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Risk Factors for Injury in High School Football Players

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Background: Many studies have reported the frequency and types of injuries in high school football players. However, few have assessed the relationship between player characteristics and risk of injury.
Purpose: To describe the epidemiologic characteristics of and risk factors for injury in high school football players and to determine whether players' characteristics could be used to predict subsequent injury.
Study Design: Prospective cohort study.
Methods: This study was part of a 2-year prospective investigation (1998 to 1999) of risk factors for injury in 717 (343 in the 1998 season and 374 in the 1999 season) high school football players in the Oklahoma City, Oklahoma, School District. Player characteristics (playing experience, position, injury history) and physical parameters (body mass index, weight, height, grip strength) were measured at the beginning of each season. Logistic regression analysis was used to determine whether any of the baseline variables were associated with the odds of subsequent injury.
Results: The physical characteristics of players, such as body mass index and strength, were not associated with risk of injury. More playing experience and a history of injury in the previous season were significantly related to increased risk. Linemen were at the highest risk of injury, particularly knee injuries and season-ending injuries.
Conclusions: Future research should focus on decreasing the risk of injury to linemen.

It is estimated that more than one million young men play high school football in the United States each year, and at least 350,000 injuries occur annually,[14,15] of which a large proportion are seen in emergency departments.[1] Attempts have been made over the years to reduce the risk of injury to football players because of the physical, emotional, and financial burden of injuries. Knowledge of the factors contributing to the risk of injury in football is important before successful prevention strategies can be developed.

Many studies have reported the frequency of injuries and examined selected risk factors that affect high school football players.[3,4,6,8,9,12,17,18,20] However, none of these studies have assessed the relationship between the players' physical characteristics and subsequent risk of injury. Our purpose was to describe the epidemiologic characteristics of and risk factors for injury in high school football players in the Oklahoma City, Oklahoma, School District and to determine whether players' characteristics measured before injury could be used to predict subsequent injury.

MATERIALS AND METHODS

This was a 2-year, prospective study (1998 and 1999) of risk factors for injury in high school football players. The study population consisted of 717 (343 in 1998 and 374 in 1999) volunteer male high school football players in grades 9 to 12. The players were from the eight high schools in the Oklahoma City, Oklahoma, School District and ranged in age from 12 to 18 years. A player was eligible to participate in the study if he was on the football team roster and present on the day baseline meas-

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urements were collected at his school. Participation in this study was completely voluntary and was approved by the Institutional Review Board of the University of Oklahoma Health Sciences Center and by the Oklahoma City School District.

Baseline physical measurements were taken, and a brief questionnaire was administered to all participating players before or within the first 4 weeks of the regular football season. Trained interviewers used a standardized questionnaire to collect information from each player, and a single interviewer conducted most (98%) of the interviews. A single observer obtained baseline physical measurements. Practice and game injuries were recorded throughout the season on a standardized injury form that captured basic information about the type of injury and the circumstances in which the injury occurred. Either the football coach or an athletic trainer initiated the injury report. Data on the type and location of the injury were confirmed by the principal investigator through telephone contacts with injured players and their parents. In addition, information was collected at that time on types of treatment and number of days of practice or play missed because of the injury.

Interview Data

The interview included demographic data, information on number of years playing football for a school team (player experience), injury history (defined as a football injury in the previous season that kept the player from at least one game), preseason conditioning (activities performed at least 2 days per week), use of special equipment (such as knee or ankle braces), and other team sports played (for example, basketball or soccer).

Baseline Physical Measurements

Physical measurements obtained from each player included height, weight, and grip strength. The Smedley grip strength dynamometer was used to measure grip strength. The best of three scores was recorded and used in the analysis for each player. Body mass index (BMI) was calculated from the formula BMI = weight (in kilograms)/height (in meters) squared.

Coaching Data

Information about the football coach was also collected with use of a standardized form. These data included years of football-coaching experience, number of coaching support staff, number of conditioning days per week during the regular season, number of full-contact practice days per week, and the average number of hours spent in practice and conditioning per week.

Injury Definition

The outcome of interest in this study was injury, defined as any incident that resulted in a football player missing one or more practices or games or a head injury that resulted in alteration or loss of consciousness and that required the player to leave the practice or game. Analyses were performed on all injuries combined and also separately for specific types (such as fracture) or locations (upper or lower extremity) of injuries. For the 1998 season, either an athletic trainer or the football coach initiated an injury report, whereas in the 1999 season, athletic trainers completed all injury forms based on examination of the athlete. There was some overlap between the two seasons in the athletic trainers. Because of the possibility of differential completeness of reporting in the 2 years, injury rates are reported separately for each year as well as for both years combined.

Whether or not it is appropriate to combine the data for types of analyses other than calculation of rates depends on whether there were differences by year in the types, location, severity, or other characteristics of those injuries that were reported. Thus, before we combined the data for both seasons for the descriptive and risk factor analyses, we compared the injury data from the 1998 season with that from the 1999 season. We also performed multivariate analyses separately for specific types of injuries within each season, as well as including calendar year as a covariate in the combined data to determine whether the variables associated with risk of injury were season-specific. There were no statistically significant differences in the injury data (types, location, severity) or in the risk factors identified within each individual year's data. Therefore, data for the 2 calendar years were combined for all analyses except the calculation of injury rates.

Statistical Analyses

Game and practice injury incidence rates were calculated as the number of injuries divided by the number of athletic exposures. One athletic exposure was defined as a player participating in one game or one practice. Game athletic exposures were calculated by multiplying the total number of players on a team by the number of games in the entire season. Practice athletic exposures were calculated by multiplying the total number of players on a team by the number of practices per week for the entire season. Game and practice athletic exposures were calculated separately for each school and then summed across schools. The relative risk of being injured in a game as compared with a practice was calculated as the ratio of game-to-practice incidence rates.

Statistical analyses were performed with use of the Statistical Analysis System 6.03 edition (SAS Institute, Inc., Cary, North Carolina). The Wilcoxon test was used for comparison of median values when the distributions were not normal, as was the case for many of the variables examined (age, height, weight, BMI, grip strength, experience). The chi-square and Fisher's exact test were used for comparisons of categorical data. Stepwise logistic regression analysis was used as an exploratory technique to determine whether baseline variables were associated with the odds of subsequent injury. Odds ratios (OR) and Wald chi-square 95% confidence intervals were calculated. Only one injury per player was counted in the anal-

ysis even though a player may have sustained more than one injury during the season. Analyses based on the entire team would include some players who played very little and some who had a lot of exposure time. On the other hand, first-string players would, on average, have similar amounts of playing time ("time at risk"). Because actual amount of playing time was not available for each individual player, analyses of first-string players were performed separately in an effort to indirectly control for playing time (exposure potential). A P value <0.05 was used to define statistical significance.

RESULTS

A total of 717 high school football players in the Oklahoma City, Oklahoma, School District participated in this study over a 2-year period. Physical measurements and other data obtained at baseline are presented in Table 1. There was more than a 250-pound difference between the heaviest and the lightest players. Seventeen percent of the players ($N = 120$) wore some sort of special equipment, with knee and ankle braces being the most common. Fifteen percent ($N = 104$) of high school players reported a football injury sustained in the previous season, and most players (82%) stated that they participated in preseason conditioning. The most common preseason conditioning activity was weightlifting, with more players focusing on upper body training than lower body training.

TABLE 1
Baseline Measurements of 717 High School Football Players from the Oklahoma City School District, 1998–1999

Variable	Median	Range
Age (years)	16.5	(13 to 19)
Weight (pounds)	166	(146 to 400)
Height (ft/in)	5'8"	(5'6" to 6'6")
BMI	25	(16 to 57)
Grip strength (kg)	49	(43 to 70)
Playing experience (years)	3.0	(0 to 6)
	N	(%)
Grade		
Ninth	175	(24)
Tenth	228	(32)
Eleventh	180	(25)
Twelfth	151	(21)
Use of special equipment	120	(17)
Type of special equipment		
Knee brace	31	(26)
Ankle brace	47	(39)
Wrist brace	2	(2)
Neck roll	14	(12)
Rib protectors	9	(8)
Other	17	(14)
Football injury last year	104	(15)
Preseason conditioning	586	(82)
Type preseason conditioning		
Weightlifting		
Upper body	477	(81)
Lower body	409	(70)
Sprints	366	(62)
Distance running	264	(45)
Biking	63	(11)
Circuit training	157	(27)
Other	12	(2)

Table 2 shows the practice, game, and combined injury rates for each of the seasons and for both seasons combined. Only one injury per player per incident was considered in calculating these rates. Practice injury rates were similar in 1998 and 1999, but game injury rates were lower in 1998, although not significantly so (note overlapping confidence intervals). The relative risk of injury was approximately 10 times higher in games compared with practices. Some players were injured more than once in a season. The proportion of injured players who sustained more than one injury was 26% in 1998 and 17% in 1999. Significantly more injuries occurred in the month of October (data not shown), which represents the middle of the season for the high school football program.

Among coaches, the median number of years of football coaching experience was 23 (range, 2 to 30 years). The median number of full-contact practices was 1 (range, 1 to 2), the number of practices per week spent on conditioning varied by school from 1 to 3, and the median number of total practice hours per week was 9 (range, 7 to 11 hours). An inverse relationship was observed between coaching experience and overall injury rate, that is, as the number of years of coaching experience increased, the overall school injury rate decreased, although this trend was not statistically significant.

There was a total of 132 injuries in 100 players over the course of two seasons (Table 3). A few players had more than one injury during the season or more than one injury at the time of an incident. All teams practiced and played on grass surfaces. Significantly more injuries occurred in the lower extremity than the upper extremity (62% versus 38%, respectively, $P < 0.05$). Injuries to the ankle and knee accounted for 76% (62 of 82) of the lower extremity injuries. Of the ankle injuries, 31 (86%) were sprains and 5 (14%) were fractures. There was a total of 26 knee injuries over the 2 seasons. Of the knee injuries for which complete information was available, six involved an ACL tear; four, medial collateral ligament tears; and three, meniscal tears (two lateral meniscal injuries and one not specified). There was one patellar fracture and one patellar tendon rupture. The remaining knee injuries were contusions.

The most common upper extremity injuries were to the shoulder and head, together accounting for 42% of the upper extremity injuries. Most of the shoulder injuries were sprains (42%) or dislocations (33%). Nine head injuries were reported during the study. Eight of those injuries were concussions and one was a head contusion without any acute neurologic effects. Seven of the eight concussions occurred in 1999. A physician evaluated 86% of all injuries.

Sprains and strains were the most commonly reported injuries (54%), followed by contusions (17%) and fractures (11%). Most of the fractures involved the ankle. Contact with another player accounted for 64% of the injuries, and noncontact injuries were more common in the 1998 season. Unfortunately, injuries as a result of contact with the ground were not separately captured.

TABLE 2
High School Practice and Game Injury Rates per 1000 Athletic Exposures

Season	Practice rate	Game rate	Relative risk[a]	Overall rate
1998 (95% CI[b])	1.11 (0.6 to 1.7)	10.37 (7.28 to 14.3)	9.34 (5.46 to 16.27)	2.64 (2.3 to 3.3)
1999 (95% CI)	1.54 (1.0 to 2.3)	16.35 (12.2 to 21.4)	10.6 (6.52 to 17.08)	3.93 (3.1 to 4.9)
Overall 95% CI	1.31 (0.9 to 1.7)	13.12 (10.4 to 16.0)	10.01 (6.78 to 16.21)	3.20 (2.7 to 3.8)

[a] Game rate/practice rate.
[b] Confidence interval.

TABLE 3
Characteristics of the 132 Injuries to High School Football Players from the Oklahoma City School District, 1998–1999

Characteristic	*N*	(% of total)
Injury location		
Upper extremities	50	(38)
Head	9	(7)
Neck	8	(6)
Face	2	(2)
Shoulder	12	(9)
Back	5	(4)
Chest/ribs	1	(<1)
Abdomen	0	
Arm (upper and lower)	3	(2)
Wrist	4	(3)
Hand/finger	6	(5)
Lower extremity	82	(62)
Knee	26	(20)
Hip/groin	4	(3)
Leg (upper and lower)	13	(10)
Ankle	36	(27)
Foot/toe	3	(2)
Injury type		
Concussion	8	(6)
Contusion	22	(17)
Dislocation	7	(5)
Fracture	15	(11)
Laceration	1	(<1)
Hyperextension	3	(2)
Nerve injury	5	(4)
Sprain/strain	71	(54)
Condition of injury		
Contact	84	(64)
Noncontact	48	(36)
Severity of injury		
<1 game missed	55	(42)
1 or 2 games missed	64	(48)
≥3 games missed	13	(10)
Injury occasion		
Game	79	(60)
Practice	45	(34)
Scrimmage	8	(6)
Field conditions		
Normal surface	90	(68)
Hard/dry	14	(11)
Unknown	10	(8)
Seen by physician	114	(86)

More injuries occurred during games (60%) than during practices (34%). Of the game injuries, more occurred during the third quarter, but this number was not significantly different from the number of injuries in the other three quarters (data not shown). Approximately 40% of all injuries required a player to miss less than one game. Fourteen of the 132 injuries (11%) occurred on a hard, dry surface, and 10 of these injuries (72%) occurred during the 1998 season. In 1998, the summer and fall were particularly hot and dry and there was little rain, contributing to a very hard field surface.

Table 4 shows the results of the univariate risk factor analysis comparing injured and uninjured football players. In general, injured players were significantly older, bigger, stronger, more experienced, more likely to have sustained an injury the previous season, and more likely to use special equipment than uninjured players. The significantly higher BMI of injured players was a reflection of their greater median weight (188 pounds versus 164 pounds); median height was 5 feet 8 inches in both groups. These differences might simply reflect the fact that stronger and more experienced players had more playing time and thus a greater opportunity for injury; to account for this, analyses were repeated for first-string players only. With the exception of use of special equipment, results were generally similar when amount of playing time was controlled.

For the multivariate analyses, player position was treated as a two-level, categorical variable: the lineman position (offensive and defensive) and all other positions. This grouping was used primarily because it reflects similar player activities within the groupings (such as blocking versus running). Because percent body fat was ascertained with different meters for the two seasons, percent body fat was removed from the multivariate analyses and replaced with BMI. When injured players were compared with uninjured players, a positive injury history and increasing player experience were the only variables significantly related to the risk of any injury (Table 5). When the analysis was restricted to first-string players, the risk of injury was nearly twice as high for linemen compared with players at nonlinemen positions. The risk of injury was also significantly higher in players from school 22 compared with all of the other schools.

For all upper extremity injuries, player experience and coaching experience were both significantly associated with the risk of injury (Table 6). For all lower extremity injuries, increasing grip strength, increasing experience, and linemen positions were associated with risk. Lineman were at a threefold increased risk of knee injury compared with all other positions. Linemen were also at a significantly increased risk of having a season-ending injury compared with players in all other nonlinemen positions. There was a nearly threefold increase in the risk of fractures in players at positions other than linemen, but this was not statistically significant (OR = 2.96, 95% CI = 0.89 to 9.86).

TABLE 4
Comparison of Baseline Measurements in Injured and Uninjured High School Football Players

Variable	Injured (N = 100)	Uninjured (N = 617)	P value
Median age (years)	16.8 (14.6 to 19.2)	16.2 (15.3 to 17.1)	0.02
Median BMI	27.2 (19.0 to 46.7)	24.1 (16.0 to 57.5)	0.001
Median grip strength (kg)	51 (47 to 69)	48 (42 to 70)	0.001
Median experience (years)	3.0 (0 to 6)	2.0 (0 to 6)	0.001
Preseason conditioning (% yes)	94	93	0.83
Injury history (% yes)	29	14	0.001
Other sports (% yes)	79	75	0.53
Special equipment (% yes)	27	16	0.01
First string only			
Variable	Injured (N = 67)	Uninjured (N = 251)	P value
Median age (years)	17.2 (14.9 to 19.2)	17.0 (16.2 to 17.8)	0.24
Median BMI	27.9 (19.0 to 46.7)	25.2 (16.2 to 54.7)	0.04
Median grip strength (kg)	52 (48 to 69)	51 (27 to 70)	0.01
Median experience (years)	4.0 (0 to 6)	4.0 (0 to 6)	0.03
Preseason conditioning (% yes)	99	95	0.32
Injury history (% yes)	31	20	0.002
Other sports (% yes)	81	78	0.87
Special equipment (% yes)	27	22	0.42

TABLE 5
Factors Significantly Associated with Odds of Injury (All Injuries Combined)

Factor	Beta	Standard error	Odds ratio	95% CI[a]
Combined (N = 100)				
Injury history	0.61	0.26	1.83	(1.09 to 3.07)
Experience	0.27	0.07	1.32	(1.14 to 1.52)
First string (N = 67)				
Linemen	0.64	0.31	1.91	(1.04 to 3.51)
Experience	0.28	0.10	1.32	(1.09 to 1.61)
School 22	0.88	0.35	2.41	(1.21 to 4.79)

[a] 95% confidence intervals (CI) that do not include the value 1.0 (indicating equivalent odds) are statistically significant findings at $P \leq 0.05$. Variables in the analysis included age, body mass index, grip strength, school, playing experience, coaching experience, and player position.

TABLE 6
Factors Significantly Associated with Selected Types of Injuries

Injury	Risk factors	Beta	Standard error	Odds ratio	95% CI[a]
Upper extremity (all) (N = 40)	Experience	0.280	0.10	1.32	(1.09 to 1.60)
	Years coaching	0.040	0.02	1.04	(1.01 to 1.07)
Lower extremity (all) (N = 54)	Grip strength	0.042	0.020	1.04	(1.01 to 1.08)
	Experience	0.295	0.094	1.34	(1.12 to 1.61)
	Linemen	0.636	0.320	1.90	(1.01 to 3.53)
Knee ligament (N = 15)	Experience	0.395	0.167	1.48	(1.07 to 2.06)
	Linemen	1.182	0.532	3.26	(1.15 to 9.26)
Season-ending (N = 12)	Linemen	1.269	0.586	3.56	(1.13 to 11.20)

[a] 95% confidence intervals (CI) that do not include the value 1.0 (indicating equivalent odds) are statistically significant findings at $P \leq 0.05$. Variables in the analysis included age, body mass index, grip strength, school, playing experience, coaching experience, and player position.

DISCUSSION

There are many articles in the literature describing the frequency of football injuries in the high school population. Some of these report the number of injuries as the proportion of injuries per 100 players,[16–18] whereas others report the incidence of injury per 1000 playing hours,[6,17] per 1000 athletic exposures,[12,17] or per hour of exposure per athlete.[4] In this study, the injury rate in 1998 was 2.64 per 1000 athletic exposures and for 1999 it was 3.93 per 1000 athletic exposures. The overall injury rate was 3.20 injuries per 1000 athletic exposures, or 16 to 20 injuries per 100 players. This rate is lower than the rate of 8 per 1000 athletic exposures, or 32.1 to 81.1 injuries per 100 players reported in other studies.[10–12,17] One reason for this lower rate may be that less severe injuries were not always reported, or, as mentioned earlier, injuries may have been underreported in 1998. A second reason may be that some players who were measured at baseline, and thus contributed to the denominator of the rate, did not have much playing time and so were at low risk of

injury. Garrick and Requa[5] found that high school football coaches recognize about 45% of practice injuries and 85% of game injuries, suggesting that coaches' reporting is fairly complete for games. Because the primary difference in rates between 1998 and 1999 was in the rate of *game* injuries, it is less likely that coaches' reporting can explain the lower game rate in 1998. In addition, the percentage of injured players in 1998 (16%) and in 1999 (20%) is similar to the proportion of players who reported an injury in the previous season (14% and 19%, 1997 and 1998, respectively), suggesting that the reporting of injuries during the study period was fairly representative of injuries that occurred in the school district and that, in fact, rates may have been truly lower in 1998.

Few studies of high school players have reported injury rates separately for games and practices. In a cohort study assessing the frequency of football injuries in approximately 100 high schools in Texas between the years 1995 and 1997, the practice injury rate was 5.3 injuries per 1000 athletic exposures and the game rate was 26.4 injuries per 1000 athletic exposures.[17] These are considerably higher than the practice and game injury rates reported in this study. In the present study, the relative risk of injury in games compared with practices was about 10-fold, which was two times higher than that reported by Powell and Barber-Foss[17] but similar to what is reported for college football.[13,23]

To our knowledge, this is the first study that has assessed the relationship between baseline physical characteristics and personal history and the risk of injury of high school football players. In general, univariate analyses indicated that injured players were significantly older, stronger, bigger, more experienced, more likely to have sustained an injury the previous season, and more likely to use special equipment compared with uninjured players. These results were observed even when the analyses were restricted to first-string players, in an attempt to control for "at risk" time. Most of these variables were not significantly associated with the risk of injury once they were considered simultaneously in multivariate analyses.

One variable was consistently associated with the risk of injury regardless of whether the analyses were done including all injuries combined or only for specific types of injuries. Overall, increasing playing experience was consistently associated with the risk of injury. This finding was also observed in a previous study of middle school football players.[21] The idea that increasing football experience is associated with an increased risk of injury has not been reported elsewhere. This association seems counterintuitive because an experienced player should be more familiar with appropriate football techniques (such as tackling or blocking) than less-experienced players, and, therefore, more experienced players would be expected to be less likely to get injured. On the other hand, increasing experience might be related to increased risk of injury through repetitive, cumulative trauma, either resulting from continuous contact (tackling or blocking) or noncontact conditions such as running and cutting on uneven field surfaces. It may also simply be that the more experienced players play more of the game and thus have a greater opportunity to be injured. We tried to deal with this indirectly by examining risk factors only among first-string players, but this approach may not have been entirely successful in controlling for exposure time.

In this study, the proportions of sprains/strains, contusions, and fractures were similar to those reported in other studies of high school football players.[3,9] The greater frequency of lower extremity injuries compared with upper extremity injuries, as well as the higher frequency of game injuries compared with practice injuries has been previously reported.[12]

Mueller et al.[12] reported in 1997 that injury to the knee is the most common type of lower extremity injury, followed by injury to the ankle. In this study, the ankle was the most common injury location (27%), followed by the knee (20%). Environmental conditions in 1998 may have increased the risk of ankle injuries in that year because the summer was particularly hot, with one of the lowest accumulated rainfall seasons on record. Water conservation restrictions limited the watering of football fields, and this made the field surfaces very hard. These hard surfaces may explain the somewhat high proportion of noncontact injuries as well as of ankle injuries (fractures and sprains) in 1998 compared with 1999 (data not shown). These differences by year in frequency of lower extremity injury were also observed for middle school football players in the same school district over the same time period.[21]

The previously reported proportions of injuries to the knee ranged from 5.5% to 36.5%.[19] In the present study, knee injuries accounted for 20% of all injuries. The fact that knee injuries were more common in offensive and defensive linemen compared with other positions is also in agreement with other studies of high school football players.[4,12,19] In the present study, the odds of a lineman sustaining a knee injury were three times greater than the risk in players at nonlinemen positions. Furthermore, linemen had a threefold increase in the odds of sustaining a season-ending injury compared with nonlinemen. The increased risk of injury for linemen was observed even after controlling for BMI, lower extremity weightlifting, grip strength, age, coaching experience, school, injury history, and race.

Weightlifting is known to strengthen tissue, including muscles, bones, ligaments, and tendons.[22] In this study, there was no association between lower extremity weightlifting and lower extremity injuries. However, when the analysis was restricted to knee ligament injuries, there was a reduced risk of injury (27%), but this did not reach statistical significance. This finding is consistent with that of another study,[2] which reported a decrease in the number of knee injuries in high school football players who participated in a preseason conditioning program.

In 1999, concussions accounted for 9% of all injuries, a percentage that is higher than that reported by Guskiewicz et al.[7] In these data, coaching experience was the only variable that was significantly associated with the risk of concussion. For every 1-year increase in coaching experience, the risk of concussion increased by 13%. The reason for this observed association is unclear. While it may represent a true difference in risk, it may also be

simply a chance observation or a result of more experienced coaches better recognizing subtler signs of concussion in their players.

There are several limitations of the present study. First, reports of injuries in 1998 were initiated primarily by coaches. They were not responsible for identifying the type or mechanism of injury, just for informing the principal investigator that an injury had occurred. Coaches were contacted at the beginning of every week to collect injury reports. Most of the coaches were cooperative and clearly interested in reducing the risk of injury to players. However, some injuries probably were unrecognized by coaches, particularly injuries that occurred during practices. Injured players who were contacted by telephone in the first season were asked to provide the names of any other players on their team who sustained an injury. This technique identified additional injuries in the 1998 season that were not initially reported by coaches. For the second season, athletic trainers recorded all injuries. Players were again asked to supply the names of other players who sustained an injury as an additional method to ascertain all injuries, but this approach did not yield as many additional cases as it had in 1998.

Although this study was sufficiently large to identify important risk factors for injury as a whole, it was not large enough to examine associations with specific types of injuries, other than to the knee or ankle. It is assumed that factors that contribute to risk of injury will likely vary by location and type of injury. Thus, future studies should be designed to investigate more homogeneous groups of injuries.

"Missed games" was not an adequate surrogate for severity of injury because some injuries occurred at the end of the football season. By definition, players who were injured toward the end of the season only missed one or two games even if their injury was severe. This is unfortunate, since some of these later injuries (such as fractures) were severe enough that the player would have missed the remainder of the season regardless of when in the season the injury occurred.

In conclusion, the physical characteristics of players, such as BMI and strength, were poor predictors of injury in this study of high school football players. Furthermore, the physical characteristics assessed in the present study were generally not good predictors of specific types of injuries or injuries to players at specific positions. The best predictor of injury in this study was playing experience. Increasing football experience was associated with a 40% to 60% increase in risk of injury for every 1-year increase in experience. Linemen were at the highest risk of injury, particularly for knee injuries. Further research should thus focus on decreasing the risk of injury to linemen since linemen were at the highest risk of injury and were also more likely to sustain a season-ending injury than players at other positions.

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