Performance After Concussion in National Basketball Association Players

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Background: Concussions have received national attention in collision sports such as football, soccer, and hockey, but less focus has been placed on basketball.

Purpose: To determine return-to-play (RTP) and player performance in the first and second season after concussion in National Basketball Association (NBA) players.

Study Design: Descriptive epidemiology study.

Methods: An online database of publicly available NBA athlete injuries was queried for instances of "concussion" between 2010 and 2018. The age at injury, team, position, height, weight, body mass index, NBA experience, date of concussion, date of return, and seasons played postconcussion was recorded for each player. Regular-season statistics (games started, games played, minutes played, and player efficiency rating [PER]) were compiled for the season before, and 2 seasons immediately after, injury. Kaplan-Meier survivorship plots were computed for athlete RTP and retirement endpoints.

Results: A total of 81 injuries were identified from 2010 to 2018, with a rate of 2.0 concussions per 100 player-years. Overall RTP was 100% after concussion, with nearly all (88%) returning in the season of injury; 12% of players experienced a season-ending concussion. RTP averaged 37.3 days after injury, varying widely (range, 2-291 days). Compared with preinjury season (78.0%), athletes played in significantly fewer overall games in the season of injury (36.6%; $P < .0001$), as well as 1 (69.5%; $P = .0229$) and 2 seasons postinjury (73.2%; $P = .3192$). PER scores were not significantly different across the study period. Each point increase in a player's preinjury PER score was associated with a 2.4% decrease in PER from the preinjury season to season of injury ($P = .0016$) and a 3.1% decrease from preinjury to season after injury ($P = .0053$). Each increasing year of age or year of experience was associated with 5% decline in PER score at 1 season after injury.

Conclusion: NBA players had a high RTP after concussion, with most returning in the same season as the injury. Players sustaining concussions played significantly fewer games for at least 2 seasons after injury. Performance via PER did not change across the entire cohort; however, players with higher preinjury PER, and older players were more likely to sustain a greater decline in performance after injury.

Keywords: concussion; NBA; performance; player efficiency rating; return-to-play

Concussions in professional athletes are an increasing concern as more evidence supports the long-term deleterious effects of head injury.[20] These effects can manifest as temporary neurological symptoms, chronic traumatic encephalopathy, and other residual neurologic symptoms.[10] The immediate effects have a significant impact on the ability of players to play and may affect their subsequent performance once they do return to sport. Performance decline after concussion can have significant financial implications for both players and owners and may even put the athlete at risk for other injuries.[11,14]

Consequences of concussions in professional athletes have been documented most widely in National Football League (NFL) players. The incidence of concussion can vary based on positioned played in the NFL, with higher relative risk in offensive players.[22] The incidence of these events may be underreported in a larger proportion of players assessed retrospectively.[15] Underreporting likely occurs across sports, which may lead to biased conclusions based on the available data. In terms of performance, Kumar et al[16] concluded there was no difference in short-term NFL player performance after a concussion regardless of games missed. However, Zuckerman et al[30] found that quarterback performance did decrease in the 3 games after injury. Thus, the mental and physical tasks of professional sports can significantly affect a player's ability to perform after a concussion. In light of these data, multiple protocols have

been implemented to protect players in sports such as the NFL.[5,7,18]

Since the implementation of the NBA Concussion Protocol, there has been an increase in the detection of concussions in the National Basketball Association (NBA).[26] However, in contrast to NFL concussion research, there has been limited evidence detailing performance outcomes in NBA players after concussion.[25,26,29] Yengo-Kahn et al[29] and Patel et al[26] have reported that NBA athlete performance does not change after injury. However, these studies only report on player performance in games immediately after injury (5 and 10 games, respectively).

The purpose of this study was to determine return-to-play (RTP) and player performance, via games played and a player efficiency rating (PER) in the first and second season after concussion in NBA players. It was hypothesized that NBA players would have high RTP rates after concussion but with differences in RTP depending on player position. It was also hypothesized that older players and players with higher preinjury PER would have more significant decline in PER compared with other players.

METHODS

Data Collection

An online database of publicly available NBA athlete injuries between 2010 and 2018 was queried for instances of "concussion."[27] These results were confirmed using NBA team websites, publicly available information online, and press releases when necessary. A total of 81 NBA players who experienced concussions between 2010 and 2018 were identified. This method of data collection has been used in several previous orthopaedic studies.[2,8,21]

Demographic information, including name, age at injury, team played for, position, height, weight, body mass index (BMI), handedness, NBA experience years, date of injury, date of RTP, number of days between and injury and return, and seasons played postinjury was recorded for each player. For the purposes of this study, the first game on an active roster defined successful RTP. Regular-season statistics for the 1 season before injury and the 2 seasons immediately after injury were compiled. Games started, games played, minutes played, and PER were recorded for seasons before and after injury. Demographic information and statistics were discovered using NBA team websites and publicly available internet-based information.[1]

PER is a commonly used, comprehensive statistic that assesses players' contributions as well as detriments on a per-minute basis standardized for position, arena, and in-game situation.[9,12] Calculated by summing positive performance measures (eg, points, rebounds, and steals) and subtracting negative measures (eg, turnovers and fouls), the PER is an objective and standardized method of assessing a player's performance and is often used by coaches and front-office administrators in making player personnel decisions.[4,11] The PER allows for comparisons of player performance across different seasons, as well as players across different teams and positions to standardize their given skillsets. The league average PER is adjusted each year to a value of 15 to standardize the scale. To minimize the effect of team or playing time variables, the PER is adjusted to a per-minute basis, and allocations are made for team pace and playing style to represent a player's overall team contribution.[4] Percentage of preinjury PER was used to evaluate for changes in performance over the course of a given player's career.

Statistical Analysis

Mean and range of player demographics at time of concussion were computed, specifically for BMI and age. Means and 95% CIs of play characteristics at concussion were also calculated for RTP rate. For years of playing experience before injury, days to RTP, and career length postinjury, median and interquartile ranges (IQRs) were calculated. Player performance was reported from the athletes in aggregate. The Wilcoxon rank-sum test was used to compare pre- and postinjury performance, specifically for percentage of games played in a season. For the performance score metric, 2-tailed paired t tests evaluated players against themselves across the different timepoints: season of injury, first season after injury, and second season after injury. Percentage change in performance scores between the preinjury season and seasons after injury was calculated for each athlete, and summary statistics were plotted. Kaplan-Meier survivorship plots were computed for athlete RTP and retirement endpoints with shaded 95% CIs. Factors contributing to days until RTP and percentage change of PER score for a player were assessed though linear regression on a panel of available player characteristics. Statistical analysis was performed using RStudio, Version 1.1.442 (RStudio). An α value of less than .05 was used to determine statistical significance.

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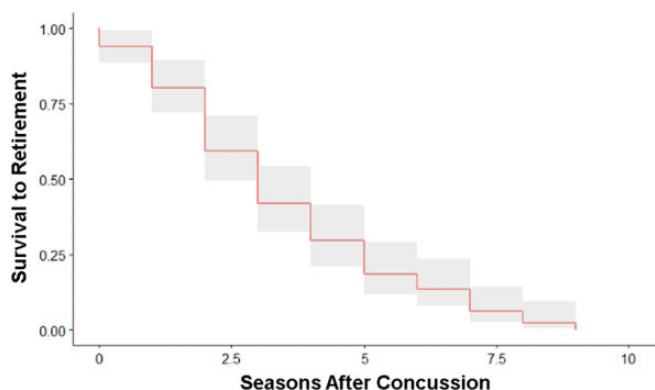
Figure 1. Career survival for National Basketball Association athlete retirement after concussion. The shaded region is the 95% CI.
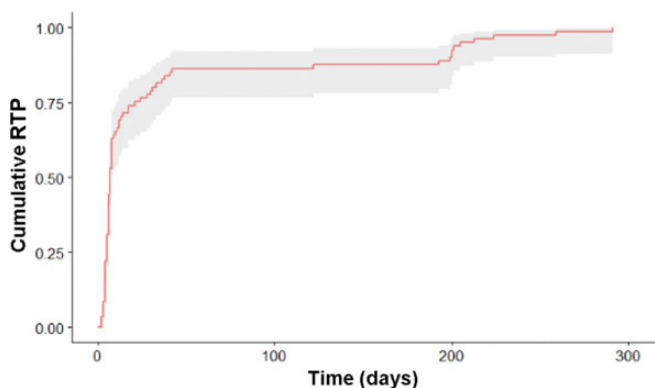

Figure 2. National Basketball Association athlete return-to-play (RTP) after concussion. The shaded region is the 95% CI.

TABLE 1
Factors Affecting Return-to-Play[a]

Risk Factor	Days Until RTP	
	β	*P*
BMI	−7.937	.1360
Preinjury PER score	0.0450	.9820
Age at injury	2.823	.2170
Years of Experience	1.774	.4621
Position (vs center)		
Forward	−46.697	**.0222**
Guard	−24.464	.2195
Mixed forward/guard	−3.556	.8948

[a]Bold indicates statistical significance ($P < .05$). BMI, body mass index; PER, player efficiency rating; RTP, return-to-play.

RESULTS

A total of 81 NBA athletes received a diagnosis of concussion between the 2010 to 2011 and 2017 to 2018 seasons. This was an average incidence in the NBA of 2.0

TABLE 2
Play Performance Before Versus After Concussion[a]

Season	% Games Played, Median (IQR)	PER, Mean ± SD
Preinjury	78.0 (23.2)	14.4 ± 4.7
Injury	36.6 (47.6)	14.3 ± 4.7
Postinjury 1	69.5 (45.1)	14.4 ± 5.5
Postinjury 2	73.2 (85.4)	15.9 ± 6.4
P value		
Injury vs pre	**<.0001**	.2409
Post1 vs pre	**.0229**	.2834
Post2 vs pre	.3192	.2304
Injury vs post1	**<.0001**	.4024
Injury vs post2	**.0057**	.3413
Post1 vs post2	**.4658**	.3681

[a]Bold indicates statistical significance ($P < .05$). IQR, interquartile range; PER, player efficiency rating; post, postinjury; pre, preinjury.

concussions/100 player-years between 2010 and 2018. The incidence did not change annually across the study period ($P = .1872$). These injured athletes had a mean (±SD) BMI of 24.8 ± 1.5 kg/m^2 (range, 20.8-28.4 kg/m^2), age at injury of 24.7 ± 3.5 years (range, 19.0-33.0 years), and a median playing experience of 2 seasons (range, 0-14; IQR, 4 seasons).

RTP and Career Length After Concussion

Of all injured athletes with concussion, 100% returned to play. Nearly all (88%) athletes returned to play in the season of injury, while 12% experienced a season-ending concussion. Athlete RTP was a median of 7 days (IQR, 16 days) after injury, with a career length after injury of, on average, 3 seasons (IQR, 3) (Figure 1). The earliest RTP was at 2 days and the longest RTP was 291 days after injury (Figure 2). Compared with players who were listed as centers, forwards had, on average, an RTP of 47 fewer days ($\beta = -46.7$; $P = .0222$) (Table 1). BMI, preinjury PER score, age at injury, and years of experience at injury were not predictive of length of time before RTP.

Performance and Outcome After Concussion

Postinjury performance was assessed relative to the player's preinjury performance via both percentage of games played after injury and the percentage change in the performance metric (Table 2). After concussion, athletes played in a significantly lower percentage of games in the total season in the season of injury (median, 36.6%; $P < .0001$) and first season after injury (median, 69.5%; $P = .0229$). However, percentage of games played in the total season was no different in the second season after injury (median, 73.2%; $P = .3192$) compared with the season preinjury (median, 78.0%). The percentage of games played significantly increased from the season of the injury to the first season after injury ($P < .0001$) as well as from

TABLE 3
Factors Affecting Percentage PER Score Change[a]

Risk Factor	PER Change to Injury Season, %		PER Change to Season 1 Postinjury, %	
	β	P	β	P
BMI	1.106	.6620	1.384	.7070
Preinjury PER score	−2.416	**.0016**	−3.148	**.0053**
Age at injury	−4.577	**<.0001**	−5.116	**.0017**
Years of experience	−3.822	**.0005**	−5.020	**.0026**
Position (vs center)				
Forward	−2.275	.8040	−5.710	.6700
Guard	9.191	.3570	5.039	.7340
Mixed forward/guard	0.5633	.9650	−9.326	.6220

[a]Bold indicates statistical significance ($P < .05$). BMI, body mass index; PER, player efficiency rating.

the season of injury to the second season after injury ($P = .0057$).

Comparisons of PER within each athlete as his own control showed no differences in play performance across the seasons after concussion and the season preinjury (Table 2). Between the season before injury and season after injury, 28.6% of players had a decrease in PER score of greater than 2, 15.9% of players had a decrease in PER score of less than 2, and 55.6% of players had either no change in PER score or in increase in PER score. Each point increase in a player's preinjury PER score was found to be associated with a 2.4% decrease in PER from the preinjury season to season of injury ($β = −2.416$; $P = .0016$) and a 3.1% decrease in PER from the preinjury season to season after injury ($β = −3.148$; $P = .0053$) (Table 3). Increasing age at injury and years of experience were also found to be associated with greater decreases in PER in both the season of injury (age: $β = −4.577$; $P < .0001$; years of experience: $β = −3.822$; $P = .0005$) and the season after injury (age: $β = −5.116$; $P = .0017$ years experience: $β = −5.020$; $P = .0026$). Each increasing year of age or year of experience was associated with 5% decline in PER score at 1 season after injury.

DISCUSSION

The present study demonstrated an RTP rate of 100% among NBA players after concussion, with nearly all (88%) returning to play in the season of injury; however, 12% of players experienced a season-ending concussion. Our RTP rate is similar to that reported in NFL and National Hockey League.[13,23,28] NBA players returned, on average, 37.3 days after injury, but this varied widely (range, 2-291 days), probably skewed by those with season-ending injuries. The median days before RTP was 7 with an IQR of 16. In addition, forwards were found to have quicker RTP than centers, potentially highlighting position-specific demands; however, no differences were found in RTP between other position comparisons. Differences in RTP timeline between athletes highlights the

spectrum of concussion severity and the resultant barriers to RTP. We identified 81 injuries from 2010 to 2018 in the NBA, with an annual rate of 2.0 concussions per 100 player-years, which is similar to findings in previous studies.[25,26]

The most notable effect on performance in NBA players after concussion was with regard to games played. Athletes played in significantly fewer games in the season of injury and the 2 seasons after injury when compared with the season before injury. NBA players participated in 78.0% of games in the season before injury while only 36.6% of games in their season of injury. Importantly, athletes demonstrated a significant increase in percentage games played from season of injury (36.6%) to their first season after injury (69.5%). However, no significant difference was found in percentage games played between the first (69.5%) and second season (73.2%) after injury. This may be a result of the recent NBA trend of load management, in which teams attempt to give players scheduled rest days, especially in light of past injuries. In addition to the effect of concussion on cognition, athletes experiencing concussion have also been shown to be more prone to other injuries, such as lower extremity musculoskeletal injuries.[3,14,24] Since concussion is thought to increase risk for these injuries due to persistent effects on gait, postural stability, and cognition, teams must consider these secondary effects of concussion when determining appropriate RTP for an athlete after concussion.[14] Awareness of these neuromuscular imbalances may cause a team to be cautious with a player's overall usage rate.

Despite the effect of concussion on athletes' games played, short- and long-term in-game performance was not affected. Average PER among NBA athletes with concussion was fairly stable from the season before injury (14.4) to the season of injury (14.3) to the first season after injury (14.4). In total, 55% of athletes had no change or an increase in their PER. These results echo the findings of Kumar et al[16] and Jildeh et al[13] among NFL players with concussions. However, others have suggested that performance after concussion may vary based on position-specific requirements.[30] In the present study, no changes in PER based on player position were found. Notably, increased age and years of experience were found to be associated with a significant decrease in PER in the season of injury and 1 season postinjury. Increased age and years of experience were associated with a 5% decrease in PER in the first season after injury.

In addition, athletes with increased PER before injury were also discovered to have greater decrease in PER after injury. Because we found no change in PER across season of concussion for the individual player but found significant predictors of decrease in PER on the study population level, it may be interaction of risk factor characteristics such as age and years of experience with concussion, rather than concussion itself, that leads to decrease in player performance. However, it is also possible that PER is not a granular enough metric to capture decreases in player performance at the individual level, detecting differences for the players only in aggregate. The spread of the metric in the season before concussion was 4.9 to 30.8.

Despite these limitations, these findings underline the demands of high-level competition and the challenges that concussion may pose in performance after RTP among older athletes and those who perform at exceptionally high levels before injury. Our findings suggest that elite level players may expect a greater impact on their performance after concussion, as it may be more difficult for those with above average PER to return to baseline. Interestingly, our findings differ from previous studies regarding player performance after concussion.[26,29]

In contrast to previous studies that examined player performance in the first 5 games after returning from concussion, we evaluated player performance over the first 2 seasons after injury to examine more fully the effect of concussion on postinjury player performance.[29] In addition, Patel et al[26] found no significant changes in player game score per minute and minutes per game after concussion. Using PER as an indicator of player performance, it is possible that our study analyzes player performance more fully rather than using isolated metrics would. We noted that, at 2 seasons postinjury, the mean PER was 15.9 compared with 14.4, though not statistically significantly higher. This may be due to natural improvement in player performance with experience in the league. For example, Lorenzo et al[17] reported specifically increases in assist and free throw performance in athletes across their career in a national league.

Limitations

Given the increasing incidence of concussions among athletes, this area of research warrants further attention.[20] This study is not without limitations. First, without access to the NBA injury database, it is possible that not all athletes were included in this review; this is a notable weakness of studying publicly available data since only patients who have their injuries made available on a team news report or in news media can be captured. While access to the NBA medical database would be the optimal method of ensuring inclusion of all injured athletes, previous literature has proven that publicly available information can be extremely effective in collecting injury data as well as postinjury performance via publicly available league sources.[6,19,20] An additional risk with this method is that selection bias may have led to a greater percentage of well-known, more popular athletes being included as opposed to backup players or players who are considered professional but may only be in the developmental leagues.

In addition, it is possible that variance in RTP postconcussion may be due to athlete's previous history of concussions, which was not accounted for in this study and thus limits the generalizability of our findings. We also did not investigate when in the season each concussion occurred, and injury timing may affect RTP. Moreover, we did not investigate the mechanism of each concussion injury either.

The use of PER as a dependent variable and measure of performance may not most reliably reflect true athlete performance. We found that age and player experience was associated with a 5% decline in PER; however, we did not have a nonconcussed or uninjured control group with which

to compare these findings. Our finding that athletes played in significantly fewer games after injury is subject to many confounding variables, as is true for any other illness or orthopaedic injury. In addition, analyzing risk factors, such as player position, is made more difficult by recent trends in the NBA of hybrid-type players (that is, the point forward), making it difficult to classify patients in the more traditional way (forward, guard, center). We used the center as our comparison group because the traditional center position is becoming less and less common as a result of changes in NBA play style, allowing our comparison group to be a more broadly defined group. However, this comparison set up is not without limitations.

There are many reasons unrelated to performance that may influence an athlete's decision to not RTP or play fewer games (eg, contract negotiations, personal factors) that were not accounted for because of limitations in the information available. As in any sport, factors outside of the players' control, such as roster changes or coaching, may have also affected playing time and performance. For the purposes of this study, the first game on an active roster defined successful RTP, but it is important to consider that this may not define the exact length of recovery. Medical clearance to RTP may predate returning to the field if during the offseason, and return time was likely skewed by the 12% who had season-ending injury.

CONCLUSION

Study results indicated that NBA players have a high RTP after concussion, with most returning during the same season as the injury. Players sustaining concussions played significantly fewer games for at least 2 seasons after injury. Performance via PER did not change across the entire cohort; however, players with higher preinjury PER and older players were more likely to sustain a greater decline in performance after injury.

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