Performance Outcomes After Surgical Repair of Achilles Tendon Rupture in the Women's National Basketball Association

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Background: Achilles tendon ruptures are devastating in elite athletes. There are currently no studies examining the effects of Achilles tendon rupture on performance outcomes in the Women's National Basketball Association (WNBA).

Hypothesis: Athletes in the WNBA who sustained an Achilles tendon rupture and underwent subsequent surgical repair will sustain declines in performance metrics when compared with their preinjury statistics and matched controls.

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

Methods: Seventeen WNBA players who sustained an Achilles tendon rupture from 2000 to 2019 were identified through publicly available injury reports and player profiles. Athlete information collected included age, body mass index, position, and service in the WNBA when the tear occurred. Statistics were collected for 1 season before and 2 seasons after the injury, and the player efficiency rating (PER) was calculated. Players were matched to uninjured controls by service in the WNBA, position, and performance statistics.

Results: On average, players were 28 years of age at the time of Achilles tendon rupture, with a service time in the WNBA of 6.5 years. Four players never returned to play in the WNBA, while 7 players failed to play more than 1 season. Players who did return played significantly fewer minutes per game compared with preinjury in both postinjury seasons 1 and 2 (mean difference, –6.11 and –6.54 min/game, respectively; $P < .01$ for both) and had a significantly decreased PER in postinjury season 2 (mean difference, –2.53; $P = .024$). After returning to play, the injured players experienced significant decreases when compared with controls in field goals (–0.85 vs +0.20; $P = .047$), free throws (–1.04 vs +0.12; $P < .01$), steals (–0.48 vs +0.24; $P = .018$), and points scored (–2.89 vs +0.58; $P = .014$).

Conclusion: WNBA players experienced significant decreases in performance metrics after Achilles tendon rupture compared with their preinjury levels and compared with uninjured controls. Overall, 23.5% of players failed to return to the WNBA, while 41.2% failed to play for more than 1 season.

Keywords: Achilles tendon rupture; Women's National Basketball Association; performance outcomes; basketball

Achilles tendon ruptures are devastating injuries in elite athletes, often requiring surgical repair and extensive rehabilitation protocols.[2,6,19,24,26] The consequences of Achilles tendon rupture in elite athletes range from career-altering to career-ending, with studies investigating effects on performance and return to play in the National Basketball Association (NBA), Major League Baseball (MLB), and National Football League (NFL) showing poor outcomes.[2,19,24,26] Specifically, Achilles tendon ruptures have the most devastating impacts on professional basketball players' careers as compared with other injuries requiring surgical intervention,[19,26] possibly because of the physical demands and unique movement patterns involved in the sport. In both collegiate and professional basketball players, Achilles tendon injuries occur most often on noncontact plays, with acceleration and pivoting being the most likely mechanisms, supporting the notion that Achilles tendon rupture is thought to be secondary to an acute, excessive, eccentric load on the tendon with preexisting degenerative changes.[4,10,14-16]

There have been multiple studies on epidemiology and performance outcomes after Achilles tendon rupture in the NBA[1,2,14,19,26]; however, there are no studies investigating the same in the Women's National Basketball Association (WNBA). Treatment of Achilles tendon rupture in professional athletes has been heavily debated; however, operative management has demonstrated a faster return to sport and lower risk of reinjury in this population and seems to be preferred over nonoperative management in elite athletes.[6,9] Because basketball is the sport with the highest

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incidence of Achilles tendon rupture in the United States,[5,13,14,25,27] investigation of the effects of the injury in the WNBA after operative repair is warranted.

The purpose of this study was to evaluate the impact of Achilles tendon rupture on return-to-play statistics and performance outcomes in the WNBA. We hypothesized that athletes who were able to return to play in the WNBA after Achilles tendon rupture would experience declines in performance metrics when compared with their preinjury statistics and matched controls. Understanding the effects of Achilles tendon ruptures on return-to-play and performance outcomes will provide valuable information to players, coaches, medical personnel, and front offices on postinjury performance expectations.

METHODS

This study was exempt from institutional review board approval. WNBA players who sustained an Achilles tendon rupture and underwent subsequent surgical repair between the 2000-2001 and 2018-2019 seasons were identified using publicly available injury reports, press releases, and player profiles. Over the 19-season study period, a total of 21 WNBA players who sustained an Achilles tendon rupture were identified, with an estimated incidence of 7 Achilles tendon ruptures per 1000 athlete-years during the study period. This is based on an estimated calculation that approximately 3000 athlete-years were played in the WNBA over the study period, which was arrived at by multiplying the total number of WNBA teams represented in each season over the 19-year study period (average, 13.15 teams) by the number of roster spots on each team (12 spots). To be included in the study, players must have had at least 1 WNBA season of statistics before the injury, and the injury must have occurred while the player was on an active WNBA roster.

Of the 21 players identified, all were treated with operative intervention and 17 met inclusion criteria and were ultimately included in the analysis. Two players were excluded because they did not have statistics from the year before their Achilles tendon rupture as a result of sustaining another injury. One player was excluded because she played in an international professional league the year before her Achilles tendon rupture occurred while she was in the WNBA. One player was excluded because she experienced her Achilles tendon rupture in the 2018-2019 season and therefore did not yet have the opportunity to return to play in the WNBA when this study was conducted. For each case, 2 matched controls were selected based on position, service time in the WNBA, and player efficiency rating (PER) statistic. Players who did not meet the criteria for statistical comparison (ie, career-ending injuries) were included in the study for return-to-play analysis.

The index season was defined as the year in which the injured players sustained the Achilles tendon rupture, and the preindex season was the year immediately before injury. Parameters of interest were collected for the preindex season and the 2 postindex seasons for players who returned to play and for controls. Player information and statistics were collected from the official WNBA website (stats.wnba.com). Data points for each player included body mass index (BMI), age, position, and number of seasons played before the index season as well as game-specific metrics from each season: field goals attempted and made, free throws attempted and made, 3-point shots attempted and made, rebounds, steals, blocks, turnovers, personal fouls, points, and minutes played. We calculated the PER to better compare the overall performance of players. This is defined as $([points + rebounds + assists + steals + blocks] - [(field\ goals\ attempted - field\ goals\ made) + (free\ throws\ attempted - free\ throws\ made) + turnovers])/games$.

An a priori power analysis was performed using independent-samples Student t tests to determine whether WNBA players who sustained Achilles tendon ruptures differed significantly from healthy controls. A 2-sided test with a power of 0.8, significance level of .05, and effect size of 1 was performed to determine that a sample size of 15 was needed with a ratio of 1:2 for the control group. It was determined that our study group needed at least 15 players and the control group at least 30.

Categorical variables are presented as counts, and continuous variables are presented as means and ranges unless otherwise indicated. The Fisher exact test was used to compare categorical data, and the independent-samples Student t test was used to compare continuous variables unless otherwise specified. Significance was assessed at the $P < .05$ level, and all P values were 2-tailed. We performed univariate logistic regression to determine which patient factors might influence their ability to return to play. As only one variable was significant, there was no need to further perform multivariable analysis. The Firth penalized likelihood procedure was applied to control for quasi-

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TABLE 1
Characteristic and Performance Data for WNBA Players With Achilles Tendon Ruptures[a]

	All Injured Players (N = 17)	Players Who Returned for ≥1 Season (n = 13)	Players Who Did Not Return for ≥1 Season (n = 4)
Age, y	28.00 (23.0-40.0)	26.54 (23.0-40.0)	32.75 (25.0-39.0)
BMI	22.71 (18.5-25.8)	22.91 (18.5-25.8)	22.08 (20.5-23.5)
No. of seasons played before index season	6.47 (3.0-16.0)	5.46 (3.0-16.0)	9.75 (5.0-12.0)
PER, preindex season	10.02 (1.53-19.88)	10.71 (3.07-19.88)	7.79 (1.53-11.21)
Minutes played per game, preindex season	22.92 (7.56-33.23)	24.27 (12.12-33.23)	18.56 (7.56-27.08)

[a]Data are expressed as mean (range). BMI, body mass index; PER, player efficiency rating; WNBA, Women's National Basketball Association.

TABLE 2
Characteristic and Performance Comparisons Between Injured Players and Controls[a]

	Injured Players (N = 17)	Controls (N = 32)	*P* Value
Mean age, y	28.00	28.06	.96
Mean BMI	22.71	22.75	.95
Mean No. of seasons played before index season	5.47	4.88	.55
Mean PER, preindex season	10.02	10.61	.7
Position, n			≥.99
Center	3	6	
Forward	7	12	
Guard	7	14	

[a]BMI, body mass index; PER, player efficiency rating.

TABLE 3
Difference in Performance Variables Between Pre- and Postindex Seasons in Players Who Returned for ≥1 Season (n = 13)[a]

	Change From Preindex Season	*P* Value
Minutes played per game		
Postindex season 1	–6.11	**<.01**
Postindex season 2	–6.54	**<.01**
PER		
Postindex season 1	–2.24	.086
Postindex season 2	–2.53	**.024**

[a]Bolded *P* values indicate a statistically significant difference compared with the preindex season ($P < .05$, paired Student *t* test). PER, player efficiency rating.

complete separation in rare event analyses.[8] We examined BMI and age as both continuous and categorical variables (BMI, >25; age, >30 years); BMI >25 was chosen as it is the cutoff point for the categorization of "normal weight" (18.5-24.9). Player positions were treated categorically as forward, center, or guard, and analysis was performed with guards treated as the reference position. Odds ratios (ORs) are reported with 95% confidence intervals (CIs) in addition to *P* values. All data analysis was performed using Python 3.8.2 and R 4.0.0 with the libraries RPy2 3.3.3, NumPy 1.18.5, SciPy 1.4.1, Statsmodels 0.11.1 for Python, and Logistf 1.23 for R.

RESULTS

We identified 17 WNBA players who tore their Achilles tendon between 2000 and 2019. These players were matched to 32 control players who did not sustain such a tear. One injured player was unable to be matched because we were unable to find a control player who satisfied our inclusion criteria. There were 13 players (76.5%) who returned to play for ≥1 season after injury, and 4 who did not (23.5%). Table 1 shows the player and select performance variables for the study group as a whole as well as for those players who did and did not return to play after injury.

To determine whether the controls were adequately matched, we compared player and performance variables between the injured and control groups (Table 2). There were no significant differences between groups with respect to mean age, BMI, number of seasons played before the index season, preindex season PER, or position.

For the 13 players who returned to play after injury, Table 3 shows a comparison between pre- and postindex minutes played and PER. Players who returned saw a decrease in the number of minutes played in both postindex seasons 1 and 2 compared with preindex (mean difference, –6.11 and –6.54, respectively; $P < .01$ for both). During postindex season 1, there was no significant decrease in PER compared with the preindex season; however, the decrease was significant in postindex season 2 (mean difference, –2.53; $P = .024$).

We then compared the change in performance metrics from pre- to postindex between the injured players and matched controls (Table 4). In comparison with the controls, the injured players were significantly more likely to experience a decrease in minutes played per game during both postindex seasons (season 1, –6.11 vs +1.05 min/game [$P < .01$]; season 2, –6.54 vs +0.53 min/game [$P = .018$]). Decreases in all reported performance metrics were seen in the injured group from pre- to postindex; in particular, when compared with controls, injured players experienced significant decreases in field goals (–0.85 vs +0.20; $P = .047$), free throws (–1.04 vs +0.12; $P < .01$), steals (–0.48 vs +0.24; $P = .018$), and points scored (–2.89 vs

TABLE 4
Comparison of Performance Metrics Between Injured Players and Controls[a]

	Change From Preindex Season		
	Injured Players (N = 17)	Controls (N = 32)	*P* Value
Minutes played per game			
Postindex season 1	–6.11	+1.05	**<.01**
Postindex season 2	–6.54	+0.53	**.018**
PER			
Postindex season 1	–2.24	+0.57	.054
Postindex season 2	–2.53	+0.33	.089
Postindex season 1 metrics			
Field goals	–0.85	+0.20	**.047**
Free throws	–1.04	+0.12	**<.01**
3 points	–0.15	+0.07	.13
Rebounds	–0.52	+0.07	.26
Steals	–0.48	+0.24	**.018**
Blocks	–0.20	–0.11	.4
Turnovers	–0.41	+0.04	**.037**
Personal fouls	–0.39	–0.26	.53
Points	–2.89	+0.58	**.014**

[a]Bolded *P* values indicate a statistically significant difference between groups ($P < .05$). PER, player efficiency rating.

TABLE 5
Univariate Binary Logistic Regression for Variables Associated With Return to Play in the Injured Players[a]

	Odds Ratio (95% CI)	*P* Value
BMI		
Continuous	1.27 (0.70-2.44)	.42
>25	1.08 (0.05-169.56)	.96
Age		
Continuous	0.83 (0.65-1.01)	.06
>30 y	0.05 (0.00-0.54)	**.01**
Center position[b]	0.12 (0.01-1.28)	.08
Forward position[b]	0.65 (0.08-5.41)	.68
No. of seasons played before index season	0.78 (0.55-1.02)	.07
PER, preindex season	1.09 (0.90-1.40)	.40
Minutes played per game, preindex season	1.09 (0.95-1.29)	.21

[a]Bolded *P* value indicates a statistically significant finding ($P < .05$). BMI, body mass index; CI, confidence interval; PER, player efficiency rating.
[b]Compared with guard position.

+0.58; $P = .014$) after return to play. Interestingly, injured players committed significantly fewer turnovers postoperatively when compared with healthy controls (–0.41 vs +0.04; $P = .037$).

To identify which preindex player variables influenced return to play, we performed univariate logistic regression with return to play for ≥1 season as the outcome of interest (Table 5). Only age >30 years was a significant predictor of failure to return to play (OR, 0.05; 95% CI, 0.00-0.54; $P = .01$). According to our data, BMI, position, number of preindex seasons played, preindex PER, and minutes played were not associated with a player's return to play after Achilles tendon ruptures. As only 1 variable was significantly associated with return to play, there was no further need to perform multivariate analysis.

DISCUSSION

Four of 17 players (23.5%) who sustained an Achilles tendon rupture and underwent subsequent surgical repair failed to return to play in the WNBA. Of those 13 players who returned to play, 3 failed to play >1 season, resulting in a 2-year postoperative return to play of 58.8%. This finding highlights the debilitating nature of Achilles tendon injuries in professional basketball players. Namdari et al[21] reported that 79% of WNBA players return to play after anterior cruciate ligament (ACL) reconstruction, slightly higher than our finding for Achilles tendon ruptures. The career-threatening nature of Achilles tendon rupture was further highlighted by Amin et al,[2] who found that 39% of NBA players failed to return to play after Achilles tendon rupture, and only 44.4% returned to play for >1 season. Achilles tendon ruptures have the lowest return-to-play percentage in professional basketball players when compared with other orthopaedic surgical procedures.[19]

WNBA players who returned to play after Achilles tendon rupture experienced a significant decrease in minutes played both 1 and 2 seasons postinjury as well as a significant decrease in PER in their second season postinjury as compared with their preinjury year. Interestingly, there was a nonstatistically significant decrease in PER in the first season after return from injury. The authors believe that this may be more indicative of our small sample size than an actual lack of significance, and while this finding is not statistically significant, we do believe it is clinically significant. Additionally, this finding suggests that athlete performance after Achilles tendon rupture continues to worsen over time, further highlighting the devastating nature of Achilles tendon injury for female basketball players. The authors also speculate that players who failed to return to play for a second season would have likely experienced lower PER statistics than their first postoperative season had they continued to play. This would have made the drop-off seen in our statistical comparison of both PER and minutes played per game even greater at 2 seasons postinjury. These findings are supported by Minhas et al,[19] Trofa et al,[26] and Amin et al,[2] who found that NBA players who sustained an Achilles tendon rupture had a significant decrease in games played, minutes played, and PER. Interestingly, after ACL reconstruction, players in the WNBA had a drop-off in all performance categories, with significant declines seen in shooting percentage and steals per 40 minutes of game play.[21]

WNBA players subject their bodies to significant physical demands during their 34-game regular season schedule, not accounting for preseason workouts, practices,

postseason games, or other professional leagues they may participate in during the offseason. To fully understand the effect that Achilles tendon rupture has on performance outcomes, all cases except for one were matched with 2 controls to assess interplayer differences. All cases experienced a significant decrease in minutes played per game and PER, while controls improved in both metrics at 2 seasons postinjury. When compared with controls, cases experienced significant decreases in field goals per game, free throws per game, steals per game, turnovers per game, and points scored per game after return to play. The decrease in turnovers seen in the injured group is likely secondary to decreased playing time rather than an actual improvement in ball security. It is important to note, however, that these are per-game averages and do not normalize for the decreased minutes played per game. However, the statistical comparison of PER, which attempts to characterize player efficiency while on the court, does show a significantly decreased PER after return to play from Achilles tendon rupture. The authors would argue that the decreases in minutes played postoperatively are likely related to the coach's subjective opinion that the player may not be performing at their preinjury level of play. While this is a subjective measure, we believe it is a good metric to show decreased return-to-play performance, especially because the aforementioned trend was shown to be true across all the cases in our study. Similarly, NBA players who sustained an Achilles tendon rupture saw all their performance metrics decline in the postoperative period versus matched controls, with significant decreases in rebounds per game, steals per game, and blocks per game.[2] These findings point to the fact that Achilles tendon injuries significantly affect both offensive and defensive performance. After ACL reconstruction, WNBA players saw no significant declines in performance outcomes as compared with matched controls,[21] further supporting the notion that Achilles tendon injuries pose the greatest threat to performance and career longevity in professional basketball players.[19,26]

Female athletes in the WNBA sustain 60% more injuries than male athletes in the NBA, with lower extremity injuries, predominantly of the ankle, accounting for 66% of all WNBA injuries.[7] Despite the majority of ankle injuries experienced in the WNBA being lateral ankle sprains,[7] Achilles tendon ruptures pose a career-threatening challenge to professional athletes in the WNBA.

The average age of our cases was 28 years old, just 1 year older than the league average (27 years), and the average playing service in the league when the tear occurred was 6.5 years. The average age for our cases was slightly older than the average age of WNBA players who underwent ACL reconstruction surgery (26.8 years).[21] In comparison, NBA players undergoing surgical repair for an Achilles tendon rupture were both the oldest (28.4 years) and the most experienced (6.5 years) as compared with those undergoing orthopaedic surgical procedures for other injuries.[19] During our study period, athletes who failed to return to play were on average older (32.8 years), played more preoperative seasons in the WNBA (9.75 seasons), and had a lower PER in the preoperative season (7.8) as compared with athletes who were able to return to play after injury (Table 1). Because players who failed to return to play had considerably longer careers than the average WNBA player (3.4 years),[18] the authors speculate that these findings suggest players may have been affected by a chronic Achilles tendon pathology preceding their acute rupture. Additionally, they may have been unable to return to the WNBA as a result of other factors associated with aging or chronic wear and tear; however, these factors were unable to be identified within the methodology of our study.

The prolonged physical and neurological stress of a long competitive season and professional career may explain the increasing incidence and earlier age at rupture in professional athletes as compared with the general population.[5,13,25,27] Interestingly, Achilles tendon ruptures are far less common in women than men,[4,27] possibly because of the protective effect of sex hormones, namely estrogen, on collagen synthesis and tendon compliance.[3,20,22,23] Higher levels of circulating endogenous estrogen in women results in decreased collagen synthesis after strenuous exercise, accounting for a smaller tendon cross-sectional area, and decreased hypertrophy, resulting in less muscle mass as compared with men.[3,12,20] This difference could account for the discrepancy seen in the incidence of Achilles tendon ruptures between men and women. In contrast to the general population, the incidence of Achilles tendon ruptures per season observed in our study was similar to that in prior studies detailing the incidence of Achilles tendon ruptures in the NBA.[2,11] This is an interesting finding considering that the WNBA regular seasons consists of fewer games (n = 34) than the NBA regular season (n = 82), indicating that female basketball players may be at higher risk for Achilles tendon rupture per game played, although this consideration does not account for the fact that some WNBA players may play in other professional or semiprofessional leagues in their longer off-season. This finding may oppose previous studies stating that men are at increased risk for Achilles tendon rupture as compared with women and warrants further investigation. The authors speculate that the greater incidence of Achilles tendon ruptures in men consistently reported in the general population may be related to the fact that men may be more likely to participate in high-risk activities, such as basketball.

Injuries in professional sports pose unique challenges compared with those sustained in collegiate, amateur, or youth athletes. These challenges often stem from the fact that the performance of professional athletes has significant financial implications, and injuries can jeopardize personal, familial, team, and organizational earnings. Despite elite athletes having access to gold-standard rehabilitation protocols and equipment, the return to play across all professional sports after Achilles tendon rupture ranges from 60% to 70%.[2,17,19,24,26] Therefore, it can be inferred that Achilles tendon ruptures pose a significant threat to players' careers. As a result, professional organizations may be reluctant to financially invest in older athletes who sustained an Achilles tendon rupture because of the high risk of decreased performance secondary to their injury.

This study presents a few inherent limitations, stemming from the identification of Achilles tendon rupture cases from publicly available resources. As a result, we were unable to identify the surgical procedure (open vs

percutaneous repair) used to repair the Achilles tendon rupture, immobilization protocols, or implementation and adherence to rehabilitation protocols. Without access to team or player medical reports, we were unable to determine if the players had sustained minor Achilles tendon injuries leading up to their rupture, which could explain degenerative changes preceding an acute rupture. However, similar methods have been used in investigations of performance outcomes.[1,2,19,21,26] We were also unable to determine and control for whether it was a physical or structural issue, as opposed to a personal, familial, or organizational reason for a player's retirement. One case was unable to be properly matched with controls, accounting for 2 less controls than a perfect 1:2 case-to-control ratio. Just 1 case had a BMI >25, making it difficult to draw conclusions between this variable and return-to-play performance metrics in players who suffered an Achilles tendon rupture. We do, however, believe BMI to be an important risk factor for Achilles tendon injury and have therefore included it for completeness. Furthermore, because of the nature of this injury, our study consists of a relatively small sample size. While this is inherently a limitation, we would argue that many, if not all, of the trends seen in our study would achieve statistical significance with a larger sample size. Finally, because of the authors' statistical comparison of players who returned to play versus those who did not, the possibility of a type 2 error must be considered.

To our knowledge, this is the first study that looks at the functional impacts on return-to-play and performance outcomes after surgical repair for Achilles tendon rupture in the WNBA. These findings should provide valuable information to guide players, coaches, medical personnel, and front offices in their postoperative management and expectations of players after Achilles tendon rupture.

CONCLUSION

In the current study, 23.5% of WNBA players who sustained an Achilles tendon rupture and underwent subsequent surgical repair did not return to play in the WNBA, and 41.2% did not return to play for >1 season in the WNBA. Of those who returned to play, significant declines were observed in both minutes played per game and PER in the postoperative period as compared with preinjury. When compared with matched controls, cases had declines in all performance metrics, with significant differences between groups observed in field goals, free throws, steals, turnovers, and points scored.

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