

Concussions in the Women's National Basketball Association

Analysis of Incidence, Return-to-Play Timing, and Player Performance From 1997 to 2020

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Background: The extent to which concussions affect Women's National Basketball Association (WNBA) athletes has not been thoroughly examined.

Purpose: To evaluate the incidence and impact of concussion injuries occurring in the WNBA.

Study Design: Descriptive epidemiology study.

Methods: Publicly available records were searched to identify all documented basketball-related concussions from WNBA seasons 1997 to 2020. Player demographics, injury details, and basketball career information were collected. Concussion incidence and return-to-play (RTP) timing were evaluated before and after the institution of the WNBA concussion protocol in 2012. Minutes per game and game score per minute were compared 5 games before and 5 games after the concussion was sustained. Player game availability and RTP performance were also compared with an age-, body mass index-, position-, and experience-matched control group of players who did not sustain any injuries during the index season.

Results: A total of 70 concussions among 55 players were reported in the WNBA from 1997 to 2020, with a mean incidence of 2.9 ± 2.3 concussions per season. After the implementation of the WNBA concussion protocol, the incidence significantly increased from 1.7 to 5.0 concussions per season ($P < .001$). All players returned after a first-time concussion, missing a mean of 3.8 ± 4.7 games and 17.9 ± 20.7 days. After the adoption of the concussion protocol, the time to RTP significantly increased with games missed ($P = .006$) and days missed ($P = .006$). Minutes per game and game score per minute were not significantly affected by sustaining a concussion ($P = .451$ and $P = .826$, respectively).

Conclusion: Since the adoption of the WNBA concussion protocol in the 2012 season, the incidence of concussions increased significantly. Athletes retained a high rate of RTP after missing a median of 4 games, and the time to RTP increased after the institution of the concussion protocol. Player game availability and performance within the same season were not significantly affected by concussion injuries after a successful RTP.

Keywords: Women's National Basketball Association; basketball; concussion; performance; return to sport

Concussions are mild traumatic injuries to the brain that can lead to functional deficiencies such as alterations in memory, concentration, mental health, and proprioception.¹ Concussions are relatively common sports injuries among athletic cohorts, often with a negative impact on performance, especially if athletes are incompletely recovered.^{9,22,26} Investigations on sex-based differences regarding the incidence and outcomes of concussions have demonstrated an increased risk of concussions in female

athletes compared with male athletes in comparable sports.^{4,16,21} Additionally, female-dominated sports, such as cheerleading, report high rates of concussions.¹²

Given the health concerns related to concussions and knowledge of their long-term effects, increased research and policies have been developed to help reduce the impact of sport-related concussions (SRCs).^{11,16} At the professional level, sports organizations have designed guidelines to provide education on concussions, perform baseline testing, and establish return-to-play (RTP) protocols.³ Patel et al²⁰ analyzed the concussion incidence and effects on RTP in National Basketball Association (NBA) players. After the implementation of the NBA's concussion policy, they

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observed approximately 17 instances per season with a high RTP rate after 3 to 4 missed games. Subsequent player performance and availability were not affected.²⁰

The Women's National Basketball Association (WNBA), the NBA's female affiliate, instituted a similar concussion policy in 2012; however, published data specifically examining concussions in WNBA athletes are limited.^{1,15} The purpose of this study was to provide an overview on concussions sustained by WNBA athletes and compare their incidence before and after the establishment of the WNBA concussion protocol. Secondary outcomes included analyses of concussion effects on player performance, RTP, and game availability. We hypothesized that the incidence of concussions and time to RTP increased after the implementation of the WNBA concussion protocol. It was also hypothesized that player performance and game availability were not significantly affected by a concussion after a successful RTP.

METHODS

Data Collection and Athlete Identification

This was a retrospective review of available injury reports and records for concussion injuries sustained by WNBA athletes during the 1997 through 2020 seasons. Of note, the WNBA originated with 8 teams in 1997 and currently consists of 12 teams, each with 12 athletes on the roster. During the regular season, all teams play 36 games with an additional 3-round postseason tournament in a 3-5-5 format. Comparatively, the NBA has a league of 30 teams, each with a 12-man active roster; during the regular season, each team plays 82 games, with an additional 4-round, best-of-7-games postseason tournament.

Data acquisition was conducted in accordance with the reported literature, analyzing publicly available data of injuries in professional sports published in multiple high-impact journals.^{1,6,13,14,18,20} This began with Google as the primary search engine for injury articles, press releases, personal or team websites, and game summaries for details of a concussion injury occurring in a WNBA player. Articles referencing players with a head injury were also evaluated for possible inclusion. Every instance of a concussive episode was cross-referenced with at least one other source to better define inclusion. Players without adequate, publicly available data (ie, conflicting injury reports, insufficient description of injury) were not included. Specific online sources for data acquisition included the official

website of the WNBA (WNBA.com) and the WNBA statistics website (stats.wnba.com). Additional online sources included news outlets such as the Associated Press (apnews.com), The Washington Post (washingtonpost.com), and CBS Sports; a professional basketball analysis website (basketball-reference.com); and the sports websites of ESPN (ESPN.com), Swish Appeal (swishappeal.com), and RotoWire (rotowire.com).

All included concussions as well as the date of injury were cross-referenced with a gap in statistics utilizing local game reports, team websites, and media guides. Only concussions that overlapped or occurred during a player's active season were indexed. Once confirmed, demographic information and player statistics were recorded including name, position, height, weight, age at the time of injury, details of the injury, date of the injury, seasons played before the injury, concomitant injuries, and number of days and games missed before RTP. WNBA players experiencing more than 1 concussion within the study period were identified and placed in a subgroup.

Before the 2012 season, SRCs were largely managed at the discretion of the individual player and team medical staff without a collective approach to treatment. In conjunction with a committee of team physicians and the WNBA Players Association, the WNBA concussion protocol was implemented at the beginning of the 2012 season. This policy was designed to maximize the neurological health of players and is reviewed periodically by a committee of team physicians. The protocol consists of education, baseline testing, assessment tools for acute evaluation and management, and procedures for RTP. Furthermore, preventive efforts have been made to better educate medical staff, coaches, and players on the impact of SRCs in sports.²³

Game Availability and Player Performance

RTP was recorded as the first competitive exposure (ie, game) after the player's injury. Any player who returned to regular-season WNBA competition for at least 1 play in a basketball game during the same season met RTP criteria. RTP analysis consisted of only players with an isolated single concussion. Those with concomitant injuries ($n = 2$), repeat concussions, preseason injuries, or postseason concussions or recovery that overlapped with the postseason were not included. Game availability and player performance were evaluated utilizing similar methods to previously described publications.^{2,20,25} As the WNBA regular season

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Ethical approval was not sought for the present study.

$$\begin{aligned} \text{Game score} = & \\ & (\text{Points scored}) + (0.4 \times \text{Field goals made}) + (0.7 \times \text{Offensive rebounds}) + (0.3 \times \text{Defensive rebounds}) \\ & + (\text{Steals}) + (0.7 \times \text{Assists}) + (0.7 \times \text{Blocked shots}) - (0.7 \times \text{Field goal attempts}) \\ & - (0.4 \times \text{Free throws missed}) - (0.4 \times \text{Personal fouls}) - (\text{Turnovers}) \end{aligned}$$

Figure 1. Formula for calculation of the game score.

is much shorter than the NBA season, game availability was evaluated by comparing the mean minutes per game from 5 games before the concussion versus 5 games after the concussion. Those with incomplete game availability data were not included in the analysis ($n = 4$). Likewise, player performance was evaluated by comparing the mean game score and the game score per minute 5 days before and 5 days after the concussion (not including the game in which the concussion was sustained). Game score is a metric estimated as a measure of a player's productivity for a single game; it accounts for a player's offensive and defensive contributions and fouls (Figure 1). Player efficiency rating, which is a rating of a player's per-minute productivity, was also utilized to compare ratings from the season before the injury, injury season, and season after the injury.²⁷

Matched Controls

Utilizing blinded matching methodology, a control group of WNBA players matched by age, position, height, weight, body mass index, and years of WNBA experience before the season of the injury was formed.^{8,20,25} All previously described data that were collected for the concussed players were also tabulated for the control group utilizing similar resources and methods. The index game was defined as the date of injury in the concussed group. In the RTP analysis, preinjury and postinjury time points refer to the index game, with included controls having played at least 5 games before and 5 games after the index date of injury for inclusion.

Statistical Analysis

All analyses were performed utilizing JMP Pro (Version 14.1.0; SAS Institute). Athletes were grouped according to single or repeat concussions and by before or after the adoption of the WNBA concussion protocol in 2012. Continuous variables were analyzed using the Student t test or Wilcoxon signed-rank test. Categorical variables were analyzed using chi-square analysis or the Fisher exact test when expected cell counts were <5 . A Kaplan-Meier survival analysis was performed to evaluate the interval free of a subsequent concussion after the index injury. Statistical significance was defined as $P < .05$.

RESULTS

Figure 2 illustrates the group sizes included in the study analyses. A total of 70 basketball-related concussions in

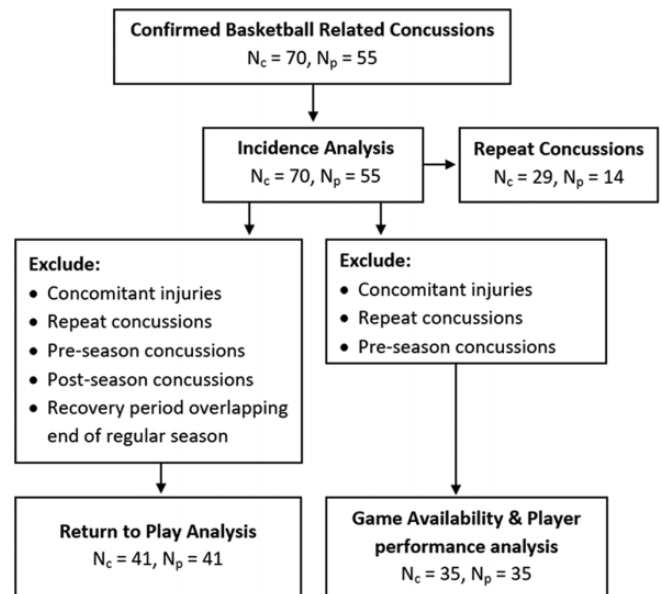


Figure 2. Study inclusion flowchart demonstrating resultant groups utilized for data analysis, including the number of concussions (N_c) and number of players (N_p) considered at each stage.

55 players were identified from the inaugural WNBA season in 1997 through the 2020 season. Of these, 41 (74.5%) players sustained a single instance of a concussion, and 14 (25.5%) players sustained multiple concussions (Table 1). Across all concussed players, guards were the most frequently affected ($n = 28$ [50.9%]), the mean age at the time of a concussion was 26.4 ± 4.3 years, and athletes played a mean of 3.7 ± 3.6 seasons before the injury. When compared with those with single concussions, players with multiple concussions were younger (24.8 vs 27.0 years, respectively; $P = .099$), taller (1.81 vs 1.88 m, respectively; $P = .009$), and heavier (74.9 vs 81.1 kg, respectively; $P = .049$). Athletes with single concussions most often played the guard position ($n = 25$ [61.0%]), and those with multiple concussions most often played the forward position ($n = 8$ [57.1%]).

The overall mean incidence was 2.9 ± 2.3 concussions per season (Table 2 and Figure 3). As the WNBA season consists of 36 games, this equates to 8.1 ± 6.3 concussions per 100 games played. After the implementation of the WNBA concussion protocol, there were significantly more concussive events identified per season compared to prior years (5.0 vs 1.7 , respectively; $P < .001$). The greatest number of concussions was recorded in 2016 ($n = 8$). All athletes were

TABLE 1
Baseline Demographic and Clinical Characteristics of Players With Concussions^a

	All Players (n = 55)	Players With Concussions		P Value
		Single (n = 41)	Multiple (n = 14)	
Age, y	26.4 ± 4.3	27.0 ± 4.4	24.8 ± 3.9	.099
Height, m	1.83 ± 0.1	1.81 ± 0.1	1.88 ± 0.1	.009
Weight, kg	76.5 ± 10.2	74.9 ± 10.6	81.1 ± 7.6	.049
Body mass index, kg/m ²	22.9 ± 2.0	22.9 ± 2.2	22.9 ± 1.4	.966
Seasons of preinjury WNBA experience	3.7 ± 3.6	3.9 ± 3.5	2.9 ± 3.7	.371
No. of preinjury-season games played	26.0 ± 10.7	26.3 ± 10.0	25.4 ± 12.9	.811
Preinjury-season PER ^b	15.6 ± 5.3	15.0 ± 5.2	17.5 ± 5.4	.243
Player position, n (%)				.030
Guard	28 (50.9)	25 (61.0)	3 (21.4)	
Forward	19 (34.5)	11 (26.8)	8 (57.1)	
Center	8 (14.5)	5 (12.2)	3 (21.4)	

^aData are presented as mean ± SD unless otherwise indicated. Boldface P values indicate a statistically significant difference between groups ($P < .05$). WNBA, Women's National Basketball Association.

^bPlayer efficiency rating (PER) is an advanced metric aimed to capture the net sum of a player's positive and negative contributions to her team, with the league's mean PER standardized to a score of 15.0.

TABLE 2
Concussion Incidence and Return-to-Play Timing Before and After Implementation of Concussion Protocol^a

	All Years		Before Protocol		After Protocol		P Value
	Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)	
Concussions per season	2.9 ± 2.3	2 (1.0-4.8)	1.7 ± 1.2	1 (1.0-2.0)	5.0 ± 2.4	6 (3.5-6.5)	<.001
Games missed	3.8 ± 4.7	1.5 (0.8-5.0)	0.9 ± 0.9	1 (0.0-1.0)	6.7 ± 3.6	4 (2.5-11.5)	.006
Days missed	17.9 ± 20.7	8 (5.5-29.0)	5.8 ± 5.5	6 (3.0-8.5)	31.6 ± 23.8	29 (10.5-45.8)	.006

^aBoldface P values indicate a statistically significant difference between groups ($P < .05$). IQR, interquartile range.

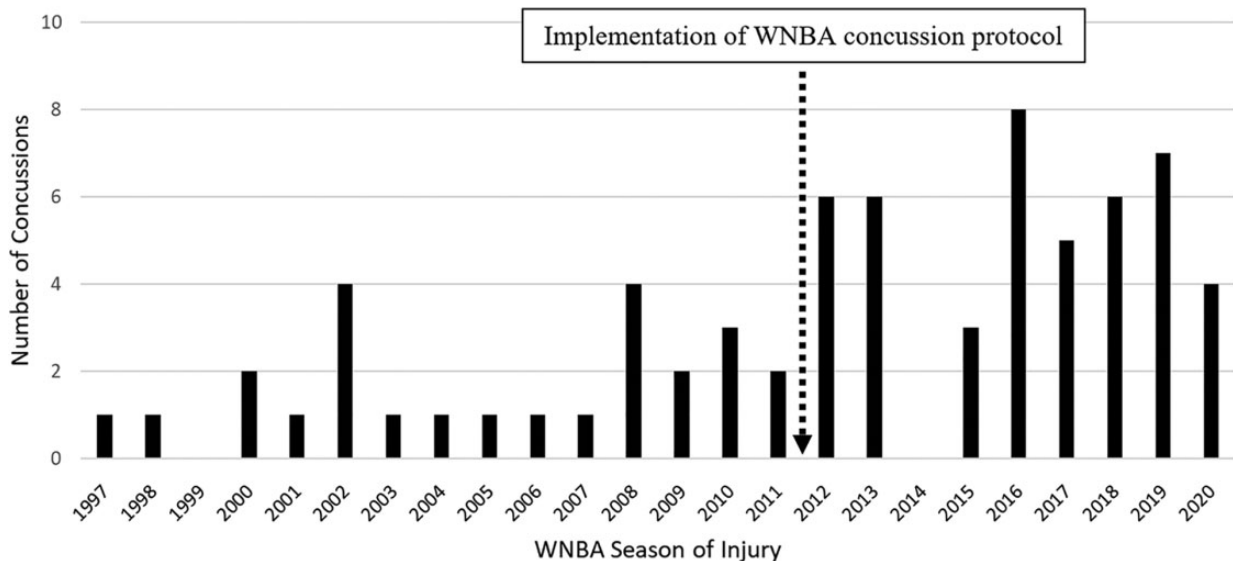


Figure 3. Number of concussions per season.

able to RTP after a first-time concussion, missing a mean of 3.8 ± 4.7 games and 17.9 ± 20.7 days. When stratified by before or after the adoption of the WNBA concussion protocol, both games missed (0.9 vs 6.7, respectively; $P = .006$)

and days missed (5.8 vs 31.6, respectively; $P = .006$) increased over the years.

Subgroup analysis of the 14 (25.5%) players who sustained multiple concussions revealed that 13 players had

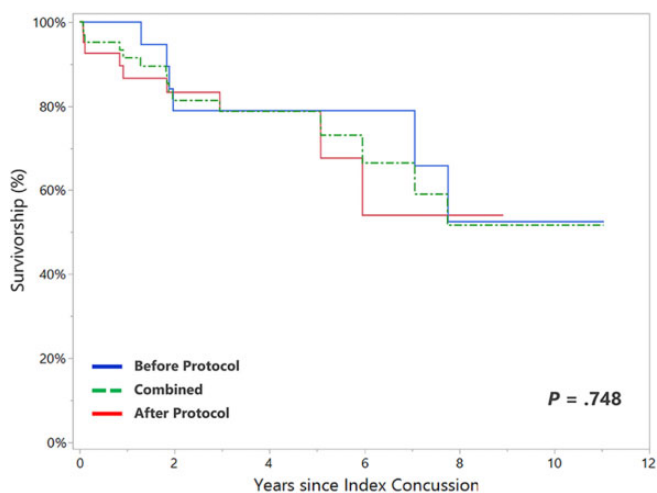


Figure 4. Kaplan-Meier analysis of survivorship free from repeat concussions categorized by occurrences before versus after the implementation of the concussion protocol.

TABLE 3
Clinical Characteristics of Players Included in Matched Control Analysis^a

	Concussed Players (n = 35)	Controls (n = 35)	P Value
Age, y	25.8 ± 4.1	26.1 ± 3.8	.746
Height, m	1.82 ± 0.2	1.83 ± 0.2	.948
Weight, kg	76.9 ± 11.2	75.9 ± 9.4	.706
Body mass index, kg/m ²	23.0 ± 2.1	22.7 ± 1.4	.520
Seasons of preinjury WNBA experience	3.1 ± 3.0	3.2 ± 3.6	.817
Player position, n (%)			.870
Guard	17 (48.6)	19 (54.3)	
Forward	13 (37.1)	11 (31.4)	
Center	5 (14.3)	5 (14.3)	

^aData are presented as mean ± SD unless otherwise indicated. WNBA, Women’s National Basketball Association.

2 concussions and 1 player had 3 concussions, equating to 29 total occurrences. The mean time between repeat concussions was 963.0 ± 938.8 days (median, 671 days [interquartile range, 307-1854 days]). A single-season recurrence of a concussion was observed at a rate of 0 instances before the institution of the WNBA concussion protocol versus 3 instances after the adoption of the concussion protocol ($P = .229$). The Kaplan-Meier analysis demonstrated that survivorship from the index concussion was 91.5% at 1 year, 81.3% at 2 years, 78.7% at 5 years, and 51.7% at 10 years (Figure 4). There was no difference in subsequent concussion-free intervals before the implementation of the WNBA concussion protocol versus after ($P = .748$).

A matched control group was generated for the RTP analysis, which demonstrated no significant demographic differences between the concussed athletes and the nonconcussed matched controls (Table 3). With respect to concussed athletes, the minutes played per game did not

differ between 5 games before and 5 games after a concussion ($P = .451$). Similarly, the mean game score per minute was not different 5 games before versus 5 games after a concussion ($P = .826$). The player efficiency rating did not demonstrate a significant difference when comparing preinjury, injury season, and postinjury values (15.7 ± 5.3 vs 15.0 ± 7.0 vs 15.7 ± 6.2 , respectively; $P = .897$). The analysis of concussed players and matched controls comparing the 5 games before and 5 games after the injury or index game demonstrated no differences in the mean minutes per game ($P = .935$), game score ($P = .102$), or game score per minute ($P = .389$). However, the concussed group achieved a higher mean postinjury game score by 2.7 points compared with the matched control group ($P = .043$). However, when evaluating the control group independently, there was a trend toward a decreased postinjury game score after the index event ($P = .055$) (Table 4).

DISCUSSION

The most important finding of this study is that there was a statistically significant increase in the mean number of reported concussions per season since the implementation of the WNBA concussion protocol (1.7 before vs 5.0 after; $P < .001$). Additionally, the mean games and days missed within concussed players increased in the seasons after the enactment of the WNBA concussion protocol. Lastly, there were no significant differences in player performance before and after sustaining a concussion (after RTP) with respect to minutes played per game or game score/game score per minute.

The short- and long-term impacts of concussions sustained within athletic populations have garnered significant attention over recent years; however, the large majority of research endeavors up to this point have focused on male athletes, despite evidence suggesting that female athletes may sustain these injuries at higher rates than their male counterparts within a given sport.^{4,16,21} The WNBA concussion protocol was designed to improve the health and safety of professional basketball athletes by bolstering player and team preseason education regarding concussion recognition and reporting to medical personnel, implementing baseline preseason testing for each athlete, delineating strategies for the diagnosis and management of concussions, and standardizing stepwise RTP guidelines after these injuries.²⁰

In the present study, we observed an increase in the incidence of concussions per season after the implementation of the WNBA concussion protocol, similar to previous investigations analyzing the effect of the NBA’s concussion policy.^{5,19,20} Of note, a recent increase in the awareness and reporting of concussions can also be observed within other professional sports leagues, such as Major League Baseball, the National Hockey League (NHL), and the National Football League (NFL).^{10,17,24} It is likely that these increases in the reporting of concussions within the WNBA, NBA, and other professional sporting bodies after policy enactment are a direct result of the improvements in, and standardization of, concussion diagnosis, treatment,

TABLE 4
Impact of Concussions on Player Performance and Game Availability^a

	Minutes Per Game	Game Score	Game Score Per Minute
Concussed group (n = 35)			
Before injury	24.5 ± 8.6	7.2 ± 5.0	0.28 ± 0.13
After injury	23.9 ± 8.0	7.6 ± 5.6	0.28 ± 0.17
Difference ^b	-0.6 (-2.2 to 1.0)	0.4 (-0.8 to 1.7)	0.01 (-0.06 to 0.07)
P value	.451	.476	.826
Control group (n = 35)			
Preinjury index game	22.5 ± 9.1	6.0 ± 3.6	0.26 ± 0.12
Postinjury index game	21.8 ± 9.1	4.9 ± 3.3	0.23 ± 0.10
Difference ^b	-0.7 (-2.6 to 1.2)	-1.1 (-2.3 to 0.02)	-0.04 (-0.09 to 0.02)
P value	.447	.055	.225
Group difference (concussed – control) ^b			
Preinjury comparison	2.1 (-2.7 to 6.9)	1.1 (-1.4 to 3.7)	0.01 (-0.06 to 0.08)
P value	.382	.372	.681
Postinjury comparison	2.2 (-2.2 to 6.6)	2.7 (0.1 to 5.4)	0.06 (-0.03 to 0.10)
P value	.315	.043	.212
Before vs after injury	-0.1 (-2.9 to 2.7)	1.6 (-0.3 to 3.5)	0.04 (-0.06 to 0.10)
P value	.935	.102	.389

^aData are presented as mean ± SD unless otherwise indicated, with game data utilizing a sample size of 5 games before and 5 games after the index game. Boldface P value indicates a statistically significant difference ($P < .05$).

^bData are presented as mean (95% CI).

and RTP guidelines as delineated by the protocol systems themselves. Furthermore, this may also represent a general change from a time in which concussions were underrecognized to a more recent time frame with an improved understanding surrounding the impact of SRCs.^{11,16}

In the present investigation, we found that RTP time after a concussion significantly increased after the implementation of the WNBA concussion protocol (games missed: 6.7 after vs 0.9 before; days missed: 31.6 after vs 5.8 before). These findings contrasted with those of Patel et al²⁰ in which RTP time was not significantly affected by the enactment of the NBA's concussion policy. However, these are in accordance with McGroarty et al,¹⁶ who found that women tend to experience prolonged symptoms and delayed recovery after concussions in comparison to their male counterparts. While there is no clear explanation, investigators postulated that biomechanical factors, hormonal factors, and/or differences in symptom reporting may be potential contributors to the observed difference between male and female athletes. Regarding the present findings, since the enactment of the WNBA concussion protocol has increased education and awareness among players and team staff on concussions and their presentation, it is possible that these WNBA athletes are now more apt to remain out of play until symptoms have sufficiently subsided.

Prior studies investigating concussions within high school and collegiate athletes have found that female athletes sustain more concussions than their male counterparts in a given sport.²¹ The present investigation found that the overall mean incidence of concussions within the WNBA was 2.9 ± 2.3 per season from 1997 to 2020 (5.0 ± 2.4 since the implementation of the WNBA concussion protocol). Patel et al²⁰ found the mean incidence of concussions per season within the NBA to be 9.7 ± 7.3 from 1999 to 2018 (16.7 ± 7.5 since the implementation of the NBA's concussion policy). However, there are substantial

differences within the WNBA compared to the NBA with respect to games played in the regular season (36 vs 82, respectively) and athletes within each league (144 vs 360, respectively). A comparison of the WNBA and NBA per 100 games played in each league equates the number of concussions to 8.1 ± 6.3 and 11.8 ± 8.9 concussions per 100 games played, respectively. Although this may suggest a lower rate of concussions in WNBA players, further investigations are warranted to determine whether the trend of female athletes sustaining concussions at higher rates than male athletes at the high school and collegiate levels holds true for professional basketball as well.

With respect to player position, the present investigation noted most of the concussions occurring in athletes who played the guard position (50.9%), followed by the forward (34.5%) and center (14.5%) positions. Additionally, athletes with single concussions most often played the guard position (61.0%). Possible reasons for the higher rate of concussions in guards include the increased likelihood of contact injuries due to the elevated amount of time that guards spend with the ball. This often results in more attention from defenders and possibly additional physical interactions with other players compared with athletes who are off the ball. Likewise, on the defensive end, guards will then generally spend more time as on-ball defenders, susceptible to incoming screens from larger players, which could also lead to SRCs. As this investigation did not perform a detailed concussion subanalysis by position, there remains room for subsequent studies to better evaluate the correlation of position played with the rate of concussions.

When analyzing game availability and performance before and after concussions, prior studies among NBA, NFL, and NHL athletes found no significant differences in athletes' performance after a concussion once they had returned to play.^{3,9,20,27} The present investigation likewise found no

significant differences in athletes' performance or game availability before or after a concussion, nor were there any differences when comparing players who had sustained concussions to their nonconcussed matched controls. Furthermore, there was no significant difference in the recurrent concussion-free time interval before and after the enactment of the WNBA concussion protocol, a finding that is also in agreement with the results of Patel et al²⁰ for NBA athletes.

Limitations

This study has several limitations. First, details regarding concussion diagnosis and management, including severity, exact medical clearance, and date of RTP, relied on publicly available information derived from online sources. This may lead to the possibility of omission, selection bias, and reporting bias within our analysis.⁷ Furthermore, comparisons of concussion numbers across other professional leagues utilizing our methodology may be influenced by the popularity of the sport or level of media coverage achieved by the affected athletes. Second, the analyses could not account for potential differences in concussion severity, underlying comorbidities within each athlete, or extrinsic factors that could affect measures of preconcussion versus postconcussion performance and game availability, such as coaching strategy or roster availability. Despite these limitations, these methods have been utilized in multiple published studies, providing useful information for clinicians and allowing for comparisons to be made.^{1,8,20}

CONCLUSION

Since the adoption of the WNBA concussion protocol in the 2012 season, the incidence of concussions has increased significantly. Athletes retained a high rate of RTP after missing a median of 4 games, and the time to RTP increased after the institution of the concussion protocol. Player game availability and performance within the same season were not significantly affected by concussion injuries after a successful RTP.

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