

Association of Prior Anterior Cruciate Ligament Tear With Decreased Career Longevity in Women's National Basketball Association

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Background: The incidence of anterior cruciate ligament (ACL) injuries in women's basketball exceeds that of men. There is a paucity of data regarding career performance in Women's National Basketball Association (WNBA) athletes with a history of ACL reconstruction.

Purpose: To determine whether WNBA athletes with a history of ACL injury prior to professional play have reduced career game utilization, defined as games played and started and minutes per game (MPG), as well as statistical performance, defined by player efficiency rating (PER).

Study Design: Cohort study; Level of evidence, 3.

Methods: Included were 42 WNBA players from 1997 to 2018 who had a history of ACL reconstruction before entering professional leagues. Body mass index (BMI), age, and position were collected for each player. Career data and performance statistics were likewise collected for each player's entire WNBA career. A control group of WNBA players with no history of ACL injury were matched by position, BMI, and age at the time of WNBA debut. Statistics compared game utilization and performance to assess the impact of ACL reconstruction.

Results: Athletes who sustained an ACL tear before entering the league played in fewer games per season in their first 3 professional seasons compared with healthy controls (24.2 ± 8.4 vs 28.2 ± 6.1 ; $P = .02$). Among athletes with a history of ACL reconstruction, 11 (26.2%) played only a single WNBA season, while no control athletes played in just 1 season. Additionally, athletes who had a previous ACL tear started significantly fewer games per season (9.0 ± 9.4 vs 14.0 ± 9.0 ; $P < .01$) and played fewer MPG (15.5 ± 7.2 vs 20.7 ± 5.5 ; $P < .01$) during their WNBA career. Athletes with a history of ACL tear had significantly shorter WNBA careers (4.8 ± 4.1 vs 8.1 ± 3.3 seasons; $P < .001$). Total professional play duration (WNBA + overseas) was significantly reduced in players with an ACL tear compared with controls ($P < .05$). PER was not significantly different between cohorts at any time point.

Conclusion: WNBA athletes with a history of an ACL tear before professional play had decreased career game utilization and workload throughout their career despite having similar PER compared with healthy controls.

Keywords: knee; ACL; female athlete; basketball

Female athletes sustain anterior cruciate ligament (ACL) tears at a higher rate than their male counterparts. A meta-analysis examining sex differences in ACL tears across multiple sports found that women were at least 3 times higher at risk than men for ACL tear during basketball.²⁹ Agel et al¹ reviewed 13 years of collegiate injury data and found that compared to men, female athletes had a higher incidence of ACL injury in both soccer and basketball.

Despite these trends, little is known about the effect of ACL tears in elite female athletes on career length, athletic participation, and performance. Lai et al¹⁶ substantiated these claims in their systematic review investigating return to play (RTP) in elite athletes and discovered that very few studies investigated the RTP data on the female athlete, despite the high rate of ACL tear.

There have been a number of investigations that evaluated professional athletes' performance after ACL reconstruction in the men's National Basketball Association (NBA).^{8,10,15,27} However, the majority of these studies evaluated injuries incurred during professional play and

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subsequent return to sport and performance. In a cohort study by Mehran et al²² evaluating ACL injuries before professional play, athletes who participated in the NBA Combine with a history of ACL reconstruction had equivalent functional outcomes to those of matched controls. Similarly, in a descriptive epidemiologic study of female athletes, McCarthy et al²⁰ reported that ACL reconstruction was the most common surgery in elite female athletes entering the Women's National Basketball Association (WNBA) Combine, noting that a history of ACL reconstruction did not affect subsequent career length in the WNBA. However, their investigation did not evaluate game utilization and performance statistics. Last, a study directly comparing injury rates between the NBA and WNBA found that the lower extremity injury rates were higher in the WNBA.⁹ The effect of ACL injury on WNBA athletes' career longevity, game utilization, and performance has yet to be elucidated.

The purpose of the present study was to determine whether elite female athletes with a history of ACL injury upon entering into the WNBA have reduced career game utilization and performance as compared with matched controls. We hypothesized that a history of ACL reconstruction would be a predictor of decreased game utilization and performance among WNBA athletes.

METHODS

All WNBA athletes from 1997 to 2018 who sustained an ACL tear and underwent reconstruction prior to their first professional game in the WNBA were retrospectively reviewed. Players who sustained an ACL injury were identified using publicly available websites utilizing previously validated methodologies.^{10,14,19,28} Each reported injury was cross-referenced with at least 2 other sources to confirm a diagnosis of ACL injury and subsequent ACL reconstruction. Additionally, the date of first game in the WNBA and the date of injury were compared to ensure the injury occurred before entry into the professional league. Players were included only if they sustained their injury before entry into the WNBA. Athletes were excluded if they participated in official WNBA play before sustaining their injuries, had a multiligamentous knee injury, had multiple ACL tears before the WNBA, played professionally overseas or in other leagues before entry into the WNBA, or had a player efficiency rating (PER) in the WNBA of 1 SD or lower below the mean of the cohort in order to exclude selection bias of lower-performing athletes.

Player characteristics, game utilization, and game performance data were collected. Game-utilization metrics include seasons played, games per season, games started, and minutes per game (MPG). Performance data collected included points, rebounds, assists, steals, blocks, field goals made, field goal percentage, free throws made, free throw percentage, and turnovers. PER is a standardized performance measure utilized in professional athletes and is a powerful tool for statistical comparison of performance in the literature. It is calculated as follows: $(\text{points} + \text{rebounds} + \text{assists} + \text{steals} + \text{blocks} - \text{field goals missed} - \text{free throws missed} - \text{turnovers}) / (\text{number of games played})$.^{2,8,26,27,32}

The control group consisted of WNBA athletes without a documented ACL injury before their first WNBA game, matched 1:1 for age, position, and body mass index (BMI), based on previously established methodology.^{10,14,19,28} The control group was used to compare performance after injury, during WNBA games. Performance metrics were not used to match controls, since unlike prior studies, no preinjury WNBA performance data exist for athletes who sustained their injury before WNBA play.^{2,32} Athletes were not included in the control group if they had a documented lower extremity injury necessitating surgery or missing game time before entering into the WNBA.

Utilization and performance comparisons were made between overall career data as well as the first 3 years of the players' career to determine if there were any early differences in utilization and performance between patients with and those without a prior ACL tear. Additionally, career longevity and risk for subsequent lower extremity injury were collected for each group. Career longevity was determined by total number of seasons in the WNBA with a documented PER. As many WNBA players also participate in overseas professional leagues, a search was conducted to determine the number of players in each group who played in overseas competition both during and after WNBA competition. From these data, the total number of seasons both in the WNBA and overseas was calculated.

Statistical Analysis

All continuous data are reported as mean \pm SD, while categorical data are reported as counts and column percentages. For continuous variables, univariate 2-group comparisons were performed using independent 2-sample *t* tests if the variable was normally distributed and using Wilcoxon rank-sum tests if the variable was non-normally distributed. For categorical variables, univariate 2-group

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comparisons were performed using chi-square tests when expected cell counts were >5 and using Fisher exact tests when expected cell counts were <5. To assess if the trajectory of games and PER significantly differed between ACL

and control groups, a repeated-measures analysis was performed. Statistical significance was set at $P < .05$. All analyses were performed using SAS 9.4 (SAS Institute).

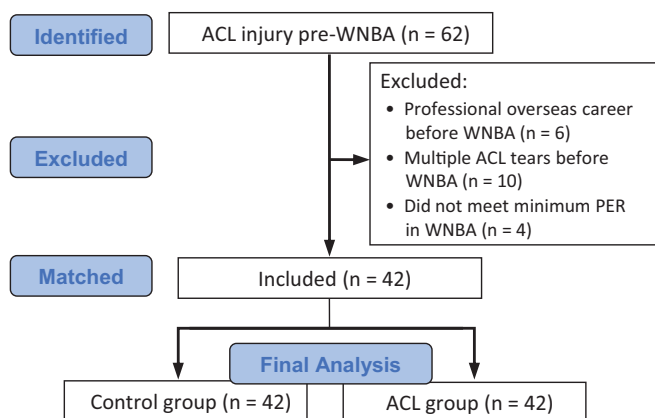


Figure 1. Flowchart of player inclusion for anterior cruciate ligament (ACL) and control groups. WNBA, Women’s National Basketball Association.

RESULTS

Overall, 62 athletes were identified who sustained an ACL tear before their entrance into the WNBA. Of those, 6 athletes were excluded because they played overseas before entrance into the WNBA, while 10 athletes sustained multiple ACL tears before WNBA play. The mean career PER was then calculated for each player, and 4 additional athletes with PER values lower than 1 SD below the mean were excluded in order to control for poor performance. Thus, the total number of athletes included in the final analysis was 42 (Figure 1).

The mean age at the time of ACL injury was 19.8 ± 1.7 years. Positions included 21 (50%) guards, 17 (40%) forwards, and 4 (10%) centers. The mean age at the start of their WNBA career was 22.7 ± 1.6 years for both groups, as matching was conducted based on age at entry into the professional league. The mean BMI was 22.8 ± 1.8 in the ACL group and 22.6 ± 1.7 in the control group ($P > .05$). Player characteristics of the ACL and control groups are outlined in Table 1.

In their WNBA careers, athletes who sustained an ACL tear before entering the league showed no significant difference in games played per season (23.4 ± 8.3 games vs 27.0 ± 4.8 games; $P = .07$). Additionally, athletes who had a previous ACL tear started significantly fewer games per season (9.0 ± 9.4 vs 14.0 ± 9.0 ; $P < .01$) and played fewer MPG (15.5 ± 7.2 vs 20.7 ± 5.5 ; $P < .01$). Player game utilization was also diminished during their rookie years in the WNBA and cumulative first 3 years compared with control groups (Table 2). Athletes who had a history of ACL reconstruction played fewer WNBA seasons compared with control athletes (4.8 ± 4.1 vs 8.1 ± 3.3 ; $P < .001$) (Figure 2).

Among the 42 athletes with an ACL tear, 11 (26.2%) played only a single WNBA season, while no control athletes played in just 1 season. Further analysis of the athletes who only played a single season demonstrated that while their mean PER was lower than that of matched controls (9.2 ± 2.6 vs 11.1 ± 4.9) during the single season, this difference was not statistically significant ($P = .25$). In the 11 athletes who played only a single WNBA season, 7 (63.6%) also participated in at least 1 overseas season. Additionally, excluding athletes who played only a single

TABLE 1
Player Characteristics^a

Variable	ACL	Control	P Value
Age at start of WNBA career, y	22.7 ± 1.6	22.7 ± 1.6	$\geq .99$
BMI, kg/m ²	22.8 ± 1.8	22.6 ± 1.7	.753
Position			
Guard	21 (50)	21 (50)	$\geq .99$
Forward	17 (40)	17 (40)	
Center	4 (10)	4 (10)	
Seasons played			
WNBA	4.8 ± 4.1	8.1 ± 3.3	<.001
Overseas	4.4 ± 3.5	5.8 ± 4.9	.287
Player efficiency rating			
Rookie season	11.8 ± 6.1	11.9 ± 5.1	.95
Cumulative 3 years	12.3 ± 5.1	13.1 ± 3.8	.47
Total career	12.2 ± 4.5	13.0 ± 2.7	.33

^aData are reported as mean \pm SD or n (%). Bold indicates a statistically significant difference ($P < .05$). ACL, anterior cruciate ligament; BMI, body mass index; WNBA, Women’s National Basketball Association.

TABLE 2
Comparison of Game Utilization for ACL and Control Athletes^a

Variable	Rookie Season			Cumulative 3 Seasons			Entire Career		
	ACL	Control	P Value	ACL	Control	P Value	ACL	Control	P Value
Games played	22.8 ± 9.6	26.9 ± 8.6	.04	24.2 ± 8.4	28.2 ± 6.1	.02	23.4 ± 8.3	27.0 ± 4.8	.07
Games started	7.3 ± 11.2	11.2 ± 11.7	.03	9.2 ± 9.9	13.3 ± 11.1	.09	9.0 ± 9.4	14.0 ± 9.0	<.01
Minutes per game	13.1 ± 8.8	19.5 ± 8.2	<.01	15.0 ± 7.9	20.7 ± 7.3	<.01	15.5 ± 7.2	20.7 ± 5.5	<.01

^aData are reported as mean \pm SD. Bold indicates a statistically significant difference ($P < .05$). ACL, anterior cruciate ligament.

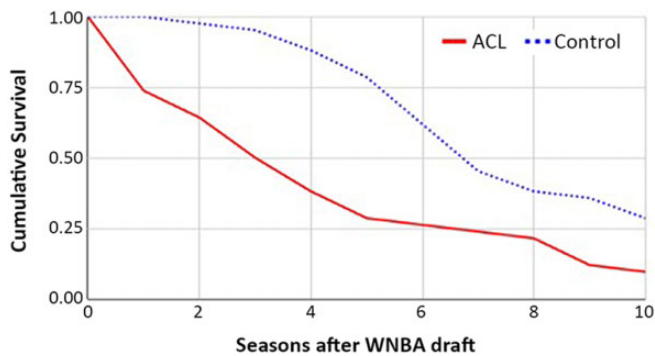


Figure 2. Kaplan-Meier survival curve for athletes with a previous anterior cruciate ligament (ACL) tear and control athletes over 10 seasons. WNBA, Women's National Basketball Association.

WNBA season still resulted in significantly fewer cumulative seasons in the ACL group compared with controls in both the WNBA (6.0 ± 4.0 vs 8.2 ± 3.5 ; $P < .05$) and overall (WNBA + overseas; 11.1 ± 6.0 vs 14.7 ± 7.4 ; $P < .05$).

There were no significant differences in player performance as calculated by PER at any time point (Table 1). While there were more subsequent injuries in the ACL group, this difference was not significant (Table 3). There were 2 additional ACL injuries in the ACL group; both were ipsilateral graft ruptures. The odds of a player with a previous ACL tear sustaining a subsequent injury was 1.90 times that of control players ($P = .34$).

Of the players who had a previous ACL tear, 83% played outside of the United States, compared with 74% of control players ($P = .29$). The majority of included athletes participated in both WNBA and overseas seasons in the same calendar year (79% of ACL vs 71% of controls; $P = .45$). On average, the ACL group participated in fewer overseas seasons (4.4 ± 3.5 seasons vs 5.8 ± 4.9 seasons; $P > .05$). The total number of career seasons (WNBA + overseas) was 9.2 ± 6.4 in the ACL group and 13.9 ± 6.8 for controls ($P < .01$).

DISCUSSION

Athletes with a history of ACL tears demonstrated fewer games played, games started, MPG, and total seasons played throughout their WNBA career compared with healthy, matched controls. Despite these findings, athletes with an ACL tear displayed similar in-game performance, as measured by PER, as compared with healthy controls.

An ACL tear can significantly impact the ability of an elite athlete to return to sport at the same level of preinjury baseline. A systematic review detailing studies that focus on RTP after ACL injury in high-level athletes noted an overall RTP rate of 83%; however, there were insufficient studies focusing on female athletes.¹⁶ The impact of ACL reconstruction on return to sport and performance has also been investigated specifically in the WNBA population. Namdari et al²⁵ retrospectively reviewed 18 WNBA athletes with ACL injury and found that 14 (77.8%) were successfully able to return to competition, and while there

TABLE 3
Number of Subsequent Injuries Sustained During Study Period Between Athletes Who Sustained ACL Injuries and Those Who Did Not^a

Injury Type	ACL	Control
ACL	2	0
MCL	1	0
Meniscus	3	1
LE fracture	0	1
Achilles	1	2
Total	7	4

^aThere were no statistically significant differences between the ACL and control groups. ACL, anterior cruciate ligament; LE, lower extremity; MCL, medial collateral ligament.

were slight decreases in games played and MPG after ACL reconstruction, these differences were not significant. In another study focusing on WNBA players who sustained ACL tears during their professional careers, Tramer et al³¹ noted that athletes returning to competition in the first year after ACL reconstruction were at risk for decreased game utilization compared with a group of healthy controls, with ACL tear athletes participating in 7.5 fewer games per season and playing 5.1 fewer MPG.

While the previous studies investigated ACL injuries incurred during professional play, the present investigation evaluated the impact of preprofessional ACL injuries on professional careers and found similar differences among the rookie season of athletes with a history of ACL tear, with a mean of 4.1 fewer games played and 6.4 fewer MPG relative to a healthy control group. Unlike the prior studies mentioned, in which the differences in game utilization were no longer apparent by 3 years postinjury, the present cohort demonstrated continued diminished workload over their first 3 years in the league and throughout their overall career. The explanation for this finding is likely multifactorial. Significant differences in rehabilitation protocols with variable efficacy have been demonstrated at both a regional and a competitive level (eg, high school, collegiate, professional), which may contribute to the disparity between athletes with a history of ACL tear and controls.¹⁷ Furthermore, athletes with an ACL tear in the present study may have undergone ACL reconstruction at any point before their time in the WNBA, from youth through college years. These athletes may have advocated for earlier RTP in high school or college in order to excel toward the next level, which may have had detrimental effects on the patients' long-term rehabilitation status and unmeasurable effects on the level of workload during professional play.

Athletes entering the WNBA after ACL injury did not demonstrate differences in performance compared with healthy controls at any time points or throughout their overall careers. This finding echoes the findings of Namdari et al,²⁵ who found that WNBA athletes returning from ACL reconstruction had similar performance metrics, such as points, rebounds, and assists per game, to a healthy control group. In a case series, Nwachukwu

et al²⁷ also demonstrated that NBA players had a significant drop in PER in the first season after RTP that resolved by postoperative season 2 compared with a control group. Similarly, Tramer et al³¹ noted a significant decline in multiple performance statistics in WNBA players' first year after RTP that also resolved at 3 seasons postsurgery. It must be noted that the aforementioned studies used the first season after RTP after ACL reconstruction as the comparative season, while the ACL cohort in the present study entered the WNBA at a mean of 3 years after their ACL reconstruction; therefore, there were no statistics readily available immediately after surgery. Thus, it is likely that the early declines in performance that were noted in prior studies occurred before the current study's data collection period. Nevertheless, there were no significant differences in performance in the rookie seasons of these athletes, reiterating the notion that athletes are likely to recover from any performance detriment by 2 or 3 seasons postinjury.

Athletes with a history of an ACL tear participated in significantly fewer WNBA seasons. Additionally, those with a history of ACL tear participated in fewer total cumulative professional seasons (WNBA + overseas). Kester et al¹⁵ evaluated the career longevity in male NBA players who underwent ACL reconstruction and found that surgery significantly decreased career longevity by 1.8 seasons. Similarly, Arundale et al⁷ found that Major League Soccer athletes returning to the sport after ACL surgery had remaining career lengths that were roughly half as long as those of healthy controls. It is difficult to ascertain the reasoning for decreased career longevity in the female athletes in the present investigation. Webster et al³³ surveyed factors associated with athlete readiness to return to sport after ACL reconstruction and noted that female patients had a more negative outlook and lower psychological readiness to return to sport after surgery than their male counterparts. Additionally, multiple investigations have demonstrated that female athletes exhibit persistent difficulty with neuromuscular control after ACL reconstruction, exhibiting increased tibial laxity and less muscle strength and endurance, which may explain the decreases in career longevity.^{11,13} Multiple studies have investigated psychological responses to knee injury, with fear of reinjury often limiting athletes' ability to remain at the same level of competition.^{5,6,21}

In the present cohort, 26.2% of WNBA athletes participated in only 1 WNBA season. Kester et al¹⁵ also found a similar phenomenon in NBA athletes after reconstruction in which athletes returning from reconstruction had a high rate of early attrition, while athletes that continued to play in the NBA followed a similar pattern compared with controls as their careers progressed. Their study also demonstrated a decreased career workload (fewer games per season and total seasons) but no significant difference in career PER between ACL tear and control athletes, similar to the results of the present investigation.¹⁵ The reasoning behind this pattern is likely multifactorial. Kester et al¹⁵ suggest that it may be the result of factors such as postoperative deconditioning or psychological reasons. Some WNBA athletes seek additional opportunities

by playing overseas; however, there was no difference in the number of athletes who played overseas or who simultaneously played both overseas and in the WNBA in the same season, between groups. While excluding the athletes who played only a single season still resulted in significantly shorter career longevity in the ACL group, it appears that if athletes are able to make it beyond the 2 or 3 years after ACL reconstruction, they have a similar career trajectory as matched controls and no significant detriment to performance.

While there was no significant difference in subsequent injuries found in this investigation, there were 2 ACL graft ruptures during the study period. Additionally, we identified 10 athletes who sustained multiple ACL tears (≥ 2) before entrance into the WNBA but were excluded from statistical comparison. Many investigations have been conducted in an attempt to determine risk for subsequent reinjury after ACL reconstruction, particularly the incidence of graft rupture.³⁴ Younger age at time of surgery and continued participation in high-risk sports have consistently been documented as major risk factors for both ipsilateral graft rupture and contralateral ACL tear.^{3,4} Maletis et al¹⁸ reviewed a database of more than 20,000 ACL reconstructions in the United States and found that patients younger than 21 years of age had significantly higher revision rates, with a 9% 5-year revision rate. Additionally, in this age group, use of a hamstring autograft had a 1.61 times higher risk of revision compared with bone-patellar tendon-bone autograft. Shelbourne et al³⁰ prospectively reviewed ACL reconstructions for 5 years after surgery and noted that young women returning to high-level activity were at significant risk of both graft rupture and contralateral ACL tears. The mean age at injury of the present cohort was 19.8 ± 1.7 years, with all athletes returning to a high-risk activity in professional basketball after their injuries, making this a particularly vulnerable group to reinjury. The incidence of subsequent ACL injury in the original 62 players identified included 10 before the WNBA and 2 during the WNBA (12/62; 19%).

Early physical therapy intervention that focuses on neuromuscular and proprioceptive training for athletes who sustain an ACL tear at a young age can be effective in improving knee biomechanics and should be implemented early in high-risk athletes such as elite female basketball players.^{23,24} Hewett et al¹² conducted a meta-analysis of studies, specifically evaluating neuromuscular training in female athletes, and found that the institution of neuromuscular training programs had a significant effect on lowering the incidence of ACL injury. Overall, female professional athletes represent a high-risk group for knee injuries, particularly those with a history of ACL reconstruction.

Limitations

There were limitations to this investigation. Data collection was limited to publicly available sources, which can have inaccuracies and reporting bias. As in previous

investigations, all data were cross-referenced with more than 1 available source.^{10,14,19,28} Additionally, ACL tears in this group occurred before entry into professional leagues, and injury reporting during high school and college may be more sporadic and limited, including differences in rehabilitation protocols and return-to-sport protocols. It is possible that tears sustained in earlier adolescence were not appropriately documented. Additionally, reporting of injuries sustained overseas may be limited in accuracy. Concomitant injuries found at the time of reconstruction (eg, cartilage injuries and meniscal injuries) were not consistently reported in the public access data. Moreover, perioperative data such as graft type, timing of surgery, surgical technique, and rehabilitation were not available, which could potentially confound the differences between groups. Athletes were not matched based on era; thus, there may be differences based on when athletes participated in WNBA play. Last, it was not possible to elucidate whether career longevity was directly altered by a history of ACL tear versus other confounding factors.

CONCLUSION

WNBA athletes with a history of an ACL tear before professional play were found to have decreased career game utilization and workload throughout their career without a significant detriment to performance.

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