


# Is hip adductor or abductor strength in healthy athletes associated with future groin pain? A systematic review and meta-analysis

Marcos Quintana-Cepedal,<sup>1,2</sup> Germán Vicente-Rodríguez,<sup>3,4</sup> Irene Crespo,<sup>1,5</sup> Hugo Olmedillas <sup>1,2</sup>

► Additional supplemental material is published online only. To view, please visit the journal online (<https://doi.org/10.1136/bjsports-2024-108836>).

<sup>1</sup>Department of Functional Biology, University of Oviedo, Oviedo, Spain

<sup>2</sup>Asturian Research Group in Performance, Readaptation, Training and Health (AstuRES), University of Oviedo, Oviedo, Spain

<sup>3</sup>Aragon Health Research Institute (IIS Aragon), Zaragoza, Spain

<sup>4</sup>EXER-GENUD (Growth, Exercise, Nutrition and Development) Research Group, University of Zaragoza, Zaragoza, Spain

<sup>5</sup>Health Research Institute of the Principality of Asturias, Oviedo, Spain

## Correspondence to

Dr Hugo Olmedillas;  
olmedillashugo@uniovi.es

Accepted 23 October 2024



© Author(s) (or their employer(s)) 2024. No commercial re-use. See rights and permissions. Published by BMJ.

**To cite:** Quintana-Cepedal M, Vicente-Rodríguez G, Crespo I, et al. *Br J Sports Med* Epub ahead of print: [please include Day Month Year]. doi:10.1136/bjsports-2024-108836

## ABSTRACT

**Objective** To systematically review the association between hip adduction and abduction strength, and adduction-to-abduction strength ratio in healthy athletes with the occurrence of future groin pain and time-loss groin injuries.

**Design** Systematic review with meta-analysis.

**Data sources** PubMed, Web of Science, SPORTDiscus, PEDro, Embase, and Scopus.

**Eligibility criteria** Studies included had to (1) measure hip adductor or abductor strength in healthy athletes, (2) conduct a follow-up period to assess the occurrence of groin pain, (3) present strength data separately for participants who remained uninjured and those who suffered an injury and (4) use a prospective design. Risk of bias was assessed according to the Quality in Prognosis Studies tool. The certainty in the evidence appraised was measured using the Grading of Recommendations Assessment Development and Evaluation approach.

**Results** Thirteen prospective cohort studies met the inclusion criteria. Overall study risk of bias was rated as low. Players who remained uninjured had stronger adduction strength compared with players who subsequently suffered groin pain (standardised mean differences with 95% CIs (SMD=−0.5, 95% CI −0.92 to −0.09)) and time-loss groin pain (SMD=−0.68, 95% CI −1.31 to −0.06). Trivial effects were observed for abduction strength (groin pain SMD=0.03, 95% CI −0.11 to 0.17; time-loss SMD=−0.07, 95% CI −0.25 to 0.11) and adduction-to-abduction strength ratio (groin pain SMD=−0.02, 95% CI −0.55 to 0.51; time-loss SMD=−0.11, 95% CI −1.11 to 0.89). Age and diagnostic criteria were not significant moderators of the relationship between adductor strength and groin pain ( $p=0.72$  and  $p=0.12$ ).

**Conclusion** There is a moderate effect of hip adductor strength on the occurrence of groin pain, while there is no relationship between either abductor strength or the ratio of adductor-to-abductor strength with the occurrence of groin pain.

**PROSPERO registration number** CRD42024548630.

## INTRODUCTION

Groin pain is a complex problem due to its high occurrence in sports that involve rapid acceleration and deceleration, sprinting and sudden changes of direction, such as soccer,<sup>1–5</sup> Australian rules football,<sup>6</sup> Gaelic football,<sup>7</sup> rugby<sup>8</sup> and hockey.<sup>9–10</sup> The classification of groin problems has become more complex, as a new injury definition includes

## WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Groin problems are among the most common injuries in multidirectional sports.
- ⇒ Hip strength plays a vital role in the prevention and rehabilitation of groin pain.

## WHAT THIS STUDY ADDS

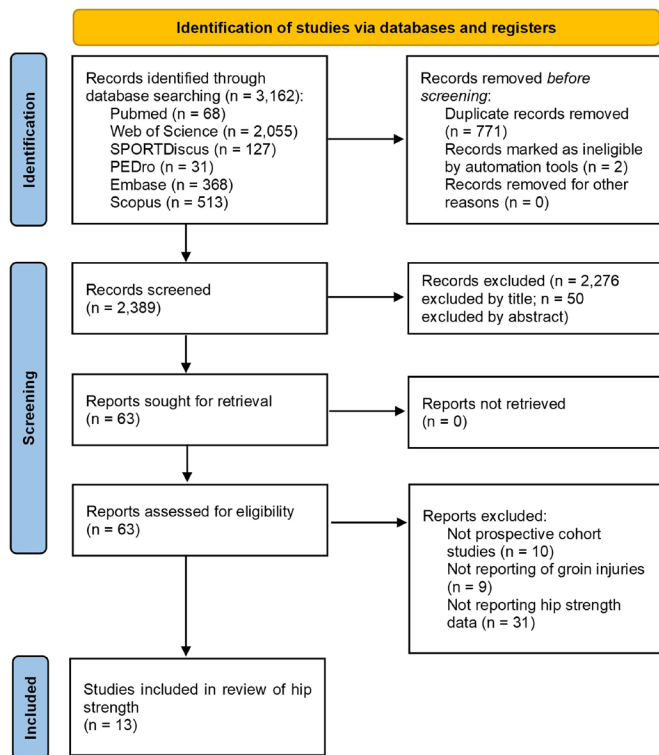
- ⇒ Hip adductor weakness is a potential risk factor for groin pain.
- ⇒ Neither abductor strength nor the adductor-to-abductor strength ratio was significantly related to the occurrence of subsequent groin pain.

## HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ These findings suggest that athlete screening should incorporate adduction strength testing to identify individuals with lower strength values and implement injury prevention strategies.

cases that affect performance without leading to activity cessation (ie, non-time-loss injuries).<sup>11</sup> In fact, considering only groin injury time-loss cases underestimates the true injury prevalence by 70% to 90%.<sup>11–12</sup> Although most groin injuries affect the hip adductor muscles,<sup>13–14</sup> different clinical entities, such as hip flexor-related,<sup>15</sup> inguinal-related<sup>16</sup> or pubic-related conditions,<sup>17</sup> can cause pain in the groin region, making athlete evaluation difficult.<sup>18–19</sup> Injuries not only affect players' health but can also contribute to a reduction in team performance.<sup>20</sup> Therefore, promoting interventions that aim to reduce the risk of developing groin pain is of utmost importance in sporting environments.<sup>21–23</sup>

Following a specific framework can help to mitigate the risk of suffering sports-related injuries. The four-step approach requires the presentation of epidemiological data and the identification of injury risk factors and mechanisms underlying injuries, followed by the introduction and testing of prevention strategies.<sup>24</sup> Research on risk factors for groin pain has increased in recent years, although the mechanisms predisposing athletes to such injuries remain elusive.<sup>25</sup> Proposed factors are a previous injury, adductor and abductor muscle weakness, male sex and deconditioning during off-season periods.<sup>26–28</sup> Among the mentioned, factors that can be modified such as hip strength have received the most attention. Indeed, the inclusion of adduction strengthening programmes has been shown to



**Figure 1** PRISMA flow diagram. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

promote adductor strength and reduce the occurrence of groin problems.<sup>29,30</sup> If hip strength is prospectively related with future groin pain, identifying healthy athletes at risk may permit the selective inclusion of corrective interventions to avoid the onset of groin pain.

No study to date has meta-analysed the relationship between hip adduction and abduction strength or adduction-to-abduction strength ratio and future groin problems. Thus, the aim of this study was to systematically review the association between adduction strength and the occurrence of future groin problems. A secondary aim was to assess this relationship for abduction strength, and for adductor-to-abductor strength ratio. Analyses were performed for all groin pain cases and for time-loss cases only.

## METHODS

This systematic review adheres to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, and it is registered in the International Prospective Register of Systematic Reviews.

### Literature search

Studies were identified through a systematic search on six databases (PubMed, Web of Science, SPORTDiscus, PEDro, Embase and Scopus), from inception until May 2024. A secondary search was performed screening previous systematic reviews on risk factors for groin injuries,<sup>26,31</sup> reference lists of the included articles were also searched for additional references. Details of the key terms used for database search are shown in online supplemental table S1. Obtained records were imported into Zotero (V.6.0.36) and duplicates were removed. Two reviewers (MQ-C and GV-R) independently screened the titles and abstracts and assessed the full text of all potentially eligible articles to evaluate

their possible inclusion in the review. Disagreement between the two reviewers was solved by discussion. A third reviewer (HO) was involved if consensus was not achieved.

### Study selection

Studies were included when they met the following criteria: (1) measured hip adduction or abduction strength in healthy athletes that (2) were followed up to assess for the occurrence of groin pain, (3) presented strength data separately for participants who remained uninjured and for those who suffered an injury and (4) used a prospective design. Studies that referred to groin pain/injuries, hip and groin pain/injuries or adductor-related groin pain/injuries were included,<sup>26</sup> irrespective of the injury definition (ie, time-loss, non-time-loss and all injuries) or onset (ie, acute or long-standing).<sup>32</sup> Studies were required to include participants involved in competitive sports, with no restrictions on sex, age, competitive level or sporting discipline. Additionally, studies were required to be written in English and published in a peer-reviewed journal. Grey literature (ie, conference papers, abstracts, theses and unpublished reports) was not considered for inclusion. Any article that failed to meet one of the inclusion criteria was excluded.

### Risk of bias assessment

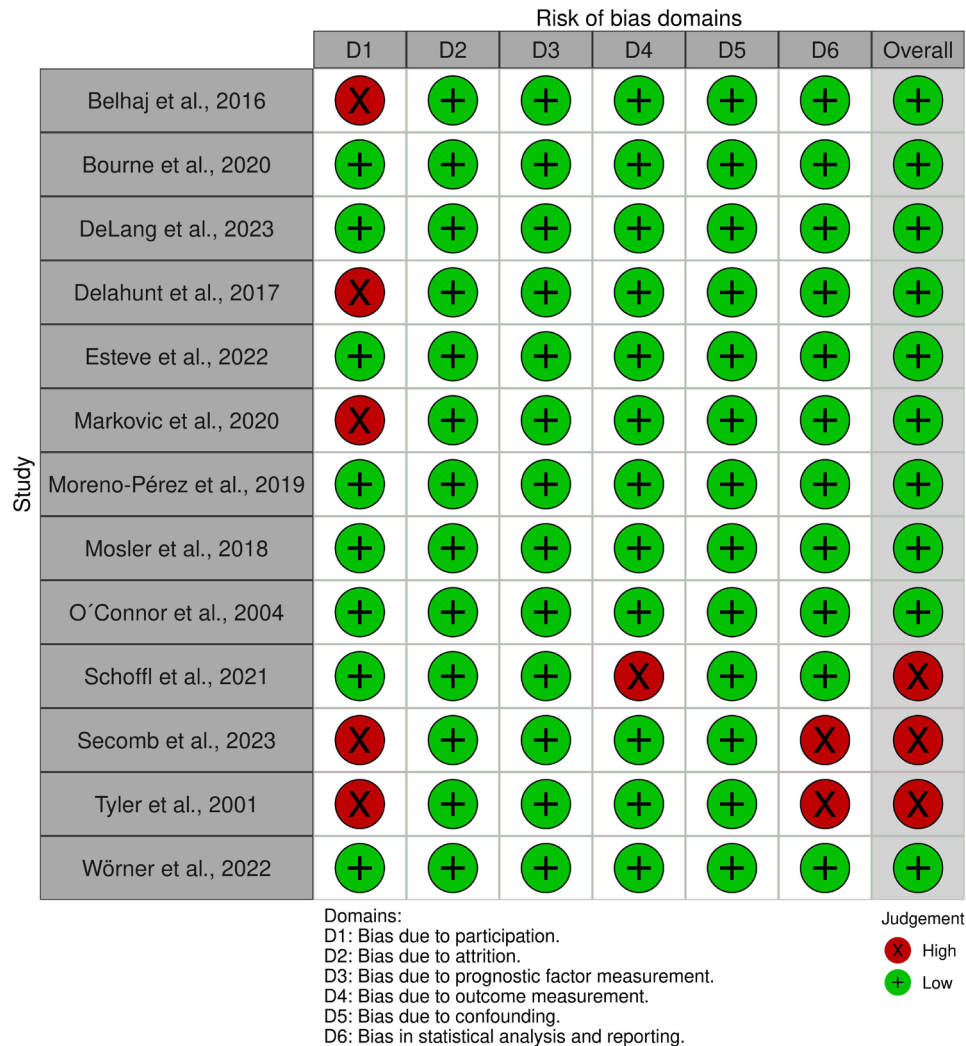
Included studies were assessed using the Quality in Prognosis Studies (QUIPS) tool, per previous similar systematic reviews.<sup>33,34</sup> This tool consists of six different items for evaluation of risk of bias (study participation, study attrition, prognostic factor measurement, outcome measurement, study confounding and statistical analysis and reporting), an individual study was considered to have a low risk of bias if five of the six domains were assessed as having a low risk of bias (defined as a score of  $\geq 75\%$  for individual criteria under each domain). Any study that was determined to have a high risk of bias in the outcome measurement domain was automatically assigned a high risk of bias.<sup>33</sup> Study quality for the included articles was performed by two reviewers (GV-R and IC) with conflicts resolved by consensus. The visual representation of the risk of bias for individual studies was performed using the robvis tool.<sup>35</sup> Funnel plots and Egger's test were used to provide an estimation of small study bias for the main outcome measure (adduction strength, all injuries).

### Certainty of evidence grading

The quality of the evidence (QoE) was graded using the Grading of Recommendations Assessment Development and Evaluation (GRADE) approach.<sup>36</sup> Initially, it was assumed that the quality was high. Quality was downgraded to moderate, low or very low when one of the following factors was rated as serious, or very serious: risk of bias, inconsistency,<sup>37</sup> indirectness, imprecision<sup>38</sup> or publication bias. Criteria used for downgrading evidence are detailed in online supplemental table S2.

### Data extraction

Data were extracted independently by two reviewers (MQ-C and HO) using Microsoft Excel. Study characteristics extracted were participant information (age, sex, height, body mass, sports), injury-monitoring data (follow-up time, injury definition, injury collection procedure, n of injured and uninjured participants) and strength assessment (muscle tested, body position, units of measurement). Measures of sample size, mean value and variance (typically SD) related to the injured and uninjured groups were also extracted for quantitative synthesis. When a study presented strength data as mean (SE), it was transformed to SD



**Figure 2** Study quality assessment results.

by multiplying an SE by the square root of the sample size to avoid inflation of the effect size.<sup>39</sup> Where required data were only presented graphically, rather than documented in-text, data

were manually extracted using WebPlotDigitizer (V.4.8). The authors of the included manuscripts were contacted via email when the studies did not provide sufficient information on

**Table 1** Characteristics of the included studies

Source	Sports	Age (years)	Height (m)	Body mass (kg)	Injury definition	n I/UI
Belhaj et al <sup>50</sup>	Football	I=24.1 ± 3 UI=23.2 ± 3.9	I=1.84 ± 0.08 UI=1.8 ± 0.06	I=78.5 ± 8 UI=73.6 ± 5.3	Adductor-related groin pain	9/12
Bourne et al <sup>46</sup>	Football	24±4.9	1.81±0.07	77.7±7.3	Time-loss	24/129
DeLang et al <sup>49</sup>	Football	14.4±1.6	1.71±0.1	62.8±13.1	All groin injuries	29/24
Delahunt et al <sup>52</sup>	Gaelic football	24±2.8	1.85±0.06	84.5±7.7	Time-loss	10/45
Esteve et al <sup>54</sup>	Football	22.9 (18-38)	1.78 (1.64–1.95)	73.7 (57-98)	All groin injuries	99/146
Markovic et al <sup>45</sup>	Football	22.8±3.5	1.82±0.06	78±7	Time-loss	10/35
Moreno-Pérez et al <sup>48</sup>	Football	22±4.2	1.79±0.06	76.9±7.5	Time-loss	18/53
Mosler et al <sup>14</sup>	Football	26±5	1.77±0.06	72±9	Time-loss	150/288
O'Connor et al <sup>8</sup>	Rugby	I=22.2 ± 2.9 UI=20.2 ± 4.5	I=1.8 ± 0.13 UI=1.78 ± 0.06	I=90.5 ± 9.5 UI=84.7 ± 10.2	Time-loss	23/77
Schoffl et al <sup>53</sup>	Football	12.7±1	1.56±0.1	46.8±9.1	All groin injuries	23/82
Secomb et al 2023	Ice hockey	26.7±6.7	1.81±0.06	88.1±18.1	Time-loss	4/21
Tyler et al <sup>51</sup>	Ice hockey	23±4.3	1.75±0.05	89±7	Time-loss/adductor strain	8/39
Wörner et al <sup>9</sup>	Ice hockey	22.6±2.3	1.82±0.05	85±7.1	All groin injuries	71/87

All studies except Esteve et al, 2022 present data for age, height and body mass as mean±SD; Esteve et al, 2022 present data as mean (range).  
I, injured; UI, uninjured.

## Systematic review

outcome measures. No follow-up email was needed since the required data were obtained after the first contact.

### Data analysis

All data analyses were conducted using R (The R Foundation for Statistical Computing), with the ‘meta’ and ‘metafor’ packages.<sup>40 41</sup> Three meta-analyses were performed: (1) studies that evaluated adduction strength; (2) studies that evaluated abduction strength; and (3) studies that evaluated the adduction-to-abduction strength ratio. Additionally, a main analysis of all injuries and a sub-analysis for time-loss injuries were performed. Standardised mean differences (SMD) with 95% CIs were calculated from the original’s data comparison (uninjured vs injured) in each study with the mean and SD. We derived a 95% prediction interval (PI) to describe the range of true effects expected in 95% of future studies on this field.<sup>42</sup> The chosen effect size was Cohen’s *d* and was interpreted using the following benchmarks: trivial (<0.20), small (0.20–0.49), moderate (0.50–0.79) or large ( $\geq 0.80$ ).<sup>43</sup> Data were pooled using a random effects model with the inverse variance method. The variability between studies was estimated with the  $\tau^2$  statistic. The statistic  $I^2$  was used to measure the percentage of total variation in the effect sizes due to heterogeneity. After running the initial analyses, a secondary analysis was performed to account for the potential influence of studies with a very large effect size (see section "Adduction strength"). Finally, meta-regression was performed to assess the impact of age and differences in diagnostic criteria as potential effect modifiers when a minimum of 10 studies were available.<sup>44</sup>

### Protocol deviations

A deviation from the PROSPERO registered protocol regarding secondary analyses was made. We did not initially plan to perform an influence analysis, as very large effect sizes were not anticipated in the included studies. Additionally, the decision to perform a meta-regression was made post hoc after including studies with substantial age differences (12 to 27 years of age) and differences in diagnostic criteria (self-reported or clinical examination).

### Equity, diversity and inclusion statement

The research team consists of one woman and three men from different disciplines with early, mid and late career researchers, although all from one country. All studies included were from high-income countries with no representation from middle-income or low-income countries. We intended to investigate the effects of sex on our findings but lacked sufficient power, as female athletes constituted 3% of the sample.

## RESULTS

### Search strategy

The electronic searches retrieved 3162 references from the literature. After removing duplicates and screening titles and abstracts, 63 full-text articles were obtained and assessed for inclusion. Thirteen prospective cohort studies met the eligibility criteria and were selected for qualitative and quantitative analysis.<sup>8 9 45–55</sup> The search results are presented in [figure 1](#).

### Risk of bias

Three of the included studies presented with a high risk of bias,<sup>47 51 53</sup> with all others rated as of low risk. Individual scores in the QUIPS tool for all included studies are presented in [figure 2](#). The use of Egger’s test and funnel plots demonstrated no evidence of small study bias (online supplemental figure S1).

**Table 2** Groin pain diagnostic procedures

Source	Diagnostic criteria	Diagnosis (n, %)
Belhaj <i>et al</i> <sup>60</sup>	Clinical examination: <ul style="list-style-type: none"> <li>▶ Tenderness localised to the adductor muscle insertion</li> <li>▶ Pain on passive adductor stretch</li> <li>▶ Pain on adduction against resistance</li> </ul>	Adductor-related (9, 100%)
Bourne <i>et al</i> <sup>46</sup>	Clinical examination: unspecified criteria	Adductor-related (67%) Psoas-related (17%) Inguinal-related (8%)
DeLang <i>et al</i> <sup>49</sup>	Self-reported	Unspecified
Delahun <i>et al</i> <sup>52</sup>	Clinical examination: unspecified criteria	Unspecified
Esteve <i>et al</i> <sup>54</sup>	Self-reported	Unspecified
Markovic <i>et al</i> <sup>45</sup>	Clinical examination and imaging: unspecified criteria	Adductor-related (7, 70%) Pubic-related (2, 20%) Psoas-related (1, 10%)
Moreno-Pérez <i>et al</i> <sup>48</sup>	Clinical examination: unspecified criteria	Adductor tendinopathy (12, 66%) Osteitis-pubis (4, 22%) FAI (2, 11%)
Mosler <i>et al</i> <sup>14</sup>	Clinical examination: unspecified criteria	Adductor-related (85, 75%) Psoas-related (15, 13%) Inguinal-related (8, 7%) Pubic-related (14, 12%) Hip-related (1, 1%)
O’Connor <i>et al</i> <sup>8</sup>	Clinical examination: <ul style="list-style-type: none"> <li>▶ Pain and tenderness in the adductors or at the adductor bone–tendon junction</li> <li>▶ Pain and weakness on resisted adduction</li> </ul>	Unspecified
Schoff <i>et al</i> <sup>53</sup>	Clinical examination: <ul style="list-style-type: none"> <li>▶ Functional movements (eg, squat, jumping, football kicking)</li> <li>▶ Passive and active joint range of motion</li> <li>▶ Manual muscle strength testing</li> <li>▶ Hip tests (Flexion adduction internal rotation, and flexion adduction external rotation)</li> </ul>	Adductor-related (5, 22%) Psoas-related (11, 48%) Mixed presentation/non-specific (7, 30%)
Secomb <i>et al</i> <sup>47</sup>	Unspecified criteria	Unspecified
Tyler <i>et al</i> <sup>51</sup>	Clinical examination: <ul style="list-style-type: none"> <li>▶ Pain on palpation of the adductor tendons</li> <li>▶ Pain on palpation of the pubic bone</li> <li>▶ Pain on resisted adduction</li> </ul>	Adductor strain (11, 100%)
Wörner <i>et al</i> <sup>9 2022</sup>	Self-reported	Unspecified
FAI, femoroacetabular impingement.		

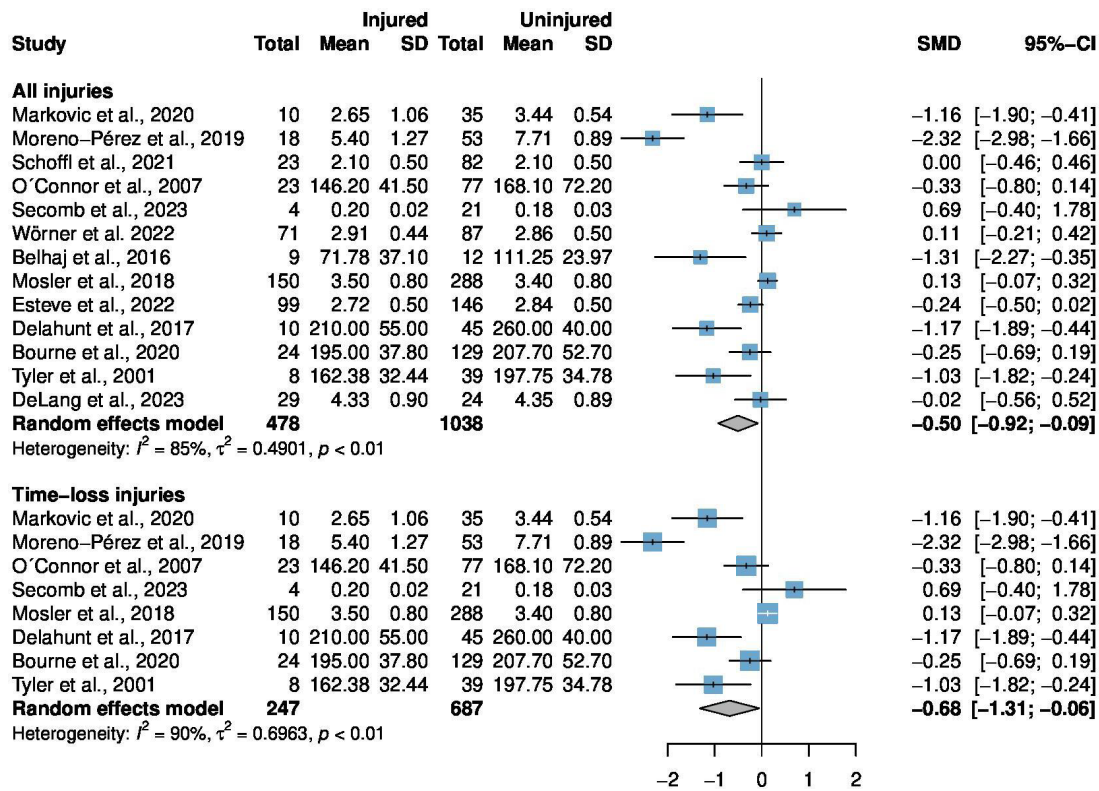
## DESCRIPTION OF STUDIES

### Participants

There were 1516 participants included in the meta-analysis, of which 478 suffered at least one episode of groin pain. Male players represented 97% (n=1469) of the entire sample. Eight studies investigated football players,<sup>45 46 48–50 53–55</sup> three studies investigated ice hockey players,<sup>9 47 51</sup> the two remaining studies investigated Gaelic football<sup>52</sup> and rugby players<sup>8</sup> ([table 1](#)).

### Testing protocol

Twelve studies conducted testing during preseason, while one study conducted testing during mid-season break.<sup>50</sup> The most



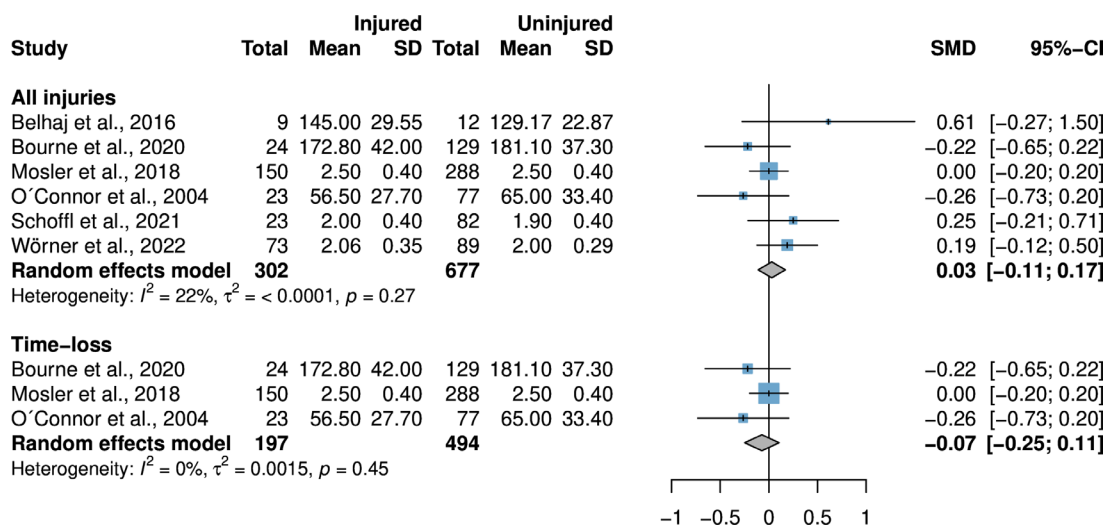
**Figure 3** Standardised mean differences (SMD) of adductor strength compared between subsequently injured and uninjured athletes. Data are subgrouped by all injuries and time-loss injuries.

used tests were the adduction squeeze at 0°<sup>45-47 49 54</sup> and 45° of hip flexion,<sup>46 48 52 54 55</sup> two studies used the unilateral isometric with neutral hips<sup>47 53</sup> and one with 25° and 50° of hip abduction,<sup>47</sup> two studies used isokinetic testing<sup>8 50</sup> while two studies used the side-lying eccentric break test.<sup>51 55</sup> Seven studies presented abduction strength data.<sup>8 9 46 50 51 53 55</sup> Data from maximal isometric testing were used over concentric or eccentric testing whenever possible, as most studies evaluated strength during isometric contractions. Additionally, results from long-lever tests were preferred over short-lever tests due to their superior test-retest precision.<sup>56</sup> When different units of

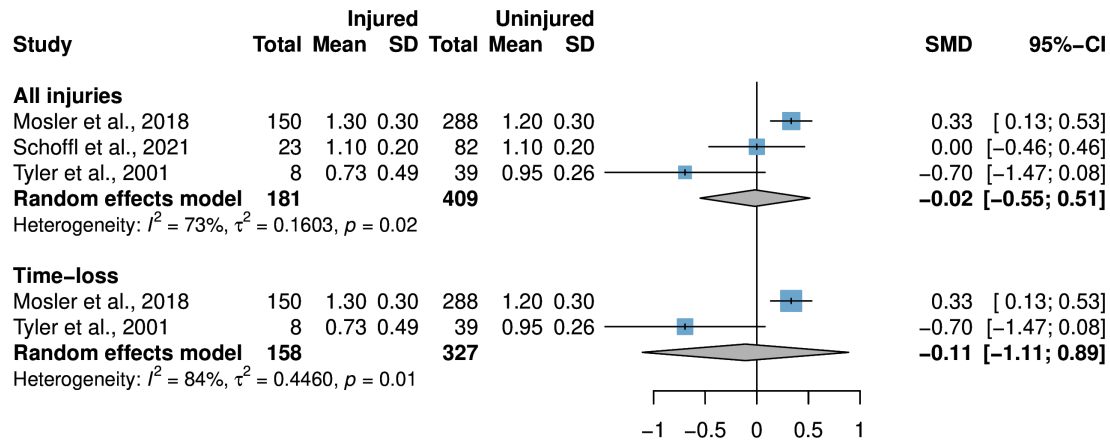
measurements were reported, relative values were preferred over absolute values (Nm/kg>N/kg>N). An overview of the methods used to measure adduction and abduction strength, along with the units of measurement, can be found in online supplemental tables S3-S5.

### Injury monitoring

Studies collected injury data during 4 weeks,<sup>47</sup> 14 weeks,<sup>49</sup> one season<sup>9 45 46 52-54</sup> or two seasons.<sup>48 51 55</sup> Two studies did not specify the duration of injury collection.<sup>8 50</sup> Groin problems were



**Figure 4** Standardised mean differences (SMD) of abductor strength compared between subsequently injured and uninjured athletes. Data are subgrouped by all injuries and time-loss injuries.



**Figure 5** Standardised mean differences (SMD) of adductor to abductor strength ratio compared between subsequently injured and uninjured athletes. Data are subgrouped by all injuries and time-loss injuries.

diagnosed by the team medical staff in nine studies,<sup>8 45 46 48 50–53 55</sup> three studies collected self-reported data from the players,<sup>9 49 54</sup> and one study did not specify the procedure of injury reporting.<sup>47</sup> The specific diagnostic criteria and characteristics from each study are presented in [table 2](#).

**META-ANALYSES**

**Adduction strength**

Athletes that remained healthy displayed significantly stronger hip adduction strength compared with those that subsequently suffered any groin problem (SMD=-0.5, 95% CI -0.92 to -0.09, PI=-2.1 to 1.1, moderate effect). The analysis was repeated after excluding one article that obtained a very large effect size (SMD=-2.3),<sup>48</sup> athletes who remained injury-free were also significantly stronger compared with injured participants (SMD=-0.32, 95% CI -0.61 to -0.03, PI=-1.31 to 0.67, small effect). For the analysis evaluating injuries that led to time-loss, a significant effect was found in favour of athletes that remained uninjured (SMD=-0.68, 95% CI -1.31 to -0.06, PI=-2.8 to 1.5, moderate effect). Influence analysis was repeated following the same principle, no significant difference was observed between injured and uninjured athletes (SMD=-0.44, 95% CI -0.9 to 0.02, PI=-1.93 to 1, small effect) ([figure 3](#)).

**Abduction strength**

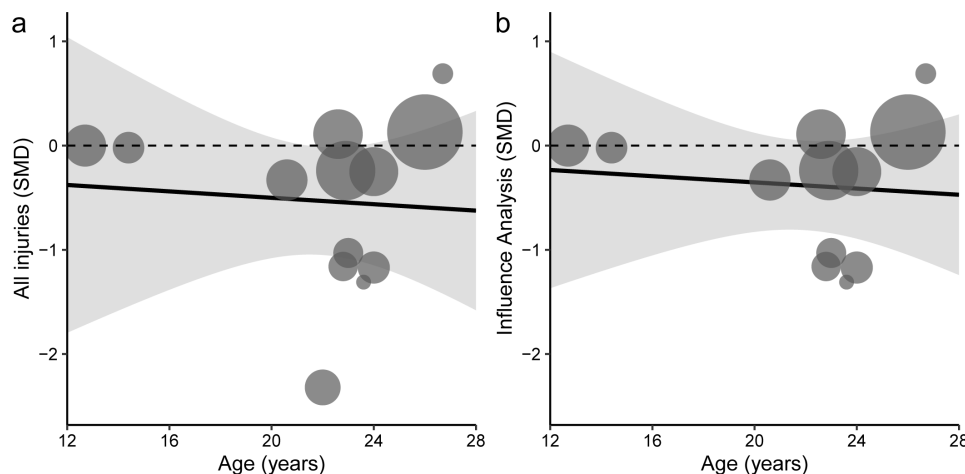
No significant differences were observed between injured and uninjured athletes for hip abduction strength, neither for all groin injuries (SMD=0.03, 95% CI -0.11 to 0.17, PI=-0.16 to 0.22, trivial effect) nor for time-loss injuries (SMD=-0.07, 95% CI -0.25 to 0.11, PI=-1.32 to 1.18, trivial effect) ([figure 4](#)).

**Adduction-to-abduction strength ratio**

No significant differences in adduction-to-abduction strength ratio were observed between players who subsequently suffered groin problems and players who did not sustain an injury (SMD=-0.02, 95% CI -0.55 to 0.51, PI=-6.16 to 6.12, trivial effect). Pooled effect sizes for time-loss injuries were also similar (SMD=-0.11, 95% CI -1.11 to 0.89, trivial effect) ([figure 5](#)).

**Meta-regression**

Neither age nor diagnostic criteria were significant moderators of the relationship between adductor strength and injury in the main analysis for all injuries ( $p=0.72$  and  $p=0.12$ ). The results remained consistent after performing the influence analysis ( $p=0.64$  and  $p=0.15$ ). Visualisation of regression analysis for age is provided in [figure 6](#). No meta-regression was performed



**Figure 6** Meta-regression analysis on the influence of age on adductor strength, comparing prospectively injured and uninjured athletes for: (A) all injuries and (B) influence analysis. The size of each bubble is proportional to the sample size of each study. The black line represents the regression line of best fit. Grey-shaded area represents the 95% CIs of the regression line. Horizontal dashed line represents no effect.

**Table 3** Summary of the certainty in the evidence appraised

Outcome	N° of studies	RoB	Inconsistency	Indirectness	Imprecision	Publication bias	Effect size	GRADE score
Adduction (all)	13	0	-2	0	-2	0	-0.5 (-0.92 to -0.09)	⊕○○○ Very low
Adduction (time-loss)	8	0	-2	0	-2	NA	-0.68 (-1.31 to -0.06)	⊕○○○ Very low
Abduction (all)	6	0	0	0	0	NA	0.03 (-0.11 to 0.17)	⊕⊕⊕⊕ High
Abduction (time-loss)	3	0	0	0	-2	NA	-0.07 (-0.25 to 0.11)	⊕⊕○○ Low
ADD:ABD (all)	3	0	-2	0	-2	NA	-0.02 (-0.55 to 0.51)	⊕○○○ Very low
ADD:ABD (time-loss)	2	0	-2	0	-2	NA	-0.11 (-1.11 to 0.89)	⊕○○○ Very low

NA (in meta-analyses of less than 10 studies), ADD:ABD = adduction-to-abduction strength ratio.  
NA, not assessed ; RoB, risk of bias.

for abduction strength and adduction-to-abduction strength ratio due to insufficient number of studies available.

### Certainty of evidence

The evidence profile according to the GRADE is presented in table 3. The resulting quality of evidence was low or very low in five out of six meta-analyses, high quality was achieved in the analysis of hip abduction strength for all groin injuries.

### DISCUSSION

This is the first systematic review with meta-analysis that synthesises the available data pertaining hip adduction and abduction strength and the occurrence of future groin pain. A moderate effect size in adduction strength was observed between athletes who experienced subsequent groin pain and those that do not. The meta-analyses of abduction strength observed trivial effect sizes between athletes who subsequently injured and those who remained uninjured, with high certainty in the evidence appraised. Conversely, meta-analyses for adduction strength and adduction-to-abduction strength ratio obtained low to very low certainty in the evidence appraised. The meta-regression analysis found that neither age nor diagnostic criteria were significant moderators of the relationship between adductor strength and injury.

#### Influence of adductor strength on the occurrence of groin pain

Adductor strength seems relevant in the prevention of groin pain, various trials have found benefit in performing adductor strengthening exercises and reducing the risk of subsequent injury.<sup>30 57</sup> Our meta-analyses observed a moderate effect of strength on subsequent appearance of groin pain, although the magnitude of the effect ranged from trivial to large. We decided to perform an influence analysis to account for a very large effect size presented in one of the included studies,<sup>48</sup> the estimate was still significant although the effect shifted from moderate to small (SMD=-0.32). Although various factors interplay in the development of injuries, it is reasonable to assume that adduction strength is an important variable to take into consideration when aiming to prevent groin pain. Athlete screening should incorporate some sort of adduction strength testing to identify individuals with lower strength values and implement corrective intervention. Evaluation of athletes on a continuous basis compared against a single evaluation can detect players at higher risk, since there is a 6% to 10% decrease on force output

the week before groin pain onset.<sup>49 58</sup> Athletes with suboptimal strength levels may struggle to meet the demands placed on the adductor muscles, potentially leading to overuse damage and subsequent pain or injury. All the included studies evaluated peak strength but adductors may injure due to repetitive submaximal stimulus rather than on all-out efforts.<sup>59</sup> Indeed, athletes who eventually develop groin pain tend to perform poorly on fatigue tests. De Queiroz *et al*<sup>60</sup> reported that players who later sustained injuries performed 14 fewer repetitions of the Brazilian Adductor Performance Test compared with their injury-free counterparts.

Although the included studies evaluated strength on a relatively neutral hip position (see online supplemental table S3), emerging evidence suggests that strength should be evaluated in an abducted position, since this is the kinematic position where athletes typically injure.<sup>47 61</sup> Interest is growing around new testing methods, but without sufficient evidence, no strong claims can be made yet.

#### Influence of abductor strength and adductor-to-abductor strength ratio on subsequent injury

Six studies compared abduction strength between athletes who got injured and those who remained uninjured. The pooling of data found no significant difference between groups, with narrow 95% confidence and prediction intervals, and the same results were observed in the subanalysis for time-loss injuries. It has been hypothesised that stronger abductor muscles are a risk factor for suffering groin pain, by imposing higher demand on the adductors to brake the shank during side-to-side cutting, striding, quick acceleration/deceleration or sudden direction changes.<sup>27 62</sup> This concept has also been associated with the force ratio, since athletes with an adduction-to-abduction strength ratio of less than 0.8 have been found to be 17 times more likely to incur a groin injury.<sup>51</sup> Our meta-analyses on adduction-to-abduction strength ratio do not support this statement. The idea of a generic ratio where that athletes outside the normative values are at risk seems unlikely, as each sport generates specific adaptations on the athlete's body. For instance, the adduction-to-abduction strength ratio has been reported to be 1.2 in football,<sup>63</sup> 1.1 in field hockey<sup>64</sup> and 1.04 to 1.53 in ice hockey.<sup>47</sup> Therefore, when attempting to associate a strength ratio with the prospective occurrence of injuries, we advocate for an approach that considers the specific context of each sport.

### Effect of age on the estimates

Older age is one of the most studied determinants for developing injuries, primarily attributed to previous injuries and deconditioning, although there is contradicting information regarding its role in the context of groin pain.<sup>26,31</sup> We conducted a meta-regression to evaluate the potential influence of age on our main outcome estimates. Age had no effect on either the overall estimate or the adjusted effect size following the influence analysis. Adult players are more prone to injury due to incomplete recovery from previous lesions and their increased years of experience, resulting in more playing time, which likely influences their odds of getting injured.<sup>65</sup> On the contrary, adolescents could also be at risk due to rapid spikes in hip adduction strength during skeletal maturation.<sup>66</sup> The passive tissues may not withstand with the force generated by the muscles, leading to potential failure and strain.<sup>67,68</sup> Since groin pain rates are high in both young and adult athletes, we encourage practitioners to monitor adduction strength in all players regardless of their age.<sup>57</sup>

### Limitations

This study is not without limitations. First, six studies used generic terms to refer to groin pain. Various clinical entities can generate symptoms in the groin region according to the Doha Agreement, and the risk factors for each entity may differ. Second, most groin pain cases included were adductor-related, which may explain the observed relationship between lower adductor strength and injury. However, this effect might be smaller for other clinical entities, although this hypothesis is yet to be confirmed. Third, 10 of the 13 studies measured hip strength using an isometric contraction, whereas groin injuries usually occur during eccentric actions. Evaluating hip eccentric strength could potentially reveal more pronounced differences between injured and uninjured athletes.<sup>69</sup> This claim cannot be strongly supported with current data since there was insufficient information to analyse studies using eccentric strength exclusively. Fourth, the follow-up time varied across studies. It could be anticipated that injuries occurring closer to the assessment moment would have a stronger relationship with the examined factor, while an athlete sustaining an injury months after the assessment might not exhibit the same strength scores as at the time of evaluation. Current information is controversial since some studies have found benefit in performing various screening sessions throughout a season while others do not.<sup>70,71</sup> Finally, generalising these results to women should be performed with caution since female participants represented 3% of the entire sample in our study. More studies are needed to assess the effect of strength on groin injury risk in female athletes.

### CONCLUSION

There is a moderate effect of hip adductor strength on the prospective occurrence of groin pain with low-quality evidence. Robust findings confirm that there is no relationship between either abductor strength or the ratio of adductor-to-abductor strength and the occurrence of groin pain. Based on the available evidence, we recommend including adductor strength testing in athlete screening.

X Marcos Quintana-Cepedal @MQuintanaPT

**Acknowledgements** The authors would like to thank Frida Eek (PT) and Tobias Wörner (PT) (Department of Health Sciences, Lund University, Lund, Sweden) for providing us with the required data to include their study in the quantitative analysis.

**Contributors** MQ-C, HO designed the research question. IC performed the searches. MQ-C, GV-R, HO screened titles and full texts. GV-R and IC performed risk of bias assessment. MQ-C performed data analysis. MQ-C interpreted the

findings and drafted the manuscript. All authors read and gave feedback on the final manuscript. HO is the guarantor of this work.

**Funding** The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

**Competing interests** None declared.

**Patient consent for publication** Not applicable.

**Provenance and peer review** Not commissioned; externally peer-reviewed.

**Data availability statement** Data are available upon reasonable request.

**Supplemental material** This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

### ORCID iD

Hugo Olmedillas <http://orcid.org/0000-0003-4625-2759>

### REFERENCES

- Thorarinsdottir S, Amundsen R, Larmo A, *et al.* Groin injuries in women's premier league football in Norway: A two-season prospective cohort study describing clinical and imaging characteristics. *Scandinavian Med Sci Sports* 2024;34:e14611.
- Quintana-Cepedal M, López-Aguado I, Fernández-Somoano A, *et al.* Injury incidence and characteristics in adolescent female football players: A systematic review with meta-analysis of prospective studies. *Biol Sport* 2024;41:137–51.
- Werner J, Häggglund M, Ekstrand J, *et al.* Hip and groin time-loss injuries decreased slightly but injury burden remained constant in men's professional football: the 15-year prospective UEFA Elite Club Injury Study. *Br J Sports Med* 2019;53:539–46.
- Mercurio M, Corona K, Galasso O, *et al.* Soccer players show the highest seasonal groin pain prevalence and the longest time loss from sport among 500 athletes from major team sports. *Knee Surg Sports Traumatol Arthrosc* 2022;30:2149–57.
- Tabben M, Eirale C, Singh G, *et al.* Injury and illness epidemiology in professional Asian football: lower general incidence and burden but higher ACL and hamstring injury burden compared with Europe. *Br J Sports Med* 2022;56:18–23.
- Orchard J, Wood T, Seward H, *et al.* Comparison of injuries in elite senior and junior Australian football. *J Sci Med Sport* 1998;1:83–8.
- Carolan D, Richter C, Thorborg K, *et al.* Hip and groin pain prevalence and prediction in Elite Gaelic Games: 2703 male athletes across two seasons. *Scandinavian Med Sci Sports* 2022;32:924–32.
- O'Connor D. Groin injuries in professional rugby league players: a prospective study. *J Sports Sci* 2004;22:629–36.
- Wörner T, Thorborg K, Clarsen B, *et al.* Incidence, Prevalence, and Severity of and Risk Factors for Hip and Groin Problems in Swedish Male Ice Hockey Players: A 1-Season Prospective Cohort Study. *J Athl Train* 2022;57:72–8.
- Quintana-Cepedal M, de Pablo Marquez B, Del Valle Soto M, *et al.* High Prevalence of Seasonal and Current Groin Problems in Rink Hockey Players. *Int J Sports Med* 2024;45:526–31.
- Harøy J, Clarsen B, Thorborg K, *et al.* Groin Problems in Male Soccer Players Are More Common Than Previously Reported. *Am J Sports Med* 2017;45:1304–8.
- Esteve E, Clausen MB, Rathleff MS, *et al.* Prevalence and severity of groin problems in Spanish football: A prospective study beyond the time-loss approach. *Scandinavian Med Sci Sports* 2020;30:914–21.
- Serner A, Tol JL, Jomaah N, *et al.* Diagnosis of Acute Groin Injuries: A Prospective Study of 110 Athletes. *Am J Sports Med* 2015;43:1857–64.
- Mosler AB, Weir A, Eirale C, *et al.* Epidemiology of time loss groin injuries in a men's professional football league: a 2-year prospective study of 17 clubs and 606 players. *Br J Sports Med* 2018;52:292–7.
- Serner A, Weir A, Tol JL, *et al.* Characteristics of acute groin injuries in the hip flexor muscles — a detailed MRI study in athletes. *Scandinavian Med Sci Sports* 2018;28:677–85.
- Forlizzi JM, Ward MB, Whalen J, *et al.* Core Muscle Injury: Evaluation and Treatment in the Athlete. *Am J Sports Med* 2023;51:1087–95.
- King E, Franklyn-Miller A, Richter C, *et al.* Clinical and biomechanical outcomes of rehabilitation targeting intersegmental control in athletic groin pain: prospective cohort of 205 patients. *Br J Sports Med* 2018;52:1054–62.
- Serner A, Rebour G, Lichau O, *et al.* Digital body mapping of pain quality and distribution in athletes with longstanding groin pain. *Sci Rep* 2022;12:9789.
- Heijboer WMP, Weir A, Vuckovic Z, *et al.* Clinical examination tests for adductor- and pubic-related groin pain in athletes with longstanding groin pain: Inter-examiner reliability and prevalence of positive tests. *Phys Ther Sport* 2024;66:9–16.

- 20 Hägglund M, Waldén M, Magnusson H, *et al.* Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA Champions League injury study. *Br J Sports Med* 2013;47:738–42.
- 21 McCall A, Pruna R, Van der Horst N, *et al.* Exercise-Based Strategies to Prevent Muscle Injury in Male Elite Footballers: An Expert-Led Delphi Survey of 21 Practitioners Belonging to 18 Teams from the Big-5 European Leagues. *Sports Med* 2020;50:1667–81.
- 22 Esteve E, Rathleff MS, Bagur-Calafat C, *et al.* Prevention of groin injuries in sports: a systematic review with meta-analysis of randomised controlled trials. *Br J Sports Med* 2015;49:785–91.
- 23 Quintana-Cepedal M, de la Calle O, Olmedillas H. Can the Copenhagen Adduction Exercise Prevent Groin Injuries in Soccer Players? A Critically Appraised Topic. *J Sport Rehabil* 2024;33:45–8.
- 24 van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med* 1992;14:82–99.
- 25 Thorborg K, Reiman MP, Weir A, *et al.* Clinical Examination, Diagnostic Imaging, and Testing of Athletes With Groin Pain: An Evidence-Based Approach to Effective Management. *J Orthop Sports Phys Ther* 2018;48:239–49.
- 26 Whittaker JL, Small C, Maffey L, *et al.* Risk factors for groin injury in sport: an updated systematic review. *Br J Sports Med* 2015;49:803–9.
- 27 Emery CA, Meeuwisse WH. Risk factors for groin injuries in hockey. *Med Sci Sports Exerc* 2001;33:1423–33.
- 28 Orchard JW. Men at higher risk of groin injuries in elite team sports: a systematic review. *Br J Sports Med* 2015;49:798–802.
- 29 Haroy J, Clarsen B, Wiger EG, *et al.* The Adductor Strengthening Programme prevents groin problems among male football players: a cluster-randomised controlled trial. *Br J Sports Med* 2019;53:150–7.
- 30 Ishøi L, Thorborg K. Copenhagen adduction exercise can increase eccentric strength and mitigate the risk of groin problems: but how much is enough! *Br J Sports Med* 2021;55:1066–7.
- 31 Ryan J, DeBurca N, McCreesh K. Risk factors for groin/hip injuries in field-based sports: a systematic review. *Br J Sports Med* 2014;48:1089–96.
- 32 Weir A, Brukner P, Delahunt E, *et al.* Doha agreement meeting on terminology and definitions in groin pain in athletes. *Br J Sports Med* 2015;49:768–74.
- 33 Opar DA, Timmins RG, Behan FP, *et al.* Is Pre-season Eccentric Strength Testing During the Nordic Hamstring Exercise Associated with Future Hamstring Strain Injury? A Systematic Review and Meta-analysis. *Sports Med* 2021;51:1935–45.
- 34 Green B, Bourne MN, van Dyk N, *et al.* Recalibrating the risk of hamstring strain injury (HSI): A 2020 systematic review and meta-analysis of risk factors for index and recurrent hamstring strain injury in sport. *Br J Sports Med* 2020;54:1081–8.
- 35 McGuinness LA, Higgins JPT. Risk-of-bias Visualization (robvis): An R package and Shiny web app for visualizing risk-of-bias assessments. *Res Synth Methods* 2021;12:55–61.
- 36 Andrews J, Guyatt G, Oxman AD, *et al.* GRADE guidelines: 14. Going from evidence to recommendations: the significance and presentation of recommendations. *J Clin Epidemiol* 2013;66:719–25.
- 37 Higgins JPT, Thompson SG, Deeks JJ, *et al.* Measuring inconsistency in meta-analyses. *BMJ* 2003;327:557–60.
- 38 Guyatt GH, Oxman AD, Kunz R, *et al.* GRADE guidelines 6. Rating the quality of evidence—imprecision. *J Clin Epidemiol* 2011;64:1283–93.
- 39 Sandercock G. The Standard Error/Standard Deviation Mix-Up: Potential Impacts on Meta-Analyses in Sports Medicine. *Sports Med* 2024;54:1723–32.
- 40 Balduzzi S, Rucker G, Schwarzer G. How to perform a meta-analysis with R: a practical tutorial. *Evid Based Mental Health* 2019;22:153–60.
- 41 Viechtbauer W. Conducting Meta-Analyses in R with the metafor Package. *J Stat Softw* 2010;36.
- 42 Borg DN, Impellizzeri FM, Borg SJ, *et al.* Meta-analysis prediction intervals are under reported in sport and exercise medicine. *Scand Med Sci Sports* 2024;34:e14603.
- 43 Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd Ed. L. Erlbaum Associates, 1988.
- 44 Higgins JPT, Thomas J, Chandler J, *et al.* *Cochrane Handbook for Systematic Reviews of Interventions*. Version 6.4 (Updated August 2023). Cochrane, 2023. Available: [www.training.cochrane.org/handbook](http://www.training.cochrane.org/handbook)
- 45 Markovic G, Šarabon N, Pausic J, *et al.* Adductor Muscles Strength and Strength Asymmetry as Risk Factors for Groin Injuries among Professional Soccer Players: A Prospective Study. *Int J Environ Res Public Health* 2020;17:1–9.
- 46 Bourne MN, Williams M, Jackson J, *et al.* Preseason Hip/Groin Strength and HAGOS Scores Are Associated With Subsequent Injury in Professional Male Soccer Players. *J Orthop Sports Phys Ther* 2020;50:234–42.
- 47 Secomb JL, Kelly M, Dascombe BJ. Hip Strength Profiling of Ice Hockey Athletes Across Various Joint-Specific Angles: Monitoring and Injury Implications. *J Strength Cond Res* 2023;37:e422–9.
- 48 Moreno-Pérez V, Travassos B, Calado A, *et al.* Adductor squeeze test and groin injuries in elite football players: A prospective study. *Phys Ther Sport* 2019;37:54–9.
- 49 DeLang MD, Garrison JC, Hannon JP, *et al.* Weekly screening of youth male football players: a 14-week longitudinal investigation of interactions between groin pain and long lever adductor squeeze strength. *J Sci Med Sport* 2023;26:159–63.
- 50 Belhaj K, Meftah S, Mahir L, *et al.* Isokinetic imbalance of adductor-abductor hip muscles in professional soccer players with chronic adductor-related groin pain. *Eur J Sport Sci* 2016;16:1226–31.
- 51 Tyler TF, Nicholas SJ, Campbell RJ, *et al.* The association of hip strength and flexibility with the incidence of adductor muscle strains in professional ice hockey players. *Am J Sports Med* 2001;29:124–8.
- 52 Delahunt E, Fitzpatrick H, Blake C. Pre-season adductor squeeze test and HAGOS function sport and recreation subscale scores predict groin injury in Gaelic football players. *Phys Ther Sport* 2017;23:1–6.
- 53 Schoffl J, Dooley K, Miller P, *et al.* Factors Associated with Hip and Groin Pain in Elite Youth Football Players: A Cohort Study. *Sports Med Open* 2021;7:97.
- 54 Esteve E, Casals M, Saez M, *et al.* Past-season, pre-season and in-season risk assessment of groin problems in male football players: a prospective full-season study. *Br J Sports Med* 2022;56:484–9.
- 55 Mosler AB, Weir A, Serner A, *et al.* Musculoskeletal Screening Tests and Bony Hip Morphology Cannot Identify Male Professional Soccer Players at Risk of Groin Injuries: A 2-Year Prospective Cohort Study. *Am J Sports Med* 2018;46:1294–305.
- 56 Light N, Thorborg K. The precision and torque production of common hip adductor squeeze tests used in elite football. *J Sci Med Sport* 2016;19:888–92.
- 57 Wollin M, Thorborg K, Welvaert M, *et al.* In-season monitoring of hip and groin strength, health and function in elite youth soccer: Implementing an early detection and management strategy over two consecutive seasons. *J Sci Med Sport* 2018;21:988–93.
- 58 Crow JF, Pearce AJ, Veale JP, *et al.* Hip adductor muscle strength is reduced preceding and during the onset of groin pain in elite junior Australian football players. *J Sci Med Sport* 2010;13:202–4.
- 59 Aiello F, Di Claudio C, Fanchini M, *et al.* Do non-contact injuries occur during high-speed running in elite football? Preliminary results from a novel GPS and video-based method. *J Sci Med Sport* 2023;26:465–70.
- 60 de Queiroz JHM, Frota JP, Dos Reis FA, *et al.* Development and Predictive Validation of the Brazilian Adductor Performance Test for Estimating the Chance of Hip Adductor Injuries in Elite Soccer Athletes. *Int J Sports Physiol Perform* 2023;18:653–9.
- 61 Serner A, Mosler AB, Tol JL, *et al.* Mechanisms of acute adductor longus injuries in male football players: a systematic visual video analysis. *Br J Sports Med* 2019;53:158–64.
- 62 Engebretsen AH, Myklebust G, Holme I, *et al.* Intrinsic risk factors for groin injuries among male soccer players: a prospective cohort study. *Am J Sports Med* 2010;38:2051–7.
- 63 Mosler AB, Crossley KM, Thorborg K, *et al.* Hip strength and range of motion: Normal values from a professional football league. *J Sci Med Sport* 2017;20:339–43.
- 64 Beddows TPA, Weir A, Agrícola R, *et al.* Hip and groin pain in male field hockey players: Prevalence, incidence and associations with patient reported outcome scores and hip muscle strength. *Phys Ther Sport* 2023;61:66–72.
- 65 Orchard JW, Chaker Jomaa M, Orchard JJ, *et al.* Fifteen-week window for recurrent muscle strains in football: a prospective cohort of 3600 muscle strains over 23 years in professional Australian rules football. *Br J Sports Med* 2020;54:1103–7.
- 66 Light N, Thorborg K, Krommes K, *et al.* Rapid Spike in Hip Adduction Strength in Early Adolescent Footballers: A Study of 125 Elite Male Players From Youth to Senior. *Int J Sports Physiol Perform* 2022;17:1407–14.
- 67 Martínez-Silván D, Wik EH, Arnáiz J, *et al.* Association Between Magnetic Resonance Imaging Findings and Time to Return to Sport After Muscle Injuries in High-Level Youth Athletes. *Clin J Sport Med* 2023;33:225–32.
- 68 Saille M, Whiteley R, Read JW, *et al.* Public apophysitis: a previously undescribed clinical entity of groin pain in athletes. *Br J Sports Med* 2015;49:828–34.
- 69 Jakobsen JR, Krosgaard MR. The Myotendinous Junction—A Vulnerable Companion in Sports. A Narrative Review. *Front Physiol* 2021;12:635561.
- 70 Opar DA, Ruddy JD, Williams MD, *et al.* Screening Hamstring Injury Risk Factors Multiple Times in a Season Does Not Improve the Identification of Future Injury Risk. *Med Sci Sports Exerc* 2022;54:321–9.
- 71 Sim A, Timmins RG, Ruddy JD, *et al.* Hamstring Strain Injury Risk Factors in Australian Football Change over the Course of the Season. *Med Sci Sports Exerc* 2024;56:297–306.