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ORIGINAL RESEARCH

# Epidemiology of 10,000 High School Football Injuries: Patterns of Injury by Position Played

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***Background:*** With more than 1.1 million high school athletes playing annually during the 2005–06 to 2009–10 academic years, football is the most popular boys' sport in the United States. ***Methods:*** Using an internet-based data collection tool, RIO, certified athletic trainers (ATs) from 100 nationally representative US high schools reported athletic exposure and football injury data during the 2005–06 to 2009–10 academic years. ***Results:*** Participating ATs reported 10,100 football injuries corresponding to an estimated 2,739,187 football-related injuries nationally. The injury rate was 4.08 per 1000 athlete-exposures (AEs) overall. Offensive lineman collectively (center, offensive guard, offensive tackle) sustained 18.3% of all injuries. Running backs (16.3%) sustained more injuries than any other position followed by linebackers (14.9%) and wide receivers (11.9%). The leading mechanism of injury was player-player contact (64.0%) followed by player-surface contact (13.4%). More specifically, injury occurred most commonly when players were being tackled (24.4%) and tackling (21.8%). ***Conclusions:*** Patterns of football injuries vary by position. Identifying such differences is important to drive development of evidence-based, targeted injury prevention efforts.

***Keywords:*** surveillance, sports, concussion, knee

During the past decade, United States (US) high school sports participation has dramatically increased to more than 7.6 million athletes.[1] Football is the most popular boys' sport with more than 6.7 million participants in the US and 1.1 million high school participants during the 2009–10 academic year.[1,2] Injuries sustained by high school athletes, especially those playing football, are a deep-rooted public health concern with estimates indicating more than 1.4 million high school sports-related injuries occur each year.[4,24] Understanding the epidemiology of football injuries sustained by high school athletes can provide clinicians, coaches, certified athletic trainers (ATs), and parents with the evidence needed to make effective, targeted injury prevention efforts.

The current literature on football injuries, though extensive, is still limited. For example, many studies focused on injuries to specific body sites, specific injury diagnoses,[12,20,23] or specific populations which may not be generalizable to high school players.[10,11,23] Additionally, most studies have been conducted in restricted geographical areas, encompassing state or local level populations.[8,9,17,21] No group has completed a longitudinal study comparing patterns of football injuries by position in a large nationally representative sample of US high schools.

Our objective was to compare the epidemiology of football injuries by position during the 2005–06 to 2009–10 academic years using a large nationally representative sample of US high school athletes. Understanding the epidemiology of football injuries by position is an important first step in the development of targeted, evidence-based interventions to effectively reduce the incidence and severity of injury.

## Methods

### Data Collection

We used the National High School Sports-Related Injury Surveillance System, High School RIO (Reporting Information Online), an Internet-based sports injury surveillance system, to collect data. The methodology of this surveillance study has been reported previously.[4,18] In brief, high schools with 1 or more National Athletic Trainers' Association–affiliated certified athletic trainers (ATs) with a valid e-mail address are invited to participate. Willing participants are categorized into 8

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strata based on school population (enrollment ≤ 1000 or > 1000) and US Census geographic location.[3] From these 8 strata, 100 high schools are randomly selected to participate. If a high school drops out of the study, a replacement school from the same stratum is selected to maintain the 100-school study population. Certified athletic trainers from participating high schools log onto the High School RIO website weekly throughout the academic year to report injury incidence and athlete exposure (AE) for 9 sports: football, boys' and girls' soccer, girls' volleyball, boys' and girls' basketball, wrestling, baseball, and softball. This study analyzed all reported football injuries. For each injury event, the AT is instructed to report the most serious injury. If an athlete sustained multiple injuries in a single injury event, the AT reports only, what in their professional opinion, is the most serious injury.

### Definition of Injury and Exposure

An AE was 1 athlete participating in 1 practice or competition. Cases where injury occurred during "other training" (ie, weight training) were excluded (n = 151). A reportable injury 1) occurred as a result of participation in an organized practice or competition, 2) required medical attention by an AT or a physician, and 3) resulted in a restriction of the athlete's participation for ≥ 1 day or 4) resulted in any fracture, concussion, or dental injury regardless of whether it resulted in restriction of the student-athlete's participation. As the purpose of this study was to compare patterns of injury by position played, cases where a specific position was not recorded (ie, variable left blank, "unknown" selected by reporter) were also excluded (n = 394).

For each injury, the AT completed a detailed injury report on the injured athlete (age, height, weight), the injury (site, diagnosis, severity), and the injury event (activity, mechanism). Throughout the study, reporters were able to view previously submitted information and update reports as needed.

### Statistical Analysis

We analyzed data using SPSS software, version 19.0 (SPSS, Chicago, Illinois). Rates were calculated by dividing incidence by AE using raw case counts. Additional analyses used national estimates calculated by applying weights based on the inverse of the probability of a school's selection into the study, with the standard errors for comparisons adjusted for the High School RIO sampling plan using the SPSS Complex Samples module.

We calculated injury proportion ratios (IPRs) with *P* values and 95% confidence intervals (CIs). We considered CIs not including 1.00 and *P* values < .05 statistically significant. An IPR > 1.00 suggests a risk association, while an IPR < 1.00 suggests a protective association. We calculated IPR as follows:

$$\text{Injury proportion ratio} = \frac{\#\text{ quarterback contusions}/\text{total }\#\text{ quarterback injuries}}{\#\text{ other offensive position contusions}/\text{total }\#\text{ other offensive position injuries}}.$$

This study was approved by the Institutional Review Board at Nationwide Children's Hospital.

## Results

### Overall

Participating ATs reported 10,100 football injuries corresponding to an estimated 2,739,187 football-related injuries nationally. The injury rate was 4.08 per 1000 athlete-exposures (AEs) overall, with injuries more commonly occurring in competition (12.61) than practice (2.35; RR 5.37; 95% CI, 5.17–5.58; *P* < .001). Offensive lineman (center, offensive guard, offensive tackle) collectively sustained the most injuries (18.3% of all injuries) of all positions on the football team; however, the running back position had the highest percentage of injury for any 1 position (16.3%; Table 1). The 3 most common body sites injured were the knee (15.4%), ankle (13.3%), and head/face (12.9%; Table 2). Diagnoses most common to football players were strain/sprain (43.0%), contusion (15.0%), and concussion (12.5%; Figure 1). Surgery was required for 6.5% of injuries overall with defensive ends having the lowest proportion (5.0%) and tight ends having the largest proportion (8.7%). More than half (53.3%) of football injuries occurred during competition (Figure 2). Four of seven offensive positions had a greater proportion of injury occur during practice than competition. Most commonly, football players returned to play after 3–6 days (27.1%; Figure 3). The leading mechanism of injury (64.0% of all injuries) was player-player contact, while player-surface contact accounted for 13.4%, no contact accounted for 12.4%, and 10.2% were accounted for by other mechanisms. More specifically, being tackled (24.4%) and tackling (21.8%) accounted for a majority of the injuries (Table 3). Activities most commonly associated with injury overall were offensive running play (28.2%), defensive running play (22.8%), and offensive passing play (10.8%).

**Table 1 Incidence of Football Injury by Type of Exposure and Position, High School Sports-Related Injury Surveillance Study, United States, 2005–06 to 2009–10 Academic Years**

| | Competition | | Practice | | Total | |
|---|---|---|---|---|---|---|
| | n | % | n | % | n | % |
| Offense | 749,675 | 51.5% | 721,141 | 56.3% | 1,470,816 | 53.7% |
| Quarterback | 90,421 | 6.2% | 37,966 | 3.0% | 128,387 | 4.7% |
| Tight end | 34,683 | 2.4% | 36,495 | 2.9% | 71,178 | 2.6% |
| Offensive tackle | 102,903 | 7.1% | 120,385 | 9.4% | 223,289 | 8.2% |
| Offensive guard | 88,213 | 6.0% | 122,261 | 9.5% | 210,475 | 7.7% |
| Center | 35,904 | 2.5% | 29,494 | 2.3% | 65,399 | 2.4% |
| Running back | 256,664 | 17.6% | 190,779 | 14.9% | 447,442 | 16.3% |
| Wide receiver | 140,886 | 9.7% | 183,760 | 14.4% | 324,647 | 11.9% |
| Defense | 608,656 | 41.7% | 515,952 | 40.3% | 1,124,608 | 41.1% |
| Defensive end | 97,293 | 6.7% | 86,786 | 6.8% | 184,079 | 6.7% |
| Defensive tackle | 132,644 | 9.1% | 112,797 | 8.8% | 245,441 | 9.0% |
| Linebacker | 217,958 | 14.9% | 190,017 | 14.8% | 407,975 | 14.9% |
| Cornerback | 106,928 | 7.3% | 93,429 | 7.3% | 200,356 | 7.3% |
| Safety | 53,833 | 3.7% | 32,924 | 2.6% | 86,757 | 3.2% |
| Special teams | 100,424 | 6.8% | 43,339 | 3.4% | 143,763 | 5.2% |
| Kicker/punter | 16,355 | 1.1% | 11,272 | 0.9% | 27,627 | 1.0% |
| Special teams | 2,086 | 0.1% | 566 | 0.0% | 2,652 | 0.1% |
| Long snapper | 81,983 | 5.6% | 31,501 | 2.5% | 113,484 | 4.1% |
| Total* | 1,458,755 | 100% | 1,280,432 | 100% | 2,739,187 | 100% |

* Categories of offense, defense, and specials teams sum to total (n and %).

**Table 2 Most Commonly Injured Body Site by Football Position, High School Sports-Related Injury Surveillance Study, United States, 2005–06 to 2009–10 Academic Years**

| Position | 1st body site (%) | 2nd body site (%) | 3rd body site (%) |
|---|---|---|---|
| Offense | Knee (16.6%) | Ankle (15.2%) | Head/face (11.0%) |
| Quarterback | Shoulder (16.3%) | Head/face (12.0%) | Knee (11.6%) |
| Tight end | Knee (19.5%) | Head/face (16.5%) | Ankle (10.9%) |
| Offensive tackle | Knee (22.2%) | Ankle (11.6%) | Head/face (10.0%) |
| Offensive guard | Knee (21.6%) | Ankle (16.3%) | Head/face (9.7%) |
| Center | Knee (21.1%) | Ankle (19.8%) | Shoulder (10.8%) |
| Running back | Ankle (19.5%) | Knee (15.0%) | Head/face (11.5%) |
| Wide receiver | Ankle (12.9%) | Knee (12.1%) | Shoulder (11.0%) |
| Defense | Head/face (14.3%) | Knee (13.8%) | Shoulder (13.4%) |
| Defensive end | Knee (14.8%) | Head/face (14.3%) | Shoulder (12.9%) |
| Defensive tackle | Knee (19.1%) | Shoulder (13.5%) | Head/face (12.7%) |
| Linebacker | Head/face (13.6%) | Shoulder (13.3%) | Knee (13.2%) |
| Cornerback | Head/face (16.4%) | Shoulder (15.0%) | Hand (10.6%) |
| Safety | Head/face (17.4%) | Ankle (11.2%) | Hand (10.9%) |
| Special teams | Head/face (22.3%) | Knee (15.7%) | Hand (8.2%) |
| Kicker/punter | Thigh/upper leg (21.0%) | Knee (18.4%) | Ankle (13.4%) |
| Special teams | Head/face (25.2%) | Knee (15.1%) | Shoulder (7.6%), Hand (7.6%) |
| Long snapper | Hand (21.9%) | Head/face (27.9%) | Wrist (19.9%) |
| Overall | Knee (15.4%) | Ankle (13.3%) | Head/face (12.9%) |

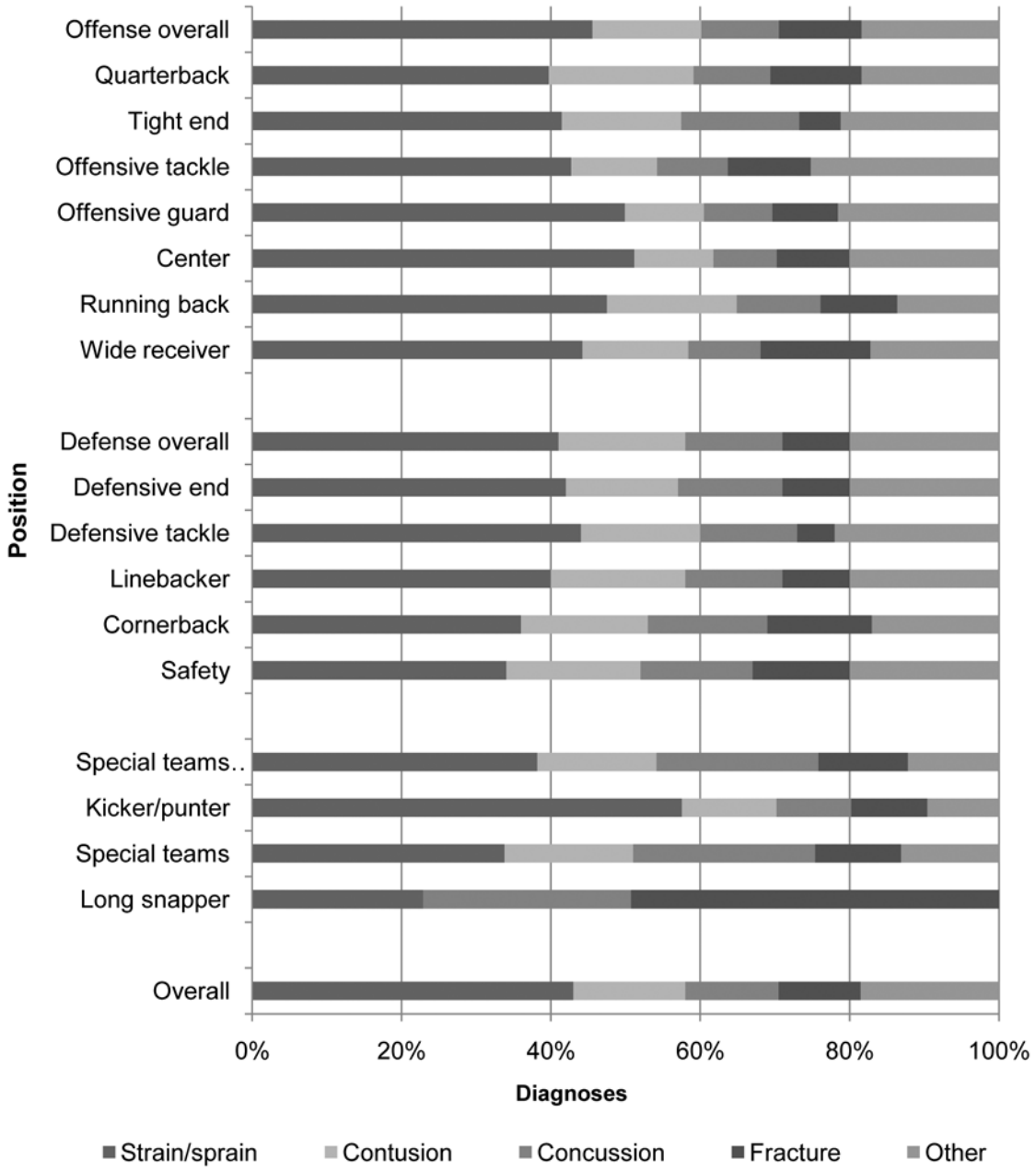


**Figure 1** — Injury diagnoses by football position, High School Sports-Related Injury Surveillance Study, United States, 2005–06 to 2009–10 academic years.

## Offense, Defense, Special Teams

The most common body site injured among offensive positions was the knee (16.6%), while injury to the head/face was most common to defense and special teams (14.3% and 22.3%, respectively; Table 2). Diagnosis most common to all 3 was strain/sprain—offense (45.5%), defense (40.3%), and special teams (38.1%) (Figure 1). Proportions of injury requiring surgery were greatest among special teams (7.6%) and the same among offense and defense (6.4% each). The proportion of injuries sustained during competition and practice were similar for offense and defense; 69.9% of special teams' player injuries occurred during competition (Table 1). All 3 commonly returned to play after 3–6 days—offense (27.3%), defense (27.2%), and specials teams (24.5%). The greatest proportion of injury was sustained by linebackers on defense (14.9%), running backs on offense (16.3%), and long snappers on special teams (4.1%; Table 1).

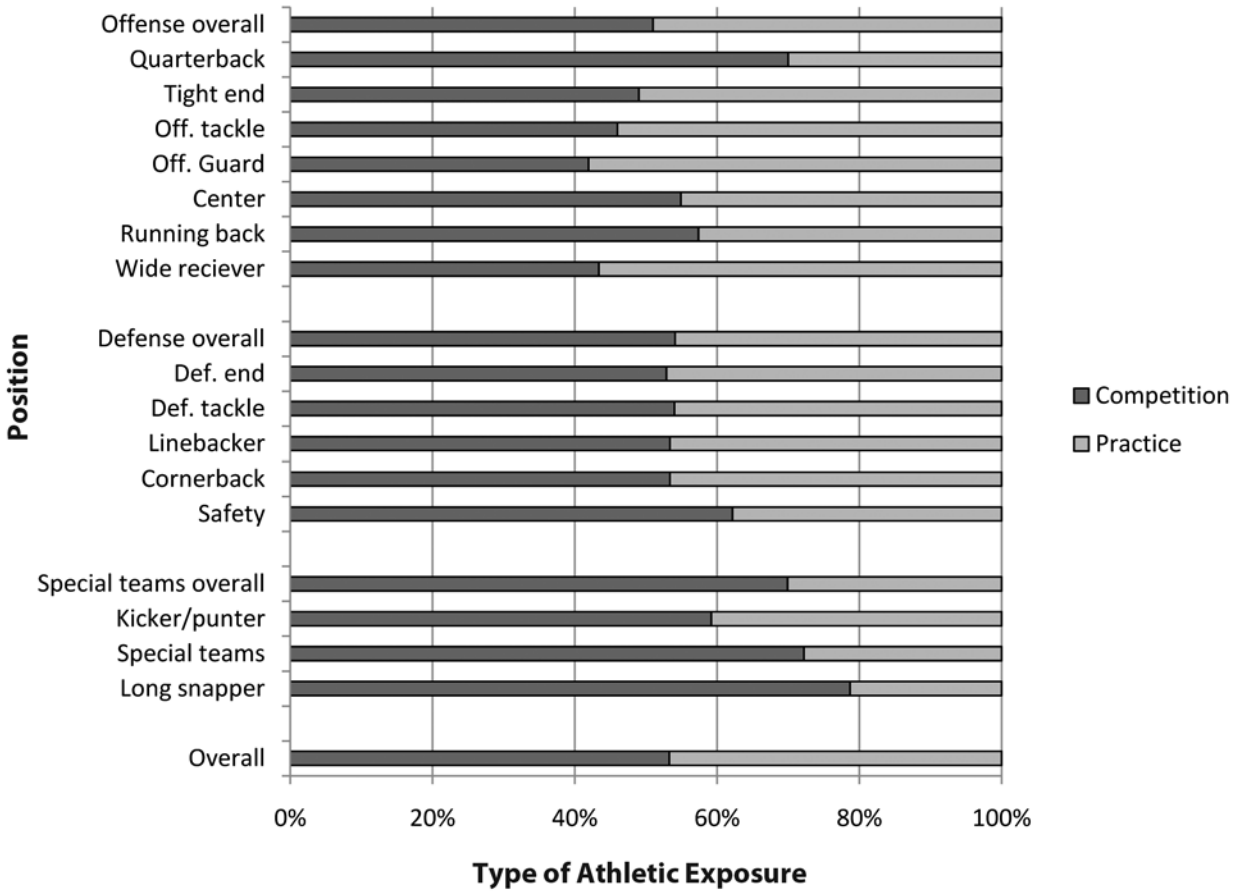


**Figure 2** — Type of exposure during which injury occurred by football position, High School Sports-Related Injury Surveillance Study, United States; 2005–06 to 2009–10 academic years.

## Quarterback

The most common body sites injured among quarterbacks were the shoulder (16.3%), head/face (12.0%), and knee (11.6%; Table 2). Quarterbacks more commonly sustained contusions (19.4%) compared with other offensive positions (14.2%; IPR 1.37; 95% CI, 1.08–1.74; $P$ = .01; Figure 1). Quarterbacks more commonly sustained injury during competition (70.4%) compared with other offensive positions (49.1%; IPR 1.43; 95% CI, 1.32–1.56; $P$ < .001). Quarterbacks sustained a greater proportion of injuries resulting in medical disqualification for the season (10.1%) compared with other offensive positions (6.7%; IPR 1.51; 95% CI, 1.06–2.14; $P$ = .03; Figure 3). Quarterbacks more commonly sustained injury during an offensive passing play (35.3%) compared with other offensive positions (18.1%; IPR 1.95; 95% CI, 1.66–2.30; $P$ < .001). More specifically, quarterbacks more commonly sustained injury by being tackled (70.5%) compared with other offensive positions (36.0%; IPR 1.97; 95% CI, 1.81–2.14; $P$ < .001; Table 3).

## Tight End

The most common body sites injured among tight ends were the knee (19.5%), head/face (16.5%), and ankle (10.9%; Table 2). Tight ends more commonly sustained injury to the head/face (16.5%) compared with other offensive positions (10.7%; IPR 1.55; 95% CI, 1.11–2.16; $P$ = .01; Table 2) and concussions (15.8%) compared with other offensive positions (10.1%; IPR 1.57; 95% CI, 1.11–2.22; $P$ = .01; Figure 1). Tight ends sustained the greatest proportion of injuries requiring surgery (8.7%) among offensive positions. Activities most commonly associated with injury were offensive running play (37.9%) and passing play (31.3%), and more specifically being tackled (34.1%), blocking (21.7%), and overuse/heat illness/conditioning (8.8%; Table 3).

## Offensive Tackle

The most common body sites injured among offensive tackles were the knee (22.2%), ankle (11.6%), and head/face (10.0%; Table 2). Although not quite statistically significant, offensive tackles more commonly sustained overuse/heat illness injuries (11.0%) compared with all other offensive positions (8.3%; IPR 1.33; 95% CI, 0.997–1.776; $P$ = .054). Overuse/heat illness injuries among offensive tackles primarily occurred during practice (87.0%). Activity most commonly associated with offensive tackles injuries were blocking (48.7%), overuse/heat illness (11.0%), and tackling

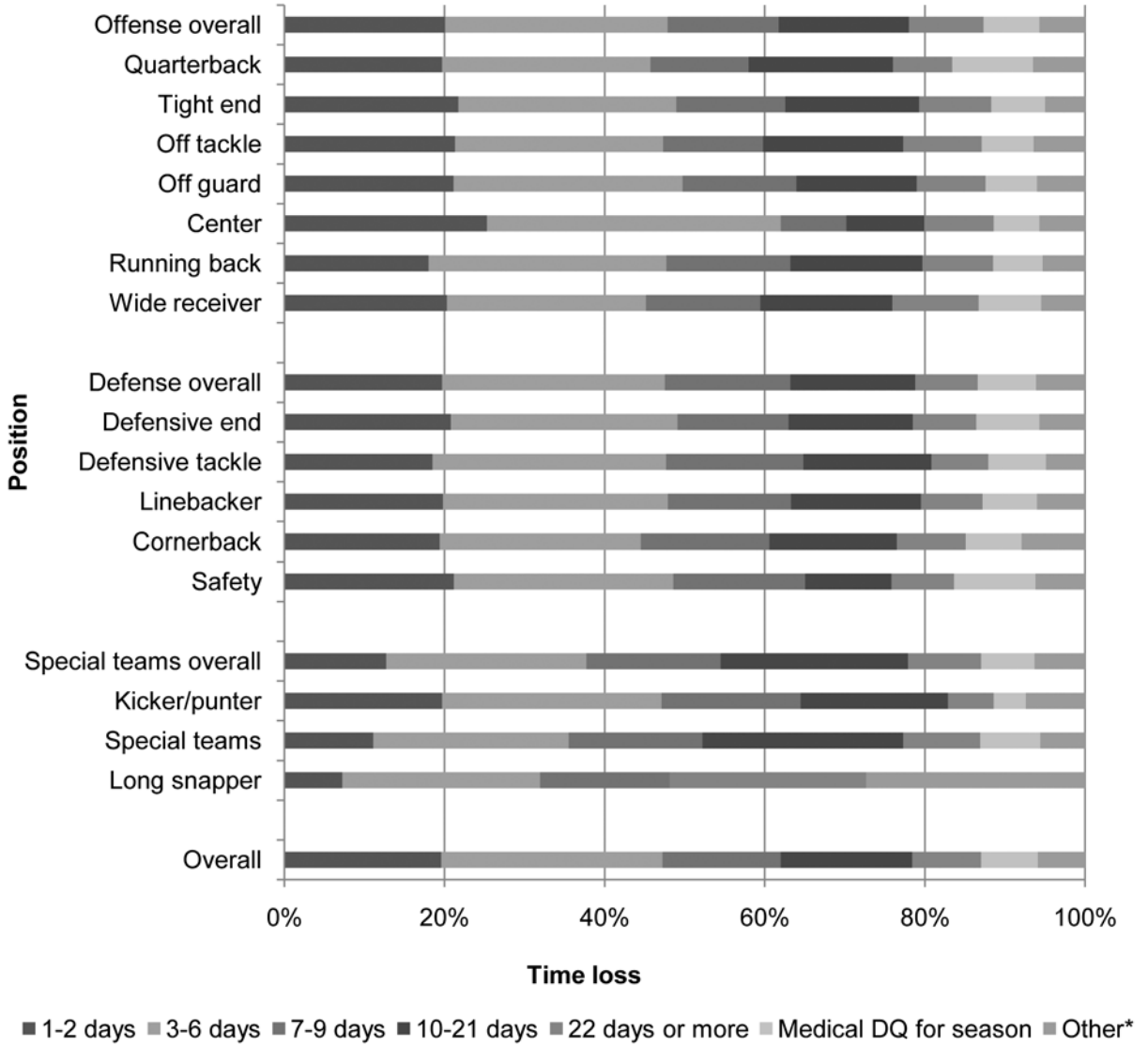


**Figure 3** — Injury time loss by football position, High School Sports-Related Injury Surveillance Study, United States, 2005–06 to 2009–10 academic years. * 'Other' time loss category comprised of < 1 day, medical disqualification for career, athlete chose not to continue, athlete released from team, and season ended before athlete could return. Overall the 'other' category was less than 6.0% of injuries.

(9.0%; Table 3). Offensive tackles more commonly sustained injury during general play (14.6%) compared with other offensive positions (8.8%; IPR 1.68; 95% CI, 1.33–2.13; $P < .001$) and blocking drills (11.7%) compared with other offensive positions (3.0%; IPR 3.91; 95% CI, 2.92–5.24; $P < .001$).

## Offensive Guard

The most common body sites injured among offensive guards were the knee (21.6%), ankle (16.3%), and head/face (9.7%; Table 2). Offensive guards most commonly sustained strain/sprains (50.0%). Activities most commonly associated with injury were offensive running play (48.2%), general play (13.1%), and blocking drill (10.5%); more specifically blocking (51.4%), overuse/heat illness/etc. (9.6%), and tackling (7.0%; Table 3).

## Center

The most common body sites injured among centers were the knee (21.1%), ankle (19.8%), and shoulder (10.8%; Table 2). Centers most commonly sustained strain/sprains (52.0%). Centers most commonly returned to play in 3–6 days (36.7%) compared with other offensive positions (27.4%; IPR 1.34; 95% CI, 1.08–1.66; $P = .01$; Figure 3). Activities most commonly associated with injury were offensive running play (61.9%), general play (8.5%),

**Table 3 Most Common Activity Associated With Injury by Football Position, High School Sports-Related Injury Surveillance Study, United States, 2005–06 to 2009–10 Academic Years**

| Position | 1st activity (%) | 2nd activity (%) | 3rd activity (%) |
|---|---|---|---|
| Offense | Being tackled (38.8%) | Blocking (22.0%) | Stepped on/fell on/kicked (5.8%) |
| Quarterback | Being tackled (70.5%) | Overuse/heat illness/etc. (6.8%) | Stepped on/fell on/kicked (4.7%) |
| Tight end | Being tackled (34.1%) | Blocking (21.7%) | Overuse/heat illness/etc. (8.8%) |
| Offensive tackle | Blocking (48.7%) | Overuse/heat illness/etc. (11.0%) | Tackling (9.0%) |
| Offensive guard | Blocking (51.4%) | Overuse/heat illness/etc. (9.6%) | Tackling (7.0%) |
| Center | Blocking (55.6%) | Stepped on/fell on/kicked (9.3%) | Tackling (8.0%) |
| Running back | Being tackled (66.9%) | Overuse/heat illness/etc. (7.1%) | Blocking (4.9%) |
| Wide receiver | Being tackled (40.8%) | Overuse/heat illness/etc. (9.7%) | Blocking (9.6%) |
| Defense | Tackling (44.3%) | Being blocked (18.9%) | Stepped on/fell on/kicked (7.1%) |
| Defensive end | Tackling (38.3%) | Being blocked (21.9%) | Blocking (9.1%) |
| Defensive tackle | Tackling (34.1%) | Being blocked (29.4%) | Blocking (9.7%) |
| Linebacker | Tackling (47.9%) | Being blocked (15.6%) | Stepped on/fell on/kicked (7.5%) |
| Cornerback | Tackling (52.1%) | Being blocked (13.6%) | Stepped on/fell on/kicked (8.3%) |
| Safety | Tackling (51.3%) | Being blocked (9.9%) | Rotation around a planted foot (8.0%) |
| Special teams | Being tackled (22.1%) | Being blocked (20.9%) | Tackling (18.0%) |
| Kicker/punter | Being tackled (21.0%) | Contact with ball (18.0%) | Stepped on/fell on/kicked (11.9%) |
| Special teams | Being blocked (24.3%) | Being tackled (22.9%) | Tackling (19.5%) |
| Long snapper | Blocking (22.6%) | Tackling (20.6%) | Stepped on/fell on/kicked (19.9%) |
| Overall | Being tackled (24.4%) | Tackling (21.8%) | Blocking (14.6%) |

and offensive passing play (6.2%); more specifically blocking (55.6%), stepped on/fell on/kicked (9.3%), and tackling (8.0%; Table 3). Centers more commonly sustained injury due to blocking (55.6%) compared with other offensive positions (20.6%; IPR 2.73; 95% CI, 2.34–3.17; $P < .001$).

## Running Back

The most common body sites injured among running backs were the ankle (19.5%), knee (15.0%), and head/face (11.5%; Table 2). Activities most commonly associated with injury were offensive running play (76.9%), general play (5.9%), and offensive passing play (4.8%); more specifically being tackled (66.9%), overuse/heat illness/etc. (7.1%), and blocking (4.9%; Table 3). Running backs more commonly sustained injury during an offensive running play (76.9%) compared with other offensive positions (40.1%; IPR 1.93; 95% CI, 1.82–2.05; $P < .001$).

## Wide Receiver

The most common body sites injured among wide receivers were the ankle (12.9%), knee (12.1%), and shoulder (11.0%; Table 2). Activities most commonly associated with injury were offensive passing play (51.7%), running play (19.5%), and general play (10.9%); more specifically being tackled (40.8%), overuse/heat illness/conditioning (9.7%), and blocking (9.6%; Table 3).

## Defensive End

The most common body sites injured among defensive ends were the knee (14.8%), head/face (14.3%), and shoulder (12.9%; Table 2). Activities most commonly associated with injury were defensive running play (57.1%), passing play (12.0%), and general play (8.5%); more specifically tackling (38.3%), being blocked (21.9%), and blocking (9.1%; Table 3).

## Defensive Tackle

The most common body sites injured among defensive tackles were the knee (19.1%), shoulder (13.5%), and head/face (12.7%; Table 2). Defensive tackles more commonly sustained strain/sprains (44.9%) compared with other defensive positions (39.0%; IPR 1.15; 95% CI, 1.04–1.27; $P < .01$) and knee injuries (19.1%) compared with other defensive positions (12.4%; IPR 1.54; 95% CI, 1.27–1.87; $P < .001$). Activities most commonly associated with injury were defensive running play (60.4%), passing play (8.3%), and tackling drill (8.2%); more specifically injuries resulted from tackling

(34.1%), being blocked (29.4%), and blocking (9.7%; Table 3). Defensive tackles more commonly sustained injury during a defensive running play (60.4%) compared with other defensive positions (51.0%; IPR 1.19; 95% CI, 1.10–1.28; $P < .001$). Defensive tackles more commonly sustained injury by being blocked (29.6%) compared with other defensive positions (16.0%; IPR 1.85; 95% CI, 1.59–2.17; $P < .001$).

### Linebacker

The most common body sites injured among linebackers were the head/face (13.6%), shoulder (13.3%), and knee (13.2%; Table 2). Linebackers more commonly sustained contusions (17.2%) compared with other defensive positions (14.3%; IPR 1.20; 95% CI, 1.00–1.43; $P = .046$). Linebackers sustained the greatest proportion of injuries requiring surgery (7.1%) among defensive positions. Activities most commonly associated with injury were defensive running play (55.6%), general play (11.3%), and defensive passing play (8.5%); more specifically, injuries were a result of tackling (47.9%), being blocked (15.6%), and stepped on/fell on/kicked (7.5%; Table 3). Linebackers more commonly sustained injury during general play (11.3%) compared with other defensive positions (8.0%; IPR 1.43; 95% CI, 1.16–1.77; $P = .001$).

### Cornerback

The most common body sites injured among cornerbacks were the head/face (16.4%), shoulder (15.0%), and hand (10.6%; Table 2). Cornerbacks more commonly sustained fractures (14.5%) compared with other defensive positions (9.6%; IPR 1.50; 95% CI, 1.18–1.92; $P = .001$). Activities most commonly associated with injury were defensive running play (38.4%), passing play (33.1%), and general play (8.6%); more specifically tackling (52.1%), being blocked (13.6%), and stepped on/fell on/kicked (8.3%; Table 3). Cornerbacks more commonly sustained injury by tackling (52.1%) compared with other defensive positions (42.8%; IPR 1.22; 95% CI, 1.11–1.35; $P < .001$).

### Safety

The most common body sites injured among safeties were the head/face (17.4%), ankle (11.2%), and hand (10.9%; Table 2). Safeties more commonly sustained injury during competition (62.1%) compared with other defensive positions (53.5%; IPR 1.16; 95% CI, 1.05–1.29; $P = .01$; Figure 2). Activities most commonly associated with injury were defensive running play (42.8%), passing play (36.0%), and general play (5.8%); more specifically, injuries were a result of tackling (51.3%), being blocked (9.9%), and rotation around a planted foot (8.0%; Table 3). Safeties more commonly sustained injury during a defensive passing play (36.0%) compared with other defensive positions (13.9%; IPR 2.59; 95% CI, 2.14–3.14; $P < .001$).

### Kicker/Punter

The most common body sites injured among kickers/punters were the thigh/upper leg (21.0%), knee (18.4%), and ankle (13.4%; Table 2). Kickers/punters more commonly sustained thigh/upper leg injuries (21.0%) compared with other special teams positions (4.3%; IPR 4.92; 95% CI, 2.55–9.48; $P < .001$) and ankle injuries (13.4%) compared with other special teams positions (6.8%; IPR 1.98; 95% CI, 0.95–4.14; $P = .07$) although the latter was not quite statistically significant. Activities most commonly associated with injury were kicking (47.7%), punt coverage (14.9%), and kickoff coverage (11.2%); more specifically being tackling (21.0%), contact with the ball (18.0%), and stepped on/fell on/kicked (11.9%; Table 3).

### Special Teams

The most common body sites injured among special teams were the head/face (25.2%), knee (15.1%), shoulder (7.6%), and hand (7.6%; Table 2). Special teams players more commonly sustained head/face injuries (25.2%) compared with kickers/punters and long snappers (11.8%; IPR 2.14; 95% CI, 1.05–4.37; $P = .02$). Activities most commonly associated with injury were kickoff coverage (38.1%), kickoff return (25.3%), and punt return (11.5%); more specifically being blocked (24.3%), being tackled (22.9%), and tackling (19.5%; Table 3).

### Long Snapper

The most common body sites injured among long snappers were the hand (21.9%), head/face (27.9%), and wrist (19.9%; Table 2). Long snappers more commonly sustained hand injuries (31.9%) compared with other special teams positions (7.8%; IPR 4.09; 95% CI, 1.37–12.16; $P = .02$). Activities most commonly associated with injury were punt coverage (40.0%), PAT/FG attempt (32.9%), and long snapping drill (16.4%); more specifically blocking (22.6%), tackling (20.6%), and stepped on/fell on/kicked (19.9%; Table 3).

## Discussion

This study, the first comprehensive examination of 10,000 football injuries by position, found an estimated 2,739,187 football-related injuries occurred among US high school student-athletes nationwide during the 2005–06 to 2009–10 academic years. With more than 1.1 million athletes competing in high school football,[1] understanding position-specific injury patterns is important in assisting coaches, ATs, physicians, and policy makers to develop effective targeted preventative interventions.

As demonstrated here, football is not a sport where injury can be assessed based on offense, defense and special teams. Injury patterns are position specific and therefore need specialized analysis. For example, centers

and long snappers are virtually the same position in different phases of play; however, they sustain very different types of injuries. Centers commonly sustain knee, ankle, and shoulder injuries while long snappers sustain hand, head/face, and wrist injuries. Coaches and ATs should recognize such position-specific differences and implement strengthening, conditioning, and training programs not just by offense and defense but also by position.

Consistent with prior studies, we found the anatomic sites most commonly injured overall were the knee and ankle.[5,9,22] Further, we found that the most common diagnosis was strains/sprains. Injury prevention is particularly important for running backs, who were found to be more likely than any other position to sustain an ankle injury as well as defensive tackles, who were significantly more likely to sustain strain/sprains compared with other defensive positions. Potential methods for injury prevention could include conditioning, stretching, and taping/bracing; however, these preventive methods require future research.

Heat illness is the leading cause of death and disability among U.S. high school athletes.[14] This study's findings show heat illness among the top 3 sport-specific mechanisms in which offensive positions sustain injury. This could be due in part to practice repetitions during the hottest, most humid summer months as well as player size and extensive padding. All heat illnesses in high school athletes are 100% preventable. Implementation of acclimatization periods is a primary component of prevention. Current NATA recommendations suggest implementation of a 14-day acclimatization period for all warm weather conditioning, with practice frequency, duration, and intensity as well as protective equipment usage increased gradually.[6,7,25] Another primary prevention strategy is educating participants about the signs and symptoms of heat-related illness and the importance of proper hydration before, during, and after strenuous activity.[6] Fluid replacement should approximate sweat and urine losses so that athletes lose no more than 2% body weight per day.[7] It is important for athletes and coaches to educate themselves in order to recognize, prevent and effectively respond to heat illness.

With concussions being the third most common diagnosis among high school age football players and 64.3% of concussions sustained as a result of tackling or being tackled, future research is needed on the football helmet (ie, weapon versus protection, proper fitting) and tackling mechanics, especially among offensive tight ends. Increased size, strength and speed among young athletes may be contributing factors to an increased incidence of concussions. In addition, advances in helmet technology, marketed to increase protection and performance, may also be delivering a false sense of security. Athletes are constantly looking for "better" equipment that will improve their performance and sporting goods companies feed that desire with a never ending line of "new" and/or "better performing" equipment. However, during this study period there were no substantive rule changes regarding allowable safety equipment in high school football (ie, the NFHS made no rule changes regarding safety equipment that would have had any noticeable impact on injury rates or patterns). A reluctance to report concussions was previously noted in high school football players,[13] when only 47.3% of those sustaining concussions reported their injury. Coaches, ATs, and parents must emphasize the need to report injuries and the risks of returning to play before full recovery. In addition, research is needed to understand players' compliance with and referees' enforcement of rules (ie, no helmet to helmet contact). Furthermore, coaches should constantly reiterate tackling mechanics (ie, never use a helmet as a point of contact when making a tackle; proper body position: back straight, head up, shoulders square) and perform helmet fitting checks to keep players safe.

Running plays were identified as a particular risk factor of concern among high school football players. Running plays were the leading cause of injury, with running backs (24.6%) and linebackers (17.1%) being the positions most commonly injured, both during running plays and overall. Running plays also accounted for the majority of concussions. In running plays, there is a high degree of proximity between players, increasing the risk of injury through both intentional and inadvertent collisions.[19] High school players may be at greater risk of injury from running plays because high school teams tend to run more and pass less than other levels. Providing improved instruction on the safest ways to tackle and block, as well as how to fall when being tackled, may help reduce the risk of injury during running plays.[19]

Like all research, this study had limitations. Eligibility was limited to high schools with NATA-affiliated ATs. Thus, although schools were selected to be nationally representative with respect to geographic location and school size, our findings may not be generalizable to schools without ATs. However, the increased quality of data provided by these medically-trained reporters justified this inclusion criterion. In addition, only those injuries in which football position was reported were included in the study. Therefore, our study undoubtedly underestimates the true incidence of injury. We believe the significance of the data outweigh the potential limitations, as this study presents the largest, most comprehensive epidemiologic investigation of high school football injuries by position to date.

High school football injury patterns vary by position. Identifying such differences is the important first step in the development of evidence-based, targeted injury prevention efforts. Given our findings, we support prior recommendations that could reduce injury patterns via primary prevention (ie, heat acclimatization, position specific conditioning, improved instruction on tackling and blocking). Coaches should teach student-athletes football position-specific techniques to prevent, or lessen the severity of injuries. Coaches can be educated to better supervise players to reduce the number of avoidable football injuries.[16] Rule books should be clearly written and readily available so all parties are knowledgeable about rules and policies.[11,15,16] When athlete collisions cannot

be prevented such as during running plays, secondary prevention efforts should be used to reduce the severity of player–player contact injuries (ie, strengthening commonly injured body sites, developing bracing/protective equipment for commonly injured body sites, emphasis on proper tackling and blocking). Future research should continue to evaluate preventative interventions, such as concussion injury prevention, acclimatization programs, tackling mechanics workshops, to determine ways to maximize their implementation and effectiveness. Continued surveillance of nationally representative samples of US high school football players is needed to monitor injury incidence and patterns over time.

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