Title: What is the prevalence of hip intra-articular pathologies and osteoarthritis in active athletes with hip and groin pain compared to those without? A systematic review and meta-analysis

Prevalence of intra-articular hip pathologies in athletes with and without pain

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What is the prevalence of hip intra-articular pathologies and osteoarthritis in athletes playing with hip and groin pain compared to those without? A systematic review and meta-analysis

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Background In athletes, hip and groin pain is considered to be associated with hip intra-articular pathologies and hip osteoarthritis. A greater understanding of the relationship between hip and groin pain and imaging findings is required.

Objective To undertake a systematic review and meta-analysis to determine the prevalence of hip intra-articular pathologies and hip osteoarthritis in athletes with and without hip and groin pain.

Methods PROSPERO registration CRD42017082457. Seven electronic databases were searched on January 29th, 2018 for studies investigating the prevalence of hip intra-articular pathologies and hip osteoarthritis using X-ray, magnetic resonance imaging, magnetic resonance arthrography or computed tomography. Two independent reviewers conducted the search, study selection, quality appraisal and data extraction. Meta-analysis was performed when studies were deemed homogenous, with a strength of evidence assigned to pooled results.

Results Twenty studies were identified reporting on the prevalence of hip intra-articular pathologies and hip osteoarthritis in athletes were identified. Included studies were considered moderate to high risk of bias, with only three studies adjudged as low risk of bias. In asymptomatic athletes, limited evidence identified a labral tear prevalence of 54% per person and moderate evidence of 33% per hip. In symptomatic athletes, moderate evidence of a labral tear prevalence of 20% per hip was found. Moderate evidence of a cartilage defect prevalence of 10% per person was reported in asymptomatic athletes. In symptomatic athletes, cartilage defect prevalence was 7% to 40%. In asymptomatic athletes, the prevalence of hip osteoarthritis was 0% to 17%, compared with 2% in symptomatic athletes.

Conclusion

The prevalence of hip intra-articular pathologies and hip osteoarthritis in symptomatic and asymptomatic athletes is variable. Labral tears and cartilage defects appear to be seen often in athletes with and without pain. Hip osteoarthritis is rarely seen in athletes either with or without hip and groin pain.

KEY POINTS

- Hip Intra-articular pathologies are seen in athletes with and without pain.
- Labral tears were identified in up to one in every two athletes without pain, highlighting a potential discordant relationship between labral tears and pain in athletes.
- Cartilage defects, bone marrow lesions, herniation pits, hip joint effusion, labral degeneration and ligamentum teres tears were observed in symptomatic and asymptomatic athletes.

- A complex relationship exists between structural hip conditions identified with imaging and pain in athletes.

1. INTRODUCTION

Hip and groin pain is common in athletes [1-11], particularly those participating in football codes [10, 11, 1, 3, 8, 12], ice hockey [5] and dancing [9]. Hip and groin pain constitutes up to 18% of all time loss injuries in professional football (soccer) [1, 13]. Moreover, in football 59% of men and 45% of women will experience groin pain/injury during a competitive season [6]. Many athletes will experience long-standing symptoms [3], with one in three sub-elite football players with hip and groin pain having symptoms for greater than six weeks. Chronicity of symptoms is associated with greater difficulties in activities of daily living, reduced quality of life and impaired athletic performance [3].

A number of different and often coexisting clinical entities are proposed to cause hip and groin pain in athletes [14-17]. Hip-related groin pain in athletes often results from femoroacetabular impingement (FAI) syndrome and labral tears [18-20, 15]. The bony morphology associated with FAI syndrome is characterized as cam and/or pincer morphology [21]. Cam morphology is present in up to 66% of athletes [22-24], with male athletes eight times more likely to have cam morphology than non-athletes [24]. In athletes, the combination of bony morphology with the repetitive end of range hip movements performed during sporting activities may predispose to mechanical abutment and the development of symptoms and pain [18-20]. Over-time, cam morphology may result in intra-articular hip conditions, including hip osteoarthritis (OA). Cam morphology is associated with intra-articular pathology including labral tears in individuals with and without pain [25-27], and increases the odds of developing OA by up to 10 times in older adults [28]. However, little is known about the risk of developing OA in athletic populations with cam morphology [28, 16].

Imaging is used to evaluate the presence of intra-articular hip conditions in athletes with hip and groin pain [29, 30]. Our recent review of studies evaluating athletes and non-athletes highlighted similar prevalence of select intra-articular hip pathologies in individuals with and without pain, regardless of level of athletic activity [31]. However, our review did not provide a detailed understanding of the prevalence of such pathologies specifically in athletes. Additional reviews on the prevalence of intra-articular hip conditions including bony morphology, labral tears and cartilage defects in athletes [22, 23] have not described all frequently reported intra-articular pathologies. The prevalence of OA in retired athletes is known [32, 33], but the prevalence in athletes currently playing sport is not. Therefore, the aim of this review was to determine the prevalence of intra-articular hip pathologies such as labral tears, cartilage defects, ligamentum teres tears, bone marrow lesions (BML), synovitis and OA in athletes with and without hip and groin pain who are currently playing sport.

2. METHODS

The preferred reporting guidelines for systematic reviews and meta-analysis (PRISMA) were used in this systematic review. The protocol for this review was registered on the PROSPERO international prospective register of systematic reviews (http://www.crd.york.ac.uk/PROSPERO) on the 11 December 2017 (registration number: CRD42017082457).

2.1. Eligibility Criteria

We included studies if they: 1) were written in English language; 2) cross-sectional, case-control, case series or cohort designs; 3) included current amateur, semi-professional or elite athletes with and without hip and groin pain; 4) utilized X-ray, magnetic resonance imaging (MRI), magnetic resonance arthrography (MRA) and/or computed tomography (CT) to determine the presence of intra-articular hip pathologies or OA; 5) had a primary aim of reporting the prevalence intra-articular hip pathologies or OA in athletes; 6) evaluated the presence of FAI (including bony morphology) or hip dysplasia and the prevalence of intra-articular hip pathologies or OA. We did not place any restrictions on the age of athletes included in the studies. We excluded studies if they: 1) reported on the prevalence of intra-articular hip pathologies or OA in athletes but this was not listed as the primary aim of the study; 2) reported on the prevalence of intra-articular hip pathologies or OA in retired athletes; 3) evaluated the prevalence of FAI (including bony morphology) and hip dysplasia but did not report the presence of intra-articular hip pathologies or OA; 4) identified the presence of intra-articular hip pathologies or OA in athletes with Legg-Calve-Perthes disease or slipped capital femoral epiphysis; 5) used ultrasound or isotopic bone scan to determine the prevalence of intra-articular hip pathologies or OA; 6) used hip arthroscopy or open hip surgery to determine the prevalence of intra-articular hip pathologies or OA in athletes; 7) included less than five athletes; 8) were unpublished data, abstracts or systematic reviews and/or were studies not published in the English language

2.2. Search strategy

Two independent authors (JJH and MJS) undertook a comprehensive search using OVID MEDLINE, PubMed, CINAHL, EMBASE, SPORTDiscus, SCOPUS and Cochrane databases from inception to 29 January 2018. Citation tracking using Google Scholar and the screening of reference lists of included articles was undertaken by one author (JJH). Database specific controlled vocabulary and keyword terms were used for each database (Online Resource 1).

Endnote X7 (Thomson Reuters, Carlsbad, California, USA) was used for management of the identified articles. Two authors (JJH, MJS) applied the specified inclusion/exclusion criteria to the articles identified during the search process. Each author (JJH, MJS) independently selected the articles eligible for final inclusion in the review. At the completion of this process, consensus was achieved between the two authors on the articles to be included in the review. A third reviewer (JLK) was utilized when the two authors could not agree upon the inclusion of an article.

2.3. Risk of bias

Risk of bias was independently assessed by two authors (JJH, DMJ). A tool designed to determine the risk of bias in prevalence literature was utilized in the review [34]. The external validity (four questions) and internal validity (six questions) of each included article was evaluated. Each of the 10 questions is scored as low risk of bias (LR) or high risk of bias (HR). If an article did not provide adequate information for a question to be scored, a HR was given. In relation to question one, an article was scored as LR if it was considered that the athletes were representative of a wider population of athletes playing the selected sport. In line with a recent review [31], question seven was modified, where an article was considered LR if it reported an intra-class correlation coefficient (ICC) greater than 0.40 and/or Cohen’s Kappa (k) greater than 40% for the method used to assess the prevalence of specific intra-articular hip pathologies and/or OA. Each included article was provided with an overall risk of bias score, as determined by the number of HR items. Articles were considered LR if they had 0-3 HR items, moderate risk of bias (MR) if they had 4-5 HR items and HR if they had 6 or more HR items [35]. In the event of author disagreement, a third author (JLK) was consulted. The inter-rater agreement was evaluated with (k), excellent agreement was achieved with (k) values above 80%, substantial agreement (60 to 80%), moderate agreement (40 to 60%) and finally poor to fair agreement with values below 40% [36].

2.4. Data extraction

Two authors (JJH, ABM) independently extracted data from all 20 included articles. The data extracted from each article included: author, study design, sport, number of athletes, number of hips, sex, age, imaging method used and prevalence of intra-articular hip pathologies and/or OA. In the event of disagreement between the authors on the data extracted, a third author (KMC) was consulted to reach consensus. Authors of the included articles were contacted if additional data were required. Authors' from nine of the 20 included articles were contacted and provided additional data upon request.

2.5. Data synthesis and analysis

For this review, athletes were defined as individuals who competed and trained in a specific sport [37]. The athletic populations investigated in this review were not representative of community-based populations, hence the reported prevalence of intra-articular hip pathologies and/or OA is representative of the frequency of such pathologies in athletic individuals with and without pain. To determine the prevalence of intra-articular hip pathologies and/or OA, the number of athletes (cases) was divided by the total athlete population included in the article. We used Comprehensive Meta-Analysis Software (Version 3.0, Biostat Inc., USA) to determine overall prevalence and 95% confidence intervals (CIs). The prevalence of intra-articular hip pathologies and OA was either reported as per person or per hip depending on the method used in the included article. Data deemed eligible for pooling were presented in either per person or per hip format. Primary subgrouping was undertaken based on the presence or absence of hip and groin pain. Secondary grouping included the type of mechanical loading placed on the hip by the sport [38, 39] and imaging modality (MRI, MRA or CT) used for each specific intra-articular hip pathology.

In line with our recent review [31], intra-articular hip pathologies were reported as being present or absent. Cartilage defects were reported in the primary analysis when femoral and acetabular defects were reported together. Studies that reported acetabular and femoral cartilage separately were analyzed qualitatively. A Tonnis grade of 2 or greater or a joint space width (JSW) of 2.0mm or less was used to define the presence of hip OA [40, 41]. A Tonnis grade of 1 was used to define minor or early features of hip OA [42]. Studies reporting prevalence of intra-articular hip pathologies in less than five athletes were not included in secondary analysis. Studies adjudged to be HR were not considered for meta-analysis [43]. Low risk and MR studies were included in meta-analyses using a random effects model. Where articles were HR or deemed clinically heterogenous, qualitative analysis was undertaken. The statistical heterogeneity present in the pooled analysis was evaluated using Q and I^2 statistics [44, 45] and classified in accordance with *Higgins et al. [45]*. A strength of evidence was assigned to the pooled results, using previously described modified criteria [46, 47, 31] as follows:

Strong evidence: pooled results derived from three or more studies, including a minimum of two LR studies, which are statistically homogenous ($p>0.05$).

Moderate evidence: pooled results derived from multiple studies, including at least one LR study, which are statistically heterogeneous ($p<0.05$); or from multiple MR and HR studies which are statistically homogenous ($p>0.05$).

Limited evidence: pooled results from multiple HR or MR studies which are statistically heterogeneous ($p<0.05$).

3. RESULTS

3.1. Search results

At the completion of database searching, 847 articles were identified (Figure 1). Removal of duplicates left 470 articles for screening by title and abstract, and 69 full text articles that were evaluated for eligibility using the listed inclusion criteria. In total, six additional articles [48-53] were retrieved and evaluated for inclusion after the completion of reference list searching and citation tracking. Fifty-five articles were excluded (Online Resource 2), with a total of 20 articles [54, 48, 55, 49, 56-59, 53, 60-63, 50, 64, 51, 65, 52, 66, 67] included in the review for qualitative and quantitative analysis (Table 1-3).

Table 1 Included studies involving asymptomatic athletes only

Author	Study design	Study population	Number of participants (hips)	Demographics	Imaging modality	Findings (Intra-articular hip pathology/osteoarthritis)
Anderson et al [54][d]	Cross-sectional	**Subjects** Senior athletes	**Subjects** 547 (1081)	**Subjects** Age[a]: 67 (8) Sex: 246 (45%) F/301 (55%) M	X-ray	**Subjects** Tonnis grade 3: 30/1081 Tonnis grade 2: 156/1081; Tonnis grade 1: 352/1086; Tonnis grade 0: 543/1081; Tonnis grade 2/3: 186/1081; Tonnis grade 0/1: 895/1081
Ayeni et al [48]	Cross-sectional	**Subjects** Ice Hockey players	**Subjects** 20 (20)	**Subjects** Age[a]: 20.6 Sex: 9 (45%) F/11 (55%) M	1.5-T MRI	**Subjects** Labral tear: 12/20; acetabular cartilage defect: 0/20; femoral cartilage defect: 2/20; herniation pit: 2/20; osseous bump: 4/20; paralabral cyst: 0/20
Farrell et al [55]	Cross-sectional	**Subjects** Rugby union academy players	**Subjects** 20 (40)	**Subjects** Age[a]: 22 (1.5) Sex: 20 (100%) M	3-T MRI	**Subjects** Labral tear: 17/20[c]; labral tear right hip: 10/20; labral tear left hip: 15/20; bilateral labral tear: 8/20; cartilage defect: 4/20[c]; cartilage defect right hip: 3/20; cartilage defect left hip: 3/20; bilateral cartilage defect: 1/20
Kapron et al [49]	Cross-sectional	**Subjects** Collegiate American football players	**Subjects** 67 (134)	**Subjects** Age[a]: 21 (1.9) Sex: 67 (100%) M	X-ray	**Subjects** Tonnis grade 0: 112/134; Tonnis grade 1: 22/134; Tonnis grade 2: 0/134; Tonnis grade 3: 0/134
Lahner et al [57]	Cross-sectional	**Subjects** Semi-professional soccer players **Controls** Amateur soccer players	**Subjects** 22 (22) **Controls** 22 (22)	**Subjects** Age[a]: 23.3 (3.3) Sex: 22 (100%) M **Controls** Age[a]: 22.5 (3.5) Sex: 22 (100%) M	1.5T MRI	**Subjects** Labral tear: 3/22; cartilage defect: 2/22 **Controls** Labral tear: 1/22; cartilage defect: 1/22
Lahner et al [56]	Cross-sectional	**Subjects** Track and Field athletes	**Subjects** 22 (44)	**Subjects** Age[a]: 23.7 (3.0) ([b]18-30) Sex: 11 (50%) F/11 (50%) M	1.5-T MRI	**Subjects** Labral tear: 2/44; acetabular cartilage defect: 1/44; femoral cartilage defect: 1/44; herniation pit: 3/44; osseous bump: 3/44
Philippon et al [58]	Cross-sectional	**Subject**s Youth ice hockey players **Controls** Youth Skiers	**Subjects** 61 (61) **Controls** 27 (27)	**Subjects** Age[a]: 14.5 (2.7) Sex: 61 (100%) M **Controls** Age[a]: 15.2 (2.7) Sex: 27 (100%) M	3-T MRI	**Subjects** Labral tear: 42/61; peewee hockey players - labral tear: 13/27; bantam hockey players - labral tear: 5/8; midget hockey players - labral tear: 24/26; cartilage defect: 5/61; peewee hockey players - cartilage defect: 0/27; bantam hockey players - cartilage defect: 0/8; midget hockey players - cartilage defect: 5/26 **Controls** Labral tear: 19/27; skier - labral tear (peewee control): 5/7; skier - labral tear (bantam control): 5/8; skier - labral tear (midget control): 9/12; cartilage defect: 1/27; skier - cartilage defect (peewee control): 0/7; skier - cartilage defect (bantam control): 0/8; skier - cartilage defect (midget control): 1/12

Table 1 *(continued)*

Author	Study design	Study population	Number of participants (hips)	Demographics	Imaging modality	Findings (Intra-articular hip pathology/osteoarthritis)
Silvis et al [59]	Cross-sectional	**Subjects** Ice hockey players	**Subjects** 39 (39)	**Subjects** Age: NR Sex: 39 (100%) M	3-T MRI	**Subjects** Hip pathology total findings: 25/39; labral tear: 22/39; cartilage defect: 7/39; hip effusion: 0/39
Yepez et al [53]	Cross-sectional	**Subjects** Youth soccer players	**Subjects** 56 (112)	**Subjects** Age[a]: 15.3 ([b]13-18) Sex: 56 (100%) M	1.5-T MRI	**Subjects** Labral tear: 10/112; degenerative labral tear: 2/112; cartilage defect: 3/112; herniation pit: 4/112; BML: 24/112; acetabular osteitis: 10/112; osseous bump 49/112
Yuan et al [60]	Cross-sectional	**Subjects** High school student with clinical signs of FAI **Controls** High school students no clinical signs of FAI	**Subjects** 13 (22) **Controls** 13 (26)	**Subjects** Age: NR Sex: 1 (8%) F/12 (92%) M **Controls** Age: NR Sex: 1 (8%) F/12 (92%) M	3-T MRI 1.5-T MRI	**Subjects** Any abnormal hip finding: 15/22; labral tear: 14/22; acetabular rim damage: 3/22; cartilage defect: 1/22; Tonnis grade 0: 22/22; Tonnis grade 1: 0/22; Tonnis grade 2: 0/22; Tonnis grade 3: 0/22 **Controls** Any abnormal hip finding: 10/26; labral tear: 10/26; acetabular rim damage: 0/26; cartilage defect: 1/26

BML bone marrow lesion, *FAI* femoroacetabular impingement, *F* female, *M* male, *MRI* magnetic resonance imaging, *NR* not reported, *T* tesla

[a] mean (standard deviation)

[b] range

[c] results from raw data obtained from author

[d] author provided additional results not presented in original article

Table 2 Included studies involving symptomatic athletes only

Author	Study design	Study population	Number of participants (hips)	Demographics	Imaging modality	Findings (Intra-articular hip pathology/osteoarthritis)
Narvani et al [61]	Case series	**Subjects** Individuals playing sport with groin pain	**Subjects** 18 (18)	**Subjects** Age[a]: 30.5 (8.45) ([b]17-48) Sex: 5 (28%) F/13 (72%) M	1-T MRA	**Subjects** Labral tear: 4/18
Nepple et al [62]	Case series	**Subjects** American football athletes at scouting combine	107 (123)	Age[c]: 22.7 (20-25) Sex: 107 (100%) M	X-ray	Tonnis grade 0-1: 121/123; Tonnis grade 2: 2/123; Tonnis grade 3: 0/123

F female, *M* male, *MRA* magnetic resonance arthrography
[a] mean (standard deviation)
[b] range
[c] mean (range)

Table 3 Included studies involving asymptomatic and symptomatic athletes

Author	Study design	Study population	Number of participants (hips)	Demographics	Imaging modality	Findings (Intra-articular hip pathology/osteoarthritis)
Dickenson et al [67][d]	Cross-sectional	**Subjects** Male golfers with hip pain **Controls** Male golfers without hip pain	**Subjects** NR (15) **Controls** NR (95)	**Subjects** Age: NR Sex: 15 (100%) M **Controls** Age: NR Sex: 95 (100%) M	1.5-T MRI	**Subjects** Labral tear: 3/15; increased labral signal: 3/15; acetabular cartilage defect 4/15; femoral cartilage defect: 1/15; acetabular subchondral edema: 3/15; femoral subchondral edema: 6/15; herniation pit: 4/15; joint effusion: 1/15 **Controls** Labral tear: 22/95; increased labral signal: 21/95; acetabular cartilage defect: 6/95; femoral cartilage defect: 3/95 acetabular subchondral edema: 10/95; femoral subchondral edema: 10/95; herniation pit: 9/95; joint effusion: 8/95

Table 3 *(continued)*

Author	Study design	Study population	Number of participants (hips)	Demographics	Imaging modality	Findings (Intra-articular hip pathology/osteoarthritis)
Harris et al [63]	Cross-sectional	**Subjects** Symptomatic/asymptomatic ballet dancers	**Subjects** 47 (94)	**Subjects** Age[a]: 23.8 (5.4) ([b]18-39) Sex: 26 (55%) F/21 (45%) M	X-ray	**Subjects** Tonnis grade 0 left hip: 40/47; tonnis grade 1 left hip: 7/47; tonnis grade 2 left hip: 0/47; tonnis grade 3 left hip: 0/47; tonnis grade 0 right hip: 42/47; tonnis grade 1 right hip: 5/47; tonnis grade 2 right hip: 0/47; tonnis grade 3 right hip 0/47; medial joint space male[a]: 3.64 [0.54]; medial joint space female[a]: 3.51 [0.65]; middle joint space male[a]: 3.93 [0.37]; middle joint space female[a]: 3.86 [0.57]; lateral joint space male[a]: 4.39 [0.55]; lateral joint space female[a]: 4.39 [0.59]; total joint space male[a]: 3.98 [0.39]; total joint space female[a]: 3.92 [0.54]
Kolo et al [50]	Cross-sectional	**Subjects** Symptomatic/asymptomatic ballet dancers	**Subjects** 30 (59)	**Subjects** Age[c]: 24.6 (18-39) Sex: 30 (100%) F	1.5-T MRI	**Subjects** Labral tear: 28/59; hips ≥ 2 labral tears: 12/59; labral degeneration: 24/59; hips ≥2 labral degenerative tears: 11/59; Labral ossification: 2/59; hips ≥ 2 ossified lesions: 2/59; acetabular cartilage defect ≤5 mm: 12/59; acetabular cartilage defect: ≥5 mm: 17/59 herniation pit: 31/59
Larson et al [64]	Cross-sectional	**Subjects** Symptomatic/asymptomatic ice hockey players	**Subjects** 59 (118)	**Subjects** Age[a]: 24.2 (4.6) Sex: 59 (100%) M	X-ray	**Subjects** Joint space[b]: 4.13 (0.62)
Mariconda et al [51]	Cross-sectional	**Subjects** Symptomatic/asymptomatic capoeira players	**Subjects** 24 (48)	**Subjects** Age[a]: 31.5 (4.5) ([b]25-42) Sex: 10 (42%) F/14 (58%) M	X-ray	**Subjects** Tonnis grade 3: 0/48; tonnis grade 2: 3/48; tonnis grade 1: 9/48; tonnis grade 0 36/48
Mayes et al [65][d]	Case-control	**Subjects** Mixed sporting population/ballet dancers with hip pain last 3 months[ef] **Controls** Mixed sporting population/ballet dancers without hip pain[ef]	**Subjects** NR (25) **Controls** NR (107)	**Subjects** Age[ae]: 27.9(4.6) Age[af]: 29 (5) Sex[ef]: 18 (72%) F/7 (28%) M **Controls** Age[ae]: 25.4 (4.7) Age[af]: 28.3 (5.6) Sex[ef]: 54 (50%) F/53 (50%) M	3-T MRI	**Subjects** Labral tear: 5/25 **Controls** Labral tear: 48/107

Table 3 *(continued)*

Author	Study design	Study population	Number of participants (hips)	Demographics	Imaging modality	Findings (Intra-articular hip pathology/osteoarthritis)
Mayes et al [52][d]	Case-control	**Subjects** Mixed sporting population/ballet dancers with hip pain last 3 months[ef] **Controls** Mixed sporting population/ballet dancers without hip pain[ef]	**Subjects** NR (25) **Controls** NR (107)	**Subjects** Age[ae]: 27.9(4.6) Age[af]: 29 (5) Sex[ef]: 18 (72%) F/7 (28%) M **Controls** Age[ae]: 25.4 (4.7) Age[af]: 28.3 (5.6) Sex[ef]: 54 (50%) F/53 (50%) M	3-T MRI	**Subjects** Ligamentum teres tear: 11/25 **Controls** Ligamentum teres tear: 22/107
Mayes et al [66][d]	Case-control	**Subjects** Mixed sporting population/ballet dancers with hip pain last 3 months[ef] **Controls** Mixed sporting population/ballet dancers without hip pain[ef]	**Subjects** NR (25) **Controls** NR (107)	**Subjects** Age[ae]: 27.9(4.6) Age[af]: 29 (5) Sex[ef]: 18 (72%) F/7 (28%) M **Controls** Age[ae]: 25.4 (4.7) Age[af]: 28.3 (5.6) Sex[ef]: 54 (50%) F/53 (50%) M	3-T MRI	**Subjects** Cartilage defect: 10/25 **Controls** Cartilage defect: 38/107

F female, *M* male, *MM* millimeters, *NR* not reported, *MRI* magnetic resonance imaging, ≥ greater than or equal to, ≤ less than or equal to;
[a] mean (standard deviation)
[b] range
[c] mean (range)
[d] author provided additional results not presented in original article
[e] male dancers and male mixed athletes
[f] female dancers and female mixed athletes

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3.2. Risk of bias within studies

Agreement between the two authors occurred on 91% of occasions (182/200 items). A κ-value of 0.82 (95% 0.74 to 0.90) was determined, indicating excellent agreement between authors [36]. In total, five of the 20 (25%) of the included articles were considered HR, 12 were considered MR and 3 LR. In summary, all of the 20 included articles had HR for items 1 and 2, outlining that no study included participants that were considered representative of a wider sporting population and that participants were often selected by convenience. Thirteen of the studies (65%) did not report the reliability of the method used to determine the presence of either hip intra-articular pathology or OA [48, 55, 63, 49, 50, 57, 56, 51, 61, 62, 58, 53, 60]. Finally, 10 (50%) of the studies reported the prevalence at a per hip level and not a per person level [54, 67, 49, 50, 56, 64, 51, 62, 53, 60] (Table 4).

3.3. Heterogeneity of included studies

Heterogeneity was considered low for pooled studies investigating the prevalence of labral tears in symptomatic athletes, and high in the studies of asymptomatic athletes. For prevalence of cartilage defects, only studies reporting in asymptomatic athletes were combined in meta-analysis. These studies displayed moderate levels of heterogeneity (I^2 43%). When categorized by mechanical hip load, the heterogeneity observed in pooled data evaluating the prevalence of labral tears and cartilage defects ranged from low (I^2 0%) to high (I^2 96%).

3.4. Deviation from prospero

The categorization of sports as either linear or multi-planar was included in the original protocol submitted to Prospero. During the review process a previously used method to categorize based on the mechanical load placed on the hip joint by the particular sport was identified [38, 39]. To improve the generalizability of the reviews findings this method used.

3.5. Study characteristics

In total, the prevalence of intra-articular hip pathologies and OA was evaluated in 1335 participants and 2352 hips. Twelve studies (315 participants, 637 hips) reported the prevalence of intra-articular hip pathologies in asymptomatic athletes using MRI [48, 55-57, 65, 52, 66, 60, 53, 59, 58, 67]. Three studies (627 participants, 1237 hips) investigated the prevalence of hip OA in asymptomatic athletes using X-ray [54, 49, 60]. Four studies (40 hips) [65, 52, 66, 67] investigated the prevalence of intra-articular hip pathologies in symptomatic athletes with MRI. One study (18 participants, 18 hips) utilized MRA to determine the presence of intra-articular hip pathologies in symptomatic athletes [61]. One study investigated intra-articular pathology in a combined population of ballet dancers with and without pain [50]. Three studies evaluated the prevalence of OA in symptomatic and asymptomatic athletes [63, 51, 64] and one study reported OA prevalence in only symptomatic athletes [62]. No studies evaluated symptomatic or asymptomatic athletes with CT. In total, 375 (28%) of the athletes were women and 960 were men. The included studies investigated different sports including American football (n=174) [62, 49], soccer (n=100) [57, 53], ice hockey (n=179) [64, 58, 59, 48], ballet (n=110) [65, 52, 66, 50, 63], rugby (n=20) [55], golf (n=55) [67], skiing (n=27) [58], track and field (n=22) [56], capoeira (n=24) [51] and mixed sports (n=624) [65, 52, 66, 61, 54, 60]. The level of play reported in the included studies included professional [63, 65, 52, 66, 50, 59, 64, 61], elite [56, 48, 67, 55, 54, 49, 62, 59], semi-professional [57], amateur or recreational [57, 65, 52, 66, 61] and youth/high school level [58, 53]. Athletes participated in cutting (n=6) [57, 65, 52, 66, 58, 53], flexibility (n=6) [63, 50, 51, 65, 52, 66], impingement (n=4) [48, 58, 59, 64], asymmetrical (n=5) [56, 67, 65, 52, 66] and endurance sports (n=1) [56] (Table 5).

Table 4 Included studies risk of bias

Author	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Overall risk of bias for study
	External validity				**Internal validity**						
Anderson et al [54]	*HR*	*HR*	*HR*	*LR*	*LR*	*LR*	*LR*	*LR*	*LR*	*HR*	***MR***
Ayeni et al [48]	*HR*	*HR*	*HR*	*LR*	*LR*	*HR*	*HR*	*LR*	*LR*	*LR*	***MR***
Dickenson et al [67]	*HR*	*HR*	*HR*	*LR*	*LR*	*HR*	*LR*	*LR*	*LR*	*HR*	***MR***
Farrell et al [55]	*HR*	*HR*	*HR*	*LR*	*LR*	*HR*	*HR*	*LR*	*LR*	*LR*	***MR***
Harris et al [63]	*HR*	*HR*	*HR*	*LR*	*LR*	*LR*	*HR*	*LR*	*LR*	*LR*	***MR***
Kapron et al [49]	*HR*	*HR*	*HR*	*HR*	*LR*	*LR*	*HR*	*LR*	*LR*	*HR*	***HR***
Kolo et al [50]	*HR*	*HR*	*HR*	*LR*	*LR*	*LR*	*HR*	*LR*	*LR*	*HR*	***MR***
Lahner et al [56]	*HR*	*HR*	*HR*	*LR*	*LR*	*HR*	*HR*	*LR*	*LR*	*LR*	***MR***
Lahner et al [57]	*HR*	*HR*	*HR*	*LR*	*LR*	*HR*	*HR*	*LR*	*LR*	*HR*	***HR***
Larson et al [64]	*HR*	*HR*	*HR*	*LR*	*LR*	*HR*	*LR*	*LR*	*LR*	*HR*	***MR***
Mariconda et al [51]	*HR*	*HR*	*HR*	*LR*	*LR*	*LR*	*HR*	*LR*	*LR*	*HR*	***MR***
Mayes et al [65]	*HR*	*HR*	*HR*	*LR*	*LR*	*LR*	*LR*	*LR*	*LR*	*LR*	***LR***
Mayes et al [52]	*HR*	*HR*	*HR*	*LR*	*LR*	*LR*	*LR*	*LR*	*LR*	*LR*	***LR***
Mayes et al [66]	*HR*	*HR*	*HR*	*LR*	*LR*	*LR*	*LR*	*LR*	*LR*	*LR*	***LR***
Narvani et al [61]	*HR*	*HR*	*HR*	*LR*	*LR*	*HR*	*HR*	*LR*	*LR*	*LR*	***MR***
Nepple et al [62]	*HR*	*HR*	*HR*	*LR*	*LR*	*LR*	*HR*	*LR*	*LR*	*HR*	***MR***
Philippon et al [58]	*HR*	*HR*	*HR*	*LR*	*LR*	*HR*	*HR*	*LR*	*LR*	*LR*	***MR***
Silvis et al [59]	*HR*	*HR*	*HR*	*HR*	*LR*	*HR*	*HR*	*LR*	*LR*	*LR*	***HR***
Yepez et al [53]	*HR*	*HR*	*HR*	*LR*	*LR*	*HR*	*HR*	*LR*	*LR*	*HR*	***HR***
Yuan et al [60]	*HR*	*HR*	*HR*	*HR*	*LR*	*HR*	*HR*	*HR*	*LR*	*HR*	***HR***
Overall risk of bias for item	*20 HR* *0 LR*	*20 HR* *0 LR*	*20 HR* *0 LR*	*3 HR* *17 LR*	*0 HR* *20 LR*	*11 HR* *9 LR*	*14 HR* *6 LR*	*1 HR* *19 LR*	*0 HR* *20 LR*	*10 HR* *10 LR*	

HR high risk of bias, MR moderate risk of bias, LR low risk of bias

Risk of bias items.

1. **Was the study's target population a close representation of the national sporting population in relation to relevant variables, e.g. age, sex, competition level?**
2. **Was the sample frame a true or close representation of the target population?**
3. **Was some form of random selection used to select the sample, OR, was a census taken?**
4. **Was the likelihood of non-response bias minimal?**
5. **Were data collected directly from the subjects (as opposed to a proxy)?**
6. **Was an acceptable case definition used in the study?**
7. **Was the study instrument that measured the parameter of interest (e.g. prevalence of low back pain) shown to have reliability and validity (if necessary)**
8. **Was the same mode of data collection used for all subjects?**
9. **Was the length of the shortest prevalence period for the parameter of interest appropriate?**
10. **Were the numerator(s) and denominator(s) for the parameter of interest appropriate?**

Table 5 Mechanical load placed on hip joint by sport	
Athlete sports category [39]	**Study**
Cutting *(soccer, basketball, lacrosse, field hockey, downhill skiing, snowboarding)*	Lahner et al [57] Mayes et al [65, 52, 66] Philippon et al [58] Yepez et al [53]
Flexibility *(dancing, gymnastics, yoga, cheerleading, figure skating, synchronized swimming, martial arts, rock climbing)*	Harris et al [63] Kolo et al [50] Mariconda et al [51] Mayes et al [65, 52, 66]
Contact *(football, rugby, wrestling)*	Farrell et al [55] Kapron et al [49] Nepple et al [62]
Impingement *(ice hockey, crew/rowing, baseball catching, water polo, equestrian polo, breaststroke swimming, weight lifting, bobsled, CrossFit, horseback riding)*	Ayeni et al [48] Philippon et al [58] Silvis et al [59] Larson et al [64]
Asymmetric/overhead *(baseball, softball, tennis, golf, volleyball, athletic field events, fencing, badminton, cricket, squash, racquetball, handball)*	Lahner et al [56] Dickenson et al [67] Mayes et al [65, 52, 66]
Endurance *(track, cross-country, other running, cycling, swimming (not breaststroke), cross-country skiing, biathlon, aerobics)*	Lahner et al [56]
Not reported	Anderson et al [54] Yuan et al [60] Narvani et al [61]

3.6. Prevalence of labral tears

Twelve studies (484 participants, 754 hips) reported the prevalence of labral tears [48, 55, 50, 56, 57, 65, 61, 58, 59, 53, 60, 67]. Five studies reported prevalence per person [61, 48, 57-59], with four studies [50, 53, 56, 67] reporting prevalence per hip and in the remaining three studies [60, 65, 55] prevalence was reported per person and per hip.

3.6.1. Symptomatic participants

One study *(MR)* [61] reported a labral tear prevalence of 22% per person, while 2 studies *(1 LR and 1 MR)* [67, 65] reported labral tear prevalence per hip in symptomatic athletes. There was moderate evidence of a labral tear prevalence of 20% (95%CI 10% to 35%) per hip from two studies *(1 LR and 1 MR)* [67, 65] (Figure 3).

3.6.2. Asymptomatic participants

Five studies *(4 MR and 1 HR)* [48, 57, 55, 58, 59] reported the prevalence of labral tears per person in asymptomatic athletes. Limited evidence from 4 studies *(4 MR) [48, 55, 58, 57]* identified a labral tear prevalence of 54% (95%CI 22% to 83%) per person (Figure 2). The remaining study *(HR)* [59] reported a labral tear prevalence of 56% in ice hockey players competing at professional and collegiate level respectively.

Five studies *(3 HR, 1 MR and 1 LR)* [53, 65, 67, 60, 56] evaluated labral tear prevalence per hip in athletes using MRI. Moderate evidence from two studies [67, 65] identified a labral tear prevalence of 33% (95%CI 16% to 57%) per hip in asymptomatic athletes (Figure 3). The three HR studies [60, 53, 56] not included in meta-analysis reported labral tear prevalence per hip in high school athletes (50%) [60], Brazilian youth soccer players (9%) [53] and track and field athletes (5%) [56].

3.6.3. Mixed participants

One study *(MR)* [50] evaluated symptomatic and asymptomatic ballet dancers and reported a labral tear prevalence per hip of 47%.

3.6.4. Mechanical hip load of the various sports

3.6.4.1. Symptomatic participants

One study *(1 LR)* [65] reported a labral tear prevalence of 33% in symptomatic athletes participating in flexibility sports. Two studies *(1 MR and 1 LR)* [67, 65] reported on the prevalence of labral tears in symptomatic athletes participating in asymmetrical sports. One study (MR) [67] of golfers identified a labral tear prevalence of 20%. The remaining study (*LR)* [65] included less than five symptomatic hips and was not included in analysis. In symptomatic basketball players (cutting sport) a labral tear prevalence of 0% was identified *(LR)* [65]. No studies investigated the prevalence of labral tears in symptomatic athletes participating in contact, endurance or impingement sports.

3.6.4.2. Asymptomatic participants

One study *(MR)* [55] reported a labral tear prevalence of 85% in athletes participating in a contact sport. Three studies *(1 HR and 2 MR)* reported the prevalence of labral tears in impingement sports. Two studies *(2 MR)* [48, 58] found moderate evidence of a labral tear prevalence of 67% (95%CI 56% to 76%) in asymptomatic ice hockey players (Figure 4). The remaining study *(HR)* [59] identified labral tears in 56% of ice hockey players without pain. One study *(LR)* [65] reported a labral tear prevalence of 43% in asymptomatic ballet dancers (flexibility sport). Limited evidence from two studies *(2 MR)* [57, 58] found a labral tear prevalence of 33% (95%CI 2% to 92%) per person in athletes participating in cutting sports (Figure 4). The remaining two studies *(1 HR and 1 LR)* [53, 65] investigating asymptomatic athletes reported a labral tear prevalence per hip of 9% and 45% respectively. Three studies *(1 HR, 1 MR and 1 LR)* [65, 67, 56] evaluated athletes competing in sports that place asymmetrical loads on the hip joint. Moderate evidence from two studies *(1 MR and 1 LR)* [65, 67] identified a labral tear prevalence of 33% (95%CI 13% to 61%) in asymptomatic athletes (Figure 4). The remaining study (HR) [56] in track and field athletes did not provide sufficient information to determine the labral tear prevalence in athletes performing asymmetrical sports, nor endurance athletes.

3.6.4.3. Mixed participants

One study *(MR)* [50] reported a labral tear prevalence of 47% in ballet dancers (flexibility sport) with and without pain.

3.7. Prevalence of cartilage defects

Eleven studies (466 participants, 736 hips) evaluated the prevalence of cartilage defects [48, 55, 50, 56, 57, 66, 58, 59, 53, 60, 67]. In total, five studies analyzed prevalence per person [48, 55, 57-59] and five studies reported prevalence per hip [50, 56, 53, 67, 60]. Finally, cartilage defect prevalence was reported per person and per hip in one study [66].

3.7.1. Symptomatic participants

Cartilage defect prevalence was not reported per person but reported per hip by two studies *(2 MR and 1 LR)* [66, 67] in symptomatic athletes. Acetabular (27%) and femoral cartilage defects (7%) were reported independently in golfers *(MR)* [67], while hip cartilage defects were reported in ballet dancers and mixed sports athletes (40%) *(LR)* [66].

3.7.2. Asymptomatic participants

Five studies *(1 HR and 4 MR)* [59, 55, 58, 57, 48] reported cartilage defect prevalence per person in asymptomatic athletes. Moderate evidence from 3 studies *(3 MR)* [55, 57, 58] identified a cartilage defect prevalence of 10% (95%CI 5 to 19%) (Figure 5). The two remaining studies *(1 HR and 1 MR)* [48, 59] reported acetabular (0%), femoral (10%) and a combined cartilage defect prevalence of 18% in ice hockey players.

Five studies (*3 HR, 1 MR and 1 LR)* [60, 53, 66, 67, 56] evaluated cartilage defect prevalence per hip. One study *(LR)* [66] reported a cartilage defect prevalence of 36% in professional ballet dancers and mixed sport athletes. Two studies *(2 HR)* [53, 60] reported on athletes competing in high school sport (4%) and youth soccer players (3%). The remaining two studies *(1 HR and 1 MR)* [56, 67] evaluated acetabular and femoral cartilage defects independently in elite track and field athletes [56] (2% and 2%) and asymptomatic golfers [67] (6% and 3%) respectively.

3.7.3. Mixed participants

One study *(MR)* [50] reported a cartilage defect prevalence of 49% in ballet dancers with and without pain.

3.7.4. Mechanical hip load of the various sports

3.7.4.1. Symptomatic participants

One study (*1 LR) [66]* reported a cartilage defect prevalence of 53% in symptomatic athletes participating in a flexibility sport. Two studies *(1 MR and 1 LR)* [67, 65] evaluated the prevalence of cartilage defects in sports that cause asymmetrical hip loading. One study (MR) [67] in symptomatic golfers reported the prevalence of cartilage defects on the acetabulum (27%) and femur (7%) separately. The final study (*LR)* [65] included less than five symptomatic hips and was not included in the final analysis. One study *(LR) [66]* reported a cartilage defect prevalence of 17% per hip in basketball athletes (cutting sport) with hip pain. None of the included studies reported the prevalence of cartilage defects in symptomatic athletes participating in contact, impingement or endurance sports.

3.7.4.2. Asymptomatic participants

Three studies *(1 HR, 1 MR and 1 LR)*[66, 67, 56] reported the prevalence of cartilage defects in athletes participating in sports that place an asymmetrical load on the hip joint. One study *(LR) [66]* reported a cartilage defect prevalence per hip of 50% in tennis players without pain. One *(MR) [67]* of the remaining two studies evaluated acetabular (6%) and femoral cartilage defects (3%) independently in golfers without hip pain. The remaining study *(HR)* [56] was not included in analysis as it combined information on athletes performing asymmetrical and endurance sports. One study *(LR)* [66] in ballet dancers (flexibility sport) reported a cartilage defect prevalence of 33%. In contact athletes, one study *(MR)* [55] identified a cartilage defect prevalence of 20%. In asymptomatic cutting athletes, moderate evidence from two studies *(2 MR)* [57, 58] identified a cartilage prevalence of 5.8% (95CI 2% to 15%) (Figure 6). Two additional studies *(1 HR and 1 LR)* [53, 66] reported a cartilage defect prevalence per hip in asymptomatic cutting athletes of 34% (basketball players) and 3% (youth soccer players). Three studies *(1 HR and 2 MR)* [48, 58, 59] evaluated the prevalence of cartilage defects in athletes participating in impingement sports (ice hockey players). Two of the three studies *(1HR and 1 MR)*[58, 59] identified a cartilage defect prevalence of 8% and 18% respectively. The remaining study reported acetabular (0%) and femoral cartilage defects (10%) independently. One study *(HR)* [56] reported the prevalence of cartilage defects in a combined population of endurance and asymmetrical/overhead athletes which resulted in the study not being included in analysis.

3.7.4.3. Mixed participants

One study *(MR)* [50] found a cartilage defect prevalence of 49% per hip in a population of ballet dancers (flexibility sport) with and without pain.

3.8. Prevalence of hip osteoarthritis

Seven studies (877 participants, 1646 hips) reported the prevalence of hip OA [54, 49, 63, 64, 51, 62, 60]. Five studies (804 participants, 1504 hips) reported prevalence per hip [54, 49, 64, 51, 62], with two studies reporting hip OA prevalence per person and per hip [60, 63].

3.8.1. Symptomatic participants

One study *(MR)*[62] reported a prevalence of hip OA per hip in symptomatic athletes. A hip OA (Tonnis grade 2 or greater/JSW of 2.0mm or less) prevalence of 2% was reported in NFL athletes attending the NFL scouting combine with a history of pain or injury around the hip [62].

3.8.2. Asymptomatic participants

Three studies *(2 HR and 1 MR)* evaluated asymptomatic athletes for hip OA using X-ray. One study *(HR)* [60] reported hip OA prevalence per person in high school athletes (0%). Two studies *(1 HR and 1 MR)* [54, 49] reported early hip OA (Tonnis grade 1) and hip OA per hip. In a group of mixed senior athletes [54] the prevalence of early hip OA and hip OA was 32% and 17% respectively. The remaining study [49] reported a prevalence of early hip OA of 16%, with no collegiate NFL players having hip OA.

3.8.3. Mixed participants

Three studies *(3 MR)* reported early hip OA and hip OA prevalence in athletes with and without pain. One study [63] reported prevalence per person and per hip in professional ballet dancers. Hip OA was not found in any ballet dancer using Tonnis grade and mean joint space. However, early hip OA were present in 13% of ballet dancers hips [63]. Two studies (*2 MR)* [64, 51] reported hip OA per hip. One study [51] evaluating capoeira players reported hip OA (6%) and early hip OA (19%) using Tonnis grade, with the remaining study [64] reporting a mean minimum joint space of 4.1mm in ice hockey players.

3.9. Other pathologies

3.9.1. Symptomatic participants

3.9.1.1. Bone marrow lesions

One study *(MR)* [67] identified the presence of acetabular (20%) and femoral head BML (40%) in golfers with hip pain.

3.9.1.2. Herniation pits

One study *(1 MR)* [67] evaluated the prevalence of herniation pits in golfers with hip pain (27%).

3.9.1.3. Hip joint effusion

One study *(MR)* [67] reported a prevalence of hip joint effusion per hip of 7% in golfers with hip pain

3.9.1.4. Labral degeneration

One study [67] reported a prevalence of labral degeneration per hip of 20% in golfers with hip pain.

3.9.1.5. Ligamentum teres tears

One study *(LR)* [52] reported the prevalence of ligamentum teres tears per hip (44%) in symptomatic ballet dancers and mixed athletes.

3.9.2. Asymptomatic participants

3.9.2.1. Bone marrow lesions

Two studies *(1 HR and 1 MR)* [53, 67] reported the prevalence of BML per hip in asymptomatic athletes. One study [53] evaluated youth soccer players (21%), with the remaining study [67] reporting acetabular (11%) and femoral BML (11%) independently in asymptomatic golfers.

3.9.2.2. Herniation pits

Four studies *(2 HR and 2 MR)* [67, 53, 48, 56] evaluated the prevalence of herniation pits in asymptomatic athletes. One study *(MR)* [48] reported a herniation pit prevalence per person in ice hockey athletes of 10%. The remaining three studies *(2 HR and 1 MR)* [56, 53, 67] reported prevalence per hip in track and field athletes (7%), youth soccer players (4%) and golfers (9%).

3.9.2.3. Hip joint effusion

Two studies *(1 HR and 1 MR)* [67, 59] identified the prevalence hip joint effusion in asymptomatic athletes. One study *(MR)* [67]reported a prevalence of 8% in asymptomatic golfers. The remaining study *(HR)* [59] in ice hockey players identified a prevalence of 0%.

3.9.2.4. Labral degeneration

Two studies *(1 HR and 1 MR)* [67, 53] reported a labral degeneration prevalence of 2% and 22% in asymptomatic youth soccer players and golfers respectively.

3.9.2.5. Ligamentum teres tears

One study *(LR)* [52] reported a prevalence of ligamentum teres tears per hip of 21% in a mixed population of athletes.

3.10. Other pathologies reported in less than two studies

Pathologies that were reported in less than one study of symptomatic and asymptomatic populations are presented in Online Resource 3.

4. DISCUSSION

This systematic review highlights that imaging defined intra-articular hip pathologies are observed in athletes with and without pain. Across the included studies, considerable heterogeneity existed in regard to the methods used to evaluate the presence of intra-articular hip pathologies. Moreover, athletes participated in a wide range of sports and competition levels resulting in limited comparability between the included studies. Hence, caution should be taken when comparing differences in prevalence of intra-articular pathologies between studies and in athletes with and without pain. In particular, we identified that labral tears on MRI are observed in up to 54% of athletes without pain and 22% of athletes with pain. Cartilage defects were identified in symptomatic (7% to 40%) and asymptomatic athletes (0% to 36%). Qualitative analysis identified that bone marrow lesions, herniation pits, labral degeneration, ligamentum teres tears and joint effusion appear to be prevalent in athletes with and without pain. Our review identified that features associated with early radiographic OA (Tonnis grade 1) appear more frequently than radiographic OA (Tonnis grade 2 or greater/JSW of 2.0mm or less) in athletes currently playing sport regardless of pain.

4.1. Review findings

Labral tears have long been considered a cause of hip and groin pain in athletes [68-70]. A combination of the dynamic movements performed in sport and the high prevalence of bony hip morphology, in particular cam morphology, is believed to place athletes at greater risk of labral tears. In athletes without pain, we identified moderate evidence of a labral tear prevalence per hip of 33%, while in athletes with pain, there was moderate evidence of a labral tear prevalence per hip of 20%. These findings provide further evidence of the complex relationship between labral tears and experience of pain [31, 71, 72, 27]. Furthermore, it appears that athletes do not have a higher prevalence of labral tears than non-athletic individuals, regardless of pain status [31, 22, 23]. Debate exists around the optimal management of labral tears [73-75]. It is proposed that the integrity of the labrum is important for joint function and maintenance of tissue homeostasis [73, 74]. Restoration of labral tissue integrity might be achieved with surgical approaches, and this may result in improved patient function and pain [73-75]. However, such approaches are supported by low levels of evidence [73-75], and may result in varied return to sport and/or performance rates in athletes[76]. Our findings highlight that up to one in every two asymptomatic athletes can be active in sport with a labral tear, ultimately questioning the clinical significance of labral tears in some athletes with pain. Moreover, it highlights the importance of considering “non-structural” factors in an athlete with hip and groin pain [77]. Future work should focus on gaining a greater understanding of the long-term implications for symptomatic and asymptomatic athletes with labral tears, in order to provide appropriate management of these athletes.

Cartilage defects were seen in symptomatic and asymptomatic athletes. The prevalence of cartilage defects in symptomatic athletes ranged from 7% to 40%, with three of the four studies reporting a prevalence greater than 25%. Our pooled data identified moderate evidence of a prevalence of 10% in asymptomatic athletes with a mean age of less than 25 years. In addition, five of remaining studies not included in the meta-analysis reported a cartilage defect prevalence of less than 10%. The high prevalence of cartilage defects seen in symptomatic athletes in this review is similar to that seen in older individuals with and without pain [71, 78], but lower than our previous review [31]. Injury to the articular cartilage affects joint homeostasis, in addition to biomechanical and neuromuscular function [79]. This alteration in joint function combined with athletic activity may accelerate hip joint degenerative change, which is known to occur more frequently in retired athletes [80, 33]. However, longitudinal studies confirming this causation are currently lacking and should be a focus of future work. Importantly, articular cartilage is deficient of neural and vascular supply rendering it unable to produce pain [81]. This understanding is reflected in the variable relationship seen between cartilage defects and pain [71, 72, 78, 82]. In relation to our findings, it is likely that the presence of cartilage defects in symptomatic athletes indicates the involvement of inflammatory mediators, subchondral bone and peri-articular tissues which are all capable of causing nociception [81]. This suggests that cartilage defects are likely to be a precursor to OA in susceptible individuals.

Our review highlights that OA is not commonly seen in athletes who are currently competing at an elite or professional level, even if they have hip and groin pain. This finding is of particular interest, as elite male athletes have a greater prevalence of OA [33] and likelihood of undergoing hip arthroplasty (Odds ratio = 2.5) after they have retired from sport compared to age matched controls [80]. The prevalence of OA in asymptomatic senior athletes appears similar to that of older non-athletic populations (17% vs 15%) [83, 54]. In addition, our review indicates that radiographic features associated with early OA are seen in younger athletes regardless of the presence or absence of pain [51, 63, 49]. Our findings highlight a discordant relationship between radiographic features associated with early OA and pain in athletes currently playing sport, which is consistent with previous work in older populations [84]. In the included studies, OA was measured using x-ray, whilst other pathologies were measured using MRI or MRA. Since radiographic measures are insensitive to early changes in articular cartilage integrity [85], our findings may underestimate the true disease prevalence in athletes. The use of imaging methods with greater sensitivity to early features of OA may be important for identifying athletes at risk of progression to OA.

Bone marrow lesions, herniation pits, labral degeneration, ligamentum teres tears and hip joint effusions were seen in symptomatic and asymptomatic athletes. These findings are congruent with our recent review [31]. Bone marrow lesions were reported in up to 40% of athletes with pain. This relationship between pain and BML has been demonstrated previously, albeit in older non-athletic populations [72, 71]. The prevalence of BML identified in this review is lower than our previous review [31]. However, BML are known to be seen more frequently in individuals with OA [71, 78, 86], which was seen in very few athletes included in this review. In relation to ligamentum teres tears, debate currently exists regarding its role in both joint stability and pain generation [87-91]. The only study that reported on the prevalence of ligamentum teres tears in ballet dancers and mixed sport athletes described a high prevalence in those with hip pain (44%) [52]. The high prevalence of ligamentum teres tears observed in athletes may reflect the demands placed on this ligament during sporting activity, particularly those sports requiring large ranges of hip motion. Hip joint effusion was present in athletes with and without pain. Hip joint effusion is often considered a surrogate marker of synovitis when evaluated by MRI without contrast [92]. However, optimal evaluation of synovitis requires contrast enhanced MRI [78, 92], which was not used in the two studies reporting hip joint effusion in our review. The prevalence rates identified appear similar to older populations with and without pain [72], but lower than individuals with radiographic OA or MRI defined cartilage defects [78, 93]. The association between pain, symptoms and effusion appears variable [72, 78] and requires greater understanding in athletic individuals to enable appropriate intervention.

Athletes competing in sports that place contact, impingement and flexibility loads on the hip joint appear to have a high prevalence of labral tears. In relation to cartilage defects, there appears less variation between sports when categorized by mechanical hip load. However, athletes performing flexibility, cutting and asymmetrical sports appear to have a high prevalence of cartilage defects. None of the included studies in our review reported the prevalence of labral tears in symptomatic athletes competing in impingement or contact sports. However, existing work not included in our review highlights that labral tears appear in similar rates in athletes with and without pain competing in impingement (67% vs 69%) [70, 48, 58] and contact sports (85% vs 89%) [94, 55]. In athletes participating in flexibility sports, labral tears (33% and 43%) and cartilage defects (53% and 33%) are commonly seen in symptomatic and asymptomatic athletes respectively. This review has highlighted the large variation of prevalence of labral tears and cartilage defects in athletes with and without pain, particularly when sports are categorized by mechanical load placed on the hip joint. As such, a combination of bony morphology, which is seen in a high percentage of athletes [22, 23, 95, 96] and specific hip load may be related to the development of specific intra-articular hip pathologies in athletes.

The diagnostic accuracy of the imaging techniques used to evaluate the presence of intra-articular pathology may have influenced the findings of this review. Magnetic resonance imaging without contrast has known limitations in relation to the identification of labral tears [97-99]. In particular, the moderate sensitivity and specificity of MRI with 1.5 and 3 tesla field strengths may result in the over and/or underestimation of the prevalence of labral tears. Since only one of the included studies used contrast enhanced MRI, the prevalence of labral tears reported in this review may have been under-estimated [98, 99, 97]. Similarly, the diagnostic accuracy of MRI without contrast for chondral defects has been shown to be variable across two reviews [100, 99]. We identified a higher prevalence of cartilage defects in athletes with pain compared to those without pain in studies using MRI without contrast. Five of the eleven studies used 3T MRI to evaluate cartilage defects [55, 58, 60, 59, 66]. The evaluation of cartilage defects with 3T MRI has shown superiority for the recognition of cartilage defects compared to lower field strength approaches [101, 102]. Importantly, six of the remaining 11 studies used 1.5T MRI which provides only limited sensitivity for the identification of cartilage defects [99, 100], this may have resulted in the under reporting of cartilage defects in some athletes included in our review.

Seventeen of the 20 included studies were considered to be moderate to high risk of bias. In particular, the included studies evaluated athletes that were selected by convenience or from specific competitions or organizations, and not deemed representative of wider athletic populations. Future work should focus on evaluating athletes from a larger range of clubs/organizations to improve generalizability. Of the included studies, only 6 (30%) reported the reliability or extent of agreement for the methods used to determine each of the imaging defined pathologies. This finding should be considered when interpreting the prevalence of intra-articular pathologies in this review. Our decision to exclude HR studies from our meta-analyses is in line with recent recommendations [43].

Moderate to high levels of heterogeneity were observed in most pooled analyses performed in this review, which may be related to the observed variability across studies in relation to sport and competition level. In addition, athlete sex, age, variation in the imaging type and specific imaging parameters should be considered. Interestingly, when data were pooled based on the mechanical hip load, two of the four pooled analyses demonstrated low levels of heterogeneity, indicating that intra-articular hip pathology prevalence may be influenced by the specific physical requirement of a sport.

4.2. Limitations

A number of limitations need to be considered when interpreting the findings of our review. First, a number of clinical entities may be associated with hip and groin pain in athletes [14, 16, 17, 15]. In this review, we evaluated athletes based on the subjective presence or absence of pain, rather than with more objective measures[14]. In light of this, many of the imaging defined intra-articular hip pathologies may indeed be incidental findings and unrelated to an athlete's hip and groin pain. Second, careful consideration is needed when generalizing the findings of our review. The included studies investigated athletes from a broad range of sports and competition levels, meaning that our findings can only be extrapolated to athletes competing at similar levels of competition and sport. The exclusion of studies investigating athletes with other hip conditions including slipped capital femoral epiphysis and Legg Calve Perthes Disease, which reduces the generalizability of our findings to athletes with such conditions. Importantly none of the athletes had their intra-articular pathologies or OA confirmed by open or arthroscopic hip surgery. The authors acknowledge that surgery is considered gold standard for the identification of intra-articular hip conditions. However, such an approach is not considered reasonable for athletes without hip pain. Finally, not including studies published in languages other than English may have resulted in some relevant studies not being included in this review.

4.3. Future directions/research priorities

Future work should establish a greater understanding of the prevalence of intra-articular hip pathologies in both symptomatic and asymptomatic athletes. To correctly select athletes for surgical interventions it would seem prudent that we understand of the relevance of imaging defined intra-articular hip pathologies in athletes with hip and groin pain. Future studies may choose to compare intra-articular findings between athletes of varying ages and/or competition levels, in order to understand the impact of age and level of play on the prevalence of findings in athletes. Using recommended clinical entities [14] to categorize an athlete with hip and groin pain may allow a greater understanding of prevalence of intra-articular hip conditions in athletes with specific clinical presentations. Finally, longitudinal studies are required to provide evidence supporting the relationship between intra-articular pathologies and OA development or progression in athletes [103].

5. CONCLUSION

Our systematic review identified that imaging defined intra-articular hip pathologies are seen in athletes with and without pain. In particular, labral tears were identified in one in every two athletes without pain, highlighting a complex, poorly-understood, and potentially arbitrary (at least in some cases) relationship between labral tears and pain in athletes. Cartilage defects are seen in athletes with and without pain. Importantly, OA was rarely seen in athletes regardless if they had pain or not. Bone marrow lesions, herniation pits, hip joint effusion, labral degeneration and ligamentum teres tears were observed in symptomatic and asymptomatic athletes. Two out of three asymptomatic athletes competing in impingement sports had imaging defined labral tears. In summary, our findings highlight the complex relationship between structural hip conditions identified with imaging and pain in athletes.

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Figure 1 Prisma flow chart

Figure 2 Prevalence and 95%CI of labral tears per person in asymptomatic athletes

Figure 3 Prevalence and 95%CI of labral tears per hip in symptomatic and asymptomatic athletes

Figure 4 Prevalence and 95%CI of labral tears per person in asymptomatic athletes in cutting, impingement and asymmetrical sports

Figure 5 Prevalence and 95%CI of cartilage defects per person in asymptomatic athletes

Figure 6 Prevalence and 95%CI of cartilage defects per person in asymptomatic athletes in cutting sports