

# Descriptive Epidemiology of Musculoskeletal Injuries and Concussions in the National Football League, 2012-2014

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**Background:** The risk of all-cause injury and concussion associated with football is significant. The National Football League (NFL) has implemented changes to increase player safety warranting investigation into the incidence and patterns of injury.

**Purpose:** To document the incidence and patterns of all-cause injury and concussions in the NFL.

**Study Design:** Descriptive epidemiology study.

**Methods:** Injury data were collected prospectively from official NFL injury reports over 2 regular seasons from 2012 to 2014, with identification of injury incidence rates and patterns. Concussion rate ratios were calculated using previously reported NFL rates.

**Results:** A total of 4284 injuries were identified, including 301 concussions. The all-cause injury rate was 395.8 per 1000 athletes at risk (AAR) and concussion incidence was 27.8 per 1000 AAR. Only 2.3% of team games were injury free. Wide receivers, tight ends, and defensive backs had the highest incidence of injury and concussion. Concussion incidence was 1.61-fold higher in 2012 to 2014 compared with 2002 to 2007. The knee was injured most frequently, followed by the ankle, hamstring, shoulder, and head.

**Conclusion:** The incidence of all-cause injury and concussion in the NFL is significant. Concussion injury rates are higher than previous reports, potentially reflecting an improvement in recognition and awareness. Injury prevention efforts should continue to reduce the prevalence of injury associated with football.

**Keywords:** National Football League (NFL); concussion; epidemiology; injury

American football (“football”) is one of the most popular sports in North America, with approximately 3 million youth, 1 million high school, and 100,000 collegiate participants annually in the United States.<sup>31,35</sup> The risk of injury associated with football is significant, and all-cause injury rates have been reported as high as 8 injuries per 1000 athlete-exposures (AEs) in high school football,<sup>24</sup> 36 per 1000 AEs in collegiate football,<sup>13</sup> and 65 per 1000 AEs in National Football League (NFL) preseason games.<sup>16</sup>

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Furthermore, football has one of the highest incidences of traumatic brain injury of all major sports,<sup>25,35</sup> and concussions have been identified as one of the most frequently occurring injuries within the sport across all ages.<sup>13</sup> This is of particular concern given the evidence of an observed association between repetitive head trauma and long-term neuropsychiatric and cognitive outcomes.<sup>30,37</sup> In 2010, the NFL’s Mild Traumatic Brain Injury Committee published the largest and most recent peer-reviewed study documenting concussion incidence in the NFL.<sup>10</sup> This study reported the incidence of concussion in the NFL over 2 time periods (1996-2002 and 2002-2007) and reported a lower incidence of concussion during the more recent time period.<sup>10</sup>

The NFL’s response to concussion and other injuries undeniably shapes the culture of the sport and influences the rules and policies adopted at all levels of play.<sup>20</sup> With the large number of youth participants, in addition to the potential long-term adverse health outcomes associated with injuries sustained during play, the NFL’s approach to injury prevention is a matter of population and public health concern.<sup>20</sup> In an attempt to increase player safety and injury awareness, the NFL has implemented numerous rule and policy changes. There is concern conveyed through media sources, however, that new rules intended to reduce

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the incidence of concussion are in fact placing athletes at greater risk for musculoskeletal injuries<sup>3</sup>; however, this has yet to be systematically evaluated. Furthermore, despite several studies documenting the prevalence of specific injury types in the NFL,<sup>7,9,15,17,27,28,34</sup> there is a paucity of evidence documenting the baseline incidence and patterns of all-cause injury in the NFL, the results of which would provide insight into the influence of future injury prevention interventions. Additionally, there has been no peer-reviewed investigation into concussion incidence since the 2007 season.

The purpose of the present study was to document the incidence and patterns of all-cause injury and concussions in the NFL over a 2-year period from 2012 to 2014. The goals of this study were to (1) provide baseline information on the prevalence of injuries within the NFL, from which the effect of future rule changes can be assessed; (2) identify the pattern of injuries in NFL players to identify areas for future injury prevention strategies; and (3) document the change in concussion incidence over time.

## METHODS

### National Football League Injury Reports

Official NFL injury reports are published weekly online by all 32 teams on each team's official website as well as on the NFL league-wide website (<http://www.nfl.com/injuries>). Each team is "required to report the level of participation in practice of any player hampered by an injury."<sup>36</sup> The NFL regular season includes 16 games per team, played over a period of 17 weeks. Injury reports are published prior to each game and, therefore, reflect injuries sustained in the previous week's game or in the current week's practices. Injury data pertaining to the final regular season game (game 16 in week 17) are only available for the 12 teams that advance to the playoffs and are not available for the 20 teams that are eliminated and are no longer required to publish injury data. Injured players who are not immediately available to participate may be placed on an injured reserve list as opposed to the weekly injury report. The injured reserve list for each team is available online and updated daily.<sup>11</sup>

Injury reports and the injured reserve list include the following information of all players on the roster diagnosed with an injury or illness by a team physician: player name, position, anatomical area injured (ankle, knee, hip, shoulder, toe, head, etc), practice status of a player for 3 practices during the week (did not practice, limited participation, full participation), and game status (probable to play, doubtful to play, out).

### Data Collection and Injury Definition

All injury report and injury reserve data were collected prospectively for each week over the 2012-2013 and 2013-2014 regular seasons for all 32 teams. Week 17 injury reports were only available for 12 teams per season. An injury was defined as any reported injury that was not documented on the injury

TABLE 1  
Injury Rate Definitions<sup>a</sup>

Variable	Definition
Injury rate per 100 TG	$\frac{\text{No. of injuries}}{\text{No. of TG}} \times 100$
Injury rate per 100 TGP	$\frac{\text{No. of injuries}}{\text{No. of TG} \times \text{No. of GP}} \times 100$
Injury rate per 1000 AAR	$\frac{\text{No. of injuries}}{\text{No. of TG} \times \text{No. of AAR per TG}} \times 1000$
AARs per TG, n	11
GP, n	
Offensive line	5
Defensive line	4
Defensive backs	4
Linebacker	3
Wide receiver	2
Running back	2
Tight end	1
Quarterback	1
Kicker, punter	1

<sup>a</sup>AAR, athletes at risk; GP, standard game positions; TG, team games; TGP, team game positions.

report 1 week immediately preceding the index injury week, indicating that the athlete was not identified as having the index injury in the previous week. Injury reports do not allow for the identification of recurrent injuries; however, applying this definition ensures that, at a minimum, any injury was not impairing an athlete the 1 week prior to its identification and inclusion. A concussion was defined as any injury reported as a concussion or a head injury.

### Data Analysis and Ethics

Injury reports do not identify the situation context (ie, game vs practice) in which the injury occurred; however, the majority of injuries within a football and NFL season occur during games.<sup>9,27,28</sup> Therefore, to estimate the injury incidence for NFL games, we assumed all injuries occurred during games for injury rate calculations.

Injury rates were reported as the number of injuries per 100 team games (TG), injury rates per 100 team game positions (TGP), and injuries per 1000 athletes at risk (AAR), with 95% confidence intervals (Table 1).

A TG is defined as a team exposure to a game and, consequently, for each game played there are 2 TGs. A TGP controls for the relative difference in the number of positions represented in a TG. The number of each position can change for each play or differ by defensive strategy; however, standard game positions (GPs), previously described by Casson et al,<sup>10</sup> quantify the average exposure of each position based on the most frequent personnel groupings. Standard GPs include 1 quarterback, 2 running backs, 2 wide receivers, 1 tight end, 5 offensive line positions (1 center, 2 guards, and 2 tackles), 4 defensive line positions (2 guards and 2 defensive ends), 3 linebackers, 4 defensive backs, and 1 kicker or punter for each TG (Table 1).

Therefore, for example, during 984 TGs, there are 4920 (5 × 984) standard offensive line positions.

To estimate the overall injury burden in the NFL, an AAR methodology was used to determine the team-level risk of injury.<sup>18,26,38</sup> In football, there are 11 AARs per team at any single time during a game. Therefore, the denominator for AAR injury rate reporting was the number of AARs multiplied by the number of TGs (11 × 984 = 10,824). The concussion incidence per 1000 AARs was calculated from Casson et al<sup>10</sup> using the same definition. The AAR approach to incidence reporting provides an estimation of the risk of injury associated with a sport as a whole and can be calculated for any sport allowing for sport-dependent comparisons of injury rates. We recognize that the AAR approach greatly overestimates the risk for an individual athlete and should not be interpreted as such, as it does not incorporate sport-specific athletic individual athlete exposure variables (number of substitutions, personnel changes, line changes, etc).

Poisson injury rate ratios (IRRs) were calculated with a significance level of  $\alpha < .05$  to quantify the difference in concussion incidence between the time period of the current study (2012-2014) and Casson et al (2002-2007).<sup>10</sup> Data were extracted from Casson et al,<sup>10</sup> and injury rates for the 2002-2007 study period were calculated using the above definitions. Statistical analysis was performed using Stata Data Analysis and Statistical Software (v 13.1; StataCorp LP). Our institutional review board deemed this study exempt from requiring ethics approval, as all included data were available in the public domain.

## RESULTS

A total 512 regular-season games, or 1024 team games, were played during the 2012-2013 and 2013-2014 regular seasons, of which 984 TGs (96.1%) were available and included in this study (Table 2). A total of 4284 all-cause injuries were identified in 1172 players, including 301 concussions in 272 players, over the 2 regular seasons. An injury occurred in 97.7% of TGs (n = 961), while 2.3% of TGs (n = 23) were injury free (Table 2).

A breakdown of the injuries by anatomical location revealed 61.9% (n = 2651) of the injuries were to the lower extremities, 18.0% (n = 771) to the upper extremities, 10.2% (n = 436) were to the head or neck, and 7.8% (n = 334) to the axial region (Figure 1). The knee was the most frequently injured location overall (n = 763; 17.8%), followed by the ankle (n = 531; 12.4%), hamstring (n = 372; 8.7%), shoulder (n = 361; 8.4%), and head/concussion (n = 301; 7.0%).

The all-cause injury rate was 435.37 per 100 TGs (95% CI, 422.43-448.60) or 395.80 per 1000 AARs (95% CI, 384.0-407.8) (Table 3). Wide receivers had the highest all-cause injury rate (30.28 injuries per 100 TGPs; 95% CI, 27.90-32.82), followed by tight ends (27.44 per 100 TGPs; 95% CI, 24.26-30.91), defensive backs (23.60 per 100 TGPs; 95% CI, 22.11-25.17), running backs (21.90 per 100 TGPs; 95% CI, 19.88-24.07), and linebackers (21.48 per 100 TGPs; 95% CI, 19.84-23.22). Quarterbacks and kickers/punters had the lowest all-cause injury rate out

TABLE 2  
Team Games Included and Injuries per Team Game

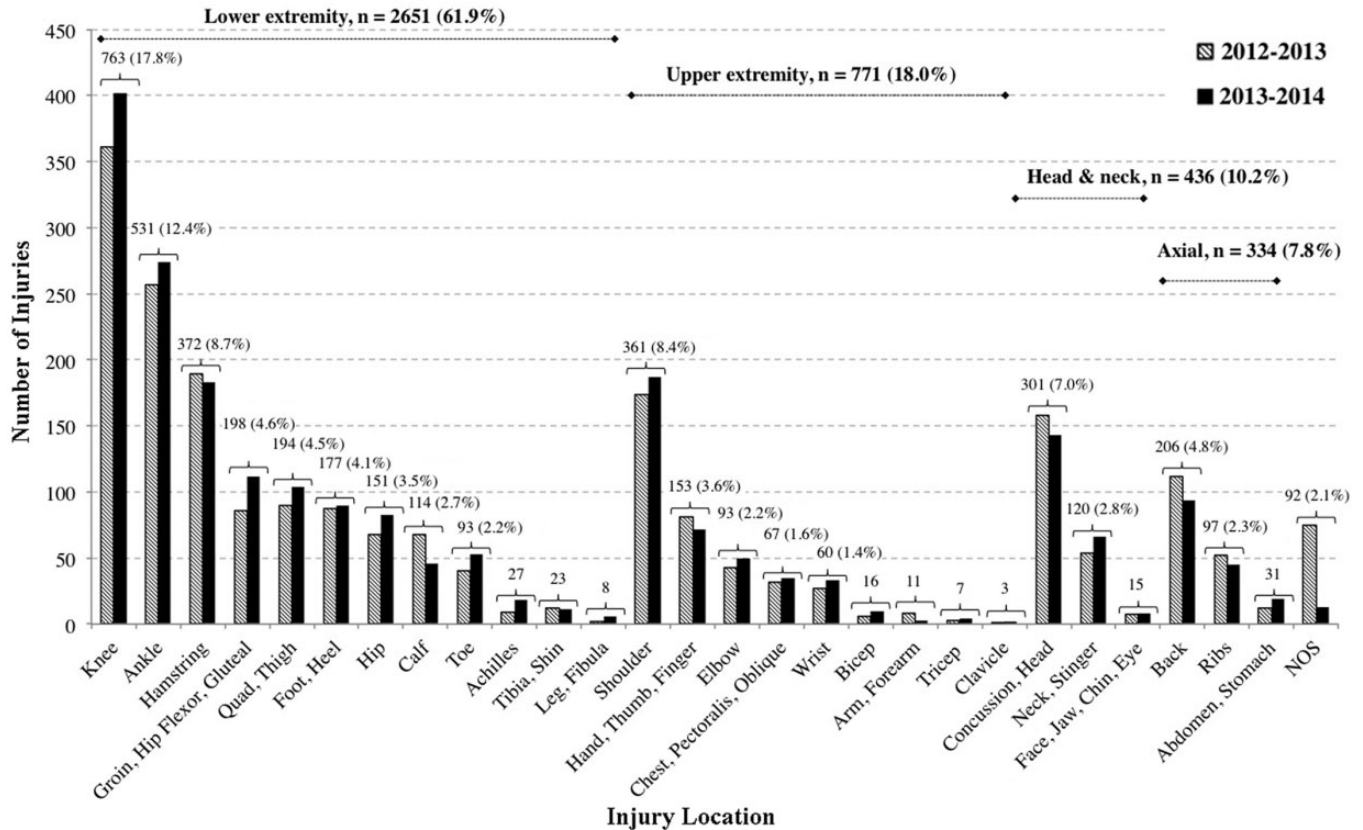
	Team Games, n (%)
Regular season (16 games, 17 weeks)	1024 (100.0) <sup>a</sup>
Weeks 1 through 16 (games 1-15)	960 (93.8) <sup>a</sup>
Week 17 (game 16) with available injury report	24 (2.3) <sup>a</sup>
Included in this study	984 (96.1) <sup>a</sup>
Injuries per team game	
Concussions	
0	731 (74.3)
1	211 (21.4)
2	36 (3.7)
3	6 (0.6)
Total	253 (25.7)
Lower extremity injuries	
0	93 (9.5)
1-3	609 (61.9)
4-7	272 (27.6)
8-10	10 (1.0)
Total	891 (90.6)
Upper extremity injuries	
0	490 (49.8)
1-2	437 (44.4)
3-5	55 (5.6)
6-7	2 (0.2)
Total	494 (50.2)
Axial injuries	
0	646 (65.7)
1-2	323 (32.8)
3-4	15 (1.5)
Total	338 (34.3)
Any injury	961 (97.7)
No injury	23 (2.3)

<sup>a</sup>Percentage calculated based on 1024 team games, otherwise calculated from 984 team games.

of all positions (12.09 per 100 TGPs; 95% CI, 10.02-14.47 and 4.88 per 100 TGPs; 95% CI, 3.60-6.47, respectively).

The concussion incidence rate was 30.58 per 100 TGs (95% CI, 27.23-34.25) or 27.80 per 1000 AARs (95% CI, 24.75-31.13) (Table 4). Tight ends had the highest concussion rate (3.56 per 100 TGPs; 95% CI, 2.48-4.95), followed by wide receivers (2.29 per 100 TGPs; 95% CI, 1.67-3.06), defensive backs (2.08 per 100 TGPs; 95% CI, 1.66-2.59), running backs (1.68 per 100 TGPs; 95% CI, 1.15-2.35), and quarterbacks (1.32 per 100 TGPs; 95% CI, 0.70-2.26). The defensive line and kickers/punters had the lowest concussion incidence of all positions (0.66 per 100 TGPs; 95% CI, 0.43-0.98 and 0.0 per 100 TGPs; 95% CI, 0.0-0.37, respectively).

Incidence rate ratios were calculated to quantify the difference in concussion rate between the 2012-2014 and 2002-2007<sup>10</sup> time periods (Table 4). Overall, concussion incidence was 1.61 times higher (95% CI, 1.40-1.84;  $P < .001$ ) in 2012-2014 compared with 2002-2007. There was a significant increase in the incidence of concussion for all positions—except quarterbacks, linebackers, and kickers—from 2002-2007 to 2012-2014. The greatest increase in incidence of concussion was identified in the offensive line (IRR, 3.11; 95% CI, 2.04-4.72;  $P < .001$ ) followed by the defensive line (IRR, 2.51; 95% CI, 1.48-4.19;  $P = .003$ ), wide



**Figure 1.** Frequency of injuries in the National Football League according to anatomical location and season (2012-2013 or 2013-2014). NOS, not otherwise specified.

**TABLE 3**  
Incidence of All-Cause Injury by Position<sup>a</sup>

Position	Injuries, n (%)	TGP or AAR, n	Injuries per 100 TG (95% CI)	Injuries per 100 TGP or 1000 AAR (95% CI)
Wide receiver	596 (13.9)	1968	60.57 (55.80-65.63)	30.28 (27.90-32.82)
Tight end	270 (6.3)	984	27.44 (24.26-30.91)	27.44 (24.26-30.91)
Defensive back	929 (21.7)	3936	94.41 (88.44-100.001)	23.60 (22.11-25.17)
Running back	431 (10.1)	1968	43.80 (39.76-48.14)	21.90 (19.88-24.07)
Linebacker	634 (14.8)	2952	64.43 (59.51-69.65)	21.48 (19.84-23.22)
Defensive line	625 (14.6)	3936	63.52 (58.63-68.70)	15.88 (14.66-17.17)
Offensive line	632 (14.8)	4920	64.23 (59.32-69.44)	12.85 (11.86-13.89)
Quarterback	119 (2.8)	984	12.09 (10.02-14.47)	12.09 (10.02-14.47)
Kicker, punter	48 (1.1)	984	4.88 (3.60-6.47)	4.88 (3.60-6.47)
Total	4284 (100.0)	10,824 <sup>b</sup>	435.37 (422.43-448.60)	395.80 (384.0-407.8) <sup>b</sup>

<sup>a</sup>AAR, athletes at risk; TG, team games; TGP, team game positions.

<sup>b</sup>AAR and injuries per 1000 AAR.

receivers (IRR, 2.50; 95% CI, 1.68-3.67;  $P < .001$ ), tight ends (IRR, 2.45; 95% CI, 1.56-3.79;  $P < .001$ ), and defensive backs (IRR, 2.25; 95% CI, 1.69-2.96;  $P < .001$ ).

**DISCUSSION**

This study is the first to document the incidence of all-cause injury in the NFL during the regular season and has identified an all-cause injury incidence of 395.8 per 1000 AARs

over 2 seasons from 2012 to 2014. The rate of injuries in the NFL is higher than reported injury rates in other team-based contact sports such as professional rugby union (121.7 per 1000 AARs, calculated assuming 30 AARs per game<sup>8</sup>), rugby league (26.4 per 1000 AARs, calculated assuming 26 AARs per game<sup>19</sup>), and professional ice hockey (15.6 per 1000 AARs<sup>29</sup>) over similar time periods.

The incidence of concussion in the NFL identified in this study was 27.8 per 1000 AARs, which is higher than reported rates in professional rugby union (9.4 per 1000

TABLE 4  
Incidence of Concussion and Change in Concussion Rate From 2002-2007 to 2012-2014 by Position<sup>a</sup>

Position	n (%)	Concussions, 2012-2014		Concussions per 100 TGP or 1000 AAR (95% CI), 2002-2007 <sup>b</sup>	Change in Concussion Rate From 2002-2007 to 2012-2014	
		Per 100 TG (95% CI)	Per 100 TGP or 1000 AAR (95% CI)		Incidence Rate Ratio (95% CI)	P Value
Tight end	35 (11.6)	3.56 (2.48-4.95)	3.56 (2.48-4.95)	1.45 (1.10-1.86)	2.45 (1.56-3.79)	<.001
Wide receiver	45 (15.0)	4.57 (3.33-6.12)	2.29 (1.67-3.06)	0.91 (0.69-1.11)	2.50 (1.68-3.67)	<.001
Defensive back	82 (27.2)	8.33 (6.63-10.34)	2.08 (1.66-2.59)	0.93 (0.78-1.08)	2.25 (1.69-2.96)	<.001
Running back	33 (11.0)	3.35 (2.304-7.1)	1.68 (1.15-2.35)	0.86 (0.65-1.06)	1.94 (1.24-2.98)	.001
Quarterback	13 (4.3)	1.32 (0.70-2.26)	1.32 (0.70-2.26)	1.20 (0.84-1.52)	1.10 (0.55-2.06)	.37
Offensive line	43 (14.3)	4.37 (3.16-5.89)	0.87 (0.63-1.12)	0.28 (0.20-0.35)	3.11 (2.04-4.72)	<.001
Linebacker	24 (8.0)	2.44 (1.56-3.63)	0.81 (0.52-1.20)	0.61 (0.47-0.75)	1.33 (0.80-2.14)	.11
Defensive line	26 (8.6)	2.64 (1.73-3.87)	0.66 (0.43-0.98)	0.26 (0.18-0.46)	2.51 (1.48-4.19)	.003
Kicker, punter	0 (0.0)	0.00 (0.0-0.37)	0.0 (0.0-0.37)	0.30 (0.16-0.53)	0.0 (0.0-1.46)	.055
Total	301 (100.0)	30.58 (27.23-34.25)	27.80 (24.75-31.13) <sup>c</sup>	17.27 (16.06-18.54) <sup>c</sup>	1.61 (1.40-1.84)	<.001

<sup>a</sup>AAR, athletes at risk; TG, team games; TGP, team game positions.

<sup>b</sup>2002-2007 incidences were calculated from Casson et al.<sup>10</sup>

<sup>c</sup>Injuries per 1000 AAR.

AARs, estimated from “central/peripheral nervous system injuries” to the “head and neck” and assuming 30 AARs per game<sup>8</sup>), professional ice hockey (6.05 per 1000 AARs, calculated assuming 10 AARs per game<sup>23</sup>), and collegiate football (3.02 per 1000 AARs<sup>12</sup>). Furthermore, the incidence of concussion in the NFL during the 2012-2014 period has increased by 61% (IRR, 1.61) compared with 2002-2007, which is consistent with increasing rates of concussion observed at all levels of play.<sup>21,25</sup>

The high burden of all-cause injury and concussion in the NFL is of significant concern. To improve player safety, specifically with respect to concussions, the NFL has implemented educational campaigns and novel concussion policies (ie, sideline assessment tool, return-to-play protocol,<sup>32,33</sup> and the installation of independent neurologists and “spotters” at games).<sup>4</sup> These strategies to increase the recognition and awareness of concussion may be the impetus driving the observed increase in rate of concussion identified by this study, suggesting that the interventions adopted by the NFL may have been effective. However, we also recognize that NFL players are becoming bigger, stronger, and faster, imposing a theoretical risk to greater head impacts and subsequent increases in concussions.<sup>1</sup> The epidemiological design of this study limits our ability to definitively identify the etiology behind the observed increase in concussion incidence and we recognize it is likely the product of a multifactorial process. Nonetheless, the observed increased rate of concussion warrants further investigation.

The NFL has also adopted numerous rule and policy changes to reduce the incidence of concussions, including, but not limited to, (1) the penalization of players who target an opponent’s head or lead with the helmet when engaging in contact, (2) expanding the definition of defenseless players who require more protection, and (3) moving the spot of a kickoff to reduce frequency of high-impact collisions. The ability to evaluate the efficacy and outcome of these rule changes is beyond the scope of this study, and it would be

inappropriate to interpret the frequency of injuries as the sole metric of the efficacy of any rule or policy change. However, it has been suggested that these rule changes have had the unanticipated consequence of increasing lower extremity injuries secondary to players adjusting their tackling methods.<sup>3</sup> Furthermore, a non-peer-reviewed, media-provided survey of 293 NFL athletes reported that 46% of athletes were most concerned about leg injuries compared with 24% for which a head injury was the most concerning.<sup>6</sup>

We identified that lower extremity injuries, and specifically knee injuries, occurred most frequently, accounting for 62% and 18% of all injuries, respectively. Concussion and head injuries were the fifth most common injury and represent 7% of all injuries in the NFL. This distribution and pattern of injuries is similar to previously reported patterns in the NFL<sup>9,17</sup> and other sports such as soccer,<sup>14</sup> rugby,<sup>8</sup> ice hockey,<sup>39</sup> and collegiate football.<sup>22</sup> Reducing football-related brain injury is of paramount concern given the early evidence documenting an association between repetitive head trauma and long-term neuropsychological and degenerative sequelae, such as chronic traumatic encephalopathy.<sup>30</sup> We have documented the relative prevalence of injuries to each anatomical location and provided baseline data for incidence comparisons when evaluating future rule and policy changes.

We identified that all-cause injuries and concussions occurred most frequently in wide receivers, tight ends, and defensive backs and that there has been a significant increase in concussion incidence in all positions except quarterbacks, linebackers, and kickers. There is ongoing emphasis placed on prevention strategies aimed at reducing injuries to quarterbacks, which have been effective given the observed lack of change in the frequency of brain injuries in this position.<sup>5</sup> Further injury prevention strategies and policies should continue to aim at increasing safety for all positions and focus on the positions with the highest identified risk for concussion, such as wide receivers, tight ends, and defensive backs.

The reporting of injury incidence rates in epidemiological studies is variable, with no generally accepted reporting method.<sup>21,38</sup> Incidence reporting is particularly challenging in football as, unlike other sports (ie, rugby and soccer) where time-based injury incidence reporting is more readily applicable and accurate (ie, injuries per 1000 hours), football is played in short intervals with frequent personnel changes. As such, we have elected to report incidence rates as injuries per 100 TGs, injuries per 100 TGP, and injuries per 100 AARs (the number of athletes in play at any one time).<sup>18,26,38</sup> This approach provides a general consideration of the injury burden of a sport and can be calculated for any sport regardless of sport-specific differences in playing style. Furthermore, this method allows for the comparison of injury rates between sports. We recognize this method of injury reporting limits the interpretation of the risk of injury as it relates to an individual; however, this information can be determined after applying sport-specific characteristics to the analysis, as we have done with position-specific injury rates.

This study has several limitations. First, the source of data utilized for this study involved team-reported injury data. The potential for discrepancy in reporting practices between teams is large and teams have previously been investigated for improper reporting practices.<sup>2</sup> Furthermore, injury data, apart from concussions, were limited to anatomic location, and information regarding the diagnosis or injury severity was not available. In addition, the injury history of the athletes was not available and, therefore, identifying recurrent versus new injuries was not possible. The precise date of the injuries included in this study was not available, and the timing of the injuries was limited to the week in which the injury occurred. As such, to calculate incidence rates, we assumed all injuries occurred during games, as previous reports indicate that the majority of injuries in an NFL season occur during games compared with practices.<sup>9,27,28</sup>

## CONCLUSION

This study addressed the all-cause injury and concussion incidence in the NFL, and a significant injury burden among NFL athletes was identified. Moreover, concussion recognition and awareness is improving, as indicated by an increase in the incidence of concussion diagnoses. Furthermore, quarterback-specific injury prevention strategies appear to be effective, as indicated by stable rates of injury in this position. However, the observed injury burden of the sport as a whole, in addition to specific position groups, is still high, and continued efforts to reduce the prevalence of injury associated with football should be a priority to increase player safety at all levels of play.

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