

## Original Article

# Performance Is Regained Within 2 Seasons After Quadriceps Tendon Tears in National Basketball Association Players

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**Purpose:** To characterize quadriceps tendon injuries over 30 National Basketball Association (NBA) seasons and assess the effects on player performance upon return to play. **Methods:** Partial and complete quadriceps tendon tears in NBA players between the 1990-1991 and 2021-2022 seasons were queried from a publicly available database. The primary outcomes were changes in player performance statistics obtained from each player's preindex season and first 2 postindex seasons. These interseason changes were compared with the changes of a healthy control cohort. Each injured player was matched with 2 controls using position, career length and win shares by season. The secondary measure of this study was the rate of return to play. **Results:** Nine quadriceps tendon tears (6 partial, 3 complete) were identified in NBA players. Seven (78%) of the players returned to play in NBA games, missing  $50 \pm 30$  games and  $214 \pm 112$  calendar days on average. Comparisons between these player's preindex and first postindex seasons revealed significant declines in games played ( $73.2 \pm 6.6$  vs  $41.8 \pm 10.8$ ,  $P = .009$ ) and minutes per game ( $27.2 \pm 2.9$  vs  $23.0 \pm 3.7$ ,  $P = .042$ ). When compared with controls, only the decrease in games played was significant ( $-31.3 \pm 7.6$  vs  $1.4 \pm 8.2$ ,  $P = .004$ ). These findings were consistent when comparing preindex and second postindex seasons (games played:  $79.6 \pm 1.9$  vs  $-28.4 \pm 5.4$ ,  $P = .006$ ; minutes per game:  $29.3 \pm 2.6$  vs  $51.2 \pm 4.6$ ,  $P = .003$ ). All other player performance metrics including player efficiency rating returned to near-baseline levels in the first 2 seasons after injury. **Conclusion:** NBA players with quadriceps tendon tears return to play in 78% of cases. These athletes achieved preinjury levels of performance within 1 to 2 seasons, but with reduced games played per season. **Level of Evidence:** IV, therapeutic case series.

The quadriceps tendon is the confluence of the 4 quadriceps muscles and is a critical component in extension of the knee.<sup>1</sup> This tendon provides substantial biomechanical support to the knee during athletic movement and sustains mechanical loads of up to 1,055 N.<sup>2,3</sup> However, sudden and eccentric contractions of the

quadriceps muscle can overwhelm the extensor mechanism and result in a partial or complete rupture of the quadriceps tendon.<sup>1,4</sup> In the general population, this injury is most common in medically complex individuals >40 years old through a low-energy mechanism. In addition, these tears also may occur in high-impact athletes who compete on hard surfaces, such as National Basketball Association (NBA) players.<sup>5,6</sup>

Repeated explosive vertical and lateral movements in basketball athletes place unique physiologic stresses on the knee joint. More than one third of basketball players suffer from knee tendonitis secondary to overuse inflammation and microtearing within the patellar or quadriceps tendon.<sup>7,8</sup> This condition can predispose individuals to propagation of tears with potential for complete rupture of either tendon.<sup>1,4,9</sup> Patellar tendon tears in NBA athletes have been associated with good return-to-play outcomes, as measured by performance efficiency rating (PER), but in some cases these injuries are devastating, as 25% of tears are career-ending.<sup>10</sup> Although the prognosis of patellar tendon ruptures in NBA players is well-characterized, little is understood

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The authors report the following potential conflicts of interest or sources of funding: A.C. reports personal fees from Arthrex, Zimmer Biomet, and Trice Medical, outside the submitted work. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).

Received June 24, 2022; accepted September 13, 2022.

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<https://doi.org/10.1016/j.asmr.2022.09.009>

about the recovery and expectations of quadriceps tendon tears in the same population. The purposes of this study were to characterize quadriceps tendon injuries over 30 NBA seasons and assess the effects on player performance upon return to play. We hypothesized that players with tears in the quadriceps tendon would achieve preinjury levels of PER in their first season after returning to play.

## Methods

### Data Collection

This study is a retrospective review of a publicly available database and was granted an exemption by the Mayo Clinic Institutional Review Board under application number 21-009369. Injury data from October 1990 through May 2022 were queried from Pro Sports Transactions ([prosportstransactions.com](https://prosportstransactions.com)), an online database that tracks (1) player movement on and off each NBA team's inactive list, (2) description of injury, (3) date of injury, and (4) return-to-play date. This database has been cited previously in numerous NBA-related studies.<sup>11-16</sup> Each injury event recorded was verified through official team press releases and media reports in addition to player game logs on Basketball-Reference ([basketball-reference.com](https://basketball-reference.com)). Information from Basketball-Reference is sourced by Sportradar US (Sportradar AG, St. Gallen, Switzerland), the official stats partner of the NBA. The return-to-play date was used to calculate games missed and days missed.

Team schedules, player demographics, and player statistics were obtained from Basketball-Reference. The season in which an individual was injured was considered the index season. Player statistics were gathered for the season before injury (preindex), first season after injury (postindex season 1), and second season after injury (postindex season 2). Statistics during the index season were not reported in this study. Games played (GP), minutes per game (MPG), and points per game (PPG) were calculated by combining all regular season and playoff statistics. Advanced statistics including PER, usage rate (USG%), and true shooting percentage (TS%) were derived from regular season statistics only. PER is a rating developed by ESPN ([ESPN.com](https://www.espn.com)) that factors in offensive and defensive performance of a player on a per-minute basis. PER is normalized so that the average PER across all NBA players is 15.0. USG% is a measure of a player's offensive involvement while on the floor given their shots attempted and turnovers. TS% represents an individual's overall shooting efficiency, accounting for 2-point field goals, 3-point field goals, and free throws.

Each player was matched with 2 control subjects using previously reported methods.<sup>17</sup> The similarity score provided by Basketball-Reference quantifies the

similarity between NBA players based off position, career length, and player performance defined by win shares. Win shares is a numeric value that represents the proportion of team wins that can be attributed to a single player's contributions. For each injured subject, the 2 players with the highest similarity scores were selected as controls. For further verification, unpaired 2-tailed Student *t*-tests were performed to rule out any significant differences in age, height, body mass index (BMI), preindex PER, and preindex career minutes played between the injured group and control group. Player statistics from the control group were chosen from the season corresponding to the injured subject's year in the NBA. For example, if an injured subject's preindex season was his fourth year in the league, the control subject's preindex statistics were gathered from his fourth year.

### Statistical Analysis

No current literature exists reporting changes in player performance, as measured by PER, before and after quadriceps tendon injuries. Therefore, this study conducted a power analysis paralleling methodology of previous studies that explored changes in PER for other NBA knee injuries.<sup>10,18</sup> A sample size of 6 was deemed acceptable to power this study ( $\alpha = 0.05$ , power = 0.8, standard deviation = 3). Three of the 9 injured players were excluded from analysis, with 2 suffering career-ending quadriceps tendon injuries, and the other having sustained his injury during the 2020-2021 season. Of the remaining 6 players, one individual retired after his first postindex season and was excluded from comparisons involving postindex season 2. Univariate comparisons of player statistics between the preindex season vs postindex seasons were conducted using paired 2-tailed Student *t*-tests. Unpaired 2-tailed Student *t*-tests were used to evaluate the changes in player statistics between the injured and control cohorts. Linear regression analysis was performed to determine whether the independent variables of age, height, BMI, years in NBA, preindex cumulative career minutes played, or preindex PER influenced the dependent variable of change in PER between the preindex season and postindex season 1. Statistically significant differences were noted if  $P < .05$ . All analyses were conducted using R, version 3.6 (R Core Team, Vienna, Austria) and Excel 2021 (Microsoft, Redmond, WA).

## Results

Nine quadriceps tendon tears (6 partial tears, 3 complete ruptures) in NBA athletes were identified across a 30-year period (Table 1). The average age at the time of injury for partial tears was  $28.7 \pm 2.8$  years, which was slightly younger than that of complete tears ( $32.0 \pm 5.3$  years). Height ( $1.96 \pm 8.6$  cm vs  $193.0 \pm 5.0$  cm) and BMI ( $24.2 \pm 2.3$  vs  $26.1 \pm 2.8$ ) were

**Table 1.** Demographic Information of Quadriceps Tendon Tears in National Basketball Association Players

	Partial Tear	Complete Tear	All Tears
No. of players	6	3	9
Age at Injury,* y	28.7 ± 2.8	32.0 ± 5.3	29.8 ± 3.8
Height,*cm	196.0 ± 8.6	193.0 ± 5.0	195.0 ± 7.0
BMI,*	24.2 ± 2.3	26.1 ± 2.8	24.8 ± 2.5
Position, %			
Center	0 (0)	0 (0)	0 (0)
Power forward	1 (17)	1 (33)	2 (22)
Small forward	1 (17)	0 (0)	1 (11)
Shooting guard	2 (33)	1 (33)	3 (33)
Point guard	2 (33)	1 (33)	3 (33)
Operative treatment, %	5 (83)	3 (100)	8 (89)
Return-to-play, %	5 (83)	2 (67)	7 (78)
Games missed	48 (0-89)	57 (27-86)	50 (0-89)
Days missed†	185 (67-332)	287 (206-368)	214 (67-368)

BMI, body mass index.

\*Reported as mean ± standard deviation.

†Reported as mean (range).

similar between the partial-tear and complete-tear cohorts. The majority of injured players (67%) played either the shooting guard or point guard position. No quadriceps tendon tears were noted at the center position. Of the 9 players with a torn quadriceps tendon, 2 (22%) did not return to play and retired. No unique player characteristics were associated with either of these career-ending injuries (Table 2). In those who did return to play, the average number of games missed, and calendar days missed were 50 and 214, respectively (Table 1). Eight players (89%) received operative treatment, including all who sustained a complete rupture. The return-to-play rate of those undergoing surgery was 75% (Table 2).

In players who returned to play, there were no significant declines in PER between the preindex season and postindex season 1 ( $16.6 \pm 2.2$  vs  $12.2 \pm 3.5$ ,

$P = .209$ ) or postindex season 2 ( $17.5 \pm 2.4$  vs  $15.6 \pm 1.4$ ,  $P = .386$ ) (Table 3). Similar results were identified for PPG, TS%, and USG%. However, there were significant decreases in average games played ( $73.2 \pm 6.6$  vs  $41.8 \pm 10.8$ ,  $P = .009$ ) and average MPG ( $27.2 \pm 2.9$  vs  $23.0 \pm 3.7$ ,  $P = .042$ ) between preindex season and postindex season 1. This decline also was seen from the preindex season to postindex season 2 with average games played ( $79.6 \pm 1.9$  vs  $51.2 \pm 4.6$ ,  $P = .006$ ) and average MPG ( $29.3 \pm 2.6$  vs  $24.7 \pm 3.6$ ,  $P = .032$ ).

Changes in player performance after return to play was compared with matched controls in Table 4. The injured and control groups both demonstrated similar changes in PER for postindex season 1 ( $-4.4 \pm 3.0$  vs  $-1.9 \pm 1.3$ ,  $P = .326$ ) and postindex season 2 ( $-1.9 \pm 2.0$  vs  $-1.2 \pm 0.9$ ,  $P = .651$ ). This finding was consistent when evaluating MPG, PPG, TS%, and USG%. Players returning to play after quadriceps tendon tear exhibited significantly greater declines in games played in their postindex season 1 ( $-31.3 \pm 7.6$  vs  $1.4 \pm 8.2$ ,  $P = .004$ ) and postindex season 2 ( $-28.4 \pm 5.4$  vs  $4.2 \pm 7.9$ ,  $P = .005$ ) when compared with matched controls.

Linear regression analysis revealed no significant relationship between age, height, BMI, years in NBA, preindex cumulative career minutes played, or preindex PER and change in PER between the preindex and postindex season 1.

## Discussion

The most important finding of this study is that most NBA players who experience an injury to the quadriceps tendon regain preinjury performance within 2 seasons. Of the 9 quadriceps tendon tears identified, 2 were considered career-ending (22%). This included a 36-year-old player with a complete rupture and 30-year-old player with a partial tear, both of whom received operative treatment (Table 2). Although both players were aged  $\geq 30$  years, there were 3 other

**Table 2.** Injury characterization of Each Quadriceps Tendon Tear in National Basketball Association Players From the 1990-1991 to 2021-2022 Seasons

Player Age, y	Tear	Surgery	RTP	Cumulative Minutes Played	
				Preinjury	Postinjury
25	Partial	Yes	Yes	2,165	7,210*
26	Partial	No	Yes	14,907	10,074*
28	Partial	Yes	Yes	14,453	173*
30	Partial	Yes	No	21,655	0
31	Partial	Yes	Yes	27,694	3,321
32	Partial	Yes	Yes	17,351	274
26	Complete	Yes	Yes	12,655	1,906*
34	Complete	Yes	Yes	42,098	2,141
36	Complete	Yes	No	43,559	0

RTP, return-to-play.

\*Currently active as of the 2021-2022 regular season.

**Table 3.** Univariate Analysis of Player Performance in the Preindex Season Compared With the First Two Postindex Seasons

	Preindex Season*	Postindex Season 1*	Change*	P Value
GP	73.2 ± 6.6	41.8 ± 10.8	-31.3 ± 7.6	.009
MPG	27.2 ± 2.9	23.0 ± 3.7	-4.3 ± 1.6	.042
PPG	13.3 ± 3.1	10.8 ± 3.2	-2.5 ± 1.9	.235
Per	16.6 ± 2.2	12.2 ± 3.5	-4.4 ± 3.0	.209
TS%	0.54 ± 0.01	0.48 ± 0.06	-0.06 ± 0.06	.336
USG%	22.35 ± 2.31	21.03 ± 2.23	-1.32 ± 0.89	.200
	Preindex Season*†	Postindex Season 2*†	Change*†	P Value
GP	79.6 ± 1.9	51.2 ± 4.6	-28.4 ± 5.4	.006
MPG	29.3 ± 2.6	24.7 ± 3.6	-4.6 ± 1.4	.032
PPG	14.7 ± 3.5	14.1 ± 3.4	-0.6 ± 1.8	.768
PER	17.5 ± 2.4	15.6 ± 1.4	-1.9 ± 2.0	.386
TS%	0.53 ± 0.01	0.53 ± 0.01	-0.02 ± 0.02	.288
USG%	22.82 ± 5.11	23.80 ± 3.31	0.98 ± 2.08	.662

GP, games played; MPG, minutes per game; PER, player efficiency rating; PPG, points per game; TS%, true shooting percentage; USG%, usage percentage.

\*Reported as mean ± standard error of the mean.

†The sample size of all comparisons involving Postindex Season 2 decreased from  $n = 6$  to  $n = 5$  due to one player retiring after Postindex Season 1.

players aged  $\geq 30$  years who sustained quadriceps tendon tears and did return to play after surgery. Further, the cumulative career minutes played between these players were comparable with those that did return to play. Neither age, operative treatment, nor cumulative minutes played appeared to influence the ability to return to NBA games. Consequently, no risk factors were identified for career-ending quadriceps tendon tears. These findings may aid NBA physicians and trainers in forming accurate expectations for players recovering from quadriceps tendon tears.

In total, 78% of NBA players who returned to play after quadriceps tendon tears achieved preinjury PER levels by their first season back ( $P = .209$ ) (Table 3). Changes in other player performance measures, including PPG ( $P = .235$ ), TS% (0.336), and USG% (0.200) were not significant upon return to play. Interestingly, each of these player statistics markedly declined in the first season back, although not significant, and improved to nearly match baseline levels by the second season postinjury. With greater power, this study may have revealed a significant decrease in player performance in postseason index 1. Nonetheless, most NBA players with a torn quadriceps tendon can expect to regain their normal on-court production sometime within their first 2 seasons after returning. However, there appears to be a significant reduction in playing time after this type of injury. This study found significant decreases in GP and MPG within player's first 2 seasons postinjury. Interestingly, comparisons with matched controls indicate the decline in MPG in injured players was similar to that of healthy players ( $P = .643$ ,  $P = .351$ ), and therefore may be an expected change at that point in their careers, independent of a torn

quadriceps tendon (Table 4). Despite this, the decrease in GP is notable and likely to be multifactorial and may be attributable to a prolonged and conservative recovery, load management, secondary injuries, and other unknown variables. Overall, these findings suggest that NBA players sustaining a major quadriceps tendon injury will likely experience reductions in games played per season but should be able to return to preinjury performance within 1 to 2 seasons.

Quadriceps tendon tears in other populations have yielded varied outcomes. In nonathletes with surgically repaired quadriceps tendons, good-to-excellent results have been achieved in 83% to 100% of cases.<sup>4,19-21</sup> Interestingly, one study noted that 51% of patients were unable to return to their preinjury level of recreational activity after surgery despite a 92% patient satisfaction rate.<sup>22</sup> In comparison, in the current study, our results demonstrated that only 22% of players with a similar injury were unable to return to play. It is important to consider that nonathletes sustaining a quadriceps tendon tear are often aged  $>40$  years and are unlikely to have the same goals or rehabilitative resources as NBA athletes. A more appropriate comparison may be between NBA and National Football League players. One study of National Football League players over a 10-year period revealed 14 individuals with quadriceps tendon tears, with only 7 (50%) returning to play in games after recovering.<sup>23</sup> Of the other 7 players with career-ending quadriceps tendon injuries, 6 were listed as offensive or defensive lineman. The BMI of players at these positions are historically greater than that of an average NBA player and may complicate the recovery of a major lower-extremity injury.<sup>24</sup> In the current study, all NBA players who

**Table 4.** Univariate Analysis of Changes in Player Performance Compared With Matched Controls

	Change From Preindex Season		P Value
	Injured Group*†	Control Group*†	
GP			
Postindex Season 1	-31.3 ± 7.6	1.4 ± 8.2	.004
Postindex Season 2	-28.4 ± 5.4	4.2 ± 7.9	.005
MPG			
Postindex Season 1	-4.3 ± 1.6	-3.0 ± 2.3	.643
Postindex Season 2	-4.6 ± 1.4	-2.5 ± 1.8	.351
PPG			
Postindex Season 1	-2.5 ± 1.9	-1.7 ± 1.7	.716
Postindex Season 2	-0.6 ± 1.8	-2.4 ± 1.5	.396
PER			
Postindex Season 1	-4.4 ± 3.0	-1.9 ± 1.3	.326
Postindex Season 2	-1.9 ± 2.0	-1.2 ± 0.9	.651
TS%			
Postindex Season 1	-0.06 ± 0.06	-0.03 ± 0.02	.512
Postindex Season 2	-0.02 ± 0.02	0.00 ± 0.00	.528
USG%			
Postindex Season 1	-1.32 ± 0.89	-0.28 ± 1.37	.506
Postindex Season 2	0.98 ± 2.08	-1.57 ± 1.47	.261

GP, games played; MPG, minutes per game; PER, player efficiency rating; PPG, points per game; TS%, true shooting percentage; USG%, usage percentage.

\*Reported as mean ± standard error of the mean.

†The sample size of all comparisons involving Postindex Season 2 decreased from n = 6 to n = 5 due to one player retiring after Postindex Season 1.

suffered a quadriceps tendon tear had a BMI  $\leq 29$  at the time of injury.

Outcomes of tears in the quadriceps tendon, as shown in this study, are similar to those reported in for patella tendon tears in basketball athletes. The current study's findings parallel previous literature on patella tendon tears in NBA players which reported significant declines in GP and MPG between a player's preindex season and postindex season 1.<sup>10</sup> The RTP rate in patella tendon tears (75%) is also comparable with that of quadriceps tendon tears (78%). Further review of other major knee injuries in NBA players reveal a similar trend in return-to-play rates: ACL tear (74%-78%), meniscus tear (81%), and knee microfracture surgery (79%-83%).<sup>25-29</sup> Consistent with the current study, no significant differences in PER were noted between preindex and postindex seasons when assessing NBA players with patellar tendon or meniscus tears.<sup>10,29</sup> The prognosis of a quadriceps tendon tear appears to be akin to other traumatic knee injuries in the NBA athlete.

### Limitations

This retrospective study had several limitations. First, injury data were extracted from a public database and verified through press releases and other public websites. Although this database has been cited by numerous publications, there may be inconsistencies

between these data and official team medical records. The lack of access to medical records also prevented reporting of valuable clinical measures, such as range of motion, pain rating, and tear description. Second, the sample size of 9 subjects is small and increases the likelihood of a Type II error. Statistical comparisons between partial and complete quadriceps tendon tears, as well as players receiving operative versus nonoperative treatment were not completed due to the lack of power. This comparison would allow a more extensive prognostication of different quadriceps tendon tears in NBA athletes. Third, the player statistics chosen in this study provide only a partial characterization of a player's overall performance and may be influenced by unaccounted factors such as team change.

### Conclusions

NBA players with quadriceps tendon tears return to play in 78% of cases. These athletes achieved preinjury levels of performance within 1 to 2 seasons, but with reduced games played per season.

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