0.80-1.0, p=0.05] 2. 179.0(0.3)/176.5(1.4), p=0.14. OR/RR: NR</td>
</tr>
<tr>
<td>Verrall et al. (2007) PC, 92%</td>
<td>29</td>
<td>4/14</td>
<td>NR</td>
<td>1. IR</td>
<td>AH</td>
<td>N / N</td>
<td>1. 15.5(2.1)/15.5(1.3), p=0.07/p=0.07. OR/RR: NR 2. 28.1(1.9)/24.0(1.4), p=0.33/p=0.04. OR/RR: NR 3. 83.1(4.3)/103.2(3.3), p=0.03. RR 0.90 [95% CI 0.83-0.99, p=0.03], robust S.E. 0.04, Z score -2.14</td>
</tr>
<tr>
<td>Engbrethsen et al. (2006) PC, 77%</td>
<td>506</td>
<td>51/10</td>
<td>61</td>
<td>1. IR</td>
<td>PS</td>
<td>N / N</td>
<td>1. 27.5(2.0)/29.8(0.5), p=NR. OR 1.06 [95% CI 0.77-1.44, p=0.73] 2. 42.3(1.8)/46.3(0.4), p=NR. OR=1.53 [95% CI 1.13-2.07, p&lt;0.01] 3. 123.7(1.5)/120.8(0.5), p=NR. OR=0.95 [95% CI 0.71-1.28, p=0.74] 4. 19.7(1.1)/20.9(0.3), p=NR. OR 1.15 [95% CI 0.85-1.55, p=0.37] 5. 52.1(1.6)/51.0(0.4), p=NR. OR 0.95 [95% CI 0.70-1.28, p=0.73]</td>
</tr>
<tr>
<td>Study</td>
<td>PC</td>
<td>Percent</td>
<td>Sample Size</td>
<td>Study Design</td>
<td>Measurement</td>
<td>Comparison</td>
<td>Outcome</td>
</tr>
<tr>
<td>----------------------------</td>
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<td>hips of I vs NI players</td>
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<td>b. 647</td>
<td>Season</td>
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<td>101</td>
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<td>a. D hips of I vs NI players</td>
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<td>(1/2 seasons Fu)</td>
<td>1. ABD</td>
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<td>a. AH b. PS</td>
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<td>23.0(±4.3)</td>
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<td>18</td>
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<td>1. IR</td>
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Table 4. Continued
### Table 4. Continued

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<th>L+R hips</th>
<th>PS</th>
<th>Y/N</th>
<th>1. R 34.4(8.1)/34.2(11.6), p=0.96, L</th>
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<td>3. Bilateral IR</td>
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<td>3. R 39.4(8.7)/40.8(7.1), p=0.66, L</td>
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<td>4. Bilateral ER</td>
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<td>5. BKFO</td>
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<td>5. not different, p=0.96</td>
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<th>Rambani et al.</th>
<th>25</th>
<th>25</th>
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<th>hips of I vs NI players</th>
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<th>N</th>
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<td>18M/7F</td>
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<td></td>
<td>23.2(NR)</td>
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<td></td>
<td>4. 35.2(NR)/35.9(NR), p=NR</td>
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<td>5. ADD</td>
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<td>5. 27.1(NR)/26.20(NR), p=NR</td>
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Abbreviations: M=male; F=female; NR=not reported; IR=internal rotation; ER=external rotation; TR=total rotation (IR+ER) per hip; FL=flexion; EXT=extension; ABD=abduction; ADD=adduction; BKFO=bent knee fall out; Data presentation per side (PS) either left(L)/right(R) or dominant(D)/non-dominant(ND), for all hips (AH) or both hips (BH) as sum scores of left and right; Y=yes; N=no; corr=correction; RR=relative risk; OR=odd’s ratio.
Table 5. Quality assessment of included studies according the CASP criteria checklist and CASP ratio positive score/negative score. A: Methodological quality scores with the total quality score for all positive validity/precision items and the percentage of the maximum attainable score (%). B: CASP ratio scores <1 (more negative than positive scores per item for all studies) are in **bold**.

### A: Methodological quality score

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### B: CASP ratio

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Abbreviations: PC=prospective cohort study; CC=case-control study; ‘+’=positive score for item criteria; ‘-’=negative score for item criteria; ‘na’=not applicable item for that study type.
The prospective studies scored relatively low for items related to the standards of injury reporting, indicating the need to report how often injuries are registered during the surveillance period. This includes checking the injury criteria over time with limited interval periods (item 12). Additionally the injury criteria need to be clearly reported (i.e. physical examination) (item 13).

The case-control studies perform relatively low on item (9), reporting whether or not the assessors were blinded for the disease status of the subjects and item (10) on assessing subjects before developing symptoms or getting injured. Item (16) on criteria for appropriate analysis (regression analysis) and item (17) on presenting probability data (odds) and item (18) on presenting confounding variables had relatively low scores.

Overall strength of evidence
Table 6 shows the strength of evidence for all ROM measures as risk factor, identified by prospective studies, or as differentiating factor as identified by case-control studies.

Table 6. Strength of evidence assessment whether (‘for’) or not (‘against’) all identified hip ROM measures have a relationship (risk of differentiating) with groin pain in athletes. (Findings are presented per hip unless otherwise stated.)

<table>
<thead>
<tr>
<th>Strength of evidence</th>
<th>Findings</th>
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| Strong               | Prospective RF studies:  
|                      | For: Lower TR of both hips (SHKF)¹⁰⁰,²⁴⁴.  
|                      | Against: Hip IR (SHKF)²⁴⁴, abduction¹⁴,⁶⁰,²⁴¹ and extension¹⁴,⁶⁰ |
| Moderate             | Differentiates asymptomatic players from symptomatic ones:  
|                      | For: Lower IR¹⁸⁵,²⁴³, ER¹⁸⁵,²⁴³ of both hips (SHKF) |
| Some                 | Prospective RF studies:  
|                      | Against: TR per hip (SHKF)¹⁰⁶, hip flexion⁶⁰ and bilateral abduction⁵³  
|                      | Differentiates asymptomatic players from symptomatic ones:  
|                      | For: Lower TR of both hips (SHKF)³⁴³  
|                      | Against: Combined (bilateral) hip IR (PHNE) and ER (SHNE)³⁴³ |
| Inconclusive         | Prospective RF studies:  
|                      | Hip ER (SHKF)³⁴³,²⁴⁴  
|                      | Differentiates asymptomatic players from symptomatic ones:  
|                      | Hip IR (PHNE)³⁴³,³⁶⁷, ER (SHNE)³⁴³,³⁶⁷ and BKFO³⁴³,³⁶⁷ |
| Not studied or single low quality study | Prospective RF studies:  
|                      | Hip IR, ER, TR (all with neutral hip extension), BKFO and adduction.  
|                      | Differentiates asymptomatic players from symptomatic ones:  
|                      | Hip extension, flexion, abduction and adduction. |

Abbreviations: RF=risk factor; TR=total rotation; IR=internal rotation; ER=external rotation; BKFO=bent knee fall out. SHKF=supine position with hip and knee flexed to 90˚; SHNE=supine hip neutral extension; PHNE=prone hip neutral extension.
Discussion

This systematic review included 7 high quality prospective and 4 case control studies (2 high and 2 low quality) on the relationship between groin pain in athletes and hip ROM. Heterogeneous definitions for groin pain/injury and measurement techniques for hip ROM prevented data pooling. A strength of evidence synthesis showed that smaller total rotational hip range of motion (hips and knees 90° flexed) is the most consistent risk factor for development of groin pain and differentiates athletes with groin pain from those without. However, the number of studies with homogeneous methods (2 and 1 respectively) is limited. These findings as well as their clinical implications are considered further in this discussion.

Heterogeneity in terminology and definitions

Heterogeneous terminology and definitions, as identified in the studies included, has also been highlighted in a Delphi study among groin pain experts. Additionally large variability was observed for the injury and time-loss criteria, reflecting different stages of the injury spectrum. This ranged from inclusion of players with pain who were still able to play to players with a first-time groin time-loss injury or those with time-loss and pain >6 weeks. Also the magnitude of time-loss ranged considerably from missing part of 1 match to missing >1 week of play. Altering thresholds for injury definition affects injury prevalence and incidence, which will influence the results and interpretation of study findings.

ROM measures

There are important issues related to heterogeneity and measurement properties to consider when interpreting these data.

Heterogeneity

Even though 11 studies report on hip ROM and groin pain, the strength of evidence assessment indicating total rotational ROM measure as being related to groin pain, was only based on two studies. Other studies could not be included in this synthesis, due to heterogeneous hip ROM measures, different assessment methods and whether or not the analysis was performed per hip or for combined (either IR or ER or bilateral) ROM values.

Validity and reliability of hip ROM measures

When measuring rotational hip ROM, the validity will be influenced by the measurement protocol. One specific element is the criterion to determine end range of motion. Overestimation is possible if the measurements are not conducted in a single plane, or if
compensation from the pelvis and lower back are permitted\textsuperscript{146}. End range of movement criteria are generally underreported\textsuperscript{59,60,100,185,243,244} which limits assessment of study validity.

A large number of raters (a range of 1-23 raters was found) will result in increased rater variability, lowers the measurement reliability\textsuperscript{4-40}, increases standard error of measurement (SEM) and minimal detectable change (MDC)\textsuperscript{141} values for hip ROM measures. Using a single examiner can address this, but this limits extrapolation of findings to different settings. Electronic assessments of forces applied may be useful to increase reliability\textsuperscript{173} but this was only performed in one of the studies\textsuperscript{14}. Reduction of compensatory movements and applying standardized force with a specially developed examination chair, has been reported to strongly increase the reliability of hip ROM assessment\textsuperscript{187}.

Measurement properties
In order to detect true differences or changes in ROM, that are not the result of measurement error, the differences found must at least equal or exceed the MDC. No studies in this review addressed this topic, yet it is essential for the clinical interpretation of the results. For IR and ER (hips and knees 90° flexed) assessed with a goniometer, the SEM (intra-rater) was previously reported to be 2° and 3°\textsuperscript{173}. Computing the MDC, based on SEM values according the formula \( \text{MDC} = (1.96 \times \text{SEM} \times \sqrt{2}) \), reveals MDC’s for both IR and ER of 7°. For assessment with hips in neutral extension the SEM (intra-rater) is 2° and 4°\textsuperscript{141} resulting in MDC for IR of 6° and ER of 11°. The differences found for rotational ROM often exceed the SEM, but not the MDC. Thus, the current available evidence suggests that ROM is not an appropriate screening measure to predict groin pain. Future studies could combine data from larger cohorts to improve the accuracy of the estimation of risk. However, in order to pool such studies, homogeneity on previous discussed items in this paper is a prerequisite.

What to consider when performing new studies?
We suggest future studies consider examining and reporting on all ROM measures available per hip either uni- or bilateral and for both hips (combined). Appropriate stabilization of the pelvis, a clear definition of end range of motion and forces applied should be used and described in detail. The number of raters should be as low as possible.

ROM and groin pain
The evidence does not support a relationship between hip ROM and groin pain, which is at odds with the clinical perceptions. It has been hypothesised that restricted hip rotations induce increased stress over the symphysis and surrounding soft tissues\textsuperscript{69,243,260}. One cadaver study\textsuperscript{22} observed that the presence of FAI morphology, which is associated with
decreased internal rotation\textsuperscript{388}, increased the shear forces and rotational movement of the symphysis. Yet, no \textit{in-vivo} validation has been performed on the effects of lower hip ROM measures. A recent paper, published after the search period of this review, showed that hip ROM, when assessed in a sport specific way, is lower on the injured side in players with unilateral longstanding adductor-related groin pain\textsuperscript{224}. It was postulated that this negatively affects biomechanical characteristics\textsuperscript{224} and hinders adequate energy transfer between body segments\textsuperscript{222} during sporting tasks, resulting in supra physiological tissue loading.

### Confounders

Previous injury is a recognized risk factor for re-injury\textsuperscript{258}. Two prospective studies accounted for this by recording re-injuries\textsuperscript{244,245} or correcting for their presence in the analyses, whereas others did not\textsuperscript{244,244,244,14}. Age is a risk factor for groin pain\textsuperscript{258}. Some prospective studies reported participant’s ages for the studied\textsuperscript{14,59,60,241} and injured\textsuperscript{59,60} populations and accounted for age in the analyses\textsuperscript{14,59,244} and two\textsuperscript{60,244} corrected for this association when indicated. However, others do not report on age\textsuperscript{100,261}. ROM is related to age and has also been shown to decrease in older players as well as in those playing at higher levels\textsuperscript{242}.

When ER and/or IR are studied in isolation, they are not found to be risk factors for the development of groin pain. However when combined (summateted) to total rotation, an increased risk is found when TR is lower. Individual anatomical differences between version of the femoral neck, resulting in greater or smaller ER or IR, may be confounders\textsuperscript{36}. Smaller internal rotation has been associated with the presence of cam morphology\textsuperscript{388}. This morphological appearance may be a confounder as it is highly prevalent in athletes, but the reported prevalence estimates suffer from a high risk of bias\textsuperscript{53}.

Future studies should report and correct for previous injury, age and presence of cam morphology, as these are recognized confounders for groin pain and ROM.

### Limitations

We acknowledge this review has limitations. We identified many factors that may influence the outcome of the selected studies like reporting of, and consistency of measurement techniques. This was generally poorly or not reported at all. There were also many differences in the definitions of “groin pain” and “injury”. This combination of poor reporting and use of heterogeneous injury definitions and measurement methods prevented the comparison of many study findings. This limited our ability to group studies together to provide higher levels of evidence.

When consulting the current strength of evidence assessment, “strong evidence” may be an “over-qualification”. The strength of evidence method used means that having 2 high quality studies qualifies the use of “strong evidence”. For some readers “strong evidence” may intuitively refer to a larger body of evidence.
A general limitation threatening the validity of this, like any other review, is that non-
published data may exist along with publication bias. A study reporting negative findings,
i.e. no relationship between ROM and groin pain, may be less likely to be published. We
used SPORTS discus and contacted experts in the field in an effort to find other papers.
A more comprehensive grey literature search could have helped.

All but one studies were on male athletes and thus, information from this review
cannot be extrapolated to female athletes, leaving space for new research.

When you are a clinician, seeing patients with groin pain you may
consider:
• Single observer ROM assessment, when performed with measurement devices, can
detect changes in hip ROM over time. However the changes may only be true if they
exceed 7° for either IR or ER (hip and knee flexed).
• Considering that total rotational ROM of both hips is lower in athletes with groin pain,
improving it as part of treatment should be considered. However as the differences
found are generally small, this should not be the only intervention. Which patients
may benefit is hard to identify.
• Screening for hip ROM to prevent groin injury is unlikely to detect athletes at risk.
When a large deficit is found, prevention can be considered although what this should
entail remains unclear.

When you perform research on hip ROM in athletes with groin
pain and want to contribute to the existing knowledge you should
consider:
• Using clear and generally accepted injury definitions and terminology52,70,250.
• Reporting the physical examination findings of injury and ROM measurement
techniques comprehensively (e.g. both IR, ER and summated measures) and providing
data on measurement properties (e.g. SEM and MDC).
• Blinding of assessors for participant’s injury status of and injured side(s).
• Presenting risk estimates (absolute risk / odds ratio / risk ratio), with and without
confounding variables.
Conclusion

There is strong evidence that lower total hip range of motion of both hips is a risk factor for the development of groin pain. There is strong evidence that internal rotation, abduction and extension are not risk factors for the development of groin pain. Screening for hip ROM is unlikely to correctly identify an athlete at risk because of the small ROM differences found, were lower than the known measurement errors.

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None

Conflict of interest
None declared
APPENDIX 1

Search strategy for review

Element 1: Groin Pain

#1 Groin [MESH terms] (3123)
#2 Pubic Symphysis [MESH terms] OR Pubic Bone [MESH terms] (2983)
#3 groin [Text Word] (9880)
#4 “Pubic Bone*” [Text Word] (1982)
#5 Adductor* [TEXT word] OR Psoas [TEXT word] OR ilioptoas [TEXT word] OR gracilis [TEXT word] OR rectus abdominis [TEXT word] OR abdominal [TEXT word] (285284)
#6 #6Search #1 OR #2 OR #3 OR #4 or #5 (296588)
#7 Pain [MESH terms] OR Abdominal Pain [MESH terms] OR Pelvic Pain [MESH terms] (315188)
#8 Tendon Injuries [MESH terms] (14600)
#9 Wounds and injuries [MESH] (724395)
#10 Sprains and strains [MESH] (14837)
#11 Tear [MESH] (8963)
#12 Athletic Injuries [MESH terms] (21082)
#14 search #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 (1275020)
#15 search #6 AND #14 (93271)
#16 Osteitis [MESH terms] (2745)
#17 Hernia, inguinal [MESH] OR Hernia, abdominal [MESH] (21797)
#18 symphysis syndrome [TEXT word] (3)
#19 “groin pain” [tiab] (1035)
#20 osteitis pubis [TEXT word] (298)
#21 pubalgia [TEXT word] (62)
#22 adductor tendinopath* [TEXT word] OR adductor tendonopath* [text word] (9)
#23 adductor tendinitis [TEXT word] OR adductor tendonitis [text word] (11)
#24 adductor strain [TEXT word] (14)
#25 gracilis syndrome [TEXT word] (5)
#26 sports hernia [TEXT word] OR sportsman* hernia [TEXT word] OR sportmen* hernia [TEXT word] OR sportsmen* groin OR sportsman* groin [TEXT word] (102)
#27 “acetabular labrum” AND tear* (138)
#28 “labrum tear” AND hip (9)
#29 "labral tear" AND hip (191)
#30 femoral neck stress fracture [TEXT word] (49)
#31 femoroacetabular impingement [TEXT word] (1064)
#32 pubic bone stress [TEXT word] (3)
#33 abdominal strain [text word] (37)
#34 search #16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33 (26715)
#35 search #15 OR #34 (117189)

Element 2: Hip Range of Motion
#36 Range of Motion, articular [MESH] (35122)
#37 Range of motion [TIAB word] (20901)
#38 Range of movement [TIAB word] (2046)
#39 ROM [TIAB word] (6586)
#40 flexibility [TIAB] (46089)
#41 search #36 OR #37 OR #38 OR #39 OR #40 (95583)
#42 Hip [MESH terms] (9905)
#43 Hip Joint [MESH terms] (21508)
#44 hip [Tiab] OR hip joint* [tiab] (98576)
#45 search #42 OR #43 or #44 (107039)
#46 search #41 AND #45 (6060)
#47 "hip flexibility"[tiab] (32)
#48 "hip mobility"[tiab] (87)
#49 "hip range of motion" [tiab] (289)
#50 "muscle flexibility"[tiab] (88)
#51 search #47 OR #48 OR #49 OR #50 (485)
#52 search #46 OR #51 (6182)
#53 search #35 AND #52 (424)

Element 3: Risk Factors/Association
#54 risk factors [MESH terms] (586066)
#55 risk assessment [MESH terms] (184656)
#56 association [MESH terms] (11859)
#57 risk* [tiab] OR association [Tiab word] (1997214)
#58 incidence [MESH] (182526)
#59 "Epidemiologic Studies"[Mesh] OR epidemiology (2618791)
#60 "cohort studies" [MESH terms] OR cohort study (1435293)
#61 "case control studies" [Mesh terms] OR case control study) (718962)
#62 "cross-sectional studies"[MESH terms] OR cross-sectional studies (213567)
#63 search #54 OR #55 OR #56 OR #57 OR #58 OR #59 or #60 OR #61
OR #62
#64 search #53 and #63

(4063538)

(234)