

## Original Investigation

# Incidence of Concussion During Practice and Games in Youth, High School, and Collegiate American Football Players

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**IMPORTANCE** A report by the Institute of Medicine called for comprehensive nationwide concussion incidence data across the spectrum of athletes aged 5 to 23 years.

**OBJECTIVE** To describe the incidence of concussion in athletes participating in youth, high school, and collegiate American football.

**DESIGN, SETTING, AND PARTICIPANTS** Data were collected by athletic trainers at youth, high school, and collegiate football practices and games to create multiple prospective observational cohorts during the 2012 and 2013 football seasons. Data were collected from July 1, 2012, through January 31, 2013, for the 2012 season and from July 1, 2013, through January 31, 2014, for the 2013 season. The Youth Football Surveillance System included 118 youth football teams, providing 4092 athlete-seasons. The National Athletic Treatment, Injury and Outcomes Network program included 96 secondary school football programs, providing 11 957 athlete-seasons. The National Collegiate Athletic Association Injury Surveillance Program included 24 member institutions, providing 4305 athlete-seasons.

**EXPOSURES** All injuries regardless of severity, including concussions, and athlete exposure information were documented by athletic trainers during practices and games.

**MAIN OUTCOMES AND MEASURES** Injury rates, injury rate ratios, risks, risk ratios, and 95% CIs were calculated.

**RESULTS** Concussions comprised 9.6%, 4.0%, and 8.0% of all injuries reported in the Youth Football Surveillance System; National Athletic Treatment, Injury and Outcomes Network; and National Collegiate Athletic Association Injury Surveillance Program, respectively. The game concussion rate was higher than the practice concussion rate across all 3 competitive levels. The game concussion rate for college athletes (3.74 per 1000 athlete exposures) was higher than those for high school athletes (injury rate ratio, 1.86; 95% CI, 1.50-2.31) and youth athletes (injury rate ratio, 1.57; 95% CI, 1.17-2.10). The practice concussion rate in college (0.53 per 1000 athlete exposures) was lower than that in high school (injury rate ratio, 0.80; 95% CI, 0.67-0.96). Youth football had the lowest 1-season concussion risks in 2012 (3.53%) and 2013 (3.13%). The 1-season concussion risk was highest in high school (9.98%) and college (5.54%) in 2012.

**CONCLUSIONS AND RELEVANCE** Football practices were a major source of concussion at all 3 levels of competition. Concussions during practice might be mitigated and should prompt an evaluation of technique and head impact exposure. Although it is more difficult to change the intensity or conditions of a game, many strategies can be used during practice to limit player-to-player contact and other potentially injurious behaviors.

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Approximately 44 million boys and girls in the United States participate in organized youth sports programs.<sup>1</sup> Football is one of most popular youth sports in the United States, with approximately 3 million youth athletes, 1.1 million high school athletes, and 100 000 college athletes participating in tackle football annually.<sup>1-3</sup> Participation in sports provides youth the opportunity for regular physical activity and is associated with many physical, psychological, social, and academic benefits.<sup>4</sup>

Despite these benefits, there is increasing attention on the safety of youth sports, particularly contact sports (eg, American football, soccer, ice hockey, or lacrosse). Sports-related concussions at all levels of sports are a growing public health concern. The Centers for Disease Control and Prevention estimates that 1.6 million to 3.8 million concussions occur in sports and recreational activities annually.<sup>5</sup> However, these figures likely underestimate total concussion burden, as many individuals who sustain concussions may not seek medical advice.<sup>5</sup>

A report on concussion by the Institute of Medicine highlighted the need for more extensive incidence data in athletes aged 5 to 23 years.<sup>6</sup> To date, there has not been a systematic observational study of injuries in football players spanning the entire spectrum of youth and adolescence.<sup>6</sup> Furthermore, despite the popularity of youth leagues, there is limited research related to injuries in football players,<sup>7-11</sup> the majority of which used emergency department data. However, emergency department-based studies have insufficient data related to competitive level of play (eg, youth league, high school, or college) or organization (eg, school based, recreational league, or “sandlot” or backyard football).

The purpose of this study was to describe the epidemiology of concussion in football players aged 5 to 23 years. Using 3 samples of football players from the youth, high school, and college levels, we estimated the rates and risk of concussion in the 2012 and 2013 seasons and compared rates and risks among the 3 levels of competition. Data were collected from July 1, 2012, through January 31, 2013, for the 2012 season and from July 1, 2013, through January 31, 2014, for the 2013 season. We hypothesized that the rate and risk of concussion would increase incrementally with level of competition, largely owing to increased intensity of practice and competition.

At a Glance

- The study provided data on 4092 athlete-seasons for youth football, 11 957 athlete-seasons for high school football, and 4305 athlete-seasons for college football.
- Concussions comprised 9.6%, 4.0%, and 8.0% of all injuries reported in the youth, high school, and college football groups, respectively.
- The game concussion rate was higher than the practice concussion rate across all 3 competitive levels.
- The game concussion rate in college athletes (3.74 per 1000 athlete exposures) was higher than that in high school athletes (injury rate ratio, 1.86) and youth athletes (injury rate ratio, 1.57).
- Concussions during practice might be mitigated and should prompt an evaluation of technique and head impact exposure.

Methods

Design

This observational cohort uses data that were collected as part of 3 larger injury surveillance programs: the Youth Football Safety Study (YFSS); the National Athletic Treatment, Injury and Outcomes Network (NATION); and the National Collegiate Athletic Association (NCAA) Injury Surveillance Program. The YFSS includes 5- to 14-year-old football players, NATION includes 27 sports from secondary schools,<sup>12</sup> and the NCAA Injury Surveillance Program has been ongoing since 1986 and includes 25 sports from each of the 3 NCAA competitive divisions.<sup>13</sup> All 3 programs use the same technology, methods, and common data elements, with slight variations accommodating for setting and level of competition.<sup>13</sup> Operational definitions for these 3 surveillance systems are provided in Table 1.

The YFSS and NATION were designed and implemented by the Datalys Center for Sports Injury Research and Prevention. The YFSS included more than 3000 individual athletes from 6 states, 13 youth football leagues, and 118 teams, providing 214 team-seasons and 4092 athlete-seasons. The NATION program included 96 secondary school football programs, providing 159 team-seasons and 11 957 athlete-

Table 1. Operational Definitions

Term	Definition
Injury	Defined as occurring as a result of participation in an organized practice or game and requiring attention from an athletic trainer or physician.
Concussion	Defined locally by the institution or state guidelines in the communities where the athletic trainers were located. In lieu of state or local guidance, athletic trainers were encouraged to follow the definition provided by the Consensus Statement on Concussion in Sport. <sup>14</sup>
Athlete exposure	One player participating in one game or one practice.
Team-season	One youth team, high school team, or college team participating in one season.
Athlete-season	One player participating in one season. Players may have participated in more than one season but are counted separately each season. The term is used as the denominator to calculate athletes at risk or the prevalence.
Risk (incidence proportion)	The proportion of athletes injured. Risk is calculated as the sum of injured athletes (numerator) who sustained at least one injury during the season divided by the sum of athlete-seasons (denominator) or the number of athletes who began the football season. The risk does not count multiple concussions sustained by the same player. Risk is often expressed as a percentage.
Rate	An estimate of the incidence that includes player-time of exposure. The injury (concussion) rate is calculated as the sum of all concussions (numerator) divided by the sum of athlete exposures. Injury rates are expressed per 1000 athlete exposures.

seasons. The NCAA Injury Surveillance Program included 24 member institutions, providing 41 team-seasons and 4305 athlete-seasons.

### Instruments

Deidentified injury and exposure information was reported by athletic trainers using an export application that extracts common data elements identically coded from several different injury documentation applications.<sup>13</sup> Each injury documentation application captures information about the type of injury, severity, mechanism, session type, and other factors. These frequencies are then aggregated into a single research database. To be included, an injury documentation application had to undergo a certification process by which known values had to be correctly exported into a test database. The applications certified to participate include the Athletic Trainer System (Kefter Development), Injury Surveillance Tool (Datalys Center), and the Sports Injury Monitoring System (FlanTech). Each application has its own proprietary data structure, but when injury data are exported from any system to the research database, they are coded the same. This approach allows athletic trainers to document injuries as part of their normal clinical practice, thus eliminating the need to enter data more than once.<sup>13</sup> The YFSS is limited to the Datalys Center Injury Surveillance Tool.

### Protocol

At all 3 levels of competition, athletic trainers attended each practice and game during the 2012 and 2013 seasons and reported injuries (including concussions) and athlete exposures (AEs; 1 player participating in 1 game or practice) via their preferred injury documentation application. Data were reviewed through both automated and manual quality control processes prior to inclusion in the research database.<sup>13</sup> Deidentified data were exported to the research database daily.

### Main Outcome Measure

All athletes with concussions were assessed by athletic trainers and/or physicians. At the youth level, all players with concussions were required to have physician clearance to return to participation following the concussion. At the high school level, *concussion* was defined locally by the institution or state guidelines in the communities where the athletic trainers were located. In lieu of state or local guidance, athletic trainers were encouraged to follow the definition provided by the Consensus Statement on Concussion in Sport.<sup>14</sup> At the collegiate level, NCAA legislation passed in 2010 requires approval from a physician and/or physician designee before a student athlete may return to play.<sup>15</sup>

The YFSS and NATION protocols were reviewed and approved by Western Institutional Review Board (Puyallup, WA), and the NCAA Injury Surveillance Program protocol was reviewed and approved by the NCAA Research Review Board (Indianapolis, IN). Because of the de-identified nature of the data collected, the YFSS and NATION protocols were deemed exempt from human subjects' protections review by the Western Institutional Review Board (Puyallup, WA). The NCAA Institutional Review Board required each student athlete

to provide written informed consent to allow their de-identified injury and exposure data to be collected.

### Statistical Analyses

Data were analyzed using SAS Enterprise Guide software, version 4.3 (SAS Institute Inc). Descriptive analyses included the frequency and proportion of injuries. Comparative analyses included the calculation of risk (ie, prevalence), injury rates, risk ratios (RRs), and injury rate ratios (IRRs). These statistics are reported with 95% CIs.

### Rates

Injury rates were computed for concussions. For comparison with other common injuries, rates were also computed across playing levels for ankle sprains, knee sprains, and fractures. The IRRs compared the magnitude of difference between 2 or more rates (games and practices or level of play):  $IRR = Rate_a / Rate_b$ , where  $Rate_a$  is the injury (concussion) rate of the first group and  $Rate_b$  is the rate of the second group.

### Risk

One-season risks were calculated for the 2012 and 2013 seasons. We obtained information regarding the number of players at the youth and high school levels. For college football, we used participation data from the NCAA to estimate squad sizes because individual team sizes were not available.<sup>2</sup> The RR was also computed, comparing the magnitude of difference between 2 or more risks:

$RR = Risk_a / Risk_b$ , where  $Risk_a$  is the injury (concussion) risk of the first group and  $Risk_b$  is the risk of the second group.

## Results

During the 2012 and 2013 seasons, 1198 concussions were reported: 141 (11.8%) in youth athletes, 795 (66.4%) in high school athletes, and 262 (21.9%) in college athletes (Table 2). Concussions comprised 9.6%, 4.0%, and 8.0% of all injuries reported in the YFSS, NATION, and NCAA Injury Surveillance Program, respectively. A slight majority of concussions occurred in games in youth football (53.9%); however, most concussions at the high school and college levels occurred in practices (57.7% and 57.6%, respectively). In addition, no concussions were reported in youth football players aged 5 to 7 years, even though this age group contributed more than 7000 AEs.

### Rates

Game and practice concussion rates are provided in Table 2. The game concussion rate was higher than those for practices among all 3 levels of competition, with the largest IRR found in college football (IRR, 7.08; 95% CI, 5.54-9.05). Among games, the college concussion rate (3.74 per 1000 AEs) was higher than those reported in high school (2.01 per 1000 AEs; IRR, 1.86; 95% CI, 1.50-2.31) and youth athletes (2.38 per 1000 AEs; IRR, 1.57; 95% CI, 1.17-2.10). No significant differences existed between high school and youth game concussion rates. Among practices, the sole difference found was that the college concussion rate (0.53 per 1000 AEs) was lower than that in high school

Table 2. Concussion Frequencies, Athlete Exposures, and Injury Rates

Level of Competition	Game			Practice			
	Concussions, No.	AEs, No.	IR <sup>a</sup> (95% CI)	Concussions, No.	AEs, No.	IR <sup>a</sup> (95% CI)	IRR <sup>b</sup> (95% CI)
Youth	76	31 869	2.38 (1.85-2.92)	65	110 667	0.59 (0.44-0.73)	4.06 (2.92-5.65)
High school	336	167 267	2.01 (1.79-2.22)	459	692 935	0.66 (0.60-0.72)	3.03 (2.63-3.49)
College	111	29 690	3.74 (3.04-4.43)	151	286 033	0.53 (0.44-0.61)	7.08 (5.54-9.05)

Abbreviations: AE, athlete exposure; IR, injury rate; IRR, injury rate ratio.

<sup>a</sup> Per 1000 AEs.

<sup>b</sup> IRR compares the game IR with the practice IR.

(0.66 per 1000 AEs; IRR, 0.80; 95% CI, 0.67-0.96). The youth practice rate was not significantly different than the high school rate.

The rates of other commonly reported orthopedic injuries in games and practices are depicted in the **Figure**. The game rates of ankle sprains, knee sprains, and fractures were significantly lower at the youth level compared with both the high school and college levels. The resulting IRRs comparing rates by level were higher than those rates obtained for concussions. Rates among practices were more similar with the exception of ankle sprains in high school. In addition, we found that, compared with game concussion rates, the game injury rates for ankle sprains, knee sprains, and fractures were much lower in youth football than in high school and college football.

### Risk

The risk of players sustaining a concussion varied by level of competition and by year (**Table 3**). Youth football had the lowest 1-season risks in 2012 (3.53%) and 2013 (3.13%). The 1-season concussion risk was highest in high school (9.98%) and college (5.54%) in 2012. The change in risk from 2012 to 2013 decreased within each level of competition. However, the largest drop in risk was in high school (from 9.98% in 2012 to 4.50% in 2013).

In 2012, the 1-season concussion risk in youth football (3.53%) was lower than those in high school football (9.98%; RR, 0.35; 95% CI, 0.28-0.45) and college football (5.54%; RR, 0.59; 95% CI, 0.44-0.79). High school football also had a higher 1-season concussion risk than college football in 2012 (RR, 1.57; 95% CI, 1.37-2.03). In 2013, the 1-season concussion risk in youth football (3.13%) was lower than those of high school football (4.50%; RR, 0.70; 95% CI, 0.54-0.90) and college football (5.52%; RR, 0.55; 95% CI, 0.41-0.74). High school football also had a lower 1-season concussion risk than college football in 2013 (RR, 0.79; 95% CI, 0.65-0.97).

### Discussion

Our study offers a unique opportunity to compare the incidence of concussion across a wide range of ages, as recommended in a recent Institute of Medicine report.<sup>6</sup> Previous studies have estimated the burden of concussion among youth football athletes.<sup>7-11</sup> However, ours is the first study to collect sports injury and exposure data using similar methods, tech-

nology, and common data elements in American youth football players ranging in age from 5 to 23 years.

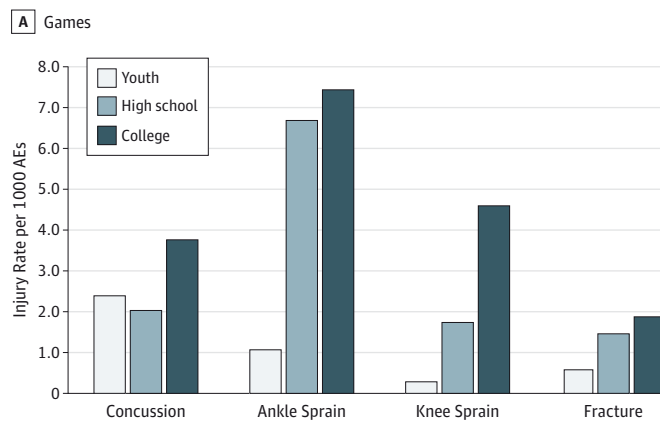
Football practices were a major source of concussion at all 3 levels. The proportion of concussions that occur in practices is lower in youth football teams (46.1%) than high school (57.7%) or college teams (57.6%), but this lower proportion may be attributable to the fewer number of players and practices per week at the youth level. Youth football teams generally practice 1 to 2 times per week and have an average of 20 to 25 players per team. High school and college teams practice more times per week, play more games, and have an average of 77 and 107 players per team, respectively.<sup>2,3</sup> The risks were also lower in youth leagues than in college and high school. Nevertheless, the findings suggest that limiting contact in practices is an important strategy for controlling the risk of concussion to football players.

The concussion rate was significantly higher in games compared with practices at all levels. The largest difference was seen at the college level. This difference may reflect increased intensity of contact in college competition or attempts to mitigate injury by limiting full or player-to-player contact during practice by focusing more on game preparation.

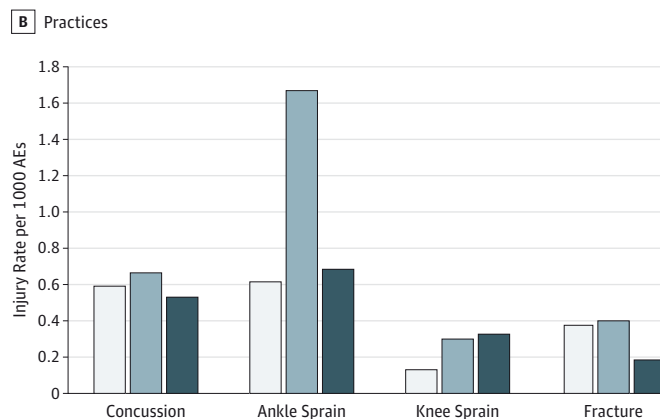
Our study collected information regarding the number of players at the youth and high school levels and used participation data from the NCAA.<sup>2</sup> As a result, unlike most previous research, our study provided risk estimates across all playing levels. Across all playing levels, the 2013 risks were lower than in 2012, with the NATION data showing the largest drop. While it is not a specific study metric, this difference may be the result of 1 school district with more than 20 schools requiring all football coaches to participate in a coaching education program prior to the 2013 season. The program provided coaches with alternatives to full-contact drills that required less player-to-player contact, recommended practice schedules, and provided concussion and injury awareness materials (available to players and parents as well). Further research is ongoing to determine if this difference is the result of yearly variation or the coaching education program.

The single-season risk provides an opportunity to make estimates of the burden of concussion in youth, high school, and NCAA football. For example, the approximate number of players in youth, high school, and NCAA football are 3 million, 1.1 million, and 71 000, respectively. Based on the average of the two 1-season risks reported in this study, as many as 182 000

Figure. Injury Rates by Level of Competition



Level of competition	Rate (95% CI)			
Youth	2.38 (1.84-2.92)	1.04 (0.69-1.39)	0.25 (0.08-0.42)	0.53 (0.28-0.78)
High school	2.01 (1.80-2.22)	6.73 (6.34-7.12)	1.72 (1.52-1.92)	1.44 (1.26-1.62)
College	3.74 (3.04-4.43)	7.48 (6.49-8.46)	4.58 (3.81-5.35)	1.85 (1.36-2.34)
Comparison	Rate Ratio (95% CI)			
College vs high school	1.86 (1.50-2.31)	1.11 (0.96-1.28)	2.66 (2.17-3.27)	1.29 (0.96-1.72)
College vs youth	1.57 (1.17-2.10)	7.19 (4.99-10.36)	18.32 (8.97-37.43)	3.50 (2.03-6.03)
High school vs youth	0.84 (0.66-1.08)	6.47 (4.58-9.14)	6.88 (3.40-13.91)	2.72 (1.66-4.45)



Level of competition	Rate (95% CI)			
Youth	0.59 (0.45-0.73)	0.61 (0.46-0.76)	0.12 (0.06-0.18)	0.37 (0.26-0.48)
High school	0.66 (0.60-0.72)	1.67 (1.57-1.77)	0.29 (0.25-0.33)	0.40 (0.35-0.45)
College	0.53 (0.44-0.61)	0.68 (0.58-0.77)	0.32 (0.26-0.39)	0.18 (0.13-0.23)
Comparison	Rate Ratio (95% CI)			
College vs high school	0.80 (0.67-0.96)	0.41 (0.35-0.47)	1.11 (0.87-1.42)	0.45 (0.34-0.61)
College vs youth	0.89 (0.67-1.20)	1.11 (0.84-1.47)	2.68 (1.51-4.77)	0.49 (0.33-0.74)
High school vs youth	1.12 (0.86-1.45)	2.74 (2.14-3.50)	2.42 (1.39-4.21)	1.08 (0.78-1.50)

Concussion, ankle sprain, knee sprain, and fracture injury rates in football games (A) and practices (B). AE indicates athlete exposure.

football players may sustain at least 1 concussion annually in youth (99 000), high school (79 640), and NCAA football programs (3905). These numbers equate to approximately 1 in 30 youth players, 1 in 14 high school players, and 1 in 20 NCAA football players. Some players may sustain more than 1 concussion in a season, so these numbers do not represent the total number of concussions but rather the number of players who may sustain at least 1 concussion.

Although our study does not analyze recovery from concussion, our findings may support reports that younger players may have a higher incidence of concussion owing to the developing brain or other factors.<sup>16</sup> This notion may be supported by our finding of greater disparities in the injury rates of other common injuries at the youth level but fewer differences in the concussion rates compared with high school and college athletes. However, the biological plausibility of

Table 3. Concussion Risk and Risk Ratios in Football<sup>a</sup>

Level of Competition	Year	Athletes With Concussion, No.	Total Athletes, No.	Risk, % (95% CI)
Youth	2012	70	1982	3.53 (2.72-4.34)
	2013	66	2110	3.13 (2.39-3.87)
High school	2012	417	4177	9.98 (9.07-10.89)
	2013	350	7780	4.50 (4.04-4.96)
College <sup>b</sup>	2012	120	2166	5.54 (4.58-6.50)
	2013	125	2264	5.52 (4.58-6.46)
				<b>Risk Ratio (95% CI)</b>
Youth vs high school	2012			0.35 (0.28-0.45)
	2013			0.70 (0.54-0.90)
Youth vs college	2012			0.59 (0.44-0.79)
	2013			0.55 (0.41-0.74)
High school vs college	2012			1.57 (1.37-2.03)
	2013			0.79 (0.65-0.97)

<sup>a</sup> Data from practices and games combined.

<sup>b</sup> Total athletes estimated from average squad size statistics found in National Collegiate Athletic Association participation data.

the developing brain hypothesis has been challenged by research demonstrating that brain development continues into the mid-20s.<sup>17-19</sup> Although similar methods were used to determine the risk and rate of concussion in youth, high school, and collegiate football, we advocate for further research to validate our findings. In particular, we found that, compared with game concussion rates, game injury rates for ankle sprains, knee sprains, and fractures were lower in youth football than in high school and college football. Future research should determine if the similar concussion rates, but dissimilar rates of other common injuries, in games is a unique attribute of football or other factors that limit generalizations across levels of play.

Our study has several limitations. The samples from all 3 programs are convenience samples, which limits generalizations. Also, the frequency of concussion at each level of competition may be influenced by several factors. The average team size was 25 for YFSS football teams compared with high school and college football teams (average team size, 77 and 107, respectively).<sup>2,3</sup> The small team size at the youth level requires players to participate in nearly every repetition during practice and games. Conversely, at the college level, there are enough players for second and third string. There are also more plays per game at the high school and college levels. The ratio of sports medicine staff to athletes may also differ by level. Most NCAA football teams will have more than 1 athletic trainer present at practices and games and sometimes a physician. At the secondary school and youth levels, there was typically 1 athletic trainer. The presence of more than 1 athletic trainer may lead to greater recognition of concussions that might otherwise go unreported.

The experience level of athletic trainers was also different across levels of competition. Although experience level was not specifically tracked in these programs, it is assumed that collegiate athletic trainers had more experience on average. Many youth athletic trainers were graduate students, but all were board certified at the time of the study. The high school athletic trainers ranged from graduate students to those with many years of experience in the same high school. Also, in post-

program interviews of the youth football athletic trainers following the YFSS, most athletic trainers cited unfamiliarity with the youth population as the greatest challenge in assessing concussion. Attendance at pediatric clinical rotations of patients younger than high school age is generally not required of athletic trainers during their education, and the trainers rarely have access to these rotations. These differences in experience level may increase or decrease the frequencies of concussion in the youth football teams in comparison with those observed in the high school and college settings.

No concussions were observed among the 5- to 7-year-old youth football players. It is unclear if this absence of observed concussions is the result of zero concussions, the inability of a 5- to 7-year-old player to recognize and report concussive symptoms, or the absence of observable symptoms (eg, unconsciousness, balance disturbances) noted by the athletic trainer. This possibility is supported by the challenges of assessing concussion in the 8- to 14-year-old players reported by the athletic trainers and recent research validating a more complete list of symptoms for children.<sup>20</sup>

Finally, the definition of *risk* in this study included players who sustained at least 1 concussion during the season divided by the number of players who started the season. Because some athletes may start but not finish the season for reasons other than concussion, the true risk may be underestimated. At the collegiate level, many players included in the risk denominator are exposed during practice but not during games, further underestimating the risk. At the high school level, this effect is likely smaller because of the smaller team size. At the youth level, all children on the teams were guaranteed the opportunity to play in games.

## Conclusions

Although each level of competition (youth, high school, and collegiate) has notable differences, the consistent methods and terminology used in this study offer a unique opportunity to make comparisons of the incidence of concussion across the

continuum of amateur football. The rate of concussion in youth players was generally not different from those in high school and college players compared with other injuries. However, football practices were a major source of concussion at all 3 levels of competition. Concussions during practice might be miti-

gated and should prompt an evaluation of technique and head impact exposure. Although it is more difficult to change the intensity or conditions of a game, many strategies can be used during practice to limit player-to-player contact and other potentially injurious behaviors.

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**Acquisition, analysis, or interpretation of data:** Dompier, Kerr, Marshall, Snook, Hayden, Simon.

**Drafting of the manuscript:** Dompier, Kerr.

**Critical revision of the manuscript for important intellectual content:** All authors.

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**Disclaimer:** The content of this manuscript is solely the responsibility of the authors and does not

necessarily represent the official views of the programs' sponsors.

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