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Treating Early Hip, Knee, and Ankle Joint Osteoarthritis in Professional and Elite Athletes – What Works? A Scoping Review

■ **OBJECTIVE:** To summarize the existing evidence regarding the effectiveness of interventions to manage early hip, knee, and ankle osteoarthritis in active elite or professional athletes.

■ **DESIGN:** Scoping review.

■ **DATA SOURCES:** Medline (PubMed), SPORTDiscus, ScienceDirect, and Epistomonikos.

■ **ELIGIBILITY CRITERIA:** Peer-reviewed publications from 2012 to 2023 in English, Dutch, or French that included active elite/professional athletes with osteoarthritis and/or cartilage injury to the hip, knee, and/or ankle joints and outcomes measured using validated tools.

■ **OUTCOME MEASURES:** Patient-reported outcome scores relating to function and return to sports.

■ **RESULTS:** Twenty-seven studies were included from 414 identified: two on exercise and rehabilitation, four on joint injections, and twenty-one on surgery. For the "Exercise and rehabilitation" category, the evidence was insufficient to recommend conventional training or whole-body vibration training for patellofemoral pain. For the "Joint injections" category, hip and knee hyaluronic acid injections appear safe and effective for improving symptoms, delaying hip joint degeneration and return to sport in 50% to 100% of athletes. Platelet-rich plasma was not as effective as hyaluronic acid in the knee joint. Strong evidence supported corticosteroids and/or local anaesthetic in relieving knee joint symptoms allowing short-term return to sport but hastening the development of knee osteoarthritis. For the "Surgery" category, there was insufficient evidence to support surgical interventions as effective interventions in the hip, knee, and ankle joints of athletic populations for managing early osteoarthritis and precursor pathology.

■ **CONCLUSION:** There was insufficient evidence to provide clear recommendations about which interventions are best for managing lower limb osteoarthritis in the elite or professional athlete.
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■ **KEY WORDS:** *active male footballer, ankle osteoarthritis, hip osteoarthritis, interventions, knee osteoarthritis*

The Union of European Football Associations (UEFA) found a significant loss of game-time due to musculoskeletal injuries from the 2000-2001 to 2018-2019 seasons.[17] Among active professional male soccer players in South Africa, Germany, and the United Kingdom, the most common injured region is the knee joint.[4,30,32] Sports-specific movements (as with soccer) result in excessive joint load, contributing to early joint degeneration and the development of osteoarthritis (OA) in retired soccer players earlier compared to the general population.[19] Rugby and soccer players who develop symptomatic hip, knee, and ankle OA after retirement[6,34,44,48] often require joint arthroplasty to improve their quality of life.[1,12,64] Effective interventions for hip, knee, and ankle early OA in active athletes may reduce the incidence of the development of OA that requires surgical intervention at a later stage.

Injuries and related surgeries of the hip,[18] knee,[66] and ankle[57] joints may trigger cartilage degeneration and early onset OA. A previous systematic review reported a 74% prevalence of premature hip and knee OA in active athletes compared to control groups of nonathletes.[38] Of these, 41% were involved in team sports soccer (21%), handball (11%), ice hockey (11%), American football (3%), and rugby (0.3%) whereas runners, dancers, and triathletes did not develop early OA compared to control groups. This may affect active athletes' ability to compete at a high level of performance. Participation may be impacted in the short, medium, or long term due to symptoms of OA. The subsequent pain, inflammation, and synovitis may require various interventions including oral medication, exercise and rehabilitation, joint injections, and surgery.

A cross-sectional analysis of the available literature by Bichsel et al,[4] concluded that there was a wide variance and strength of recommendations for the different interventions in managing hip and knee OA in the athletic population. The OPTIKNEE group later developed a consensus statement on optimizing knee health

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in this at-risk group[66] (the athletic population). The OPTIKNEE consensus details the burden and risk of knee OA after anterior cruciate ligament and meniscus injuries or repairs, and provides (1) evidence-based recommendations on the most appropriate rehabilitation to reduce the risk of knee OA and (2) preferred assessment tools for measuring function, strength, and patient-related outcome scores (PROMs). There are no consensus recommendations for managing the risk of hip and ankle OA in athletes.

Our scoping review aims to summarize the most effective interventions for managing hip, knee, or ankle OA or its precursors in athletes. This will help athletes and clinicians make informed choices about strategies to help athletes to continue competing and reduce the need for later surgery.

MATERIALS AND METHODS

Study Design

We conducted a scoping review of the literature and no consent was required. There is no previously registered protocol with the same objectives. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR)[60] checklist was used to improve reporting and transparency.

Key Terminology and Definitions

We used the following key terms and defined them for clarity for the purposes of this scoping review.

- Elite/professional athlete: an individual (any gender) aged between 18 and 70 years, who presently participated in any sport at a competitive level at an individual, club, provincial, national, or international level and may derive an income from such participation
- Osteoarthritis: clinical OA as defined by the National Institute for Health and Care Excellence (NICE) National Clinical Guideline (2014) with various degrees of joint pain and functional limitation
- Cartilage involvement: acute traumatic cartilage damage or cartilage degeneration from overuse or previous injury/surgery
- Management: management or treatment of hip, knee, and/or ankle joints with clinical OA or cartilage injury using the following interventions: exercise and rehabilitation, joint injections, or joint surgery.

Inclusion Criteria

We applied the following inclusion criteria:

- Peer-reviewed clinical research published in English, Dutch, or French language between 2012 and 2023.
- Active elite/professional athletes
- Any gender
- Aged between 18 and 70 years
- Any sport
- Participates competitively at an individual, club, provincial, national, or international level and may derive an income from such participation
- Diagnosed with OA via clinical examination and/or radiographs
- Cartilage involvement of the hip, knee, and/or ankle joints
- Management of OA and/or cartilage damage of the hip, knee, and/or ankle joints either using exercise and rehabilitation, joint injections, joint surgery, or a combination of these interventions
- Outcomes measured using validated PROMs for level of activity or function (eg, Tegner activity score and Knee injury and Osteoarthritis Outcome Score [KOOS]).

Data Sources and Search Strategy

We searched the SPORTDiscus, Medline (PubMed), ScienceDirect (by Elsevier), and Epistemonikos electronic databases due to their accessibility and size. Searches were conducted on June 27, 2023. Synonyms of keywords were combined with the Boolean expression "OR" while categories of keywords were combined using the Boolean expression "AND." Excluded categories used the Boolean expression "NOT." These expressions were used as allowed by each search engine. In PubMed, publication titles and abstracts ("tiab") were searched together with medical subject headings (MeSH):

- synonyms of the phrase "elite/professional athlete athlete" to identify the population under investigation;
- synonyms of the terms "osteoarthritis", "hip and/or knee and/or ankle osteoarthritis," and "cartilage" to identify OA in the population under investigation;
- synonyms of "surgery and/or injury and joints," "osteoarthritis and/or management and/or treatment," "joint injections and/or intra-articular injections," "PRP and/or platelet rich plasma injections," "prolotherapy," "hyaluronic acid," "corticosteroid and/or cortisone," and "exercise and/or rehabilitation";
- categories that included "osteoarthritis treatment/management" and "professional/elite athlete".

The specific search strategy for each database is outlined in **SUPPLEMENTAL FILE 1** (Database Search strategy).

Study Inclusion

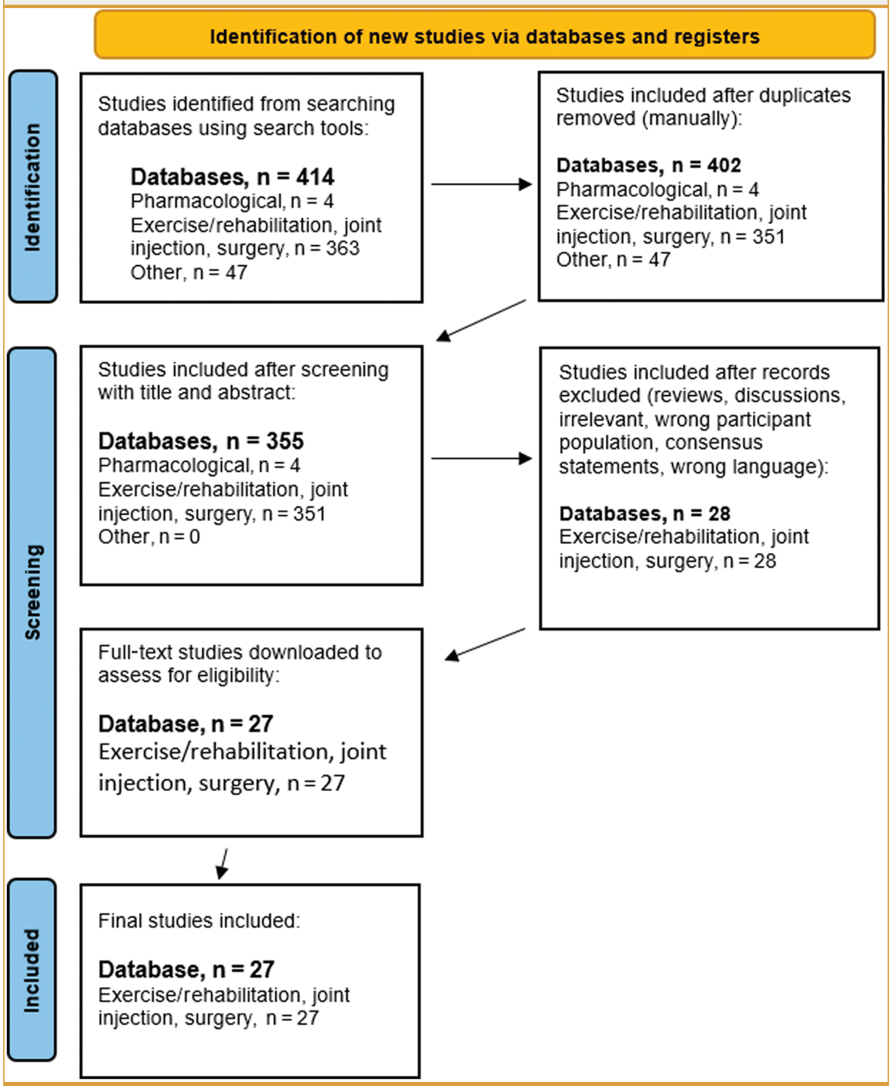
The search strategy was applied to each database by L.P. and S.d.B. independently. Results were compared, collated, and summarized. Duplicates were removed. Results were included if the title and abstract conformed to the inclusion criteria. Full texts of the included studies were downloaded and further confirmed to conform to the inclusion criteria. The university librarian was asked for assistance where full-text downloads could not be found. Where there were disagreements on including studies, this was resolved through consensus among all the authors.

Data Charting

Data charting was performed by L.P. and S.d.B. independently for each of the selected studies. We charted the following:

(a) first author and year of publication, (b) study design and level of evidence, (c) data characteristics (eg, the number of participants, mean age, gender, type of sport), (d) joints involved, (d) intervention, (e) PROMs, and (f) key findings. Any data charting disagreements were resolved between L.P. and S.d.B. after a discussion with the other authors.

FIGURE 1
Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) flow figure for the study selection process.



Methods of Critical Appraisal of Source of Evidence

We used the Cochrane Risk-of-Bias tool (ROB 2.0)[58] to evaluate randomized clinical trials (RCTs) using the "intention-to-treat" as the outcome measure. The Downs and Black tool[16] was used to evaluate the quality of nonrandomized studies. Downs and Black score ranges were given corresponding quality levels as previously reported: excellent (26-28), good (20-25), fair (15-19), and poor (≤14). We used the Oxford Center for Evidence Based Medicine (OCEBM) tool[27,28,42] to determine the level and quality of evidence and the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) system for judging the certainty of evidence.[53] We allocated a GRADE rating of high, moderate, low, or very low for each study, reflecting the degree of confidence in the effect estimate. Where there was more than 1 study in a category, the mathematical average was used to determine the category GRADE rating. This was done by a point system where high = 2, moderate = 1, low = 0, and very low = –1. The same was done for nonrandomized studies where required.

RESULTS

The search strategy yielded 414 records. Twelve duplicates were excluded, 374 studies were excluded (wrong language, reviews, discussions, wrong population, consensus statements), and 1 study was excluded as a full text could not be traced. Ultimately, a total of 27 studies were included (**FIGURE 1**). Three were RCTs, and the remainder were nonrandomized studies (11 case series studies, 3 prospective cohort studies, 3 retrospective cohort studies, 6 observational studies, and 1 secondary analysis of a prospective cohort study).

Data Charting and Categorization of Included Studies

A detailed data charting of included studies can be found in **SUPPLEMENTAL FILE 2**. A summarized version is in **TABLE 1**. Included studies were categorized according to interventions:

(1) Exercise and rehabilitation: 1 RCT and 1 nonrandomized study with both involving the knee joint in male and female athletes. There were no studies included that involved the hip or ankle joint.

(2) Joint injections: 1 RCT study involving the hip joint, and 3 nonrandomized studies involving the knee joint. All study participants were male athletes. There were no studies included that involved the ankle joint.

(3) Surgery: 1 RCT and 20 nonrandomized studies involving the hip (seven

TABLE 1
Summary of Demographics of Included Studies

	n Studies	Total n Cohort	Mean Age (years)	M/F (%)	Joint	Sport
Exercise and rehabilitation	2	234	29.2	70/30	Knee	Multiple sports, team/individual ball sports
Joint injections	4	1315	45.8	100/0	Hip and knee	Football, cycling, and tennis
Surgery	21	2459	39	58.7/41.3	Hip, knee, and ankle	Football, cycling, tennis, skiing, athletics, golf
Total	***27***	***4008***	38	76.2/23.8		

Abbreviations: F, female; M, male.

studies), knee (11 studies), and ankle (three studies) joints involving male and female athletes.

Each category was then divided into subgroups involving the (1) hip, (2) knee, and (3) ankle joints.

Critical Appraisal of Source of Evidence

We found the risk of bias among two of the RCTs (one in the joint injection and the surgery categories) low due to consistency and precision concerns from the small participant numbers and heterogeneity. The GRADE rating was low certainty for both studies. The remaining RCT in the exercise and rehabilitation category had a very high risk of bias due to its lack of consistency, directness, and precision and a high GRADE rating. All RCTs had publication bias due to the very specific participant population. This information can be found in **SUPPLEMENTAL FILE 3** (Grading and Risk of Bias for RCTs).

The quality of the nonrandomized studies was fair. Most had heterogeneity among the participants and outcomes, and lacked sufficient reporting and internal and external validity. They were considered as having publication bias due to the narrow research question being investigated. The exercise and rehabilitation category had a low-certainty GRADE rating, whereas the joint injections and surgery categories had moderate-certainty GRADE ratings (**SUPPLEMENTAL FILE 4** [Downs and Black non-RCTs tools] and **SUPPLEMENTAL FILE 5** [Grading of non-RCTs]).

In summary, the level and quality of evidence of all studies were low to moderate.

Analysis of Included Studies

Included studies consisted of mixed methods (quantitative and qualitative data). Due to the outcome heterogeneity of the components of the included studies and the fact that we performed a scoping review, we did not pool data. We summarized the types of interventions, outcome measures, and common outcome measures for each category and their subgroups and commented on them in **TABLE 2**.

Results of Outcome Measures of Included Studies for Each Category

All included studies in each category (exercise and rehabilitation, joint injections and surgery) reported significant improvement in most PROMS (between $P<.0001$ and $P<.05$) and return to sport (between 55% and 100%) depending on the intervention and level of participation in physical activity. These outcome measures are summarized in **TABLE 2** due to the variety of PROMs used. No studies reported effect sizes so we reported on the odds ratios where they were included as study results (**TABLE 3**).

Data Synthesis

For exercise and rehabilitation, there was insufficient evidence to recommend conventional training or whole-body vibration training (WBVT) for patellofemoral pain (PFP). These interventions may instead be considered as part of a specific treatment and rehabilitation program and not in isolation.

For joint injections, hip and knee hyaluronic acid injections appeared safe and effective for improving symptoms, delaying hip joint degeneration and allowing for return to sport. Platelet-rich plasma (PRP) injections did not appear as effective as hyaluronic acid injections for the knee joint. Although there was strong evidence supporting that corticosteroids and/or local anaesthetic may assist in knee joint–related symptoms to allow short-term return to sport, the injections hastened the development of knee OA. While the evidence did not clearly establish a superior effectiveness of 1 intervention over another, it suggested that the choice of the intervention must consider short-term goals of return to sport, and practitioners and athletes must be aware of the potential influence on joints in the short, medium, and long terms to make informed decisions.

For surgery, surgical interventions were not effective for managing hip, knee, and ankle OA or precursors. Even when athletes returned to sport at the same level of participation than prior to surgery, some procedures may put them at risk of worsening early OA. Athletes with surgically treated ankle joints compared to hip and knee joints had poorer return to sport outcomes, independent of the procedures performed.

DISCUSSION

We aimed to summarize the existing evidence regarding the effectiveness of interventions to manage

TABLE 2
Interventions and Outcome Measures

	Intervention	Outcome Measure	Common Outcome Measures Between Studies (n Studies) of Each Joint
Exercise and rehabilitation	CT, WBVT, ACLR, and conservatively managed ACL injuries	NPRS, KPS, number of leg presses, KOOS, clinical knee OA, and LSI	None
Joint injections	HA, PRP, corticosteroids, and local anaesthetic	HAS, HAGOS, HOAMS, VAS, KOOS, subjective and objective IKDC and Kellgren-Lawrence classification for hip and knee OA	**Hip studies** None **Knee studies** KOOS (2), VAS (2)
Surgery	ACLR, open mini direct surgical approach for hip pathology, arthroscopy for various types of hip pathologies and lateral ankle instability, THA, MF, OAT, MAT, ACI, meniscal repair, meniscectomy, DLO, AMIC	AOFAS, EQ, EQ-5D, FAOS, HAGOS, HAS, HHS, HOAMS, HOOS, HOOS-sport, HOS, HOS-SSS, HSAS, iHOT-12, IKDC, ICRS, KOOS, KPS, MOCART, NAHS, NPRS, SF-12, SF-26, SUSHI, UCLA, VAS, VR-12, WOMAC, Kellgren-Lawrence radiological classification for hip and knee OA, Lysohlm and Tegner activity scores, handicap, drive length, Marx scores, and Ahlback radiological classification for knee OA.	**Hip studies** HOOS (2), HHS (3), VAS (4) **Knee studies** Ahlback classification (2), Tegner activity score (8), Lysholm activity score (7), Kellgren-Lawrence classification (5), IKDC (6), KOOS (5), ICRS (2), UCLA (2). **Ankle studies** MOCART (2), AOFAS (2)

Abbreviations: ACI, autologous chondrocyte implantation; ACLR, surgical anterior cruciate ligament repair; AMIC, autologous matrix-induced chondrogenesis; AOFAS, American Orthopaedic Foot and Ankle Score; CT, conventional training; DLO, double-level osteotomy of the lower limb; EQ, European quality of life; EQ-5D, EuroQol - 5 Dimension; FAOS, foot and ankle outcome score; HA, hyalouronic acid; HAGOS, hip and groin outcome score; HAS, Heidelberg Activity Score; HHS, Harris Hip Score; HOAMS, hip osteoarthritis magnetic resonance imaging score; HOAMS, hip osteoarthritis magnetic resonance imaging scoring system; HOOS, hip disability and osteoarthritis outcome score; HOOS-sport, hip disability and osteoarthritis outcome score for sport; HOS, Hip Outcome Score; HOS-SSS, Hip Outcome Score Sports-Specific Subscale; HSAS, Hip Sports Activity Scale; ICRS, International Cartilage Repair Society IHOT-12, International Hip Outcome Tool; IKDC, International Knee Disease Committee; KOOS, Knee injury and Osteoarthritis Outcome Score; KPS, Kujala Patellofemoral Pain Score; LSI, Limb Symmetry Index; MAT, meniscal allograft transplant; MF, microfracturing; MOCART, magnetic resonance observation of cartilage repair tissue; NAHS, Non-Arthritic Hip Score; NPRS, numeric pain-rating scale; OAT, osteochondral allograft transplant; PRP, platelet-rich plasma; SF-12, 12-item Short Form Survey; SF-26, 26-item Short Form Survey; SUSHI, Super Simple Hip Score; THA, total hip arthroplasty; UCLA, University of California, Los Angeles activity score; VAS, visual analogue scale; VR-12, Veterans RAND 12-Item Health Survey; WBVT, whole-body vibration training; WOMAC, Western Ontario and McMasters Universities Arthritis Index.

early hip, knee, and ankle osteoarthritis in active elite/professional athletes. Ultimately, 27 studies with low to moderate quality were included. There was insufficient evidence to suggest specific recommendations in each of the categories of interventions (exercise and rehabilitation, joint injections and surgery) at this stage. More research in the form of improved level of evidence is needed in the athletic population to provide improved recommendations.

Exercise and Rehabilitation

Rehabilitation was the most common intervention in a sports-specific clinical setting after any injury or surgery.

According to the PFP Consensus statement, the consequence of persistent PFP is patellofemoral OA.[67] The presence of patellofemoral cartilage lesions after anterior cruciate ligament reconstruction (ACLR) was associated with poorer outcomes at 3 years.[14] A systematic review proposed exercise as the best management of PFP compared to other methods.[62] A previous RCT[11] found the combination of WBVT and exercise (stretching, strengthening, and proprioception focusing on hip, pelvis, knee, and ankle kinematics[10]) yielded the best results for improvement in knee extension and pain. However, previous studies did not particularly investigate PFP in the athletic population. We found that even though both WBVT and conventional training were effective interventions by improving pain and the number of leg presses (both $P<.001$)[54] in this small cohort ($n = 30$), the evidence was not strong enough to recommend it in isolation, but rather part of a tailored treatment and rehabilitation plan to treat the primary cause and not just PFP symptoms.

We agree with the recent OPTIKNEE[66] consensus statements to use exercise for strength, flexibility, and proprioception[10] in managing and preventing posttraumatic knee OA, to delay OA development and progression, and to improve OA symptoms. The included study that concluded that quadriceps strength and Limb Symmetry Index (LSI) are important risk factors for the development of clinical knee OA after ACLR (4% odds of developing knee OA if there is a 1% LSI deficit)[2] may agree with aspects of research involving strength[10] but the clinical relevance of these odds after 5 years postoperatively has not been determined in a strong manner as the clinical knee OA diagnosis was made using the Luyten criteria (an interpretation of KOOS) and is not a widely accepted criterion for the diagnosis of OA.

With only two studies included in our scoping review that only involved the knee joint, there is a need for more research

TABLE 3
Key Findings and Conclusions of Included Studies

Authors and Year of Publication	Study Design (Level of Evidence)	Key Findings and Conclusion
Exercise and rehabilitation		
Shadloo et al, 2021[54]	RCT (I)	Significant pain intensity ↓ (NPRS $P<.001$), pain ↓ (KPS $P<.001$) & an ↑ in the n of leg presses ($P<.001$). WBVT & CT improved PFP.
Arhos et al, 2022[2]	Secondary analysis (III)	LSI → with ↓ odds of clinical knee OA (OR = 0.99; 95% CI: 0.93, 0.99). ↑ LSI → ↓ odds of clinical knee OA.
Joint injections		
Rando et al, 2021[51]	Retro. Cohort (III)	HAS & HAGOS ↑ ($P<.05$). HOAMS - 92% ↔; ↓ (4%). IA HA for hip OA ↓ further degeneration of cartilage & subchondral bone injury.
Tamburrino et al, 2016[59]	Prosp. Cohort (II)	VAS ↑ at 1, 3 & 6 months ($P<.05$). KOOS ↑ ($P<.05$). IA knee HA - ↓ walking & resting pain in professional footballers with chondral defects.
Papalia et al, 2016[45]	RCT (I)	HA & PRP groups - ↑ IKDC, KOOS & VAS at 3 ($P = .000$ ↔ $P = .002$) & 6 months ($P = .006$ ↔ $P = .043$). HA & PRP improve OA symptoms.
Fernandes et al, 2020[20]	Cross-sectional (III)	7.5 KIA → 44.5% of active player (CS = 70.6%; LA = 4.8%; COM = 16.37%). RKOA → 64%. KIA ↔ KP (OR = 1.81; 95% CI: 1.40, 2.34) & TKR (OR = 2.21; 95% CI: 1.43,3.42). Significant relationship ↔ n KIA injections ↔ KP & TKR ($P<.001$). KIA injections of CS & LA in active athletes may be → KP & TKR.
Surgery		
Hip		
Cohen et al, 2012[9]	Case series (IV)	↑ SF-36, WOMAC, HHS and general & activity SUSHI ($P<.001$↔ $P = .048$). 55% RTS. Safe alternatively surgical approach for FAI.
O'Reilly et al, 2022[41]	Case series (IV)	↑ PROMs ($P<.001$). ↑ HHS males (88%) > females (70.79%). 81.8% RTS. ↑ outcomes for RTS in males > than females after arthroscopy for FAI.
Larson et al, 2020[33]	Case series (IV)	↑ PROMs improved (all $P<.01$). Improved radiographic OA (all $P<.001$). 63% RTS. RTS & improved PROMs 3 years after hip arthroscopy.
Owens et al, 2022[43]	Retro. Obs. (III)	↑ PROMs (all $P<.001$). 90% RTS. Arthroscopic surgery for athletes with FAI & labral pathology → favorable outcomes for RTS after 5 years.
Pioger et al, 2021[49]	Retro. Obs (III)	98.5% RTS → THA. ↑ playing time, handicap ↓ ($P = .012$), ↓ pain ($P<.001$). 32.8% ↑ driving length. RTS → improvement in VAS and performance.
Perets et al, 2017[46]	Case series (IV)	82.9% RTS. ↑ PROMs ($P<.0001$). Improvement & maintenance of sport participation at 2 years after arthroscopy for capsular plication.
Snaebjörnsson et al, 2021[55]	Case series (IV)	↑ PROMS ($P<.0001$). 11% → elite level, 30% → same level, 28% ↓ level of activity. Arthroscopy for FAI → ↓ RTS but ↑ PROMs.
Knee		
Gudas et al, 2012[23]	RCT (I)	↑ Tegner activity score ICRS, OAT & MF ($P<.001$). OAT ↑ > than MF ($P<.001$) at 3 & 10 years. Tegner activity score ↑ OAT (3 years – $P = .006$; 10 years – $P = .003$) & MF (3 years – $P<.001$; 10 years – $P = .03$). Tegner activity score > OAT than MF ($P = .028$). 75% OAT & 37% MF ↔ level of activity. OAT> MF for RTS.
Gobbi et al, 2013[21]	Retro. & Prosp. Cohort (III)	↑ PROMs → 2 years, ↓ 5 years & 15 years. 60% RTS → 2 years. 20% RTS → 15 years. -ρ → Tegner activity score & lesion size (r = 0.076-0.384). 40% → RKOA. MF - young athlete - √ short-term outcomes in small chondral lesions but ↓ - 2 & 5 years postoperatively. RKOA → older athletes → multiple large lesions.
Pestka et al, 2015[47]	Retro. Obs. (III)	40% ↔ sports. 48.9% ↓ & 10.8% ↑ intensity. ↓ Tegner activity score ($P<.001$). ↓ n sessions ($P = .0135$) and τ spent ($P = .0015$) doing sports. Males > Tegner activity scores than females ($P = .032$). 73.1% → lower-impact sports. Satisfactory return for daily activities but not RTS after ACI.
Chalmers et al, 2013[8]	Case series (IV)	77% RTS → 16.5 months..↑ KOOS, IKDC and Lysholm activity score ($P<.05$). Kellgren-Lawrence ↑ by one for n = 5. RTS to desired level after MAT
Marcacci et al, 2013[35]	Case series (IV)	92% RTS → 12 months. ↑ PROMs ($P = .0021$ ↔ $P = .0391$). RTS 36 months later after MAT.
Hiyama et al, 2018[25]	Prosp. Cohort (II)	After ACLR and meniscus surgery - non-contact groups PROMs ↑ ($P<.01$ ↔ $P = .03$) > than the fighting group. Contact group, ↑ PROMs → chronic subgroup ($P = .02$ ↔ $P = .03$). Non-contact group ↑ PROMs → chronic subgroup ($P<.01$). Fighting group ↑ PROMs → chronic subgroup ($P<.01$ ↔ $P = .03$). ↓ PROMs in fighting group ↔ contact & non-contact group. ↑ PROMs → chronic > acute repairs.
Hoffelner et al, 2012[26]	Case series (IV)	75% ↑ hop > uninjured limb. All participants RTS → 8 months. OA ↔ of the operated and un-operated knee (MRI $P = .64$; x-ray $P = 0.73$). Risk for OA after ACLR 10 years later ↔ operated knee & uninjured knee.
Van Yperen et al, 2018[63]	Retro. Cohort (II)	OA ↔ operative and non-operative groups 10 & 20 years after ACL injury (surgical or conservative management).

(Table continues on next page.)

TABLE 3
Key Findings and Conclusions of Included Studies (continued)

Authors and Year of Publication	Study Design (Level of Evidence)	Key Findings and Conclusion
Nakanyama et al, 2017[40]	Case series (IV)	↑ PROMs (P<.01) 1 year postoperatively. 80.4% RTS. Good outcomes after isolated meniscus repairs in athletes and no OA risk after 1 year.
Sonnery-Cottett et al, 2013[56]	Case series (IV)	RTS → 6-12 months. All → lateral compartment OA - Kellgren-Lawrence classification. Chondrolysis after meniscectomy → RKOA.
Caubere et al, 2021[7]	Retro. Obs. (III)	87.5% RTS → 6 months. ↑ UCLA and KOOS scores (P<.001). Rapid return to sport (6 months) with good outcomes.
Ankle		
Valderrebano et al, 2013[61]	Case series (IV)	↑ AOFAS & VAS (P<.01). MOCART → 85% → defect filling postoperatively. AMIC has good clinical and MRI results.
Keszeg et al, 2022[31]	Retro. Obs. (III)	95% RTS. 67% RTS → preinjury level. T RTS → 13.84 years. Good PROMs and outcomes for RTS after 13 years.
Bouveau et al, 2022[5]	Retro. Obs. (III)	55% RTS → 12 months ↔ or ↑ level. ↓ NPRS (P<.001) ↑ AOFAS scores (P<.001). Fair RTS → 12 months after arthroscopy for lateral ankle instability.

Abbreviations: ACI, autologous chondral implantation; ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament rupture; AMIC, autologous matrix-induced chondrogensis; AOFAS, American Orthopaedic Foot and Ankle Score; ASG, autologous spongiosa graft; BHD, bilateral hip dysplasia; CI, confidence interval; COM, combination; CS, corticosteroids; CT, conventional training; EQ, European quality of life; EQ-5D, EuroQol - 5 Dimension; FAI, femoroacetabular impingment; FAOS, foot and ankle outcome score; HA, hyalouronic acid; HAGOS, hip and groin outcome score; HAS, Heidelberg Activity Score; HHS, Harris Hip Score; HOAMS, hip osteoarthritis magnetic resonance imaging scoring system; HOOS, hip disability and osteoarthritis outcome score; HOOS-sport, hip disability and osteoarthritis outcome score for sport; HOS, Hip Outcome Score; HOS-SSS, Hip Outcome Score Sports-Specific Subscale ; HSAS, Hip Sports Activity Scale; iHOT-12, International Hip Outcome Tool; ICRS, International Cartilage Repair Society; IKDC, International Knee Disease Committee; KIA, knee intra-articular; KOOS, Knee injury and Osteoarthritis Outcome Score; KP, knee pain; KPS, Kujala Patellofemoral Pain Score; LA, local anaesthetic; LSI, Limb Symmetry Index; MAT, meniscal allograft transplant; MF, microfracture; MRI, magnetic resonance imaging; MOCART, magnetic resonance observation of cartilage repair tissue; n, number; NAHS, Non-Arthritic Hip Score; NPRS, numeric pain-rating scale; OA, osteoarthritis; OAT, osteochondral autologous transplant; OR, odds ratio; PFP, patellofemoral pain; PROM, patient-reported outcomes measures; Prosp. Cohort, prospective cohort; PRP, platelet-rich plasma; QOL, quality of life; Retro. Cohort, retrospective cohort study; RCT, randomized clinical trial; Retro. Obs., retrospective observational; RKOA, radiographic knee osteoarthritis; RTS, return to sport; SF-12, 12-item Short Form Survey; SF-26, 26-item Short Form Survey; SUSHI, Super Simple Hip Score; TKR, total knee replacement; THA, total hip arthroplasty; UCLA, University of California, Los Angeles activity score; VAS, visual analogue scale; VR-12, Veterans RAND 12-Item Health Survey; WBVT, whole-body vibration training; WOMAC, Western Ontario and McMasters Universities Arthritis Index; ↔, between; →, refers to; ↑, increase ↓, decrease.

exploring the efficacy of exercise and rehabilitation in the active elite/professional athlete with early hip, knee, or ankle OA. The recently launched supervised exercise therapy and patient education rehabilitation (SUPERknee) trial will compare SUPER with minimal intervention in young adults at risk of knee OA after ACLR.[15] The results of this trial will assist in developing stronger exercise and rehabilitation recommendations for the athletic population at risk of the development of knee OA.

Joint Injections

Joint injections are commonly performed in the sporting environment to treat acute, acute/chronic joint-related conditions. Various preparations are used,[52] which include corticosteroids, PRP, and hyaluronic acid.

Even though we found that joint injections of the hip and knee joints with hyaluronic acid was a more effective (earlier return to sport and degenerative protection in the hip) and a safe (no complications) intervention[45,51,59] compared to PRP, one of the included studies (a small cohort of 30) relating to hip OA, involved cyclists (non–load-bearing) and tennis players (load-bearing, short sprints ,and pivot shift movements in a small area). Hyaluronic acid in hip and knee joints may not be viable interventions due to (1) the availability of the product (different hyaluronic acid products were used in the studies), (2) the cost of the product, (3) the cost of the procedure,[50] and (4) number of injections. Recent systematic reviews of PRP use have negated its effects of improving healing after ACLR[37] and ankle pathology[29] and suggested a further review of protocols, PRP preparation, and research.[13]

Corticosteroids affect knee cartilage volume more than saline (between-group difference, −0.11 mm; 95% CI: −0.20, −0.03 mm).[36] There is a dose-response relationship between the number of intra-articular knee injections and knee pain/TKR at a later stage in an athlete's career and into retirement.[20] Hence, there should be a strong risk-benefit analysis made when considering corticosteroids/local anaesthetic or a combination, bearing in mind the short-term gain and medium- to long-term consequences.

More research is needed in using different types of injections for hip, knee, and ankle joints, especially among other sports (eg, rugby and athletics). This will assist physicians to consider the most effective substance, combination, and preparation (in the case of PRP), to allow for RTS for the athlete and development of early OA development. Of the 4 included studies, three involved football players and only male athletes. The effect of these substances on the cartilage of female athletes needs further investigation.

Surgery

Surgery is often required for treating joint-related pathology in athletes. Several different OA surgical intervention methods are used in managing precursor conditions or early OA.

Hip pain has multiple causes. In 94% of hip-related pain complaints, the prevalence of femoroacetabular impingement is 10% to 15%.[24] Hip-related surgical interventions (open surgery or arthroscopy) for femoroacetabular impingement and other hip pathology showed improvement in all PROMs and RTS.[9,33,41,43,46,49,55] However, most of the included studies were either retrospective cohort or case series studies with a weak level of evidence. We therefore concluded that the existing evidence was insufficient to recommend these interventions strongly.

Knee surgery showed efficacy depending on the procedures performed. Meniscal allograft transplant (MAT) allowed for symptomatic relief only and was not chondroprotective.[65] We found that in athletes undergoing osteochondral autologous transplant (OAT)[23] or MAT[8,35] procedures, return to sport was better than in those undergoing microfracture.[21] Those undergoing meniscal repair[40] and double-level osteotomy[7] procedures also returned to sport sooner. There was an increase in ACLR where nonsurgical treatment was appropriate.[39] After 20 years, even though OA occurs in the operated knee (12.8% of the time), only 1.1% required total knee replacement (TKR).[22]

We found that several years (10-20 years) after ACLR and return to sport, athletes had less OA compared to those with an ACL injury that was managed nonsurgically.[25,26,63] With surgery, various factors (surgeon experience, surgical technique, injury type, technical difficulty of the procedure, compliance to rehabilitation protocols postoperatively)[56] all likely play an important role in determining outcomes. The level of evidence was mostly weak consisting of case series; hence, any one of the described study interventions cannot be strongly recommended.

All ankle joint surgery interventions had poor to fair outcomes independent of the techniques used (mosaicplasty,[31] autologous chondral implantation,[47] autologous matrix-induced chondrogenesis,[61] arthroscopy[5]). We concluded that ankle interventions required much more research in the athletic population, especially in those participating in weight-bearing and multidirectional sports involving pivot shifting. The evidence was insufficient to provide recommendations for preferred interventions.

Limitations

Ours is the first scoping review related to the evidence base of effective interventions in active elite/professional athletes with clinical OA. Previous reviews involved the retired athlete. As we performed a scoping review, we did not register the review on PROSPERO or any other review registration database. Due to the limited data found, the conclusions and recommendations should be considered preliminary, and further research is required to either support or negate our findings.

Implications in Clinical Practice and Recommendations

This scoping review may inform clinicians and athletes on appropriate shared decision making depending on the pathology. In active athletes, PFP, and early knee OA, exercise and rehabilitation as an intervention should focus on limb strength symmetry, flexibility, and proprioception in combination while addressing sport-specific performance requirements. When considering joint injections for the athlete with early OA, we recommend that clinicians use appropriate risk evaluation and cost-benefit analysis while understanding the short-term gain and long-term consequences of various preparations and the availability of evidence-based interventions. The evidence was insufficient to provide recommendations for using specific products and clinical experience with different products will dictate this. For best outcomes following surgery, we recommend referral to expertise in hip arthroscopy, ACLR, OAT, MAT, meniscal repair, double-level osteotomy, mosaicplasty, and ankle arthroscopy. However, an individual risk evaluation is required as short-, medium-, and long-term outcomes vary.

Implications for Research

There is a need for more robust research in the field of hip, knee, and ankle OA in active professional and elite athletes and effective interventions. Researchers should focus on randomized controlled trials to provide a stronger level of evidence.

CONCLUSION

The evidence is presently insufficient to provide clinicians with clear recommendations as to which intervention is best for managing early OA in the elite or professional athlete.

KEY POINTS

FINDINGS: There is insufficient evidence to provide clear recommendations for the most effective interventions for hip, knee, and ankle OA in the professional and elite athlete.

IMPLICATIONS: More robust research is required in this cohort.

CAUTIONS: Presently, recommendations must take clinical experience and athlete access to medical care.

STUDY DETAILS

AUTHOR CONTRIBUTIONS: L.P. and S.D.B. conceptualized, designed, and performed the literature searches and data extraction. L.P. did the initial write-up and revisions. V.G., D.C.J.v.R., and G.K. reviewed the manuscript and supplemental material, and provided a critical review. L.P., V.G., D.C.J.v.R., and G.K. approved the final version of the manuscript. L.P. (drpillay@absamail.co.za) takes responsibility for the integrity of the manuscript.

DATA SHARING: All data relevant to the study are included in the article or are available as supplemental files.

PATIENT AND PUBLIC INVOLVEMENT: There was no patient involvement, and no consent was required. ■

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