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ORIGINAL RESEARCH

Multivariate Analysis of Risk Factors for Injury and Surgical Interventions in Ankle and Knee Injuries in NBA Athletes

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Objective: Lower extremity ankle and knee injuries occur at a high rate in the National Basketball Association (NBA) often requiring surgical intervention. This study aimed to identify surgical rates and risk factors for surgical intervention using multivariate analysis in ankle and knee injuries in NBA player.

Methods: Player demographics, performance metrics, advanced statistics, and injury characteristics were recorded using publicly available data. To standardize injury events over multiple years, injury events per 1000 athlete exposure events (AE, one player participating in one game) were calculated. Descriptive analysis and multivariate logistic regression were completed to find associations with surgical intervention in ankle and knee injuries.

Results: A total of 1153 ankle and knee injuries were included in the analysis with 73 (6.33%) lower extremity injuries treated with surgery. Knee injuries had a higher incidence of surgical intervention (0.23 AE) than ankle injuries (0.04 AE). The most frequent surgical knee injury was meniscus tear treated with meniscus repair (0.05 AE) and the most frequent ankle surgery was surgical debridement (0.01 AE) Multivariate logistic regression indicated lower extremity injuries that required surgery were associated with more minutes per game played (odds ratio [OR] 1.13; $p = 0.02$), a greater usage rate (OR 1.02 $p < 0.001$), the center position (OR 1.64; 95% [CI] 1.2–2.24; $p = 0.002$) and lower player efficiency rating (OR 0.96; 95% $p < 0.001$).

Conclusion: Knee surgery was significantly more frequent than ankle surgery despite similar injury rates per 1000 exposures. The center position had the greatest risk for lower extremity injury followed by minutes played while a higher player efficiency rating was protective against surgical intervention. Developing strategies to address these factors will help in the management and prevention of lower extremity injuries requiring surgical intervention.

Plain Language Summary: It is known that ankle and knee injuries make up a significant proportion of injuries in professional athletes with some of these injuries requiring surgical intervention. The current literature is inconclusive on the impact of demographic and performance metrics on risk for surgical intervention in knee and ankle injuries. Through multivariate analysis, our findings indicate that demographic variables, such as weight and player position, along with player performance metrics like minutes per game and usage rate, play a significant role in increasing risk for surgery in NBA athletes. In addition to identifying risk factors, we also describe the rates of surgical intervention and the epidemiology of ankle and knee injuries in the National Basketball Association. Overall, identifying surgical rates and risk factors is crucial for developing preventive strategies, and optimizing performance in professional NBA athletes.

Keywords: National Basketball Association, Knee, Ankle, Multivariate, Meniscus, Orthopaedic Surgery, Injury risk factors

Introduction

National Basketball Association (NBA) players are at risk of suffering injuries from minor sprains and strains to more serious injuries such as fractures and tendon ruptures. These injuries are due to the natural flow of basketball gameplay,

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which includes repeated jumping, landing, player-to-player contact, frequent falls to the ground, and sudden pivoting at high speeds.[1,2] NBA athletes are at a significantly higher risk of game-related injuries in comparison to their collegiate counterparts.[3] The increased risk for NBA players is related to several factors including increased court length, distance covered per game, number of minutes played per game, weekly practice time, season length, and overall older age.[1–4] These injuries have negative effects on many stakeholders. For athletes, these injuries can be life-altering including shorter and less productive careers, and increased pain and surgeries post-retirement.[2,5] Additionally, injuries have legal and financial implications for the league and teams.[6,7] Studying risk factors for these injuries can help identify potentially modifiable factors to minimize the impact of these injuries on players, teams, and executives.

Lower extremity injuries consistently have the highest rates of injury in the NBA.[7,8] In the NBA, lower extremity injuries account for 62.4% of all injuries and 72.3% of games missed due to injury.[1] Due to changes in strategy and gameplay, basketball in the NBA has evolved to encourage high-value offensive opportunities; these include increased 3-point attempts and more frequent drives to the basket.[9] Most injuries that occur from these situations in the NBA are minor injuries that require limited rehabilitation and missed time.[1,2] Alternatively, there are other injuries that require surgical intervention and extensive rehabilitation. These injuries can have the largest negative effects on all stakeholders with prolonged periods of recovery and rehabilitation. Lower extremity injuries following surgical intervention had lower return-to-play rates and poor performance postoperatively.[1,2] Many athletes are unable to return to the NBA after surgical intervention with 39% not returning after Achilles tendon reconstruction,[10] and only 14% of players returning following an anterior cruciate ligament reconstruction.[11]

Previous studies have evaluated the distribution of lower extremity injuries in the NBA, including injuries that require surgical intervention.[1] While some studies have shown inconclusive results on the relationship between demographic variables and injury risk[2] the use of multivariate analysis has identified risk factors in NBA athletes which include both demographic and performance metrics.[12] We hypothesize that demographic variables like players age and weight and performance metrics like usage rate and minutes played will significantly increase players risk for surgery. Despite the effectiveness of multivariate analysis, these methods has not been used to identifying risk factors for ankle and knee surgery. This study aims to identify surgical rates and risk factors for surgical intervention in ankle and knee injuries in NBA players.

Methods

Eligible participants were NBA players aged 18 years and older who missed at least one game due to injury between 2015 and 2021 seasons with a lower extremity ankle or knee injury. All data was retrieved from the NBA's public injury reports from NBA.com, prosportstransactions.com, and basketballreference.com to identify players placed on injury reports. The use of publicly available injury reports is common in peer-reviewed epidemiological studies.[1,12–14] Within the dataset, an injury event was classified as a player who missed at least one game due to injury. Each injury event included player name, date of injury, description of injury, and the player's team at the time of injury.

Metrics

For each player injury demographics, performance metrics, advanced statistics, and injury characteristics were recorded (See Table 1). Injury rates were standardized based on athlete exposure to injury to accurately compare injury rates between different seasons of differing lengths. For the purposes of this study, an athletic exposure was defined as one athlete appearing in one game and the injury rate was calculated per 1000 athlete exposures.[1,13,15,16] Therefore, athlete exposures were calculated by the total number of NBA games played for each team, multiplied by the 15 players on the team's NBA roster. Practice was not included in the athlete exposure formula and no distinction was made between minutes played following the protocol outlined by Drakos et al.[1] Injuries sustained in non-game situations were included in the total number of injury events.

Analysis

Analyses were performed on the database from the 2015–2021 NBA seasons for any game played in the NBA during this time including preseason, regular season, and postseason games. Total injury events and athlete exposures were calculated for each season. Incidence rates were calculated and defined as the number of injuries per 1000 athlete exposures (Total

Table 1 Description of the Advanced Performance Metrics and Statistics Included in Analysis

Statistic	Description
Player efficiency rating (PER)	Rating of player's per-minute productivity
Personal fouls (PF)	Number of fouls a player commits per game
Steals	Defensive statistic credited to player when they legally cause a turnover
Weight	Player weight at the time of injury
Usage rate	Percentage of team plays a player is involved in while in the game
Minutes played	A player's average minutes played per game
Games played	A player's total number of games played in one season
True shooting percentage (TS%)	Player's efficiency at shooting the ball
3Par	Percentage of field goal attempts from 3-Point Range
Offensive rebound %	Estimate of the percentage of available offensive rebounds a player grabbed while on the floor
True rebound % (TR%)	Estimate of the percentage of available rebounds a player grabbed while on the floor
Assist %	Estimate of the percentage of teammate field goals a player assisted while they were on the floor
Steal %	Estimate of the percentage of opponent possessions that end with a steal by the player while they were on the floor
Block %	Estimate of the percentage of opponent two-point field goal attempts blocked by the player while they were on the floor
Turnover %	Estimate of turnovers committed per 100 plays
Defensive win shares (DWS)	Estimate of the number of wins contributed by a player due to defense
Win shares (WS)	Estimate of the number of wins contributed by a player created by accumulating all the statistics provided into a single statistic
Win shares per 48 minutes (WS/48)	Estimate of the number of wins contributed by a player per 48 minutes
Field goals made	Total number of field goals made from anywhere on the court
Field goals attempted	Total number of shots attempted by a player from anywhere on the court

Number of Injury events/Total number of athlete exposures x 1000). The incidence of injuries per 1000 game exposures for each season was calculated and results were reported for continuous and discrete variables. Factors associated with lower extremity surgical injuries in NBA players were assessed using multivariate analysis accounting for player demographics, and other performance metrics. Multivariable logistic and negative binomial regression analyses were completed and reported in odds ratios, confidence intervals, and associated p-values. Critical values for statistical significance were assumed at an alpha level of less than 0.05 and all statistical analyses were performed using R Studio Version 4.01.

Results

A total of 1153 lower extremity ankle and knee injuries were included in the analysis with 73 (6.3%) lower extremity injuries treated with surgery. There were 596 ankle injuries (2.16 AE) and 563 knee injuries (2.04 AE) (See Table 2).

Knee Injuries

There were 596 knee injuries with significantly more non-surgical injuries at 532 (89.3%) than surgical injuries at 64 (10.7%) ($p < 0.001$). Among non-surgical injuries, the soreness was the most common with 163 (30.6%), followed by

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Table 2 All Ankle and Knee Injuries and Associated Incidences in NBA Athletes per 1000 Athlete Exposures

	Injury Type		Number of Injuries	Injury Incidence (Per 1000 Athlete Exposures)
NonSurgical Injury	Knee	Soreness	163	0.59
		Knee Sprain	98	0.36
		Contusion/Inflammation	75	0.27
		Hyperextension	12	0.04
		Tendinitis	34	0.12
		Other	42	0.15
		Unspecified	108	0.39
		Total	**532**	**1.93**
	Ankle	Sprain	406	1.47
		Soreness	61	0.22
		Fracture	5	0.02
		Contusion/Inflammation	8	0.03
		Other	35	0.13
		Unspecified	37	0.13
		Total	**552**	**2.00**
Surgical Injury	Knee	Meniscus	20	0.07
		ACL	10	0.04
		Arthroscopic Debridement	19	0.07
		Cartilage/Tendon Repair	10	0.04
		Other/Multiple*	5	0.02
		Total	**64**	**0.23**
	Ankle	Arthroscopic Debridement	4	0.01
		Ankle Reconstruction	3	0.01
		Surgical Ligament Repair	2	0.01
		Microfracture Surgery	1	0.004
		Fracture Repair	1	0.004
		Total	**11**	**0.040**
		Combined Total	**1153**	**4.185**

Note: Bolded Values Indicated Totals of Numbers of Injuries and Injury Incidence per 1000 Athlete Exposures.

knee sprains at 98 (18.4%), and contusion or inflammation at 75 (14.1%). For all non-surgical knee injuries, the overall risk was 1.93 injuries per 1000 exposures.

Knee injuries that required surgery made up 10.7% of knee injuries with an overall risk of 0.23 injury events per 1000 exposure events. The most cited surgical intervention performed was Meniscus repair with 20 (31.25%) followed by Arthroscopic debridement with 19 (29.7%) and ACL reconstruction with 10 (15.62%).

Ankle Injuries

There were 563 ankle injuries with significantly more non-surgical injuries 552 (98.1%) than surgical injuries 11 (2.0%) ($p < 0.001$). The most cited non-surgical injury was ankle sprain with 406 (73.6%), followed by ankle soreness at 61 (11.1%). For all non-surgical knee injuries, the overall risk was 2.00 injuries per 1000 exposures.

Ankle injuries that required surgery made up 2.0% of ankle injuries with an overall risk of 0.04 injury events per 1000 exposure events. The most cited surgical intervention performed was arthroscopic debridement with 4 (36.4%) followed by ankle reconstruction with 3 (27.3%). Ankle and knee injuries had similar frequency (1.93 AE and 2.00 AE, respectively). However, there was a higher incidence of knee injuries requiring surgical intervention (0.23 AE) than ankle injuries (0.04 AE).

Multivariate Regression

Multivariate logistic regression indicated lower extremity injuries that required surgery were associated with more minutes per game played (odds ratio [OR] 1.13; 95% confidence interval [CI] 1.02–1.26; P = 0.02). Demographic variables associated with increased risk for surgical intervention were increased body weight (OR 1.01; 95% [CI] 1.01–1.03; P < 0.001) and the center position (OR 1.64; 95% [CI] 1.2–2.24; P = 0.002). Other demographic variables including height and age were not associated with an increased risk for lower extremity surgical intervention. Advanced statistical metrics that were associated with increased risk for surgical intervention include greater usage rate (OR 1.02; 95% [CI] 1.01–1.03; P < 0.001). Increased steals per game (OR 1.001; 95% [CI] 1.001–1.003; P = 0.008) was statistically significant, a higher Player Efficiency Rating was associated with decreased risk for surgical intervention (OR 0.96; 95% [CI] 0.94–0.98; P < 0.001). Although statistically insignificant, higher win shares per 48 games had the highest risk for surgery with an odds ratio of 3.27 (1.89, 4.64). Most other advanced statistics were not significantly associated with increased risk for lower extremity surgery including Offensive and defensive rebound %, Turnover %, Field Goals Made, True Shooting %, assist %, and steal %. (See Table 3)

Discussion

Multivariate analysis showed that risk factors significantly associated with increased risk of surgical intervention were minutes per game, usage rate, weight, and the center position. Multivariable analysis has been used in the literature reporting on basketball injuries to help identify or support the basketball-related injury's epidemiology, risk factors, effect

Table 3 Multivariable Logistic Regression Analysis of Factors Associated with Ankle and Knee Lower Extremity with Associated Odds Ratios and p-values. Bolded Values Indicate Statistical Significance with a p-value <0.05

Variable	Odds Ratio	P-value
Age	1.00 (0.99 1.003)	0.137
Height	0.99 (0.99 1.00)	0.45
Weight	1.01 (1.01 1.019)	**0.04**
Center Position	1.64 (1.2–2.24)	0.**002**
>30 Minutes	1.11 (1.00, 1.22)	**0.046**
Games Played	0.99 (0.99 1.00)	0.609
Performance Metrics		
Usage Rate	1.02 (1.01, 1.03)	**<0.001**
PER	0.96 (0.94, 0.98)	**<0.001**
Steals per game	1.001 (1.00, 1.003)	**0.008**
Personal Foul	0.99 (0.99, 0.99)	**0.03**
TS %	2.06 (0.73, 3.40)	0.29
3PAr	0.98 (0.39, 1.57)	0.95
FTr	0.94 (0.81, 1.08)	0.42
Offensive Rebound %	1.03 (0.97, 1.10)	0.33
Defensive Rebound %	1.03 (0.96, 1.09)	0.42
Assist %	1.00 (1.00, 1.01)	0.49
Steal %	0.97 (0.93, 1.01)	0.15
Block %	1.00 (0.98, 1.03)	0.84
Turnover %	1.00 (1.00, 1.01)	0.69
DWS	0.94 (0.68, 1.20)	0.65
WS	1.03 (0.77, 1.29)	0.81
WS/48	3.27 (1.89, 4.64)	0.09
Field Goals Made	1.00 (1.00, 1.00)	0.85
Field Goals Attempted	1.00 (1.00, 1.00)	0.67

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on player return to play, and effect on player's performance post-injury. While other studies have investigated the effects of surgical repair of Achilles tendon rupture[17] and knee microfractures[18] our study has looked more comprehensively at lower extremity knee and ankle injuries that could necessitate surgery, expanding the current literature on basketball.

Our results indicate the association of injury and demographic variables like age, weight, and height yielded mixed conclusions.[1,2,9,19] The demographic risk factors of age and height had no association with increased risk for surgical intervention, which has been highlighted in previous literature.[1] Weight and the center position were both independently correlated with increased risk of surgical intervention with the center position having the greatest risk of all variables. Although increased weight was statistically associated with surgical intervention it is likely not clinically significantly with such low odds ratio. The increased risk in the center position is likely more clinically relevant and may be attributed to increased weight, with reports of the average center weighing 245 lbs (111.5 kg) in addition to the physicality necessary to play the position.[20] Increased forces and stresses at higher weights resulting in lower extremity joint stress in addition to more in-game impacts with other players.[21] Svilar et al found that centers have the highest number of total and high-intensity accelerations compared to forwards and guards.[22] Furthermore, centers average scientifically more jumps than other positions, likely due to their role in shot blocking and rebounding.[23] Each position will have unique demands with differing frequency of jumping with both single- and double-leg landings placing differing stresses on each position.[24] Thus, the findings from our study emphasize the need to consider position and player size when designing injury prevention and rehabilitation programs. These injury prevention programs may include position specific neuromuscular balance, proprioceptive and strength training.[25–27] The need for specificity in training programs based on position has previously been outlined and focuses on matching the volume and intensity of competition in the training environment.[28]

Our analysis showed that risk factors significantly associated with increased risk of surgical intervention were minutes per game, and usage rate, while greater player efficiency was associated with decreased risk for surgical intervention. These findings support the hypothesis observed in the literature of increased physiologic stress leading to increased injury rates injury risk.[7,29] Increased physiologic stress in the form of more physical play, longer seasons, and higher-intensity movements place great stress on the lower extremities leading to increased lower extremity injury rates.[1,2,9,19] Prevention strategies targeting physiologic stress through player rest and load management may provide meaningful decreases in injury.[21]

Previous studies have evaluated injury rates at all levels including professional,[1,2,7,10,12] collegiate[12,30] and high school levels[4,31,32] with professional athletes having the highest rates of injury.[2–4] Our results confirmed high rates of injury in professional athletes with non-surgical ankle injuries being the most frequent lower extremity injury.[1,7] Of these ankle injuries, ankle sprains caused the greatest proportion of these reported injuries. These results are unsurprising with the high frequency of stress on ankles due to cutting, driving to the basket, and jumping at high velocity.[7,29]

Non-surgical knee injuries accounted for 1.9 injuries per 1000 exposures. These rates are similar to rates reported by both Deitch et al[33] and Drakos et al[1] of 2.5 injuries per 1000 exposures and 1.5 injuries per 1000 exposure, respectively. Across both ankle and knee injuries, we found that soreness and inflammation made up most knee injuries in the NBA. The causes of the high rates of soreness and inflammation are likely multifactorial.[12,30]

Despite higher rates of non-surgical ankle injuries, our results indicate that knee surgery occurred significantly more often than ankle surgery. Bullock et al and McKay et al similarly demonstrated increased severity of knee injury incidence compared to ankles.[8,34] We found similar results to Minhas et al that reported high rates of ACL reconstruction and meniscus repair.[10] High-intensity movements at the professional level leads to high shear and compression forces at the tibiofemoral joint and may play a role in the high rates of surgical intervention at the knee.[10]

Limitations

There were several limitations to our study, including the constraints of the publicly available data, and constraints of a retrospective study. Lack of standardization may lead to minor injuries going unreported, which may have inflated the rates of surgical intervention. Additionally, publicly available databases may not provide accurate or specific medical details on the type and mechanism of injury. Public data does not allow for the quantification of missing data points, which decreases the precision of these results. Subclinical injuries that did not result in games missed were not captured in these data. Finally, as this study was only performed on professional basketball athletes, there is decreased generalizability to other sports and levels of competition.

Conclusion

Lower extremity knee and ankle surgeries occurred in 6.33% of players in this study with an overall rate of 0.265 injuries per 1000 game exposures. Knee surgery was significantly more frequent than ankle surgery despite a similar incidence of ankle and knee injuries. Significant risk factors associated with injury were minutes per game, usage rate, and the center position, while higher player efficiency was significantly associated with a decreased risk of surgery. As rates of injury and surgical intervention in the NBA increase, negative impacts are felt by multiple stakeholders. It is important to understand the distribution and associated risk factors to prevent injury and inform strategies to improve player health and safety.

Disclosure

Dr Benjamin Service reports personal fees from Stryker, FarmaceuticalRx for consulting, stock/equity from OXOS, education/training for Reel Surgical, Inc., stock from ProBox Recovery Partners LLC, outside the submitted work. The authors report no other conflicts of interest in this work.

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