Original Research

Performance After Operative Versus Nonoperative Management of Shoulder Instability in the National Basketball Association

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Background: Although nonoperative management after shoulder instability injury allows an athlete to return to play sooner than operative intervention, higher rates of recurrence have been observed after nonoperative management. However, no study has investigated the differences in performance of National Basketball Association (NBA) players after index shoulder instability events managed nonoperatively versus operatively.

Purpose/Hypothesis: The purpose of this study was to identify shoulder instability events in NBA athletes and assess differences in performance after injury with nonoperative versus operative management. We hypothesized that players who undergo operative intervention have reduced risk of recurrence and are able to continue their elite level of play as opposed to those who undergo nonoperative management.

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

Methods: Publicly available injury data from the 1986-1987 through 2017-2018 seasons were reviewed to identify NBA athletes sustaining a shoulder instability event. In addition to characteristics, player performance information, including games played, player efficiency rating (PER), and win shares, was analyzed before and for 3 seasons after injury. Statistical learning models were applied to identify performance variables that have the greatest predictive value to determine players who would benefit from surgery.

Results: A total of 60 players with shoulder instability events were identified between 1986 and 2018. After injury, 37 players (61.7%) eventually underwent surgery and 23 players (38.3%) did not. Players who were treated nonoperatively had significantly decreased PER, games played, and offensive win shares in the season after injury ($P < .05$). Players who underwent surgery did not see a decline in PER, games played, or win shares. Random forest modeling found that true shooting percentage and win shares per 48 minutes were the performance variables most predictive in determining which players would benefit from surgery after shoulder instability.

Conclusion: Players who underwent surgical intervention for shoulder instability maintained their PER, games played, and win share performance characteristics, whereas players who did not undergo surgery had declines in these parameters. Given the demands of shoulder function in basketball and the risk of recurrence after an instability event, surgery enhances a player's opportunity to maintain a high level of performance after injury.

Keywords: shoulder instability; National Basketball Association; nonoperative; operative

Professional basketball is a competitive and physically demanding game that involves a significant amount of overhead activity, resulting in a wide range of injuries. Injuries are twice as likely to occur in the National Basketball Association (NBA) than in collegiate basketball, with contributory factors such as game schedule, team size, and play intensity.[20,23,24] Among NBA players, injuries of the upper extremity account for roughly 15% of total injuries, and injuries to the glenohumeral joint account for 3% to 4% of all observed injuries.[5,11]

Glenohumeral instability, which entails both dislocation and subluxation events, can be particularly troublesome for NBA players. Such injuries may result in apprehension with overhead activities, such as shooting and rebounding, subsequently leading to a decline in performance. As these athletes' livelihoods depend on their ability to perform such

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activities, professional NBA players are under unique pressure when making decisions regarding their treatment.

Some players may pursue nonoperative management for instability because surgical stabilization is often season-ending, with lengthy return times and concern for diminished performance on return.[2,11,18,23] However, one study found that NBA players undergoing surgery for shoulder instability injuries were found to have the second highest return-to-play rate, after hand or wrist fracture surgeries.[17] Further, extensive data demonstrate superior outcomes after the surgical management of shoulder instability in athletes compared with nonoperative management, including decreased risk of recurrent instability, improved player performance, and improved player satisfaction.[6,12,13,14,22] Interestingly, no studies to date have assessed management trends in shoulder instability among NBA athletes, nor are data available comparing performance after an instability event in NBA athletes between those who underwent operative versus nonoperative management.

Given the paucity of such data, the purpose of this study was to identify the epidemiological patterns of shoulder instability events within the NBA and determine the differences in performance outcomes between athletes undergoing operative and nonoperative management. We hypothesized that those undergoing operative intervention would have a lower recurrence rate and improved postinjury performance compared with those who did not undergo operative intervention.

METHODS

Data Sources

Previously published methods of assessing NBA injuries were used to identify shoulder subluxations and dislocations.[1-5] In brief, public records in the form of press releases, newspaper archives, team injury reports, and player profiles were queried between the seasons 1986-1987 and 2017-2018 for shoulder subluxation and dislocation. Given varying provider levels of what may potentially be qualified as subluxation or dislocation, these injuries were classified overall as shoulder instability events. Player information was cross-checked with team transaction and injury reports from official NBA team websites.

Player and Performance Variables

Players were characterized by age, height, weight, body mass index, position, and years of experience in the NBA before injury. Frequently used player performance measures involving number of games played, player efficiency rating (PER), win shares, offensive win shares, and defensive win shares were recorded before injury and for 3 seasons after injury; these variables are referred to as "player and performance variables."

PER is used as an objective measure of performance calculated by summing positive performance statistics such as points, rebounds, steals, and assists and subtracting negative variables, including turnovers and fouls. The score is adjusted by team and playing style and standardized to a league mean of 15.0.[1]

The "win shares" is a number representing an estimate of game wins contributed by a player. Offensive win shares represent game wins contributed by a player due to his offense, whereas defensive win shares are due to his defense.[1]

Statistical Analysis

To assess whether lack of surgery had an adverse effect on player performance variables, an analysis of variance was used to compare differences in games played, PER, win shares, offensive win shares, and defensive win shares for players who did and did not have surgery. A P value less than .05 was considered statistically significant.

Predictive Modeling to Identify Players Who Would Benefit From Surgery

Using available player performance variables, we applied several statistical learning models to predict whether a player would benefit from surgery. Given our analysis of PER, we determined a benefit to surgery as being a PER the season after injury that was within 0.5 or more of what it was the prior season (eg, if PER was 10, then benefit would be a PER of $\geq$9.5). For each player, there were 155 variables, including age, height, weight, and the player and performance variables listed previously. The player and performance variables were collected for the season before the injury, the season in which the injury occurred, and 3 seasons after injury.

To reduce model complexity, optimal covariates to determine benefit of surgery were chosen for further analysis via a logistic regression model constructed for various sets of potential covariates. A logistic regression model was initially built using no covariates. Subsequent models were then constructed through successive addition of variables to the model until the addition of a variable did not improve the model's performance. Ultimately, the set of variables

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Ethical approval was not sought for the present study.

that minimized the Akaike information criterion were chosen to be the variables used in our models. These variables included years since injury (number of years since a player last sustained an injury), injury recurrence, defensive rebounds per game (DRB), offensive box plus/minus (OBPM), steal percentage (STL), turnover percentage (TOV), true shooting percentage (TS), value over replacement player (VORP), and win shares per 48 minutes (WS.48); full definitions for these covariates are provided in the Appendix.

Using the variables deemed most significant by the logistic regression model, we constructed a random forest model to determine how important the variables selected by the logistic regression model are in predicting change in PER. Random forest models create an ensemble of decision trees that allows predictions to be made by traversing along these trees. Moreover, at the time these trees are constructed, only a random subset of all variables are considered, leading to a more robust and flexible model because the collection of trees now constitutes an aggregate of the individual output of each tree. More important to our study, the split at each decision tree allowed us to quantify the relative importance of each variable in predicting change in PER. As such, we used the random forest model primarily as a means of determining the relative importance of the variable output by the logistic regression model.

Variable analysis within the random forest model was reported by a mean decrease in Gini (MDG). In this case, the MDG is a measure of how important a variable is for estimating a benefit from surgery across all the trees that make up the random forest model. A demonstrated higher MDG indicates a higher importance of the variable in the predictive model.

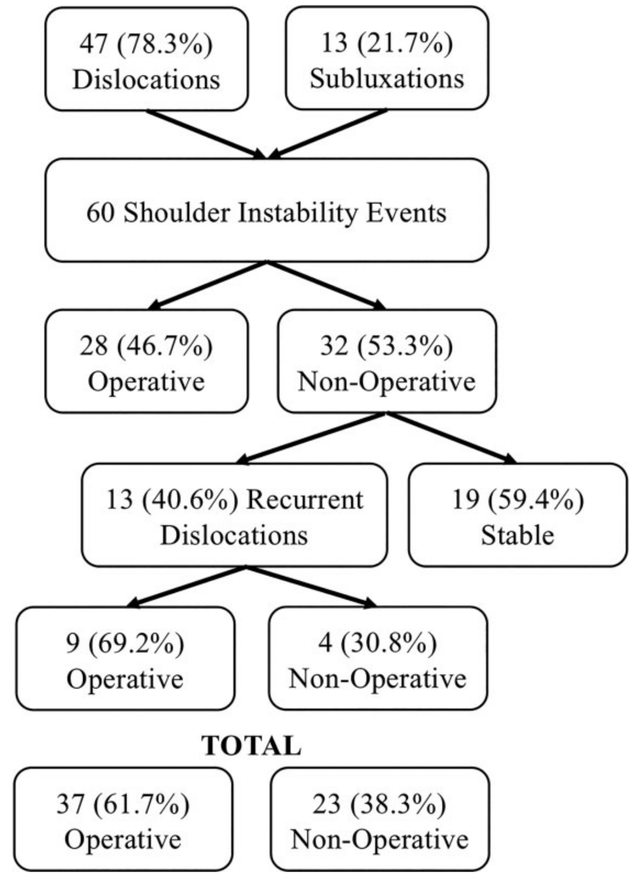

Figure 1. Flowchart of shoulder instability events, treatments, and recurrences in the National Basketball Association between the seasons 1986-1987 and 2017-2018.

RESULTS

We identified 60 players who experienced a shoulder instability injury, of which 47 (78.3%) were classified as dislocation events and 13 (21.7%) as subluxation events. After the initial index instability event, 28 players (46.7%) underwent surgery and 32 (53.3%) underwent nonoperative management. Of the 32 players managed nonoperatively after their instability event, 13 players (40.6%) experienced recurrent dislocations. From these 13 players with recurrent dislocations, 9 (69.2%) underwent surgery. Ultimately, players who underwent surgery did not report any further instability events. In total, 37 players (61.7%) underwent surgery and 23 players (38.3%) did not (Figure 1).

Between the nonoperative and operative groups, no significant differences were found in the player characteristics for age, height, weight, or body mass index ($P > .05$) (Table 1).

TABLE 1

Player Characteristics Between Those Undergoing Nonoperative Versus Operative Treatment[a]

	Nonoperative	Operative	*P* Value
Age, y	26.08 ± 4.02	24.68 ± 3.45	.11
Height, in.	79.58 ± 3.45	79.72 ± 3.03	.84
Weight, lb	223.87 ± 29.45	224.65 ± 25.22	.90
Body mass index, kg/m^2	24.77 ± 2.11	24.80 ± 1.98	.94

[a]Results are reported as mean ± SD. $P < .05$ is considered statistically significant.

Games Played and Player Efficiency Rating Differ Between Operative and Nonoperative Treatment

Players who did not undergo surgery after a shoulder instability event played in significantly fewer games the season after injury and in the third season after injury compared with the season before injury ($P < .05$) (Table 2). In comparison, players who underwent surgery did not have significant differences in the number of games played between the preinjury season and any of the 3 seasons immediately after injury.

The PER for players who did not undergo surgery was significantly less the season after injury compared with preinjury ($P = .017$) (Table 2). However, no differences were found in PER after injury for players who underwent surgery (Table 2). After the first year after injury, no significant differences were seen between pre- and postinjury PER for either operative or nonoperative management.

TABLE 2
Differences in Games Played and Player Efficiency Rating for NBA Players Undergoing Operative Versus Nonoperative Management After Shoulder Instability Events

	Preinjury	Postinjury Season 1		Postinjury Season 2		Postinjury Season 3	
	Mean ± SD	Mean ± SD	*P* Value	Mean ± SD	*P* Value	Mean ± SD	*P* Value
Games played							
Nonoperative	67.7 ± 12.7	57.9 ± 24.5	.04[a]	58.8 ± 25.5	.073	56.8 ± 25.5	.032[a]
Operative	59.6 ± 18.6	61.4 ± 20.1	.73	61.9 ± 20.5	.65	62.4 ± 19.2	.59
Player efficiency rating							
Nonoperative	15.2 ± 4.21	11.9 ± 6.88	.017[a]	14.3 ± 6.16	.47	13.5 ± 6.38	.2
Operative	14.7 ± 5.36	12.4 ± 5.65	.103	15.5 ± 4.48	.54	15.9 ± 4.88	.43

[a]Statistically significant difference compared with preinjury ($P < .05$).

TABLE 3
Differences in Win Shares for NBA Players Undergoing Operative Versus Nonoperative Management After Shoulder Instability Events

	Preinjury Season	Postinjury Season 1		Postinjury Season 2		Postinjury Season 3	
	Mean ± SD	Mean ± SD	*P* Value	Mean ± SD	*P* Value	Mean ± SD	*P* Value
Win shares							
Nonoperative	4.69 ± 3.28	3.38 ± 3.35	.11	4.21 ± 3.74	.58	4.04 ± 3.42	.45
Operative	3.96 ± 3.9	3.49 ± 3.04	.61	4.24 ± 3.48	.77	4.75 ± 3.39	.44
Offensive win shares							
Nonoperative	2.61 ± 2.35	1.45 ± 1.97	.032[a]	2.18 ± 2.33	.46	2.07 ± 2.29	.37
Operative	2.10 ± 2.78	1.65 ± 1.81	.46	2.23 ± 2.36	.85	2.62 ± 2.47	.48
Defensive win shares							
Nonoperative	2.10 1.23	1.93 ± 1.60	.63	2.03 ± 1.70	.85	1.99 ± 1.54	.75
Operative	1.86 ± 1.42	1.84 ± 1.40	.97	2.02 ± 1.51	.67	2.12 ± 1.33	.49

[a]Statistically significant difference compared with preinjury ($P < .05$).

Offensive Win Shares Differ Between Operative and Nonoperative Treatment

Overall win shares did not differ between pre- and postinjury for either the operative or nonoperative group. However, offensive win shares were significantly decreased the season after injury for players who underwent nonoperative treatment ($P = .032$) (Table 3). No differences were found in defensive win shares between players who did and did not undergo surgery after shoulder instability. After postinjury season 1, no significant difference was seen between pre- and postinjury in either group regarding offensive and defensive win shares.

Metrics Predicting Surgical Benefit After Shoulder Instability Event

Random forest modeling was used to determine an order of importance of the player and performance metrics in predicting benefit to surgical intervention. TS was the greatest predictor (MDG, 5.49), followed by WS.48 (MDG, 3.4) (Figure 2). Recurrence (MDG, 0.52) and history of any prior surgery (MDG, 1.41) had the lowest predictive contribution of the variables used in model.

DISCUSSION

After a review of publicly available injury records and treatments of shoulder instability in the NBA, we found that players who underwent surgical management did not see a significant change in PER, whereas those managed nonoperatively experienced a significant decrease in PER the season after injury. In addition, games played and offensive win shares were significantly decreased with nonoperative management compared with operative management after injury. In contrast, win shares and defensive win shares remained relatively the same between operative and nonoperative management. With random forest modeling, variables most useful for predicting players who would benefit from surgery were preinjury TS and WS.48.

Professional basketball is physically demanding, particularly with regard to overhead shoulder activity. Despite this, a paucity of literature is available regarding the outcomes of shoulder instability in NBA players and the optimal treatment protocol. McCarthy et al[16] found shoulder injuries to occur in 4.7% of athletes at the Women's National Basketball Association (WNBA) Combine from 2000 to 2008. Deitch et al[5] retrospectively reviewed injury data from the NBA and WNBA for 6 seasons and found similar rates of shoulder injury, with the shoulder

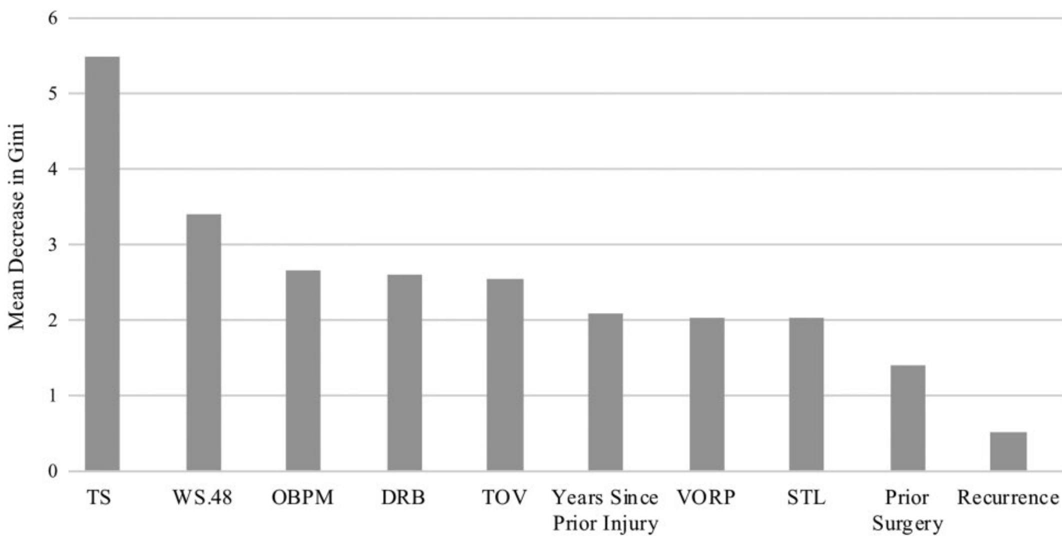

Figure 2. Player and performance variables evaluated by random forest modeling and arranged by mean decrease in Gini (MDG) values. A higher MDG indicates a more significant variable of importance in the predictive model. DRB, defensive rebounds per game; OPBM, offensive box plus/minus; STL, steal percentage; TOV, turnover percentage; TS, true shooting percentage; VORP, value over replacement player; WS.48, win shares per 48 minutes.

accounting for 3.4% and 3.9% of injuries in the NBA and WNBA, respectively. However, that study did not investigate rates of surgery or return to play after injury but rather simply characterized injury rates. In a 10-year study of injury rates in the NBA, Starkey[23] found that shoulder injuries were responsible for 3.0% of all NBA injuries, with athletes missing a total of 2386 games over 10 years (3.6% of all missed time). Although shoulder injury may be responsible for only 3% to 4% of NBA injuries, shoulder instability can have serious implications for player performance as well as a team's decision to offer long-term compensation, especially given the lack of literature on outcomes after these injuries.

Although data are lacking regarding return to play in NBA athletes, researchers have examined return to play in other sports after both operative and nonoperative management of shoulder instability. When considering treatment with nonoperative management, it is important to distinguish between return to play and recurrent rates of instability. For instance, Buss et al[3] examined return-to-play rates in 30 athletes with instability who were managed nonoperatively over a 2-year period. Initially, 26 (87%) athletes returned to play and completed the season; however, 10 (33%) athletes experienced recurrent sport-specific instability. Furthermore, 53% of patients underwent surgery in the following off season. Dickens et al[7] prospectively examined the natural history of nonoperative treatment after traumatic anterior shoulder instability in 45 collegiate athletes over 2 years. After an accelerated rehabilitation protocol, 73% of athletes were able to return to sport after a median of 5 days lost from competition. However, of these participants, only 27% were able to successfully complete the season without a recurrent instability event. Although not specific to basketball athletes, these studies show that while nonoperative management of shoulder instability may be successful in returning athletes to play quickly in the short term, over the course of the season most athletes will experience recurrent instability and require surgical intervention. Our study examining player performance showed similar trends. A majority of players treated with surgical stabilization continued to perform at a similar level the year after injury compared with preinjury.

However, players managed nonoperatively experienced a decrease in PER, most notably on the offensive side of the ball. This could be due to the movements required to effectively shoot a basketball, including abduction and external rotation, resulting in the perceived sensation of instability and apprehension. Furthermore, we demonstrated that athletes managed nonoperatively played significantly fewer games than those managed surgically in the 3 seasons after injury. Multiple explanations may exist, including undocumented or unperceived recurrent instability in the form of subluxations, leading to pain and declines in performance. Additionally, our predictive model found that shooting metrics, defensive rebounding (both overhead actions), and win shares were the most useful in predicting the benefit of surgery. In particular, this implies that players with high shooting percentages and win shares are at a greater risk of experiencing performance declines as a result of electing nonoperative management. These are important considerations for a player's longevity in the league and for coaches and general managers in considering whether to add a player to their roster in the seasons after shoulder instability.

To date, most of the studies regarding outcomes of nonoperative versus surgical management of shoulder instability in professional athletes have been performed on collision athletes, and their findings have mirrored those in the present study regarding a noncollision sport, suggesting superior outcomes in those managed surgically.[9,19,21]

Competitive athletes in other sports have also had successful outcomes and return to play after surgical intervention. Mazzocca et al[15] found a 100% rate of return to play in collision and contact athletes after arthroscopic stabilization. Within this group, 2 of the collision athletes had recurrent instability, although 1 of these athletes had recurrence 2 years after surgery and the other athlete experienced recurrence 3 after surgery during an event outside of athletic activity. Castagna et al[4] reviewed 67 adolescent overhead athletes who underwent arthroscopic capsular repair for instability and found that at 63-month follow-up, 21% of patients had experienced recurrent instability, which was correlated with the type of sport, as rugby and water polo players had the highest rates of recurrence. Of note, no relationship was found between recurrence and poor outcomes, and all athletes improved after stabilization.

After data acquisition and analyses of player performance metrics, our findings support the recommendation for surgical stabilization after shoulder instability in NBA athletes. We demonstrated similar findings to the aforementioned studies, which include superior performance metrics, specifically PER and offensive win shares, after surgery as opposed to nonoperative management. Based on our results, we recommend shoulder instability surgery for NBA athletes, especially those who are shooting or defensive rebound specialists, as these skills appear to be most positively correlated with surgical intervention. Furthermore, recent data have emerged to suggest that recurrent instability is not benign and results in cumulative damage to the glenohumeral joint, most importantly glenoid bone loss, which has been associated with inferior outcomes even in athletes who eventually pursue operative intervention.[8,10]

This study is not without limitations. We did not have access to player medical records, and therefore we were only able to characterize an athlete as having "instability" (either dislocation or subluxation) but were not able to classify history of injury, the degree of injury, the extent of injury, or other concomitant injuries such as Hill-Sachs lesion or associated bone loss. Additionally, we were not able to characterize the type of surgery performed after the instability event (open vs arthroscopic Bankart repair) or any additional procedure performed (eg, remplissage). Given the retrospective nature of the study, our data collection was dependent on player and team self-reports of injury. It is possible that an athlete may have experienced another instability event and not reported the injury. Nonetheless, investigations using these methods of data acquisition have been published and formed the basis for this study.[1-5] Last, our study is susceptible to limitations from having a small sample size. Because shoulder injury historically accounts for only 3% to 4% of all injuries in the NBA, it would take quite some time to accrue a large cohort. However, to our knowledge, our sample of 60 NBA players with instability is the largest such cohort reported in the literature. Despite the limitations of this study, it offers valuable information with respect to the optimal management of shoulder instability in the NBA player and the expected performance after both operative and nonoperative management.

CONCLUSION

NBA players managed with surgical intervention for shoulder instability on average played in significantly more games in the 3 seasons after injury compared with players treated nonoperatively. Additionally, players who did not undergo surgery experienced a decrease in performance as demonstrated by a decline in PER and offensive win shares in the season after injury, albeit returning to their baseline performance in the second season after injury. Defensive metrics did not change significantly, regardless of management. Random forest modeling had the highest predictive power in identifying players who would benefit from surgery based on their performance. With this model, TS was the greatest predictor, followed by WS.48 and DRB. Players who underwent surgical intervention could expect to perform overhead activities as well as or better than they did preoperatively compared with players who did not undergo surgery. The findings of this study are worth considering when one is counseling an elite basketball player regarding the treatment options and expected outcomes after shoulder instability. Based on our results, we recommend surgical stabilization for NBA athletes who experience glenohumeral instability.

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APPENDIX

Definitions

Player efficiency rating (PER): Objective measure of performance made by summing positive performance statistics such as points, rebounds, steals, and assists and subtracting negative variables, including turnovers and fouls. The score is adjusted by team and playing style with standardization to a league mean of 15.0.

Win shares: Number representing an estimate of game wins contributed by a player.

Offensive win shares: Number representing game wins contributed by a player due to his offense.

Defensive win shares: Number representing games wins contributed by a player is due to his defense.

Surgery: A binary variable representing whether a player will undergo or has undergone surgery (1) or will not undergo or has not undergone surgery (0).

Years since injury: An integer representing the number of years since a player last sustained an injury.

Injury recurrence: A binary variable representing whether the shoulder injury sustained has previously occurred (1) or is new (0).

Defensive rebounds per game (DRB): A number between 0 and 100 representing an estimate of the percentage of defensive rebounds a player grabbed while on the floor.

Offensive box plus/minus (OBPM): A box score estimate of the offensive points per 100 possessions a player contributed above a league-average player, translated to an average team.

Steal percentage (STL): A number between 0 and 100 representing an estimate of the percentage of opponent possessions that ends with a steal by a player while on the floor.

Turnover percentage (TOV): A number between 0 and 100 representing an estimate of turnovers committed per 100 plays.

True shooting percentage (TS): A number between 0 and 100 representing shooting efficiency. Only free throws, 2-point field goals, and 3-point field goals are considered.

Value over replacement player (VORP): A box score estimate of the points per 100 team possessions that a player contributed above a replacement-level player, translated to an average team and prorated to an 82-game season.

Win shares per 48 minutes (WS.48): An estimate of the number of wins contributed by a player per 48 minutes.