Risk Factors for Injury Among High School Football Players

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Background: Football is the most popular interscholastic high school sport in the United States. Prior research has described a higher rate of injury among high school football players than in other sports, but few studies have examined potential predictors while controlling for other risk factors.

Methods: Using a 2-stage cluster sampling technique, we conducted a prospective cohort study from 1996 to 1999 among varsity athletes from 12 sports in 100 North Carolina high schools. A total of 3323 football players participated. Injury exposure and risk factor data were collected by trained school personnel. Incidence rates, rate ratios, and odds ratios (ORs) were estimated using Poisson and logistic regression.

Results: There were 1064 injured athletes and 1238 injuries; 106 injuries resulted in greater than 3 weeks lost from participation. The overall incidence rate was 3.54 per 1000 athlete-exposures (95% confidence interval [CI] = 3.31–3.78). The rate of game injury was 9 times that of practice injury (OR = 9.2; 95% CI = 6.6–11). Athletes with a prior injury had twice the injury rate of those without (1.9; 1.5–2.4). Among those injured, having a coach with more experience, qualifications, and training was associated with half the odds of severe injury (0.49; 0.27–0.92).

Conclusions: Prior injury, additional years of playing experience, and older age were predictors of injury incidence after controlling for multiple risk factors. A high level of coaching skills did not reduce the injury rate, but was protective against severe injury.

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Football is the most popular interscholastic high school sport in the United States, with more than 1 million young men participating during the 2006–2007 school year—one-quarter of all male high school athletes.[1] Football, the most popular interscholastic sport in North Carolina, engages 32% of male high school athletes.[1]

Football is associated with more catastrophic injuries than any other high school sport,[2] the greatest number of injuries, as well as the highest rate of injury per unit of exposure.[3–6] In the United States between 1982 and 2006, there were 100 direct fatalities, 241 permanent disabilities, and 241 temporary disabilities among high school football players.[2] Among 5- to 24-year olds, an estimated 355,000 football-related injuries were treated in emergency departments nationwide during 1998.[7] Reported incidence of injury in high school football varies widely in the literature, ranging from 2.6 to 8.1 injuries per 1000 athlete-exposures.[3,8,9] However, nonuniform definitions of injury and varying methods of data collection make it difficult to compare injury incidence across studies.

Few studies of high school football have used multivariable techniques to examine potential predictors; most have presented stratified results for each potential risk factor.[9–13] The purpose of this study was to examine the effect of multiple potential predictors of injury incidence and injury severity among high school football players. In addition, we present multivariate analyses of high-severity injuries compared with low-severity injuries, a topic not previously examined.

METHODS

Sample Selection

These data come from the North Carolina High School Athletic Injury Study (NCHSAIS), a prospective cohort study of high school varsity athletes conducted between 1996 and 1999. Football was 1 of the 12 sports for which injury and risk factor data were collected during the 3-year study period. A total of 3323 high school football athletes participated in the study. In North Carolina, football preseason practices start in mid-August and the regular season lasts through mid-November. Schools play 11 games during the regular season with the potential of postseason play on the basis of their regular season record.

Sampling Methods

The NCHSAIS sampling methods have been described extensively.[14–17] Briefly, the original study sample of 100 public schools was selected using a stratified 2-stage probability proportional to size cluster sampling technique.[14,18] The sample was stratified by the presence of a certified athletic trainer, competition division, geographic region, and average school attendance.[14] The school contact responsible for timely completion of data collection forms was either the athletic trainer (69%) or, in schools that did not have an athletic trainer on staff, the athletic director (31%). The overall response rate was 68% for participating football players from participating teams (83% × 81% = 68%). Normalized weights (sample weights multiplied by the sampling fraction) were used in all analyses in this study.

Definition of Injury and Severity

A reportable injury was defined as "a result of participation in a high school sport that either limited the student's full participation in the sport the day following the injury or required medical attention by a medical professional (ie, athletic, trainer, physician, nurse, emergency medical technician, emergency room personnel, or dentist)."[14]

On the basis of prior analyses of the NCHSAIS data,[16] we defined severe injuries as those that prevented participation in the sport for more than 3 weeks postinjury. Nonsevere injuries were those in which the athlete returned to play within 3 weeks.

Data Collection

Data about risk factors and injuries were collected using an athlete's demographic questionnaire, a coach's demographic questionnaire, a weekly participation form, and an injury report form. Athletes (n = 3323) and coaches (n = 100) completed their respective questionnaires at the start of each season. The school contact completed an injury report form during the football season for each sustained injury; thus, an athlete who suffered multiple injuries at 1 time had multiple injury reports. The school contact also completed a weekly participation form that tracked the number of games and practices per week throughout the football season. The NCHSAIS project staff communicated with the school contacts throughout the study period by using site visits and telephone calls to encourage timely reporting and to verify that any reports of no injuries were actually injury-free seasons rather than lack of reporting.

Exposure

Exposure was assessed in 2 ways. For most analyses, athlete-exposures were computed by summing the total number of practices and games during the preseason and regular season for each athlete. These exposures represent any opportunity for an athlete to be injured and can be used to estimate the rate of injury during practices (practice athlete-exposures) and games (game athlete-exposures). For analyses involving injury rates by position, we multiplied the aggregate number of games during the regular season, across all teams, by the number of positions on a football team to estimate the position-game exposure.[19] For example, there were 1166 games during the study period and each team had 1 quarterback; thus, there were a total of 1166 position-game exposures for quarterbacks. This technique can be used only to estimate injuries during games and was used solely for injured athletes because position was not collected on the preseason athlete's survey.

Risk Factors

On the basis of a review of the literature and previous studies, the following potential risk factors were evaluated: grade, multiple sport participation, years of playing experience, prior injury in that sport, age, body mass index (BMI) for age, competition division, and coaching experience, qualifications, and training (Coach EQT). Study year was also included in the models to control for year-to-year changes in the injury rate and the odds of severe injury.

Prior injury in football included the following injuries: knee, ankle, shoulder, wrist, elbow, fracture, concussion, and heat-related injury. Coach EQT was an index variable based on coaches' answers to 5 yes/no questions: completion of at least a college degree, completion of a coaching class, current certification in first aid or cardiopulmonary resuscitation (CPR), at least 1 year of coaching experience in that sport, and at least 1 year of playing experience in that sport. Coach EQT was categorized as "low" if they answered yes to none, 1 or 2 questions, as "medium" if they answered yes to 3 questions, or "high" if they answered yes to 4 or 5 questions. Competition division (Division 1A–4A) was based on school enrollment: Division 1A (<668 students), Division 2A (668–957 students), Division 3A (967–1308 students), and Division 4A (1314–2600 students). The BMI-for-age variable was based on sex- and age-specific national percentiles for adolescent populations.[20]

Data Analysis

Analyses were performed to model 2 outcomes: the incidence rate of injury and the odds of severe injury, conditional on being injured. Incidence rates were estimated as the number of injuries divided by either the sum of athlete-exposures or position-game exposures (for rates by playing position). Poisson regression was used to estimate unadjusted and adjusted incidence rates and incidence rate ratios (RR) associated with each risk factor. Because of the difficulty in measuring time-at-risk during the postseason, the Poisson analysis included injuries and exposure time only during the preseasons and regular seasons. A fully adjusted Poisson regression model was used to estimate the incidence rates and RR associated with each risk factor, to evaluate the effect of each risk factor on injury incidence after controlling for all other risk factors. Because players could sustain multiple

injuries throughout the season, and could participate in the study for up to 3 seasons, a longitudinal data set was constructed for the rates analysis that summarized the number of athlete-seasons (1 athlete participating for 1 season) and injuries per football player.

To examine severe injuries, a separate analysis was restricted to football players who sustained injuries during the 3 seasons, including the postseason play. Logistic regression was used to estimate the effect of each risk factor on the odds of severe injury (missing >3 weeks of participation) versus nonsevere injury (≤3 weeks lost), given that an injury had occurred. Again, unadjusted and adjusted models were used to evaluate the association between each risk factor and the odds ratio (OR).

In the Poisson regression models, years of playing experience, age, and grade met the model assumption of linearity in the log rate and were included as continuous variables, whereas the remaining variables were included as categorical variables. In the logistic regression models, BMI and study year met the model assumption of linearity in the log odds and were included as continuous variables. On the basis of assumption of linearity and cell sizes, grade, years of playing experience, and age were recategorized into the 9th to 10th grade versus 11th to 12th grade, 0 to 1 year versus 2 to 4 years versus 5 to 8 years of playing experience, and 16 years or younger compared with 17 years or older. For informational purposes, continuous variables were also categorized and the resulting incidence rates, RRs, and ORs are presented. All reported statistical analyses were performed using SAS-callable SUDAAN version 8.0 (Research Triangle Institute, Research Triangle Park, NC) to account for the complex sampling design.[21]

RESULTS

Our study included 3323 football players, 3948 athlete-seasons, and 253,891 athlete-exposures during the 3 football seasons. For the entire study period, there were a total of 1064 injured athletes and 1238 injuries. More injuries were reported for games (700) than practices (360).

Study Population

A majority of athletes were at least 17 years old and had at least 4 years of experience of playing football (Table 1). Nine football players were women, and 1 was injured during the course of the study. These female athletes were included in all analyses, but because there were so few, it was not possible to adjust for sex.

The ankle, knee, and shoulder were the most common body parts injured and sprains, strains, and bruises were the most common types of injury. A majority of injuries (74%) were treated outside the emergency department, whereas the remaining 26% were treated in a hospital emergency department or admitted to the hospital. The most frequent hospital-treated injuries were ankle sprains (10%), knee sprains (8%),

TABLE 1. Distribution of Risk Factors Among Injured and Noninjured Football Athletes, Using Normalized Weights, NCHSAIS, 1996–1999

Risk Factor	Overall		Injured		Noninjured	
	Number	%	Number	%	Number	%
Total	3323		1064	32	2259	68
Study year						
1996–1997	680	21	224	21	456	20
1997–1998	1612	49	573	54	1040	46
1998–1999	1031	31	267	25	764	34
Prior injury						
No	1832	55	453	43	1379	61
Yes	1491	45	611	57	880	39
Years of playing experience						
0	85	3	14	2	71	4
1	204	7	27	3	177	9
2	393	14	114	13	279	15
3	447	16	116	13	330	17
4	599	22	201	23	399	21
5	485	17	161	18	324	17
6	423	15	176	20	245	13
≥7	154	6	65	7	88	5
Missing	534	16	189	18	345	15
Age; y						
≤14	83	3	13	1	70	4
15	275	9	65	7	210	11
16	853	29	252	26	602	30
17	1156	39	412	42	744	37
18	567	19	212	22	355	18
≥19	58	2	30	3	28	1
Missing	331	10	79	7	252	11
BMI for age						
Underweight	5	<1	1	<1	4	<1
Normal weight	1352	49	406	47	946	50
Risk of overweight	668	24	212	24	457	24
Overweight	737	27	254	29	483	26
Missing	561	17	191	18	369	16
Play >1 sport						
No	950	29	280	26	670	30
Yes	2373	71	783	74	1589	70
Grade						
9	192	7	20	2	171	9
10	454	16	153	17	301	16
11	1156	41	349	39	807	41
12	1036	37	366	41	670	34
Missing	486	15	176	16	310	14
Coaching experience, qualifications, and training						
Low	358	11	112	11	245	11
Medium	1233	37	386	36	847	38
High	1732	52	565	53	1168	52
Competition division						
Division 1A	602	18	204	19	398	18
Division 2A	1010	30	295	28	715	32
Division 3A	961	29	310	29	651	29
Division 4A	750	23	255	24	495	22

and concussions (5%). Seventy-three percent of the reported injuries resulted in less than 1 week lost from participation, 19% lost 1 to 3 weeks, and 9% lost more than 3 weeks.

Overall Injury Incidence

The overall injury rate was 3.54 per 1000 athlete-exposures (95% confidence interval [CI] = 3.31–3.78). Common circumstances surrounding the injuries are shown in Table 2. The most common player activity at the time of injury was tackling. This was also the most common injury

TABLE 2. Circumstances of Injury for All Football Injuries (n = 1238), in Descending Order of Frequency, Using Normalized Weights, NCHSAIS, 1996–1999

	Percent
Player's activity at time of injury	
Tackling	29
Blocking	23
Running with the ball	17
Defending	11
Receiving	6
Other	5
Warm-up	5
Passing	3
Kicking or punting	2
Missing	2
Contact proximate to injury	
Tackling	33
Blocking	22
Being tackled	19
Slipped, tripped, or fell	7
Other	12
Collision with teammate	3
Clipped	2
Heat illness	1
Collision with out-of-bounds object	<1
Missing	2
Team's activity at time of injury	
Running play	59
Passing play	18
Other	9
Warm-up	6
Kick-off	3
Punt play	2
Broken play	1
Field goal attempt	<1
Missing	2
Location on playing field	
Between 20-yard lines	53
Inside 20-yard line	15
Other	8
End zone	1
Locker room	<1
Weight room	<1
Missing	20

mechanism; contact injuries accounted for 79% of all reported injuries. More than half of the injuries occurred when teams were executing a running play, and occurred between the 20-yard lines.

Intrinsic Risk Factors

Intrinsic risk factors included injury history, years of playing experience, BMI, age, and multiple sport participation (Table 3). Increasing years of playing experience was associated with an increased rate of injury in both the adjusted and unadjusted models. Older players had an increased rate of injury than the younger players. Injury rates appeared higher among the underweight players, although there were too few for precise estimates.

Having had any prior injury was associated with a higher rate of injury (RR = 1.9, 95% CI = 1.5–2.4), including reinjury to the same site. In comparison with athletes with no prior injury, recurrence of injury at the same site was high for ankle, knee, and shoulder, with RR up to 15 (eTable 1, http://links.lww.com/A760).

Extrinsic Risk Factors

Extrinsic risk factors included study year, grade, coach-related factors, and competition division (Table 3). There were negligible changes in the rate of football injury over the 3 years. In the unadjusted model, there was a 31% increase in the injury rate for every increase in grade, although this association was greatly attenuated after controlling for other variables. There was little effect of the coach's skill level on the injury rate in both the unadjusted and adjusted analyses. Division 3A schools had the lowest injury rates.

Situation: Games Versus Practices

The injury rate was 9 times higher in games than in practices (RR = 9.2, 95% CI = 6.6–12). The injury rate for games was 15.7 per 1000 athlete-exposures (13.6–18.2) in comparison with a practice rate of 1.7 per 1000 athlete-exposures (1.3–2.3).

Table 4 shows the adjusted injury RRs associated with each risk factor for both practices and games. For intrinsic risk factors, a prior injury was associated with an increased injury rate in both situations, although it was higher during practices. Underweight athletes had twice the rate of practice injury in comparison with normal weight athletes, but a lower rate of injury during games. A similar association was also present for overweight players compared with normal-weight players. There was a 14% increase in the rate of game injury for every year of playing experience, but no increase in the rate of practice injury. Also, increasing age was associated with a 33% increase in game injuries, but no increase in practice injuries.

For extrinsic risk factors, coaches with a medium level of coaching skills had a higher rate of both game injury and practice injury in comparison with coaches with the lowest

TABLE 3. Incidence of Injury Per 1000 Athlete-Exposures for All Risk Factors (3948 Athlete-Seasons), Using Normalized Weights, NCHSAIS, 1996–1999

Risk Factor	No. Injuries[a]	Unadjusted Injury Rate (95% CI)	Unadjusted Rate Ratio (95% CI)	Adjusted Rate Ratio (95% CI)
Prior injury				
No	334	2.3 (1.8–3.0)	1.0 (Referent)	1.0 (Referent)
Yes	575	5.0 (4.0–6.1)	2.1 (1.7–2.7)	1.9 (1.5–2.4)
Years of playing experience				
0	11	1.7 (0.76–3.8)	1.0 (Referent)	1.0 (Referent)
1	36	1.8 (1.05–3.2)	1.1 (0.45–2.6)	1.1 (0.48–2.4)
2	81	3.3 (2.06–5.2)	1.9 (0.86–4.2)	1.7 (0.87–3.3)
3	138	3.4 (2.50–4.6)	2.0 (0.95–4.1)	1.6 (0.83–3.2)
4	185	4.0 (3.02–5.2)	2.3 (1.0–5.2)	1.9 (0.92–3.9)
5	173	4.0 (3.27–4.9)	2.3 (1.0–5.2)	1.7 (0.87–3.1)
6	155	5.2 (4.09–6.6)	3.0 (1.4–6.7)	2.1 (1.1–3.9)
≥7	57	5.1 (3.62–7.1)	3.0 (1.2–7.0)	2.0 (0.99–4.2)
Per year	—	—	1.1 (1.1–1.2)	1.1 (1.0–1.2)
Age; y				
≤14	10	2.1 (0.72–6.2)	1.0 (Referent)	1.0 (Referent)
15	59	2.5 (1.5–4.1)	1.2 (0.54–2.5)	1.1 (0.55–2.0)
16	180	2.7 (2.0–3.5)	1.3 (0.46–3.5)	1.0 (0.43–2.4)
17	375	4.3 (3.4–5.4)	2.0 (0.76–5.4)	1.4 (0.64–3.3)
18	224	4.8 (4.0–5.9)	2.3 (0.78–6.6)	1.5 (0.62–3.8)
≥19	19	4.1 (2.4–7.3)	2.0 (0.64–6.0)	1.7 (0.68–4.3)
Per year	—	—	1.3 (1.1–1.4)	1.2 (1.0–1.3)
BMI for age				
Underweight	9	5.3 (1.8–16.3)	1.5 (0.46–4.7)	1.3 (0.62–2.7)
Normal	392	3.6 (2.9–4.6)	1.0 (Referent)	1.0 (Referent)
Risk of overweight	257	3.9 (3.0–5.0)	1.1 (0.86–1.3)	1.1 (0.88–1.3)
Overweight	179	4.0 (3.0–5.2)	1.1 (0.91–1.3)	1.10 (0.90–1.4)
Play >1 sport				
No	195	2.5 (1.9–3.2)	1.0 (Referent)	1.0 (Referent)
Yes	714	3.9 (3.1–5.0)	1.6 (1.2–2.1)	1.19 (0.92–1.54)
Grade				
9	24	1.4 (0.6–3.5)	1.0 (Referent)	1.0 (Referent)
10	130	3.4 (2.3–5.2)	2.4 (1.1–5.7)	2.4 (0.83–6.8)
11	285	3.3 (2.6–4.2)	2.4 (0.94–6.0)	1.9 (0.74–4.8)
12	400	4.8 (4.0–5.7)	3.4 (1.4–8.5)	1.1 (0.93–1.2)
Per grade	—	—	1.3 (1.1–1.5)	1.0 (0.85–1.3)
Coaching experience, qualifications, and training				
Low	64	3.5 (2.4–4.9)	1.0 (Referent)	1.0 (Referent)
Medium	345	3.1 (2.0–4.8)	0.91 (0.52–1.6)	1.16 (0.71–1.88)
High	500	3.9 (3.1–4.8)	1.1 (0.73–1.7)	1.14 (0.79–1.64)
Competition division				
Division 1A	187	3.8 (2.4–5.8)	1.0 (Referent)	1.0 (Referent)
Division 2A	233	3.8 (3.0–4.8)	1.0 (0.61–1.7)	0.90 (0.51–1.6)
Division 3A	144	1.9 (1.1–3.3)	0.5 (0.2–1.0)	0.47 (0.22–1.0)
Division 4A	345	5.0 (3.8–6.6)	1.3 (0.79–2.3)	1.2 (0.66–2.2)

[a]Unweighted number of injuries were used for frequency only.

level of coaching skills. There appeared to be no difference, regardless of game situation, between coaches with either high or low skill levels. Within competition division, there was little difference in the injury RRs for practices in comparison with that for games. However, larger schools had slightly lower injury rates in comparison with smaller schools in both situations. Tenth graders had a higher rate of game injury and practice injury than 9th graders (IRR = 2.4; 95%

TABLE 4. Injury Incidence for Games and Practices Per 1000 Athlete-Exposures for All Risk Factors (3948 Athlete-Seasons), Using Normalized Weights, NCHSAIS, 1996–1999

Risk Factor	Adjusted Rate Ratio for Practices (95% CI)	Adjusted Rate Ratio for Games (95% CI)
Prior injury		
No	1.0 (Referent)	1.0 (Referent)
Yes	2.2 (1.5–3.2)	1.9 (1.5–2.5)
Years of playing experience		
0	1.0 (Referent)	1.0 (Referent)
1	1.0 (0.39–2.6)	1.7 (0.6–4.7)
2	1.6 (0.54–4.9)	2.7 (1.3–5.8)
3	1.4 (0.55–3.6)	3.5 (1.3–9.3)
4	1.5 (0.55–4.0)	3.2 (1.4–7.6)
5	1.2 (0.52–3.0)	3.5 (1.4–8.8)
6	1.2 (0.46–2.9)	4.4 (1.9–10)
≥7	0.88 (0.34–2.3)	4.5 (1.9–11)
Per year	0.96 (0.85–1.1)	1.1 (1.1–1.2)
Age; y		
≤14	1.0 (Referent)	1.0 (Referent)
15	0.53 (0.18–1.5)	4.6 (1.1–21)
16	0.58 (0.13–2.6)	5.2 (1.1–26)
17	0.61 (0.12–3.1)	7.7 (1.4–42.0)
18	0.64 (0.11–3.8)	9.2 (1.6–52)
≥19	0.77 (0.08–7.2)	13.5 (2.3–80)
Per year	1.0 (0.71–1.5)	1.3 (1.1–1.6)
BMI for age		
Underweight	2.1 (0.67–6.5)	0.7 (0.11–4.4)
Normal	1.0 (Referent)	1.0 (Referent)
Risk of overweight	1.2 (0.73–1.8)	0.94 (0.74–1.2)
Overweight	1.9 (1.2–2.9)	0.91 (0.71–1.2)
Play >1 sport		
No	1.0 (Referent)	1.0 (Referent)
Yes	1.1 (0.71–1.7)	1.1 (0.81–1.6)
Grade		
9	1.0 (Referent)	1.0 (Referent)
10	2.3 (0.91–5.8)	2.4 (0.89–6.7)
11	1.3 (0.58–2.8)	1.9 (0.74–4.9)
12	2.7 (1.2–6.1)	1.6 (0.61–4.5)
Per grade	1.2 (0.95–1.6)	0.90 (0.71–1.1)
Coaching experience, qualifications, and training		
Low	1.0 (Referent)	1.0 (Referent)
Medium	1.3 (0.59–2.9)	1.2 (0.76–1.8)
High	1.0 (0.47–2.2)	1.0 (0.66–1.5)
Competition division		
Division 1A	1.0 (Referent)	1.0 (Referent)
Division 2A	0.4 (0.23–0.73)	0.64 (0.43–0.96)
Division 3A	0.7 (0.42–1.3)	0.59 (0.40–0.88)
Division 4A	0.97 (0.51–1.8)	0.93 (0.56–1.6)

CI = 0.89–6.7). This increase may be partially explained by the fact that there were more athlete-exposures in the 10th, 11th, and 12th graders—regardless of game situation—than for the 9th graders. For the study period, there were about 14,000 total athlete-exposures among the 9th graders in comparison with 44,000 to 128,000 for older grades. This differential persisted in both games and practices. Therefore, the increased rate in older grades may be at least partially explained by playing time.

Rate of Injury Per Position-Game Exposure

Injury rates by position are shown in eTable 2 (http://links.lww.com/A761). The total number of position-game exposures varied depending on whether it was a single position (ie, quarterback) or multiple-player position (ie, defensive linemen). Although defensive linemen had the greatest number of injuries, running backs and quarterbacks had the highest injury incidence. Kickers had the lowest injury incidence.

Odds of Severe Injury

One hundred six of the 1238 football-related injuries resulted in more than 3 weeks lost from participation (9% of injuries), with an overall incidence rate of severe injury of 0.32 per 1000 athlete-exposures (95% CI = 0.23–0.40). We classified these injuries as higher severity and the remainder as lower severity. There was no evidence that a history of injury, increasing years of playing experience, competition division, BMI, or multiple sport participation were associated with the risk of severe injury (Table 5).

However, there was an association between higher levels of coaching skills and lower odds of severe injury (Table 5). Athletes whose coach had a high skill level had half the odds of severe injury (95% CI = 0.27–0.92) in comparison with athletes with coaches with a low skill level. Further, the effect differed depending on whether the severe injury occurred during a practice or game. There appeared to be no protective effect of having a coach with a high skill level on the risk of severe injury in practices (OR = 1.1; 95% CI = 0.17–7.4), but there was an apparent benefit in games (OR = 0.31; 95% CI = 0.17–0.58), which persisted even after controlling for all other risk factors (OR = 0.37; 95% CI = 0.18–0.76).

We also examined which specific coaching characteristics might explain the lower risk with highly skilled coaches. There were noticeable differences in the education levels, coaching classes, and first aid or CPR certification. None of the low skilled coaches had a college degree in comparison with 79% of coaches with a high skill level. Similarly, none of the low-skilled coaches had taken a coaching class compared with 99% of high-skilled coaches. Finally, only 16% of low-skilled coaches were currently certified in first aid or CPR in comparison with 56% of coaches with a high skill level.

DISCUSSION

Intrinsic risk factors appeared to be more predictive of injury incidence than extrinsic risk factors, with the exception of competition division. Of the risk factors examined, prior

TABLE 5. Unadjusted and Adjusted Odds Ratios for Severe Injury (1238[a] Injuries), Using Normalized Weights, NCHSAIS, 1996–1999

Risk Factor	No. Overall Injuries[b]	Unadjusted Odds Ratio (95% CI)	Adjusted Odds Ratio (95% CI)
Injury history			
No	334	1.0 (Referent)	1.0 (Referent)
Yes	575	0.77 (0.39–1.5)	1.03 (0.46–2.3)
Years of playing experience			
0–1	47	1.0 (Referent)	1.0 (Referent)
2–4	404	0.51 (0.15–1.7)	0.57 (0.18–1.9)
5–8	385	0.64 (0.18–2.2)	0.72 (0.19–2.8)
Age; y			
≤16	249	1.0 (Referent)	1.0 (Referent)
≥17	618	0.89 (0.42–1.9)	0.79 (0.41–1.5)
BMI			
Under/normal weight	401	1.0 (Referent)	1.0 (Referent)
Risk of overweight	257	0.92 (0.47–1.8)	0.81 (0.38–1.7)
Overweight	179	0.79 (0.41–1.5)	0.76 (0.39–1.5)
Per BMI category		0.89 (0.65–1.2)	0.87 (0.61–2.0)
Play >1 sport			
No	195	1.0 (Referent)	1.0 (Referent)
Yes	714	0.60 (0.30–1.2)	0.75 (0.38–1.5)
Grade			
9–10	154	1.0 (Referent)	1.0 (Referent)
11–12	685	1.0 (0.43–2.4)	1.2 (0.44–3.5)
Coaching experience, qualifications, and training			
Low	64	1.0 (Referent)	1.0 (Referent)
Medium	345	0.32 (0.18–0.55)	0.59 (0.31–1.1)
High	500	0.41 (0.24–0.69)	0.49 (0.27–0.92)
Competition division			
Division 1A	187	1.0 (Referent)	1.0 (Referent)
Division 2A	233	0.67 (0.41–1.1)	0.72 (0.36–1.4)
Division 3A	144	0.54 (0.31–0.96)	0.53 (0.22–1.3)
Division 4A	345	0.75 (0.43–1.3)	0.84 (0.46–1.5)

[a]There were 106 severe injuries of 1238 total injuries.
[b]Unweighted number of injuries.

injury, older age, multiple sport participation, and increasing years of playing experience were associated with an increase in injury incidence overall; grade and coaching skills did not appear to be associated with the injury rate. A lower BMI and higher grade were associated with the injury rate in practices but not in games. Conversely, increasing age and playing experience were associated with the injury rate in games but not in practices. Finally, having a coach with a high skill level was not associated with a decreased injury rate, but was associated with decreased odds of severe injury if an injury occurred.

These analyses support results from descriptive studies of the frequency and severity of high school football injuries.[5,9,10,12,22] In another study of high school football injuries conducted during the same time frame, the overall injury rate was similar to ours.[8] That study had considerably fewer participants (717 athletes in 8 high schools during 1998–1999). Those authors concluded that prior injury and years of playing experience (range, 0–6 years) were predictive of injury incidence. Although our results are consistent with their conclusion, we also investigated predictors of severe injury, including coaching factors.

Significance of Findings

A priori, we expected the effect of age, years of playing experience, and grade to be closely correlated with one another. Although the RRs decreased after adjustment for other risk factors, independent effects of age and years of playing experience persisted.

Having had a prior injury was a strong predictor of injury incidence. There may be physiologic or skeletal changes in the joints or musculature, which occur as a result

of an initial injury that leaves athletes more susceptible to reinjury. Furthermore, athletes who return to play too soon before the injury has fully healed may also be susceptible to a new injury at the same site. We observed this association in the elevated rates of recurring injury to ankle, knee, and shoulder. Identifying factors related to injury prevention and identifying ways to provide injured athletes with adequate medical care and rehabilitation should be further explored.

The importance of coaching factors has been noted in other high school sport injury studies of incidence, but not studies of injury severity.[16] Surprisingly, a high skill level for coaches was not associated with the injury rate in this study. However, given that an injury occurred, having a coach with a high skill level was protective against severe injury. It may be that coaching factors are indicators of the school and community environment. For example, schools that hire football coaches with more experience, qualifications, and training may have access to higher quality medical resources (ie, orthopedic specialists) and provide better care for injured football players.

Strengths and Limitations

This study has several limitations. Missing data were a problem for some risk factors such as BMI (17%), years of playing experience (16%), and grade (15%). To the extent possible, the pattern of missing data was examined and it appeared to be noninformative with respect to other risk factors. There are also potential limitations related to self-report data and different reporting sources. The demographic questionnaires were subject to a potential reporting bias (ie, height, weight, and formal coaching qualifications) and the use of both athletic trainers and athletic directors as school contacts could have resulted in inconsistent data reporting patterns. To minimize this risk, the NCHSAIS staff made extensive efforts to promote and support accurate reporting, including training for school staff, and subsequent site visits and phone calls throughout the study period.

Another limitation was the lack of individual-level exposure data for uninjured athletes (eg, position, activity at the time of injury). Unfortunately, position data were collected only at the time of injury, so we were unable to evaluate position as a predictor. However, using the position-exposure method, we were able to estimate and compare injury rates among various football positions. Using this method, our results indicate that running backs and quarterbacks had the highest injury rates. These results differ to some extent from those of others who have investigated injuries by position.[23,24] It should be noted that the results of any positional injury analysis are dependent on how the positions are grouped and how time at risk is conceptualized (athlete-exposures, player-hours, etc.). In addition to refining this approach, future high school football studies should also examine characteristics of player position that may predict the risk of injury, such as type of activity involved (eg,

blocking vs. rushing) and physical characteristics associated with specific positions. Including these variables into epidemiologic investigations may provide additional insight into injury prevention.

Similarly, we were unable to assess potential environmental predictors such as type of turf (artificial vs. natural grass) and weather and field conditions. All football fields in the NCHSAIS were natural grass and weather and field conditions were collected only as part of the injury report.

Finally, the use of athlete-exposures controlled for variations in sports with different practice and competition schedules but did not account for residual variation in the actual amount of time players participated. To date, the cost of collecting individual-level time at risk (ie, athlete-minutes or athlete-hours) has been prohibitive in large prospective cohort studies consisting of multiple schools and sports, but the collection of this added information would help clarify the role of exposure-related variables such as playing experience and age.

This study also had several strengths, including the sampling methodology and study size. Additionally, the use of multivariable techniques in examining several potential risk factors, as well as the additional focus on severe injuries, provides novel information beyond the contribution of the large number of descriptive high school football injury studies. By simultaneously controlling for several risk factors, we identified specific risk factors that were persistent predictors of injury incidence and severity.

The results of this study suggest that having had a prior injury, being older, and increasing years of playing experience are predictors of injury among high school football players and that having coaches with a high skill level may be protective against severe injury. The increased rates of reinjury among athletes in this population with a history of injury emphasize the need to consider improving treatment and rehabilitation and to identify modifiable risk factors to prevent the initial injury.

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