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Original Article

Prognosis of elite basketball players after an Achilles tendon rupture

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ABSTRACT

Objective: Professional Basketball players are at high risk of Achilles tendon rupture. Despite this, there remains limited research into the factors affecting rehabilitation and the long term outcomes of these players. Our aim is to quantify the effect of a player's Achilles tendon rupture on their post-injury performance, and also to explore for correlations between their recovery timeline and pre-injury characteristics. Creation of an injury timeline of past incidents will allow injured players to better track their progress and also inform them about the probable impact on their careers.

Hypothesis: Players with Achilles tendon rupture injury will exhibit decreased performance compared to their pre-injury self and their non-injured peers after recovery.

Methods: Professional basketball players who sustained a unilateral Achilles tendon rupture from 1992 to 2016 were collected. 12 players met our inclusion criteria and their Player Efficiency Ratings (PER) were obtained as primary outcome measures; matched controls were chosen based on the PER, Age and playing position. The players' index season PER was compared against the PER during the 10 games immediately following the players' return and the PER of their post-injury peak performing season. The same data analysis was performed against their control group. To investigate the factors affecting the recovery and long-term consequences of their injury, we correlated the variables of Age, BMI, Time of Injury and pre-injury PER with the player's time to return to play and their post-injury PER.

Results: 2 out of 12 players failed to return to playing in the elite professional league following an Achilles Tendon Rupture, others returned after a mean recovery time of 10 months. When compared to players' index PER, the mean PER reduction during the 10 games immediately following the players' return was 7.15 ($P < .000$). Players on average took 1.8 seasons to reach their post-injury peak performance, with only 1 player returning to his pre-injury performance. Others suffered a mean PER reduction of 3.5 ($P = .004$) when compared to their index PER and 5.4 ($P = .045$) against their matched controls.

Conclusion: Achilles tendon rupture can be a career-ending injury for professional basketball players. They are expected to miss 10 months for rehabilitation and reach their post-injury peak performance level at the 2nd season back. The post-injury peak performance is significantly worse than the pre-injury level, but is similar to matched non-injured players.

Introduction

Professional basketball players are at high risks of sustaining an Achilles tendon rupture (ATR).[1] A torn Achilles tendon is a potentially devastating injury in athletes, and returning to play is often impossible[2–4]. Players with an Achilles rupture face long periods of rehabilitation and some even had to prematurely end their career. Despite such catastrophic outcomes in this relatively common basketball injury,[5–7] there remain some knowledge gaps into which factors affect their long term outcomes and career prospects.

The prognosis of an Achilles tendon rupture in basketball players is often regarded as poor,[8,9] but there are some athletes who seemed to out-perform others. Our aim is to investigate which factors affect elite athletes' prognosis. We want to assess the optimal time needed for a player with an ATR to return to play (RTP), along with comparing their performance with their potential career trajectory if there was not an injury by comparison with non-injured counterparts with similar pre-injury characteristics.

In order to investigate the effects and outcomes of an ATR amongst elite athletes, we have accessed the publicly available

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archived data of the National Basketball Association (NBA) athletes. Since this is a retrospective review of public data, we were unable to perform standard outcome scoring for the subjects.[10] Thus, we have quantified a player's performance through the widely used Player Efficiency Rating (PER), which is an overall statistical measure to objectively evaluate a player's on-court contribution.[7] We hypothesise that a player's PER will decline after an ATR, and that such an injury would hinder them from reaching their original performance potential.

Although it is difficult to generalise results from world-class elite athletes due to their personal outstanding physical capabilities and well-funded rehabilitation teams,[11] the results from this analysis may serve as an illustration of a best-case scenario for regular athletes with ATRs.

Method

Eligibility

All NBA players included in this study were identified through injury reports, press release and player profiles on NBA.com, ESPN.com and BasketballReference.com.[12–14] To minimise pre-injury performance discrepancy between players, rookies that have played less than 2 seasons in the NBA are excluded. Player data and performance statistics (1. Points per game (PPG) 2. Minutes per game (MPG), 3. Rebounds per game (RPG), 4. Assists per game (ASG), 5. Steals per game (SPG) 6. Blocks per game (BPG), PER) were collected using the official NBA website along with variables including age, body mass index (BMI), player position and number of years before injury. Details of the inclusion and exclusion criteria are as follows:

Inclusion criteria

1. All participants are NBA players
2. All participants have suffered from an Achilles tendon rupture between 1992 and 2016
   - Justification: Our data shows that the most common highest performing season after the injury is the 2nd/3rd season. Therefore, players with injuries after 2017 will less likely be able to reach their highest performing season in the year 2019.
3. All players suffered an unilateral Achilles tendon rupture
4. All players have first time Achilles tendon rupture with no other identifiable concordant lower limb injuries and past surgeries
   - Justification: Achilles tendon rupture is the most significant factor affecting the player's post-injury deterioration of performance and not other lower limb injuries or recoveries.
5. Players that have played at least 2 seasons in the NBA
   - Justification: Exclude rookies and sophomore who may still be adapting to the level of play of the NBA, therefore not reflecting the effects of an Achilles tendon rupture on the performance of an elite professional basketball player.
6. Players that played at least 58 games of the regular season (or 70% in lockout seasons or seasons without 82 games) in the most recent season prior to the season of injury, and averaging >/=12min per game
   - Justification: 58 games is the benchmark used by NBA officials to determine if a player has played enough games to be considered significant and therefore be listed on statistical leader boards. This theory suggests that players playing less than 58 games are not significant players contributing to the performance of play in the NBA that season, therefore would be excluded in our study. Furthermore, 12 min is the median number of minutes per game listed out of all NBA players. Therefore, 12 min would be the benchmark in our study to determine is a player is significant on a per-game basis.

Exclusion criteria

1. Players with bilateral/recurrent Achilles tendon ruptures
2. Players with concordant lower limb injuries or past surgeries
3. Players that are rookies or sophomores
4. Players that played less than 58 games of the regular season in the most recent season prior to the season of injury, and averaging <12 min per game

Amongst the included players, they were assessed on their ability to RTP. RTP was defined as the first time in which an injured player can play 7 out of 10 consecutive games in the regular season for at least 12 min. This definition arrived through consideration of load management, whereby NBA coaches restrict a rehabilitating player's court time to 5–10 min until the players/coaches feel comfortable playing with regular minutes and in important moments of games. We wanted our definition of RTP to truly depict a player's ability to return and play at a competitive level.

To objectively assess the effects of an ATR on a player's post-injury performance, matching injured players with a control group of players of similar statistics who had not experienced an ATR allowed us to create a realistic benchmark for comparison of post-injury performance between a player with an ATR and those who had not. Players of different ages, level of performances and positions are expected to react differently to an ATR. By matching an injured player to a control player with similar player characteristics, we are able to more accurately attribute any change in performance to their ATR instead of other uncontrolled factors.

A control group was matched for all returning players based on PER during the year of injury (iPER), age and playing position (Centre, Forward, Guard). The selection of matched controls was conducted through matching iPER of injured players to all current and retired NBA players who had the same PER ± 0.3 during any regular season. Then, players of the same position were chosen, with age ± 3 years. If multiple players matched the prerequisites, the one with the same PER that was closest to the time of injury year of the injured player was chosen as the control. Additionally, the control group had to have no significant injury in subsequent years so as to allow for a better estimation of the ATR players' career projection. An independent-samples T-test with a P interval of .990 was performed comparing the index PER of players, suggestive of a suitable control as their values are not significantly correlated (Table 1).

Return to Play PER (rPER) is the mean PER of the 10 games immediately following the ATR player's RTP, and illustrates the performance level during the initial RTP period. Each player's recovery time was recorded, and rPER for their respective control was calculated using their performance after adding the same duration of 'recovery time' so as to control for age-related changes in performance. For example, if ATR player was injured in 2013 and took 3 years to RTP, the rPER of the control would be taken 3 years after the point in time where his iPER was taken.

Table 1
Independent samples test between players and controls.

	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
Index PER	-.013	18	.990	-.0200
	-.013	18.000	.990	-.0200

Post-injury peak PER (pPER) serves as a measure of the ceiling of performance after a player's ATR. pPER is the highest PER achieved by the player during any regular season post-RTP, with a similar definition for the control group.

Data processing

A statistical analysis using SPSS paired T-test to compare rRTP and pRTP.

Pearson's correlation was also adopted to calculate the correlation between change from iPER to rPER and cPER of the injured group with variables such as age, BMI, number of seasons played before injury and playing position.

Results

30 players in total were found to have suffered from an ATR, with 12 meeting the inclusion criteria. The mean age at the time of injury was 28.2 years (range, 24.0–30.0; SD ± 2.6). The player's mean BMI was 25.7 (range, 22.5–30.1; SD = 2.32). The mean season of injury was the 7th season (7.4) (range, 4.0–11.0; SD = 2.22). The mean iPER of the injured players was 16.7 (range, 10.4–23.1; SD = 3.5) (Table 2).

2 players out of 12 players failed to RTP following an ATR, whereas the others returned after a mean recovery time of 10.1 months (range, 5.0–19.0; SD = 4.1) and subsequently reached their pPER in an average of 1.8 seasons (21 months) (range, 1.0–3.0; SD = 0.8) (Table 2). Player A and Player B were the 2 players that did not RTP as both suffered from injuries during their first 10 consecutive regular-season games after returning from their ATRs. Player A was able to play a stretch of 6 games during 08/12 - 17/12/2013 after being side-lined for 8 months before suffering from a left lateral tibial plateau fracture which left him side-lined for another 10 months, whereas Player B was only able to play 3 games during 28/11–3/12/2012 after being side-lined for 9 months before suffering from tendinitis in his left foot, which side-lined him for another 2 months. Even though both players did eventually return to play in 10 consecutive NBA regular-season games after rehabilitation, the dates of those 10 consecutive games are not representative of the dates of RTP from their ATRs but instead of their subsequent injuries, thus leaving the date of RTP from their ATRs undetermined.

Upon comparing the player's post-injury performance with their performance during the year of injury; the difference between iPER and rPER was 7.2 (P = .000) and the difference between iPER and pPER was 3.5 (P = .004) (Table 3, Graph 1). This shows that their performance level in both RTP and peak season post-injury was lower than their level of play during the year of injury. Only 1 player returned to his pre-injury performance level (iPER = 23.1, rPER = 24.1 and pPER = 18.5). The time for this player to reach pPER was 3 seasons, which was the longest time out of all 12 players.

Comparing the injured players' rPER and pPER with their respective controls', injured players' rPER and pPER were both lower than that of the controlled players. There was a mean PER difference of 5.4 (P = .045) in rPER and 2.6 (P = .191) in pPER. (Graph 1).

The Pearson's Correlation Test for the injured player's i) Age ii) BMI iii) Season of injury and iv) iPER against 1) Difference between injured players' iPER & rPER and 2) Difference between injured players' iPER & pPER was done. Each player's season of injury had a weak correlation of r = −0.590 with the reduction in pPER from iPER. (Graph 2). Players' iPER was found to have a weak correlation of $r = -0.665$ with change in pPER from iPER (Graph 3).

Investigating the same variables (age, BMI, season of injury and iPER of injured players) against the 3) Difference between injured and controlled players' rPER and 4) Difference between injured and controlled players' pPER, only the age and index PER of the injured players showed a statistically significant correlation with the difference between injured and controlled players' pPER. There is a negative correlation of r = − 0.475 (Graph 4) between the age of players and the difference between injured and controlled player's pPER. This shows that if a player is older at the time of injury, there is less difference between the peak PER of injured and controlled players. Players' index PER is strongly correlated (r = 0.713) (Graph 5) to the difference between injured and controlled player's pPER. This finding illustrates how players with higher initial performance see a greater post-injury peak performance deterioration compared to their peers, in line with the conclusion drawn from Graph 3.

Discussion

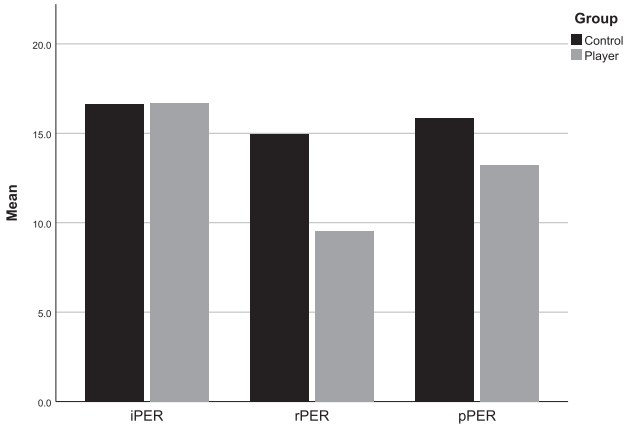
Achilles tendon rupture (ATR) is a serious injury that poses career-changing consequences to professional basketball players.[15] Most elite athletes with ATR undergo surgical repair and around 83% will ultimately return to play.[16] Almost all players failed to return to their pre-injury performance level despite extensive rehabilitation. Similar studies were done by Lemme et al. and Amin et all. Compared to their outcomes, players in our study had a higher RTP rate (83.3% vs 61.4% and 79.5%) but with a bigger drop in Player Efficiency Rating Immediately Following Players' return to play (rPER) (−7.2 vs −4.4 and −2.9).[2] These differences may be explained by the tighter inclusion criteria used in our study, as well as the date when these studies were conducted. We excluded players who had played less than 2 years in the NBA, played less than 58 games in the previous 2 regular seasons (total games in a regular-season = 82) and/or players who average less than 12 min a game. This allowed us to focus our observation on professional players who are not injury-prone and have been acclimatised to the schedule and competition level of the professional league. Furthermore, there is a significant difference in the definition of rPER between our study and the above-named studies. The rPER of Lemme and Amin's studies were defined as the PER of the first season of play post-injury. Therefore, it is reasonable to see a much lower drop in rPER from iPER in our study, as the PER was taken as an average over a much longer period of time, which means players had more time to train and adapt to the level of play in the NBA. rPER was taken over the first 10 games of returning to play in our study, which depicts a more accurate reflection of the player's condition during the initial RTP period. Different players return at different timepoints in the NBA season, so by taking the initial 10 games they play post-injury, we are able to better observe their

Table 2
Performance statistics of NBA players.

	Mean (Range)	Std. Deviation
iPER: Player Efficiency Rating Before Injury	16.7 (10.4–23.1)	3.48
rPER: Player Efficiency Rating Immediately Following Players' return to play	9.53 (2.80–24.1)	5.91
pPER: Peak Player Efficiency Rating Post Injury	13.2 (10.4–18.5)	2.65
Time to Return To Play (Months)	10.10 (5.00–19.00)	4.07
Time to reach Post Injury Peak PER (Seasons)	1.80 (1.00–3.00)	0.89

Table 3
Paired Samples Test of Player's Index PER (iPER) and Post Injury PERs (rPER & pPER).

	Mean	Paired Differences		
		Std. Deviation	95% Confidence Interval of the Difference	
			Lower	Upper
iPER: Player Efficiency Rating before Injury	16.680	3.4848		
rPER: Player Efficiency Rating Immediately Following Players' return	9.530	5.9116		
pPER: Peak Player Efficiency Rating Post Injury	13.220	2.6461		
iPER-rPER: Reduction in Player Efficiency Rating from before injury to immediately after players' return.	7.1500	4.0371	4.2620	10.0380
iPER-pPER: Reduction in Player Efficiency Rating from before injury to the peak performing season post injury.	3.4600	2.7961	1.4598	5.4602



Graph 1. Bar Chart Comparing Players and Control's Mean iPER, rPER and pPER.

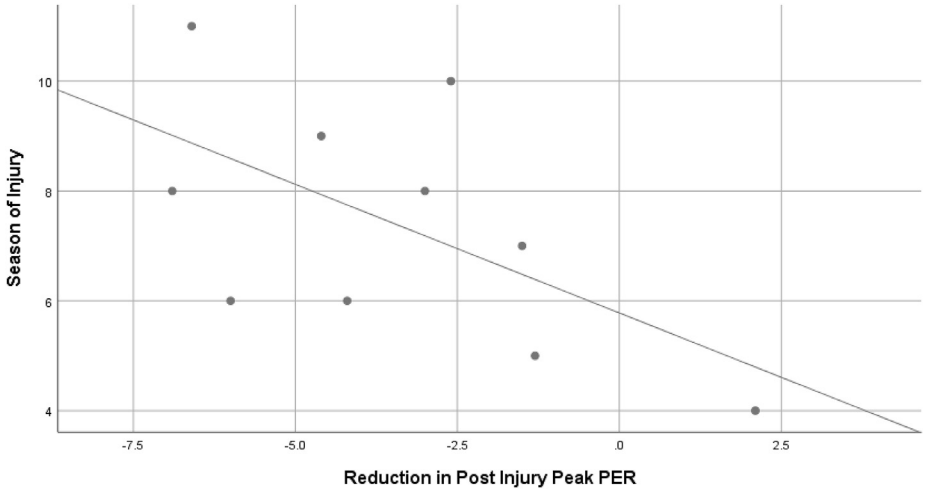
performance level in the early stages of rehabilitation from this devastating injury.

Moreover, our study included players that had been injured as recently as 2016. The surgical technique in ATR repair has evolved throughout the years,[19] and so has the post-surgical rehabilitation protocol. Controversy remains in which repair method is superior and which rehabilitation protocol yields the best results, however[17–19] this discussion is outside the scope of this article.

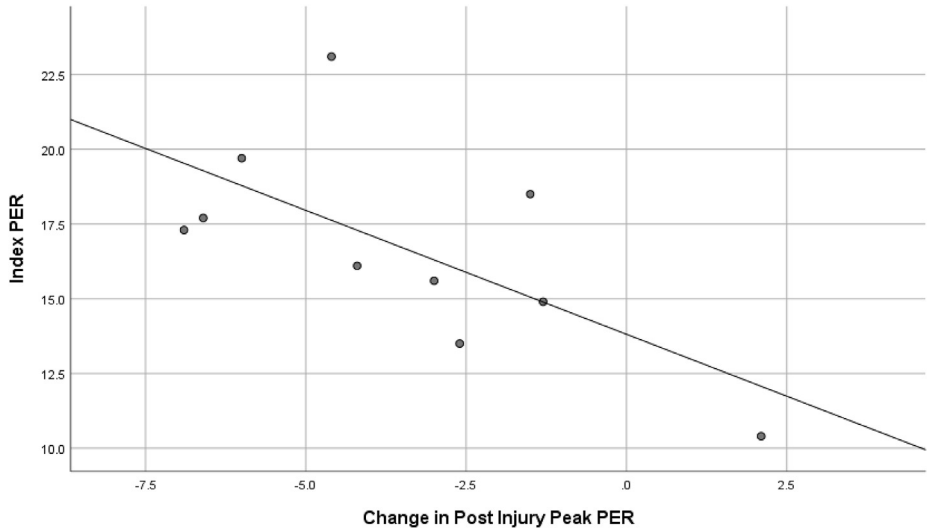
The mean time needed to RTP by injured players is 10 months and players on average reach their post-injury peak performance after 1.8 seasons. Players experienced a 43% drop in performance during the immediate return to play, but slowly regain up to 80% of the pre-injury performance level.[1] The ability for a player to regain his pre-injury performance level is a multifactorial affair, involving structural changes of their calf muscles and the quality of rehabilitation following surgery.[20] According to previous studies, the Achilles tendon lengthens an average of 1.8 cm after its rupture, resulting in a 40% fall in work production.[21] Therefore, immediate reconstruction along with full weight-bearing and early ankle mobilization in rehabilitation to enhance recovery may play a significant role in reducing muscle atrophy and limiting tendon elongation following an ATR.[20]

Although our study effectively illustrates how an ATR is detrimental to an NBA player's performance, confounding time-related deterioration is also a significant determinant of performance decline: Players injured after a longer time playing in the NBA suffer a greater pPER decline post-injury (Graph 2). Despite this, the older the players, the smaller the difference in reduction in pPER when compared to their Control group peers. (Graph 4). The mean age of injury is 28.2 years old, and the mean season of injury is 7.4 seasons. 28.2 years old is higher than the average NBA player's age at 26 years old and the mean season of injury of 7.4 season is also similar to the average career span of an NBA player. Players suffering from an ATR are likely those with more seasons played and therefore have undergone more wear and tear throughout their careers. We also predict that NBA players who are overweight are at comparatively higher risk of ATR as shown by the mean BMI of injured players being 25.1, which is higher than the average BMI of NBA players at 24.8.

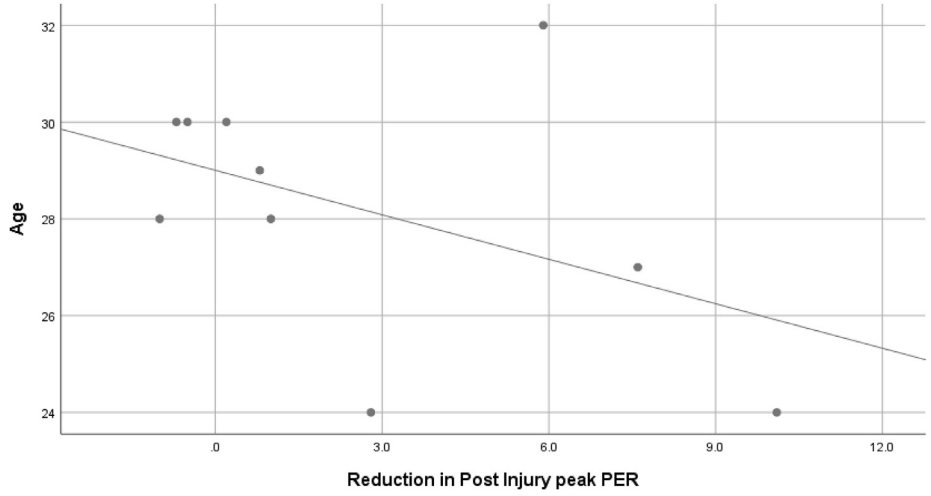
In our study, only 10 out of 12 players returned to play following at ATR. 4 of those players were able to play more than 2 NBA



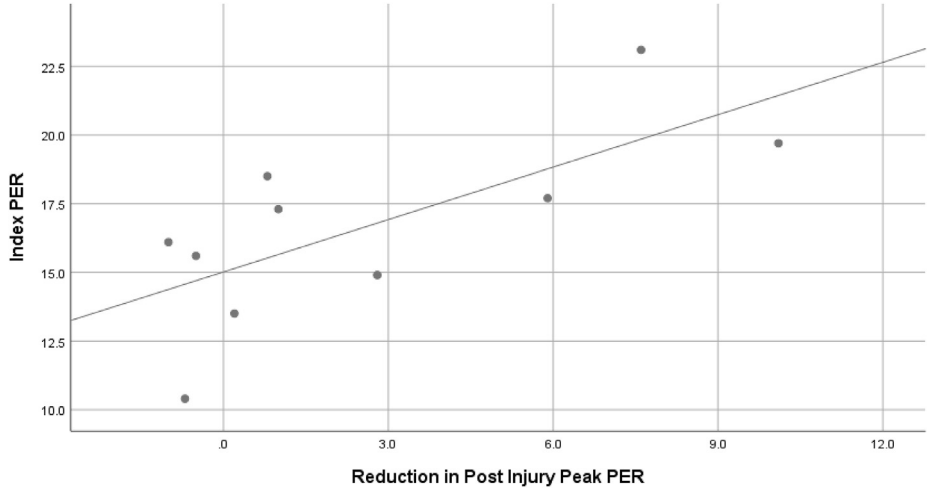
Graph 2. Relationship between Player's season of Injury and Reduction in Post Injury Peak PER(compared to Index PER).



Graph 3. Relationship between Player's Index PER and Change in post injury Peak PER(from Index PER).



Graph 4. Relationship between Player's Age and Reduction in Post Injury peak PER(compared to control).



Graph 5. Relationship between Player's index PER and reduction in Player's post injury peak PER(Compared to control).

seasons and 6 of them only played 2 more seasons before retiring. PER during return to play and during peak season after injury were on average 7.2 and 3.5 lower than the PER during the year of injury respectively. Only 1 player was able to regain his pre-injury performance level and recorded a return to play PER of 1.0 higher than their PER during year of injury. Time to return to play was on average 10.1 months, and it took on average 3 seasons for the injured players to reach their highest performance after injury.

Limitations

Our rigid inclusion and exclusion criteria inevitably limit our sample size. The rationale for only including players who played at least 58 games of the regular season with an average of >/ = 12 min per game was to ensure that player statistics were consistent and contained a large enough sampling database. This limits the likelihood of other confounding factors that had already existed before the injury which may affect the post-injury PER decline.

Regarding the 2 players who failed at a meaningful RTP, both players suffered from other injuries during their initial post-ATR games and were therefore counted as failing to RTP. The purpose of our stringent RTP definition was to assure those players who returned executed meaningful playtime, which we believe is an important aspect of RTP.

The decision to use PER as a reflection of players' performance rests on its universal usage and inclusion of a wide range of skilful components that can be generalized across different players positions. However, the PER calculation is still biased towards offensive players, where most of its components rest upon offensive statistics. Defensive abilities which do not directly translate into statistics are not taken into account and hence neglected in the observation of a player's performance level.

Furthermore, there is position-specific wear and tear patterns which may also affect the players' PER decline. Centers and Forwards tend to play at a slower pace, while guards play at a much higher pace and conduct more cutting and driving. These factors and how they affect ATR and subsequent RTP warrants further investigation.

The cases spans >20 years and there have been changes in the treatment regimens during this time span which may induce some bias. However, the low caseload does not allow us to have perform an accurate sub-group analysis; the authors believe that future studies can include more professional leagues to have a higher sample size.

Lastly, professional players have access to top-class rehabilitation programs and immediate medical attention. They are also more active than a non-professional athlete, and put themselves through physical stress due to increased height and weight. Hence, the findings here cannot be directly translated to clinical service to the general public.

Conclusion

Most elite basketball players are able to return to play after an Achilles rupture, they are expected to miss 10 months (one season) for rehabilitation and often resume their post-injury peak level at the 2nd season back (3 years after the injury).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.asmart.2020.03.002.

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