

Systematic Review of Orthopaedic and Sports Medicine Injuries and Treatment Outcomes in Women's National Basketball Association and National Basketball Association Players

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Background: Athletes in the Women's National Basketball Association (WNBA) and National Basketball Association (NBA) are subject to high injury rates given the physical demands of the sport. Comprehensive data regarding injury patterns and rates in these athletes are limited.

Purpose: To summarize available data on orthopaedic and sports medicine-related injuries through 2020 in professional female and male basketball players.

Study Design: Systematic review; Level of evidence, 4.

Methods: A search was conducted using PubMed and Embase through April 5, 2020, to identify injury studies regarding WNBA and NBA players. Studies were included if the injury or surgery was considered a direct consequence of game play including musculoskeletal/orthopaedic, concussion, ophthalmologic, and craniomaxillofacial injuries. Systematic reviews, screening studies, or studies without sufficient WNBA or NBA player subgroup analysis were excluded.

Results: A total of 49 studies met inclusion criteria, 43 (87.8%) of which detailed musculoskeletal injuries. The lower extremity represented 63.3% of studies. A majority (59.2%) of studies were level 4 evidence. The source of data was primarily comprehensive online search (n = 33; 67.3%), followed by official databases (n = 11; 22.4%). Only 3 studies concerned WNBA athletes compared with 47 that concerned NBA athletes. The lowest return-to-play rates were cited for Achilles tendon repairs (61.0%-79.5%). Variability in return-to-play rates existed among studies even with similar seasons studied.

Conclusion: The majority of literature available on orthopaedic and sports medicine-related injuries of NBA and WNBA athletes is on the lower extremity. The injuries that had the greatest effect on return to play and performance were Achilles tendon ruptures and knee cartilage injuries treated using microfracture. The reported outcomes are limited by heterogeneity and overlapping injury studies. There are limited available data on WNBA injuries specifically.

Keywords: basketball; Women's National Basketball Association; National Basketball Association; injury outcomes; professional athlete; sports medicine

Basketball is one of the most popular team sports, with an estimate of at least 450 million players worldwide.²⁰ Participation spans youth and high school, recreational, intramural, collegiate, and professional levels. Basketball is played by both women and men across all ages, and players in the Women's National Basketball Association (WNBA) and National Basketball Association (NBA) influence young athletes aspiring to compete at the professional level.

Even at younger ages, however, basketball is a significant cause of injury, serving as the leading cause of injuries seen in the emergency department throughout pediatric development.⁴⁸ At the professional level, the incidence of injury is up to 24.9 per 1000 athlete-exposures in the WNBA and up to 19.3 per 1000 athlete-exposures in the NBA.¹²

Epidemiology of injury in sport is crucial for establishing both prevention and treatment strategies. Sports medicine physicians and orthopaedic surgeons can utilize this type of information to appropriately counsel athletes and coaches on expectations after injury, including clinical outcomes, return to sport, and performance metrics. Recently, a

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systematic review of orthopaedic literature in the National Football League provided an excellent overview of injury studies relating to professional football players.²⁷ However, there have been no recent studies on injury epidemiology and outcomes of treatment of female and male professional basketball athletes.

The purpose of this review was to aggregate and summarize orthopaedic injury literature in the WNBA and NBA. With these data, we aimed to understand the sources most commonly used to analyze injuries in professional basketball players, evaluate the quality of data available, demonstrate the spectrum of injuries discussed, and compare the available literature between the WNBA and NBA. We hypothesized that the majority of the literature would be of lower-level evidence from retrospective online searches, with fewer articles available on WNBA compared with NBA athletes.

METHODS

A search was conducted on PubMed and Embase through April 5, 2020, to identify studies involving orthopaedic injuries in the NBA and WNBA. The systematic review was registered on the international prospective register of systematic reviews (PROSPERO) (CRD42020178222). Search terms included “(national basketball association) OR (NBA) or (WNBA).” Studies were included if they discussed musculoskeletal injuries or injuries that occur directly from game play and are frequently encountered by sports medicine physicians, including concussions, facial injuries, and eye injuries. Exclusion criteria for studies were case reports; imaging studies; systematic reviews of studies; studies involving multiple sports of professional athletes that did not have sufficient subgroup or injury data on NBA or WNBA athletes; and studies regarding non-sports medicine conditions, such as general illness, infectious conditions, or mortality. Cardiac and vascular complications were excluded, as these were not direct consequences of game play. Screening studies were excluded. Studies involving the NBA Combine, NBA G-League (formerly D-League), other professional leagues, or intercollegiate athletics were also excluded.

The search was conducted independently by 2 authors (S.A., F.S.) and findings were compared. Any article that was included by 1 author was evaluated through initial screening to remain comprehensive. The articles were divided into 9 categories based on the musculoskeletal or anatomic location of concern including general injury/surgery, hand/forearm, shoulder, hip, knee, foot/ankle, spine, neurologic injuries/concussions, and ophthalmologic/craniofacial injuries. Data collected from articles included level of evidence, years/seasons included, league

(NBA, WNBA), and data source. Level of evidence was extracted from the publication and was assigned and agreed upon by the authors. Data, such as return to sport, time missed, and player efficiency rating (PER), were collected. Data were compiled for descriptive analysis. Data classified as general injury/surgery were excluded from summary tables that summarize data on studies focused on specific injuries/surgeries only.

RESULTS

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart for the search is demonstrated in Figure 1. A total of 1190 articles were found through the database searches after removing duplicates. Sixty articles were assessed in full text for eligibility, with 49 studies meeting final inclusion criteria.

Of the 49 included studies, 33 (67.3%) were cited utilizing an online or public data search, including injury reports, player profiles, press releases, and online transactions. Eleven (22.4%) were cited utilizing a database, such as the National Basketball Athletic Trainers Association database or the NBA electronic medical record. Three studies included patients treated by surgeon-authors,^{18,40,42} 1 study was a survey,¹³ and 1 included prospective leaguewide data collection.⁵⁷ Twenty-nine (59.2%) were deemed level 4 evidence, and the remaining 20 (40.8%) were level 3 evidence.

Thirty-one (63.3%) studies concerned injuries to the lower extremity, with the knee being the most common (30.6%), followed by foot/ankle (18.4%) and hip (14.3%). Forty-three (87.8%) were orthopaedic specific/musculoskeletal. The distribution of studies by injury type is demonstrated in Figure 2.

General Injury/Surgery

Five studies were general injury/surgery studies.^{10,12,18,35,50} Three utilized the National Basketball Athletic Trainers Association database,^{10,12,50} 1 used data from a surgeon in a single franchise,¹⁸ and 1 involved a comprehensive online search.³⁵ The study by Deitch et al¹⁰ also incorporated use of data obtained from the WNBA league office.

The injury rate to the lower extremity was consistently the highest and comprised up to 65% of all injuries, resulting in up to 72.3% of games missed.^{10,12,50} In 1 study on a single franchise between 1973 and 1980, 94% of games missed were attributable to knee, ankle, and foot injuries.¹⁸ Ankle sprains were also consistently reported as the most common type of injury among NBA and WNBA athletes.^{10,12,50} Injuries overall may be increasing over time, with a 12.4% increase in game-related injuries between

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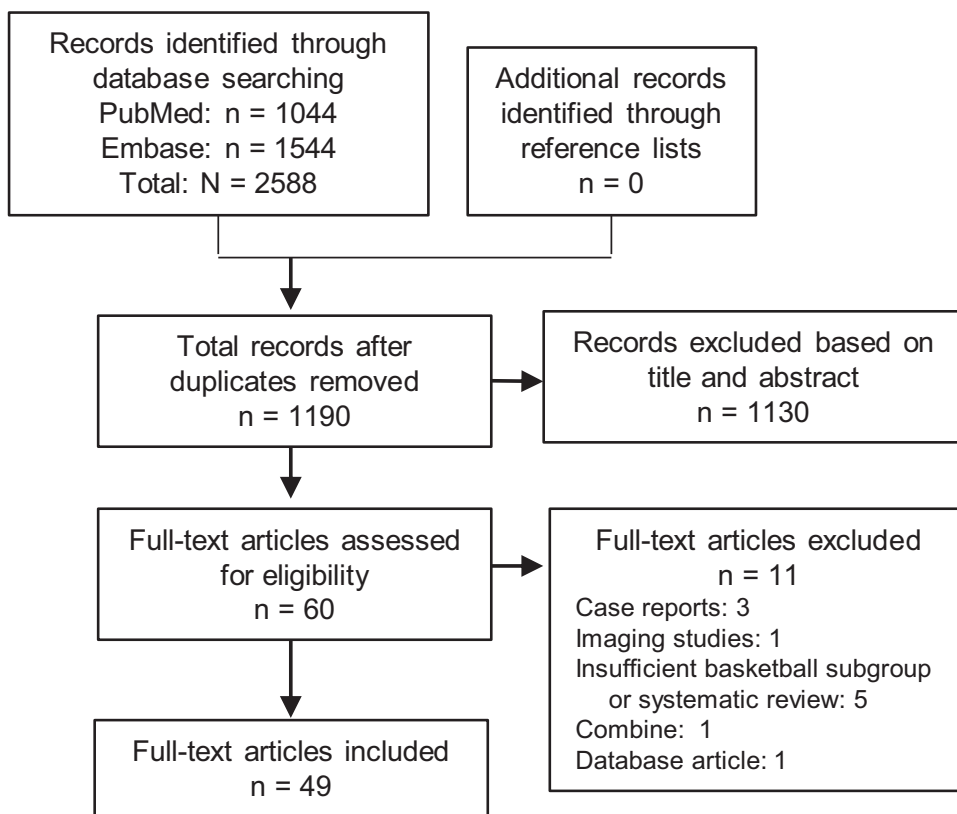


Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart demonstrating 49 final included studies in the review.

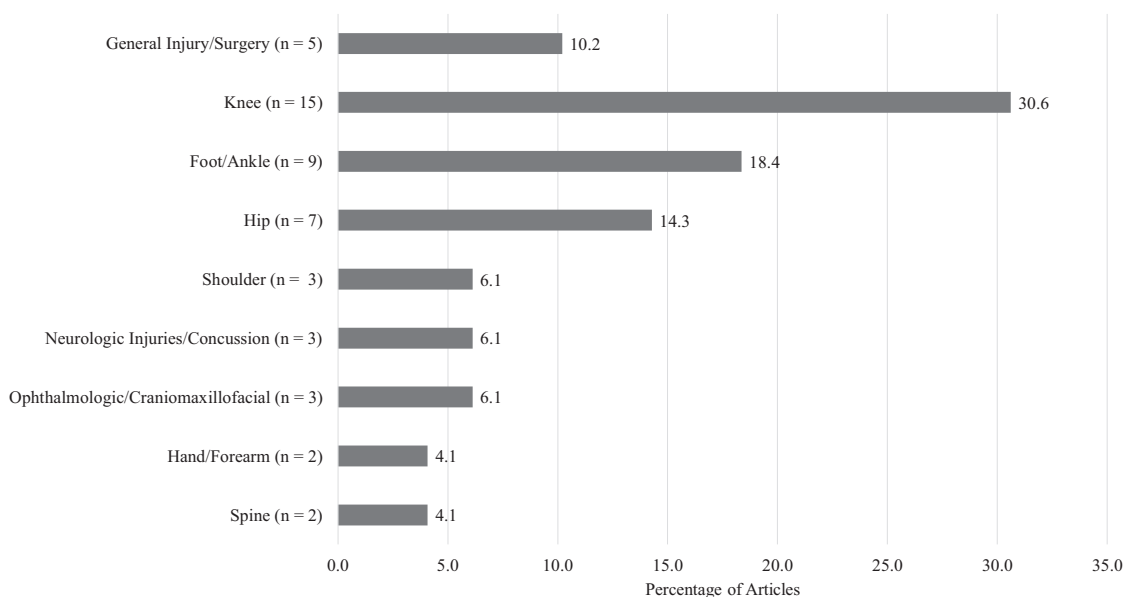


Figure 2. Percentage of articles included by type of sports medicine-related injury.

1988 and 1998, which may be due to increased contact or improved injury reporting.^{12,50}

In an evaluation of orthopaedic surgeries on NBA players, most surgeries were also on the lower extremity.³⁵

Lower extremity operations also had poorer outcomes compared with upper extremity operations.³⁵ Those undergoing Achilles tendon repair, anterior cruciate ligament (ACL) reconstruction (ACLR), meniscal surgery, and knee

TABLE 1
Studies on Outcomes of ACLR in NBA and WNBA Athletes^a

Study	Study Period	N	Follow-up, Season	RTP, %	Change in PER	Change in Minutes Played	Change in Games Played	Career Length After Injury, Season	Other Key Findings
Busfield ⁶	1993-2005	27	1	78.0	-0.4	-4.2	-10.9	—	PER postoperative season 1 decreased by >1 point in 44% of patients.
Harris ¹⁶	1975-2012	64	1	86.0	—	-3.6	-8.1	4.3	All centers (12/12, 100%), 95% (21/22) of forwards, 71% (17/24) guards returned to play. Revision ACLR rate: 3.1%.
Kester ²⁵	1984-2013	79	1	86.1	-2.3	-4.1	-12.1	4.6	Patient career length significantly shorter than that of controls ($P = .001$). Revision ACLR rate: 1.3%. Experience ≥ 4 y, age ≥ 26 y, BMI ≥ 25 , and position were not significant predictors of RTP.
Mai ³²	1984-2013	76	3	85.5	-1.2	—	-11.5	4.5	PER postoperative season 1 decreased by 15.7% ($P < .001$) but recovered to preinjury level by seasons 2 and 3 ($P = .22$).
Nwachukwu ⁴⁰	2008-2014	12	2	88.9	-2.5	-6.4	-5.4	—	PER postoperative season 1 decreased by 4.9 ($P = .05$) but recovered to preinjury levels by season 2.
Okoroa ⁴¹	1984-2015	83	1	94.0	-1.1	-1.9	-8	4.4	Players with ACLR had a decrease in PER the following season compared with controls ($P < .01$). Minutes played in a single NBA game did not contribute to risk of ACL injury.
Namdari ^{38b}	1998-2008	18	2	78.0	—	-2.5	-2.9	—	Shooting percentage and steals per 40 min significantly decreased 2 seasons after ACLR. Revision ACLR rate: 5.6%. RTP not influenced by age, season played before injury, BMI, or position.
Trojian ^{53b}	1999-2003	9	—	—	—	—	—	—	OR of ACL tears in White European American vs non-White European American WNBA players was 6.55 (95% CI, 1.35-31.73).

^aThe National Basketball Association (NBA) and Women's National Basketball Association (WNBA) data are not mutually exclusive. Boldface values denote statistical significance. Dashes indicate data was not available from the individual studies. ACL, anterior cruciate ligament; ACLR, ACL ligament reconstruction; BMI, body mass index; OR, odds ratio; PER, player efficiency rating; RTP, return to play.

^bWNBA study.

microfracture procedures played significantly fewer games at 1 and 3 years postoperatively compared with their pre-injury numbers.³⁵ Furthermore, age >30 years and body mass index (BMI) >27 were independently associated with an increased risk of retirement without returning to play. Those undergoing Achilles tendon surgery had the lowest return-to-play rates (70.8%); these patients also tended to be older (mean age, 28.4 years).³⁵ Additional return-to-play rates in this study after orthopaedic surgery procedures included: ACLR, 84.6%; foot fracture stabilization, 90.2%; hand/wrist fracture stabilization, 98.1%; lumbar discectomy, 79.4%; meniscus surgery, 81.5%; knee microfracture, 71.9%; shoulder stabilization for instability, 93.5%.³⁵

Knee

Fifteen articles were included specifically about the knee.[‡]

ACL Injuries

Eight studies focused specifically on injuries to the ACL,^{6,16,25,32,38,40,41,53} 2 of which evaluated tears in WNBA athletes^{38,53} (Table 1).

The prevalence of ACL injury in the NBA was 0.64% to 2.7% of players,^{6,32} with approximately 2.5 ± 1.7 injuries occurring per season.¹⁶ The role of fatigue in sustaining ACL tears has been investigated, but no significant differences have been found relating to minutes played or quarter during which injury occurred, although 40% of tears occurred in the fourth quarter and 62% occurred in the second half.^{16,41}

In the WNBA, Trojian and Collins⁵³ evaluated a small sample of 9 athletes and suggested a possible role of race in ACL tears, with an odds ratio (OR) of 6.55 for White European players compared with non-White European players. Overall, the return-to-play rate in WNBA players has been cited at 78%.³⁸ In these athletes in the study by Namdari et al,³⁸ there was no statistically significant decrease in performance variables when normalized per 40 minutes of play aside from steals per minute (-0.3 ± 0.5 ; $P = .03$) and

[‡]References 6, 8, 16, 17, 25, 28, 32, 37-41, 47, 53, 55.

TABLE 2
Studies on Outcomes of Knee Microfracture in NBA Athletes^a

Study	Study Period	N	Follow-up, Season	RTP, %	Change in PER	Change in Minutes Played	Change in Games Played	Career Length After Injury, Season	Other Key Findings
Cerynik ⁸	1996-2006	24	2	79.1	-2.7	-3.0	—	—	Mean time to RTP: 7.5 mo. PER and MPG significantly decreased in postoperative season 1 compared with preinjury level (mean, -3.5; $P < .01$) but not season 2. PER and MPG of injured athletes were significantly lower than those of matched controls ($P < .001$).
Harris ¹⁷	1985-2012	41	5 ^b	73.0	—	-4.1	-11.1	4.1	Mean time to RTP: 9.2 mo. Revision rate: 5%. PPG, SPG, and FT% declined compared with preinjury levels ($P < .05$). Compared with controls, patients had worse PPG, FG%, and FT% ($P < .05$).
Namdari ³⁷	1997-2006	24	1	66.7	—	-6.0	-6.0	—	Postoperative PPG, APG, and RPG declined compared with preinjury levels ($P < .05$). Increased number of preoperative seasons played was an independent predictor of RTP (OR, 1.49; $P = .001$).
Schallmo ⁴⁷	1991-2015	34	3	82.4	-9.7	—	—	4.1	Mean time to RTP: 8.5 mo. Games played in postoperative season 1 significantly decreased compared with preinjury ($P < .001$).

^aThe National Basketball Association (NBA) data are not mutually exclusive. Boldface values denote statistical significance. Dashes indicate data was not available from the individual studies. APG, assists per game; FG%, field goal percentage; FT%, free throw percentage; MPG, minutes per game; OR, odds ratio; PER, player efficiency rating; PPG, points per game; RPG, rebounds per game; RTP, return to play; SPG, steals per game.

^bThe postoperative data were averaged over the remaining career or up to 5 years.

shooting percentage ($4.2\% \pm 6.9\%$; $P = .04$).³⁸ One (5.6%) player required revision reconstruction.

In the NBA, the return-to-play rate after ACLR ranged from 78.0% to 94.0%.^{6,16,25,32,35,40,41} The mean time to return to play ranged from approximately 9.8 to 14.1 months, which meant a player missed at least the remainder of the season in which he was injured.^{6,16,25,32,40,41} Identified factors for not returning included concomitant knee pathology⁶ and those playing the guard position.¹⁶ Retear rates ranged from 1.3% to 3.1%.^{16,32}

The effect of ACLR on performance in the NBA varied, with some studies suggesting a temporary decrease in performance after initial return for 1 season,^{25,32,40} no difference in performance after return,^{16,38} and persistent decreases in number of games played and field goal percentage that did not improve over time.⁶ Interestingly, Okorooha et al⁴¹ found that, after returning, starters and lottery picks played more minutes and started in more games, which may demonstrate either a capacity for higher-contributing players to recover or a preferential commitment to these athletes from the team.

As a whole, NBA players took significantly longer to return to play after ACLR compared with other male professional athletes, but they had a longer career length.³² However, relative to basketball controls, NBA players' postoperative career lengths may be shorter by 1.84 years.²⁵

Meniscal Injuries

Two articles specifically concerned meniscal injuries.^{28,55} Meniscal injuries tended to be isolated (87.8%).⁵⁵ Rates of lateral meniscal injury (58.0%-59.2%) were higher than medial meniscus rates (40.8%-42.0%).^{28,55} Lateral meniscal tears were more common in younger athletes and were more prevalent in athletes up to 30 years of age.⁵⁵ Furthermore, those with a BMI >25 had a statistically higher rate of lateral meniscal tears compared with medial meniscal injuries (1.4 vs 0.7 per 1000 athlete-seasons; injury rate ratio (IRR), 1.7; 95% CI, 1.03-2.29; $P < .05$). BMI >25 also increased the risk of meniscal tears in general (IRR, 1.6; 95% CI, 1.2-2.3, $P < .05$).⁵⁵

Return to play after meniscal injuries was found to be 80.5% without a significant difference in pre- and postinjury PER,⁵⁵ which is similar to the 81.5% return to play found by Minhas et al.³⁵

The influence on the affected meniscus and return to sport was variable among studies. Krinsky et al²⁸ found medial meniscal injuries caused athletes to miss significantly more games than did injuries to the lateral meniscus (20.1 vs 15.0; $P < .01$). Conversely, Yeh et al⁵⁵ found that isolated lateral meniscal injuries caused athletes to miss 43.8 ± 35.7 days compared with isolated medial meniscal injuries (40.9 ± 29.7 days missed), although this difference was not statistically significant.

TABLE 3
Studies on Outcomes of Achilles Tendon Repair in NBA Athletes^a

Study	Study Period	N	Follow-up, Season	RTP, %	Change in PER	Change in Minutes Played	Change in Games Played	Career Length After Injury, Season	Other Key Findings
Amin ²	1988-2011	18	2	61.0	-4.4	-4.4	—	—	2-y survival: 44.4%. PER 2 y before injury was a predictor of RTP after surgery (OR, 1.18; $P = .049$).
Lemme ²⁹	1969-2018	44	2	79.5	-2.9	—	-28.6	2.8	Achilles tendon rupture most frequently occurred during early-season play (27%; mean, 20.6 games into season). Patients with preoperative PER <15 had a greater decline in postoperative PER ($P < .001$). Most common mechanism of rupture (67%): takeoff, with foot dorsiflexed, knee in early flexion, and hip in extension.
Trofa ⁵²	1989-2013	25	2	68.0	-3.5	-6.5	-23.2	—	

^aThe National Basketball Association (NBA) data are not mutually exclusive. Boldface values denote statistical significance. Dashes indicate data was not available from the individual studies. OR, odds ratio; PER, player efficiency rating; RTP, return to play.

Articular Cartilage Injuries

Four studies utilizing an online search of public information specifically on microfracture for chondral injuries of the knee were included.^{8,17,37,47} Outcomes after microfracture are summarized in Table 2. No information on the size or location of cartilage defects was available to compare.

In these studies with overlapping years, the return-to-sport rate ranged from 66.7% to 82.4%.^{8,17,37,47} Time to return ranged from approximately 210 to 276 days.^{8,17,37,47} Compared with controls, it appeared that those undergoing microfracture experienced a significant decline in points per game, field goal percentage, play time, and PER ratings across studies.^{8,17,35,37,47}

Unlike other injuries in which performance metrics may improve in seasons beyond the first year back after injury or surgery, microfracture may bring a more sustained decline in performance into subsequent seasons.⁴⁷ While other data have suggested that less of a difference may have existed in those playing longer relative to preinjury levels (3.5 PER decrease in season 1, $P < .01$; 2.7 PER decrease in season 2, $P > .05$), there was still a significantly decreased PER compared with controls (3.1; $P < .001$) at 2 years.⁸ Those undergoing microfracture were 8.15 times less likely to remain in the NBA than were controls after the index year, with only 58.3% returning for more than 1 season.³⁷ Total career length was found to not be significantly different between groups in the NBA cohort by Harris et al,¹⁷ although at years 3 and 4, there were significantly more controls in the NBA.

Patellar Tendon Injuries

One study focused on patellar tendon injuries.³⁹ Nguyen et al³⁹ evaluated 13 patellar tendon tears in 12 NBA

athletes between 1999 and 2015. Nine (75%) players were able to return to play. The cohort was narrowed to 7 athletes for performance analysis against controls after excluding partial, repeat, and concomitant injuries.³⁹

There was a significant decrease from 1 year before injury to after injury in total minutes played (2598 ± 100 vs 1695 ± 78 minutes; $P = .012$), number of games played (74.8 ± 1.9 vs 60.5 ± 1.4 ; $P = .04$), and minutes played per game (34.8 ± 1.5 vs 28.2 ± 1.8 minutes; $P = .02$).³⁹ Comparing 2 seasons before with 2 seasons after injury, there was a significant decrease in total minutes played (2491 ± 190 vs 799 ± 280 minutes; $P = .045$).³⁹ No significant difference was present in this comparison in number of games played (78 ± 2 vs 40 ± 12 ; $P = .13$) or minutes played per game (32.4 ± 2.7 vs 15.5 ± 2.5 minutes; $P = .13$).³⁹ Although no significant difference was observed, the PER at 2 years postoperatively decreased from 15.8 to 6.3, and games played decreased from 78 to 40.³⁹ Interpretation of these data may be limited by small sample size subject to type 2 error.

Foot/Ankle

Nine studies described foot/ankle injuries.^{1,2,5,19,26,29,42,49,52}

Ankle Sprains

One study met criteria for ankle sprains.¹⁹ The single-season risk of an ankle sprain established through the NBA electronic medical record database was 25.8% (95% CI, 23.9%-28.0%), highlighting the high incidence of ankle sprains in professional basketball players.¹⁹ Compared with previous evaluations, the incidence of ankle sprains increased from 3.2 to 3.5 per 1000 player-games to 4.5 per

TABLE 4
Studies on Outcomes of Surgical Treatment of Fifth Metatarsal Fractures in NBA Athletes^a

Study	Study Period	N	Follow-up, Season	RTP, %	Change in PER	Change in Minutes Played	Change in Games Played	Career Length After Injury, Season	Other Key Findings
Begly ⁵	1994-2013	26	3	85.0	0.46	-1.0	—	—	Refracture rate: 19%.
Khan ²⁶	2005-2015	14	2	57.1	—	—	—	—	
O'Malley ⁴²	1989-2013	10	2	100	—	—	—	—	Mean time to RTP: 2.5 mo. Refracture rate: 30%. Highest metatarsus adductus angle was observed in the refracture group.
Singh ⁴⁹	1986-2016	42	3	99.0	0.4	—	—	5.4	Median time to RTP: 3.8 mo. Refracture rate: 11%. Increased number of games started 1 season after primary surgery was predictive of reinjury ($P = .001$). Time to RTP after revision was significantly longer (9.2 mo; $P = .04$). No difference between primary and revision groups with regard to PER, games played, or career lengths.

^aThe National Basketball Association (NBA) data are not mutually exclusive. Dashes indicate data was not available from the individual studies. PER, player efficiency rating; RTP, return to play.

1000 player-games.^{10,12,19,50} Sprains tended to be most common during games (71%), and 56% did not require players to miss games beyond the game, practice, or activity during which the injury occurred.¹⁹ However, if an ankle sprain did require a player to miss a game, return to play was a median of 8 days (2 NBA games missed), with high ankle sprains resulting in a median of 24 days to return to play (5 NBA games missed).¹⁹

In total, the incidence of ankle sprains appeared to be higher in professional players compared with competitors in the National Collegiate Athletic Association (1.4-2.3 per 1000 player-games),^{11,58} although NBA athletes younger than age 26 years had a higher risk than did older athletes (IRR, 1.54; 95% CI, 1.27-1.86).¹⁹ A history of ankle sprains is a major risk factor for future ankle sprains. Among NBA athletes, the incidence of ankle sprains in games was 41% higher among players with a history of ankle sprains in the past year ($P = .002$).¹⁹

Achilles Tendon Injuries

Four studies^{1,2,29,52} specifically focused on Achilles tendon injuries, 3 of which were on tendon repairs (Table 3). Video analysis demonstrated ruptures to be noncontact in nature when taking off from a stopped position before toe-off from a dorsiflexed foot position.²⁹ Achilles tendon ruptures may occur earlier in the season, with preseason and early season play accounting for 45.5% of ruptures.²⁹

Rates of return were worse with frank rupture, with return-to-play rates after rupture treated using repair ranging from 61.0% to 79.5%, which were lower than the rates for other common orthopaedic procedures in the NBA.^{2,29,35,52} After repair, the mean time to return to play was 10.5 months.²⁹

Veteran athletes with older age (particularly age >30 years; OR, 3.85; 95% CI, 1.24-1.91) or longer preinjury career play had worse outcomes after Achilles tendon injury.^{1,2,29,35,52} Even in those with Achilles tendinopathy without frank rupture who had a return-to-play rate of 86% for at least 1 season after injury, the odds of returning were significantly decreased by 21% for every increase in preinjury season played ($P = .027$).¹ Players who did not return were older (mean age, 32.3 years) than those who did return for at least 1 season (mean age, 28.3 years).¹

While those with tendinopathy who return may not see significant declines in performance relative to controls, players with ruptures should expect significant declines in PER relative to preinjury (2.9-4.4 decrease) and relative to controls, with fewer games played and decreased play time (23.2-28.6 fewer games and 4.4-6.5 minutes less).^{2,29,52} NBA players may have worse performance outcomes compared with players in other sports after Achilles tendon repairs.⁵²

Stress Injuries/Fractures and Fifth Metatarsal Fractures

Four studies were categorized into stress injuries and fractures of the foot/ankle.^{5,26,42,49} Khan et al²⁶ evaluated bony stress injuries in the lower extremity between 2005 and 2015, and 76.1% of these occurred in the foot or ankle. Stress reactions had a 13% progression rate to fracture, and those with stress injuries had a significant decline in number of games played after injury (2 years before vs 2 years after, 72.0 ± 12.7 vs 61.3 ± 20.2 , respectively; $P = .014$).²⁶ Stress fractures most commonly occurred in the fifth metatarsal (18.4%), followed by other stress fractures to the foot (14.5%).²⁶ Fractures of the fifth metatarsal were also the most common foot fractures that were treated surgically (41/51, 80.4%).⁴⁹ Outcomes after surgical treatment of fifth metatarsal fractures are demonstrated in Table 4.

TABLE 5
Studies on Outcomes of Hip Arthroscopy for FAI in NBA Athletes^a

Study	Study Period	N	Follow-up, Season	RTP, %	Change in PER	Change in Minutes Played	Change in Games Played	Career Length After Injury, Season	Other Key Findings
Christian ⁹	2000-2016	20	3	81.0	-1.9	—	-4.7	2.3	Median time to RTP: 5.8 mo.
Jack ²¹	2000-2017	24	1	87.5	-1.8	—	-8.1	4.4	Mean time to RTP: 5.7 mo. No significant difference in PER and games played/season relative to controls ($P = .57$ and $.15$, respectively).
Schallmo ⁴⁶	1999-2016	28	3	85.7	-10.4	—	12	3.7	Mean time to RTP: 8.1 mo. Age was a significant negative independent predictor of postoperative career length ($P = .001$), whereas games played during the season before surgery was a positive independent predictor ($P = .007$).

^aThe National Basketball Association (NBA) data are not mutually exclusive. Dashes indicate data was not available from the individual studies. FAI, femoroacetabular impingement; PER, player efficiency rating; RTP, return to play.

Return-to-play rates for fifth metatarsal fractures varied from 57.1% to 100%, with up to 10.0 to 16.4 weeks before return to play.^{5,26,42,49} However, NBA athletes had a 14.6% refracture rate, with 10.5% requiring reoperation, and those undergoing reoperation required significantly longer time to return (275 vs 130 days; $P = .04$).⁴⁹ In another study, there was a 30% refracture rate despite evidence of previous radiographic healing.⁴² Once able to return, athletes appeared to have minimal detriment to performance.^{5,49} PER before injury may be associated with PER at 1 year (beta = 0.79; 95% CI, 0.405-1.183; $P < .001$) and 3 years (beta = 0.69; 95% CI, 0.372-1.015; $P < .001$) postoperatively, but athletes did not see declines in minutes per game or PER after injury.⁵

There may be a trend toward higher shoe size (19.0 ± 2.0 vs 16.1 ± 2.3 ; $P = .097$) and higher Engel metatarsus adductus angles ($27.9^\circ \pm 2.9^\circ$ vs $19.6^\circ \pm 6.8^\circ$; $P = .083$) in those who refracture.⁴² Bone grafting may be considered in larger athletes with increased adductus or in revision cases in addition to standard fixation.⁴²

Hip

Seven studies focused on the hip and pelvis.^{9,13,21-23,44,46}

General Hip Injury Studies

Jackson et al²³ performed a descriptive epidemiology study evaluating pelvis, hip, and thigh region injuries between 1988 and 2012 using the US NBA epidemiological database and identified 2852 (14.6% of athletic injuries) injuries in 967 players. With 61.2% of these occurring in games, the game-related injury rate was 3.26 per 1000 athlete-exposures.²³ On average, the mean time missed was 6.3 ± 10.2 days.²³ Strains were the most common injury type and caused players to miss on average 7.4 days. The hamstring was the most frequently strained muscle.²³ However,

overall, the quadriceps was the most injured structure (including strains, contusions, and other injuries), and extra-articular structures in general were more commonly affected than were intra-articular ones.²³

In a survey of retired players in the National Basketball Players Association with 108 (12% response rate) respondents, 41 (38%) reported sustaining hip or groin injuries while in the NBA, with groin pull/sports hernia and labral tears accounting for 85.4% and 12.2%, respectively.¹³ Of note, those with hip/groin pain at the time of the survey had significantly lower Tegner activity level scores compared with those who did not (median, 2.5 vs 4; $P = .017$), significantly lower EuroQol 5 Dimensions pain/discomfort scores (median, 3 vs 4; $P < .001$), and significantly lower health scores (68.8 ± 19.3 vs 77.2 ± 15.1 ; $P = .009$).¹³ These findings, in addition to a total hip arthroplasty rate of 15%, suggest that hip/groin injuries and pain can be long lasting and detrimental to health in the long term after career play.¹³

Hip Arthroscopy for Femoroacetabular Impingement

Four studies focused on outcomes after hip arthroscopy for femoroacetabular impingement, 2 of which investigated the same cohort of players^{9,21,22,46} (Table 5). NBA players were found to be significantly younger (mean age, 26.6 ± 3.8 years) than were other professional athletes in the National Football League, Major League Baseball, and National Hockey League undergoing hip arthroscopy (age, 29.3 ± 4.1 years; $P = .001$); had a significantly lower BMI (24.4 ± 1.2 vs 28.3 ± 4.1 ; $P < .001$); and had a lower ratio of games started to games played before surgery (0.45 ± 0.34 vs 0.64 ± 0.35 ; $P = .017$).⁴⁶ A higher prevalence of hip arthroscopy was seen in small forwards ($n = 8$; 33.3%) and point guards ($n = 7$; 29.4%) in a study of 23 NBA players, suggesting that they may face more repetitive loading positions on the hips than do more stationary position players, such as centers and power forwards.²¹

TABLE 6
Studies on Outcomes of Shoulder Instability in NBA Athletes^a

Study	Study Period	N	Follow-up, Season	RTP, %	Change in PER	Change in Minutes Played	Change in Games Played	Career Length After Injury, Season	Other Key Findings
Kester ²⁴	1994-2014	35	3	91.8	-0.7	-2.2	1.2	4.2	Compared with controls, no significant difference in performance measures at 1 or 3 y.
Li ³⁰	1986-2018	37	3	100	1.2	—	2.8	—	Recurrent instability rate: 0%. Compared with operative treatment, nonoperatively treated players had a significant reduction in games played and PER 1 y after injury ($P < .05$) and games played at 3 y ($P < .05$). Surgery benefited TS and win shares per 48 min.
Lu ^{31b}	1999-2018	25	3	100	—	—	—	—	Mean time to RTP: 18.7 weeks (operative), 3.6 weeks (nonoperative, subluxation), 7.1 weeks (nonoperative, dislocation). Recurrent instability rate: 8% (operative) vs 24% (nonoperative). Operative shoulder had a significant longer time to recurrence (69.6 weeks vs 28.5 weeks; $P = .001$).

^aThe National Basketball Association (NBA) data are not mutually exclusive. Dashes indicate data was not available from the individual studies. PER, player efficiency rating; RTP, return to play; TS, true shooting.

^bPerformance measures not stratified by operative treatment.

Return-to-play rates after hip arthroscopy ranged from 81.0% to 87.5%.^{9,21,22,46} However, those who returned to play were significantly younger (age, 26.0 ± 3.7 vs 30.0 ± 2.3 years; $P = .05$) and played fewer years before injury (4.8 ± 3.1 vs 8.5 ± 2.5 years; $P = .032$) compared with those who did not return to play.⁴⁶ Jack et al²² found that the career-related decline among NBA players undergoing hip arthroscopy was similar to that of control groups without performance detriment. There were no significant declines in number of games played (11% decline at year 1, 7% decline at years 2 and 3; $P > .05$) or performance scores after surgery (23% decline at year 1, 13% decline at years 2 and 3; $P > .05$).^{9,46}

Hip Adductor Injuries

Hip adductor injuries were reported at a rate of 0.27 per 1000 athlete-exposures.⁴⁴ The majority of injuries were strains (91%).⁴⁴ Patients with tears missed significantly more games (17.5 ± 1.8) and days (36.8 ± 43.8) compared with patients with strains (6.4 ± 7.9 games, $P = .04$; 14.4 ± 16.8 days, $P = .04$).⁴⁴ Furthermore, those undergoing surgery missed significantly more time than did those treated conservatively (34.3 ± 15.5 games vs 6.2 ± 7.0 games, $P < .001$; 72.7 ± 28.2 days vs 13.7 ± 14.7 days, $P < .001$).⁴⁴ Adductor injuries did not cause significant performance detriments in any category within athletes or when compared with controls including no differences in career longevity.⁴⁴

Shoulder

Three studies specifically discussed shoulder injuries, all of which reported on shoulder instability.^{24,30,31} Injuries to

the shoulder may encompass 3% to 4% of injuries to professional basketball athletes.^{10,50} Shoulder stabilization accounted for 13.2% of orthopaedic surgeries in the NBA between 1984 and 2012 (1.6 per season).³⁵ Outcomes for shoulder instability in NBA athletes are presented in Table 6. Return to play ranged from 91.8% to 100%.^{24,30,31}

Nonoperative management in NBA players has been associated with quicker return to play (nonoperative subluxations, 3.6 weeks; nonoperative dislocations, 7.1 weeks; operative management, 18.7 weeks).³¹ Despite the benefit of early return to sport, there was a trend toward risk of recurrent instability (24%-40.6%) with nonoperative management compared with surgical treatment.^{30,31} Furthermore, surgical management delayed the time between recurrent episodes (69.6 vs 28.5 weeks; $P = .001$).³¹

Performance analysis demonstrated that those with high baseline true shooting percentages and high win shares per 48 minutes were more likely to benefit from surgical stabilization.³⁰ PER may decrease in those managed nonoperatively in the season after injury (15.2 ± 4.2 vs 11.9 ± 6.9 ; $P = .017$) but not by postinjury season 3 (13.5 ± 6.4 ; $P = .20$).³⁰ Other studies did not show differences in performance between patients and controls.²⁴

Shoulder instability may not be career ending or significantly career altering, but the risks of surgery and time taken to return to play should be balanced with the risk of recurrence and risk of playing in fewer games at 1 and 3 years postinjury in nonoperatively managed patients.³⁰

Neurologic Injuries/Concussions

Three studies were included on concussion.^{43,45,56} The reporting of concussion has increased in recent studies, which may be because of increased awareness; increased

reporting; mandated preseason education; the standard use of screening tools, such as the Sport Concussion Assessment Tool; and the institution of the NBA Concussion Protocol (NBACP) in 2011.^{12,43,45} Patel et al⁴⁵ noted significantly greater concussive events recorded per season after (16.7 ± 7.5) compared with before (5.7 ± 2.8) institution of the policy ($P = .007$). Return to play did not significantly differ before and after institution of the NBACP. Performance after concussion appeared to be minimally affected.^{43,45,56}

Ophthalmologic/Craniomaxillofacial Injuries

Two studies were included on ophthalmologic injuries^{14,57} and 1 was included on craniomaxillofacial injuries.⁵⁴ Zigelbaum et al⁵⁷ performed a prospective collection of data over a 17-month time frame between 1992 and 1993 including players on 27 teams. Go et al¹⁴ performed a more recent study prospectively evaluating players in the 2018 to 2019 season on an online fantasy sports database. Between 1992 and 1993, eye injuries comprised 59 of 1092 (5.4%) athletic injuries included and almost always occurred when players were not wearing protective eyewear (96.6%).⁵⁷ Eyelid abrasions or lacerations represented 38.0% of injuries between 1992 and 1993 but only 14.3% of injuries between 2018 and 2019, when corneal abrasion was the most common ophthalmologic injury (42.9%).^{14,57} Centers may be at the highest exposure risk (1.94 incidence per 1000 game-exposures), with the most common injury mechanism being a finger to the eye (35.6%) and the most common action occurring during rebounding (30.5%-33.3%).^{14,57} Furthermore, a majority of injuries (55.6%) occurred in the paint, and 50% occurred in the fourth quarter.¹⁴ Despite players being injured, the rate of those wearing eye protection upon return was low (8.5%-16.7%).^{14,57}

Wu et al⁵⁴ evaluated craniomaxillofacial injuries in the NBA between 2013 and 2018 and identified 49 injuries, with a mean of 9.8 ± 1.9 injuries per season. Of the 49 injuries, 41 (83.7%) occurred to the midface; 5 (10.2%), to the lower face; and 3 (6.1%), to the upper face.⁵⁴ Players with these injuries averaged 9.9 ± 12.5 days on the injured list, and 3 (6.1%) injuries were season-ending facial fractures.⁵⁴

Hand/Forearm

Two studies specifically evaluated the hand and forearm.^{15,36}

Hand/wrist fractures in general after orthopaedic surgery appeared to have a relatively high return-to-play rate of 98.1%.³⁵ Those undergoing surgery for metacarpal fractures had a significantly longer time to return to play (56.7 ± 26.3 days) compared with those who were managed nonoperatively (26.3 ± 12.1 days) ($P < .01$); overall, metacarpal fractures resulted in 16 ± 12 games missed compared with 11 ± 8 games missed for phalangeal fractures.³⁶ Hand fractures were frequently treated operatively in NBA players, ranging from 44% to 50%, which may be higher than in general athlete populations because of the increased demand of optimal hand function in NBA players.^{15,36}

Ligamentous tears to the thumb often require surgery and have significantly longer return-to-play rates (67.5 ± 17.7 days, 25 ± 11 games missed) compared with metacarpal and phalangeal fractures ($P < .05$).³⁶

There were no significant differences in performance between those undergoing surgery and those managed nonoperatively.¹⁵ Compared with matched controls, those with fractures did not have significant differences in PER or performance variables per 36 minutes.¹⁵ Multiple regression analysis demonstrated that preinjury PER was associated with a significant increase in PER 1 year ($P < .001$) and 2 years ($P < .001$) postoperatively.¹⁵

Of note, while right-handed players did not have differences in return to sport for either dominant or nondominant hand injuries, left-handed players required significantly greater time to return to play for nondominant hand injuries (53.3 ± 24.6 vs 19.9 ± 22.3 days; $P < .05$).³⁶

Spine

Two studies were included regarding spine injuries or surgeries, both of which focused on lumbar disk herniations.^{3,34} The return-to-play rate after lumbar discectomy was reported at 75% to 79.4%.^{3,34} The 2 studies, however, did include overlapping time frames, with Anakwenze et al³ reporting between 1991 and 2007 and Minhas et al³⁴ reporting between 1984 and 2014. Minhas et al³⁴ also incorporated athletes with nonoperatively managed lumbar disk herniations and found no difference in return to play in these athletes (77.8%) compared with those undergoing surgery. While those undergoing surgery may have played fewer games and had a lower PER 1 season after surgery, it appeared that these differences resolved with no significant differences thereafter.^{3,34} Centers may have a lower likelihood of returning to play than do players at other positions.³⁴

WNBA Athletes

Through our search, there were 3 studies concerning WNBA athletes, with 1 of these studies focusing on general injury patterns between the WNBA and NBA¹⁰ and the other 2 evaluating ACLR.^{38,53} Deitch et al¹⁰ demonstrated in a 6-season analysis that WNBA athletes had a higher game-related injury rate compared with NBA players (24.9 vs 19.3 per 1000 athlete-exposures; $P < .05$) including a higher lower extremity injury rate than NBA players (14.6 vs 11.6 per 1000 athlete-exposures; $P < .05$).

DISCUSSION

This systematic review provides a comprehensive summary of orthopaedic and sports medicine-related literature concerning WNBA and NBA players. Most data existed on injuries and surgeries in the lower extremity, which was also the most injured region. Of the surgeries included, Achilles tendon repair and knee microfracture had the consistently greatest effect on an athlete's ability to return to play; additionally, from the literature reviewed, it appears

that athletes can expect performance detriments if they do return to sport. Of importance, there is a paucity of literature available in the WNBA, in stark contrast to the injury data available for NBA athletes.

In our review, 31 of the 49 (63.3%) articles pertaining to orthopaedic-specific injuries concerned the lower extremity, which is similar to the injury rates cited in the lower extremity in professional basketball athletes.^{10,12,50} Makhni et al³³ performed a comprehensive search of publications in various sports through January 2013, and at that time, 9 (45%) orthopaedic injury studies included in the NBA focused on the knee and lower leg, followed by 5 (25%) categorized as general orthopaedics. Despite ankle sprains being the most frequent injury noted in epidemiologic data, only 1 article specifically evaluated the outcomes after ankle sprains in the NBA.¹⁹ The lower frequency of studies on ankle sprains may reflect the relatively quick return to play and less controversial management of lateral ankle sprains.

Of the surgical procedures included, Achilles tendon repairs appeared to have the poorest consistent return-to-play rates, between 61.0% and 79.5%.^{2,29,52} This observation is corroborated by data from Minhas et al³⁵ demonstrating that athletes with an Achilles tendon repair had the lowest return-to-play rate (70.8% overall) of any orthopaedic surgical procedure. The lower return-to-play rate may be in part attributable to the poorer healing potential of the Achilles tendon and also secondary to the older age of players who tended to sustain Achilles tendon injuries later in their career; age >30 years was independently associated with an increased risk of retirement without return to play in all orthopaedic procedures.³⁵ Furthermore, those undergoing arthroscopic knee microfracture surgery were identified as having low return-to-play rates, ranging from 67.0% to 82.4%.^{8,17,35,37,47} This is consistent with the reported return-to-play rate in the literature of 75% among all athletes, albeit with pain and activity scores deteriorating by the 3- and 6-year follow-ups. Interestingly, there were no studies specific to either league that met inclusion criteria on osteochondral autograft/allograft transfer or autologous chondrocyte implantation, which have reported return-to-play rates of 89% and 84%, respectively, with longer sustained high clinical outcome scores.⁷ One study reported on osteochondral allograft transplantation for chondral injuries in 11 basketball athletes, but the only information specific to NBA players was a return-to-play rate of 75% (3/4) at a median of 20 months (range, 10-26 months) after surgery.⁴ Future studies including these data can help direct further research on how to optimize return-to-play outcomes for athletes with cartilage injuries.

With our inclusion and exclusion criteria, only 3 studies were included for WNBA athletes compared with 47 studies in NBA athletes (1 was a general injury study including NBA and WNBA athletes).^{10,38,53} The small number of studies available on injuries in the WNBA is not reflective of a lower injury rate; in fact, Deitch et al¹⁰ demonstrated a higher injury rate per exposure for WNBA athletes compared with NBA athletes. The total number of WNBA athletes covered in the 2 injury-specific articles on ACL injury was only 27 and likely included an overlap of players.^{38,53}

More investigations should be performed to include female athletes and WNBA players. Female athletes may face different risk factor and injury profiles compared with their male counterparts, and the limited data available in the WNBA make it difficult to draw conclusions on any injury risks or injury patterns. One component of the limited data on WNBA athletes may be the shorter time since the inaugural season in 1997 compared with the inaugural season in male professional basketball with the Basketball Association of America in 1946 and the formal merge to the NBA in 1949. Furthermore, the WNBA currently has 12 teams with a 36-game season compared with the NBA's 30 teams with an 82-game season.

One area that warrants further investigation is the timing of injuries and the potential role of fatigue on injuries in professional basketball players. Teramoto et al⁵¹ found that playing back-to-back games or playing 4 games in 5 days alone was not associated with an increased rate of game injuries. For example, while there were trends toward ACL tears in the latter half of the game, there were not significant associations found between ACL tears and game-play timing.^{16,41} However, Teramoto et al did identify a significant positive association between game injuries and playing away from home ($P < .05$). Additionally, there is a suggestion that Achilles tendon injuries may occur earlier in the season, perhaps related to conditioning or other factors. Aggregating injury data may serve as an impetus to drive potential rule changes to optimize player safety. For instance, the NBACP led to an increased identification of concussions in athletes.^{12,43,45} Understanding the reasons for injuries in away games and if other injuries are influenced by cumulative game time could be beneficial in deciding how much rest players should have.

All data were of lower-level evidence, with the majority being level 4 studies and the remainder being level 3 studies. The majority of available data were derived from searches of online publicly available injury reports, player profiles, team reports, and press releases and less commonly from professional basketball-specific databases. There appeared to be inconsistency in data comparing the 2 techniques for data acquisition, and the validity of comprehensive online searches to access data should be questioned. For example, when evaluating outcomes after fifth metatarsal fractures, the range of return to play was 57.1% to 100% depending on the cohort.^{5,26,42,49} Khan et al²⁶ utilized the National Basketball Players Association injury database and identified 14 players between 2005 and 2015 with a return-to-play rate of 57.1%; on the other hand, Singh et al⁴⁹ between 1986 and 2016 and Begly et al⁵ between 1994 and 2013 utilized online searches with 42 and 26 players and return-to-play rates of 85% and 99%, respectively. With the majority of seasons overlapping, the differences in return-to-play rates vary more than what may be expected. Therefore, evaluation of data from a single study should be used with caution, and studies should be evaluated in concert with others on similar injuries for a more holistic understanding of return-to-play and performance changes. Furthermore, because of the overlap of players and years, statistical analyses and aggregation of current return-to-play data and performance metrics would not

accurately represent outcomes. The availability of a league-wide, Health Insurance Portability and Accountability Act-compliant centralized database would ameliorate many of the challenges in data inconsistency.

Limitations

Because of the heterogeneous nature of published information in the WNBA and NBA, it was difficult to aggregate many outcomes. Variable definitions exist for return to sport and must be evaluated carefully when interpreting data. Many studies overlapped in types of injuries and years studied; therefore, when interpreting rates between studies, it is important to evaluate with caution for athletes included in multiple studies. The lack of consistent access to a centralized database with less consistency in data collection furthermore complicated the reliability of data, which were often pooled from multiple public sources and subject to error.

CONCLUSION

The majority of literature available on orthopaedic and sports medicine-related injuries of NBA and WNBA athletes is on the lower extremity. The injuries with the greatest effect on return to play and performance were Achilles tendon ruptures and knee cartilage injuries treated using microfracture. The reported outcomes are limited by heterogeneity and overlapping injury studies. There are limited available data on WNBA injuries.

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