Authors:

Eric D. Zemper, PhD

Affiliations:

From Exercise Research Associates, Ann Arbor, Michigan; and the Department of Physical Medicine and Rehabilitation, University of Michigan, Ann Arbor, Michigan.

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Correspondence:

All correspondence and requests for reprints should be addressed to Eric D. Zemper, PhD, Department of Physical Medicine and Rehabilitation, University of Michigan Health System, 1500 East Medical Center Drive, D4100 MPB, Ann Arbor, MI 48109.

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Research Article

Two-Year Prospective Study of Relative Risk of a Second Cerebral Concussion

ABSTRACT

Zemper ED: Two-year prospective study of relative risk of a second cerebral concussion. *Am J Phys Med Rehabil* 2003;82:653–659.

Objective: To prospectively measure the relative risk of cerebral concussion among those with a history of concussion compared with those having no previous concussions by using a population of high school and college football players.

Design: A representative national sample of high school and college football players was followed for two football seasons over a 2-yr period (1997–1998) as part of a national football injury surveillance project. There were a total of 15,304 player-seasons and over 1 million athlete-exposures to the possibility of injury in practices and games; 975 of the player-seasons (6.4%) had a history of concussion in the previous 5 yr.

Results: There were 572 concussions recorded, 161 among those with a history (16.5%) and 411 among those with no history (2.9%). Relative risk for individuals with a history of concussion is 5.8 times greater than for individuals with no history (95% confidence interval, 4.8–6.8).

Conclusion: This large prospective cohort study indicates the risk of sustaining a cerebral concussion is nearly six times greater for individuals with a history of concussion than for individuals with no such history.

Key Words: Brain Concussion, Traumatic Brain Injury, Relative Risk, Athletic Injuries, Football

There has been a common presumption for many years that an individual who has incurred a cerebral concussion is at greater risk for sustaining another such injury. However, the relative risk for sustaining a concussion (the ratio of the risk among those with a history of concussion to the risk among those with no history of concussion) has not been adequately defined.[1,2] There have been occasional reports that mention relative risks ranging from three[3,4] to six,[5] but a commonly quoted figure is from a study by Gerberich et al.[6] that found a relative risk of four times higher. However, their study was a retrospective mail survey of high school football players and coaches, which presented methodologic problems, primarily with regard to accuracy of recall of the number and severity of concussive incidents. In addition, whereas other parts of the article dealt with concussive injuries without loss of consciousness, the calculation of relative risk considered only head injuries severe enough to cause loss of consciousness. As noted by others,[7–10] concussion covers a spectrum of signs and symptoms that do not necessarily include loss of consciousness.

The American Academy of Neurology defines a concussion as a traumatically induced alteration in mental status (e.g., confusion, amnesia) that may or may not involve loss of consciousness.[11] A more extensive definition was proposed in 2001 by the Concussion in Sport Group, a committee formed at the first International Symposium on Concussion in Sport, which met in Vienna, Austria, and was organized by the International Hockey Federation, the Federation Internationale de Football Association, and the International Olympic Committee. This group defines concussion as "a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces," and then lists five common features that may be used in defining the nature of a concussive head injury, including that it may or may not involve loss of consciousness.[12] These definitions were developed in an attempt to be more inclusive of what have been recognized as signs and symptoms of milder concussion that were not included in the long-standing definition of cerebral concussion published >35 yr ago by the committee on head injury nomenclature of the Congress of Neurological Surgeons.[13]

With regard to concussion in a sport setting, McCrory et al.[2] questioned whether there truly is an increased risk of concussion for those with a history of concussion. In any collision sport, they presume risk of concussion to be directly proportional to the amount of playing time, and the more time exposed, the more chance for a concussion. Therefore, they propose that the risk of repeat injury may only reflect the cumulative amount of exposure.

There is a need for studies addressing this issue of the existence and magnitude of the relative risk for those with a history of concussion. A prospective study of the general population to define the relative risk of a second concussion would be challenging because the prevalence of this injury is small enough that a large population must be followed for a considerable period of time. In addition, many milder concussions go unreported to and untreated by medical personnel. These difficulties can be avoided by studying a special population with a relatively high risk of concussion compared with the general population and that is under constant observation by medical personnel during participation in this high risk behavior: high school and college football players. Although within the brain the pathophysiology of concussion and thus the intrinsic risk of concussion in these individuals is the same as for the general population, this subpopulation regularly participates in an activity with a higher extrinsic risk for sustaining this injury, providing a convenient "laboratory" for studying the specific question of the intrinsic risk of a second concussion.[14]

As part of a general study of football injuries, data were collected during two fall football seasons (1997–1998) from a large national sample of high school and college football players. For the purpose of further defining the relative risk of a second concussion, specific items of information were included in the data collection process that made it possible to do detailed studies of head injuries in this population. From these data, it is possible to calculate the relative risk of concussion among individuals with a history compared with those with no history of concussion.

METHODS

Football injury data used for this study were collected by the Athletic Injury Monitoring System (AIMS) from a national sample of 56 high schools and 42 colleges for the 1997 season, and 33 high schools and 43 colleges during the 1998 season. The sampling frame for this study was all high schools and colleges in the United States sponsoring the sport of football. Schools were randomly selected within four geographic regions (high school and college) and within three sizes of athletic programs (college) to provide a proportional stratified sample based on geographic region and size of program. The subjects in this study were all individuals playing football at the selected schools during the 1997 and 1998 seasons. AIMS is operated by Exercise Research Associates and is a national sports injury data collection system designed by this author and capable of doing injury surveillance on a variety of sports. AIMS meets the major criteria for reliable studies of sports injury rates outlined in 1987 by the American Orthopaedic Society

for Sports Medicine.[15] Data collected by AIMS previously have been used for published reports on a number of issues in sports medicine, including general injury rates,[16] concussion rates,[17] prophylactic knee braces,[18,19] and football helmets.[5]

The high school and college samples for this study were distributed by four geographic regions, and the college sample also was distributed by size of program (National Collegiate Athletic Association and National Association of Intercollegiate Athletics divisions). Based on geographic region and size of program of NCAA and NAIA members sponsoring football during the period of this study, a χ^2 test of goodness of fit showed no significant difference between the sample distribution and the actual distribution ($\chi^2 = 4.701$, $\alpha = 0.05$, $df = 11$, critical value = 19.675). This indicates the college sample was representative of the entire country by region and size of program, and therefore, the results presented here for the collegiate level can reasonably be projected to the country as a whole.

The nature of the high school sample precludes as rigorously representative a sampling as possible with the colleges. The study protocol required a medically trained person on site (specifically, a certified athletic trainer), and only a relatively small proportion ($\sim$15%) of the >13,000 high schools that sponsor football teams in the country have athletic trainers on staff (compared with essentially all colleges). Very few of the athletic trainers who are working at the high school level are in smaller schools. Under these conditions, the most reasonable approach was to sample a large number of schools (albeit a small proportion of the total), keeping the sample representative by geographic region. The high schools in this sample were statistically representative by geographic region ($\chi^2 = 1.570$, $\alpha = 0.05$, $df = 3$, critical value = 7.815), and with >7000 total player-seasons (one player participating for one football season) over the two seasons, the total high school sample was considered adequate for the purposes of this study.

At the beginning of each season, certified athletic trainers at each participating school completed a form indicating how many players had a history of concussion anytime during the previous 5 yr. This information was based on the known medical history of each player while at the high school or college and on detailed medical histories obtained for each player when they enter a collegiate program. Individuals in the high school and college programs in this study are under continuous medical surveillance while participating in football or any other sport, and their medical records are kept current by the certified athletic trainers from the time they enter the school sports program. Combined with data collected throughout each season from individual injury reports on concussions, which included information on whether the concussed player had a history of concussion, these data allow calculation of relative risk and 95% confidence intervals.

Utilizing simple, easy-to-use forms, data on exposure to the possibility of injury in practices and games, and on any injury that kept a player from participating for 1 day or more (including any head injury, regardless of whether time loss was involved), were returned on a weekly basis throughout each season by the athletic trainers at each participating school. As data arrived each week, it was logged in and screened for completeness and consistency by the author and subsequently entered into the computer database. A common problem with surveillance systems of this sort is incomplete data submission from the field. To prevent this problem in this study, the author maintained frequent mail and telephone contact with the athletic trainers, obtaining corrections of any inconsistencies in the reported data and reminding them to submit missing data. Through this process of "preventive maintenance," the response rate for data submission was extremely high. For the college sample, 99.3% of the weekly reports were submitted, and for the high school sample, the response rate was 98.5% over the two seasons.

This study used the definition of concussion (noted previously) and the grading system for severity of concussion developed by the American Academy of Neurology,[11] the most current schema available at the time of this study. Grade 1 on the American Academy of Neurology scale indicates transient confusion that resolves in <15 min (the "bell ringer"); grade 2 indicates symptoms (transient confusion) that last longer than 15 min, but there is still no loss of consciousness; and grade 3 is used for any concussion involving loss of consciousness.

The AIMS injury surveillance project, from which the data used in this report were derived, received approval from the Exercise Research Associates human subjects review committee as exempt research involving collection of existing publicly available data, documents, or records, with the information recorded in such a manner that subjects cannot be identified directly or through identifiers linked to the subjects.

RESULTS

General. During the two seasons, there were 572 reported concussions in this sample (240 in high school and 332 in college). This injury comprised about 10% of the total reported injuries (Table 1). Approximately 4.1% of the sample population incurred concussions during this study. With an estimated 1.08 million participants in organized football in this country, this projects a total of approximately 44,000 concussions occurring each year for football play-

TABLE 1
Summary of exposure and injury rates for a national sample of high school and college football players, 1997–1998 seasons

	No. of Player-Seasons[a]	No. of Athlete-Exposures[b]	Total Injuries/ 1,000 A-E	Total No. of Concussions	Concussions/ 1,000 A-E
High School	7,197	475,589	4.93	240	0.50
College	8,107	582,659	5.91	332	0.57
Combined	15,304	1,058,248	5.49	572	0.54

[a]A Player-Season is one player participating in one football season. The total number of individual players in this study will be less than this number, because many players were participating in both seasons.

[b]An Athlete-Exposure (A-E) is one player participating in one game or practice, where he is exposed to the possibility of being injured.

ers in this country. This is considerably less than the estimate of 250,000 commonly seen in the literature based on the study by Gerberich et al.,[6] but it does agree with recent, more refined estimates.[20,21]

Injury rates are calculated by AIMS based on total athlete exposures, utilizing the formula:

([number of injuries reported]

÷ [number of exposures]) × 1000

= injury rate per 1000 athlete-exposures

(1)

(An athlete-exposure is one player participating in one game or practice in which the player is exposed to the possibility of being injured.) The concussion rates at the high school and college levels were quite similar, with a rate of 0.50 concussions per 1000 athlete-exposures for high school players and 0.57 per 1000 athlete-exposures for college players. The combined rate is 0.54 concussions per 1000 athlete-exposures. This is equivalent to one concussion in every 1850 times a player participates in a game or practice. For a team of 100 players (generating 100 athlete-exposures in every daily practice and every game, assuming they all played in the game), this would be one concussion in every 18–19 days of activity. A less accurate and less useful "rate" still commonly seen in sports medicine literature is the number of injuries per 100 players. For concussions in this sample, there were 3.33 concussions per 100 high school players per season and 4.10 concussions per 100 college players per season. Although this seems to indicate the rate for college players is over 20% higher, because college players typically have more exposures (practices and games) during a season, the data from this study show the more accurate rates based on athlete-exposures for high school and college players are in reality quite similar. This is one illustration of how attempting to make comparisons using injuries per 100 players as a rate can be misleading.[22]

Relative Risk. From the information collected at the beginning of each season on how many players had a history of concussion, plus data from the individual injury forms indicating whether a concussion being reported occurred in a player with a previous concussion, it is possible to calculate relative risk. A summary of the data used in these calculations is presented in Table 2.

At the high school level, the sample for the calculation of relative risk consisted of 7197 player-seasons. Of those, 296 player-seasons (4.1%) had a history of concussion sometime during the previous 5 yr. There were a total of 240 concussions recorded in this sample, 53 among players with a history of concussion and 187 in

TABLE 2
Summary of concussion history and concussion experience of a national sample of high school and college football players, 1997–1998 seasons

	No. of Team-Seasons	No. of Player-Seasons	No. with Hx	No. with No Hx	Total No. of Conc.	No. of Conc. with Hx	No. of Conc. with No Hx
High school	89	7,197	296	6,901	240	53	187
College	85	8,107	679	7,428	332	108	224
Combined	174	15,304	975	14,329	572	161	411

TABLE 3
Grade of cerebral concussion by history of concussion

Grade[a]	No History (%)	History (%)	Total (%)
1	268 (65.2)	101 (62.7)	369 (64.5)
2	132 (32.1)	52 (32.3)	184 (32.2)
3	11 (2.7)	8 (5.0)	19 (3.3)

History vs. no history comparison: $\chi^2 = 3.338$; $\alpha = 0.05$; $df = 2$; critical value = 5.991.

[a]American Academy of Neurology classification.

players with no history of concussion. Using this information, the relative risk is calculated as follows:

$$\text{Relative risk (high school)} = \frac{(53/296)}{(187/6901)} = \frac{0.1791}{0.0271} = 6.6 \text{ (95\% confidence interval} = 5.0\text{–}8.8) \quad (2)$$

Among those high school players with a history of concussion, 18% sustained a new concussion, and among those with no history, <3% sustained this injury. At the high school level, the relative risk of sustaining a concussion during a given season among individuals with a history of concussion is over six times greater than for those with no history of concussion.

At the college level, the sample for this calculation consisted of 8107 player-seasons. A total of 679 player-seasons from this sample (8.4%) had sustained a concussion within the previous 5 yr. Out of the total of 332 concussions recorded during the two seasons for this sample, 108 occurred in players with a history and 224 occurred in players with no history. The relative risk therefore is calculated as follows:

$$\text{Relative risk (college)} = \frac{(108/679)}{(224/7428)} = \frac{0.1591}{0.0302} = 5.3 \text{ (95\% confidence interval} = 4.3\text{–}6.6) \quad (3)$$

Sixteen percent of college players with a history of concussion sustained a new concussion, whereas 3% of those with no history sustained concussions. At the college level, the relative risk of sustaining a concussion during a given season among those individuals with a history of concussion during the previous 5 yr is more than five times greater than for those with no history of concussion.

Combining the high school and college data results in the following calculation of risk:

$$\text{Relative risk} = \frac{(161/975)}{(411/14329)} = \frac{0.1651}{0.0287} = 5.8 \text{ (95\% confidence interval} = 4.8\text{–}6.8) \quad (4)$$

Therefore, in this large national sample of high school and college football players over two seasons, the risk of sustaining a concussion is 5.8 times greater for individuals with a history of concussion during the previous 5 yr than for those with no history of concussion. From a different perspective, approximately 1 in 35 individuals with no history will sustain a concussion during a given season, whereas approximately one in six with a history will sustain a new concussion.

As shown in Table 3, the distribution of concussions by grade is essentially the same between those with no history and those with a history of concussion ($\chi^2 = 3.338$, $\alpha = 0.05$, $df = 2$, critical value = 5.991). Therefore, a history of concussion does not seem to have a impact on the severity of a new concussion. Because grades 1 and 2 do not involve loss of consciousness, these data also show that >95% of the concussions in this sample did not involve loss of consciousness. To investigate the possibility of player position being associated with greater risk, an analysis of concussions by position played was performed. It showed there were no differences by position between those with a history and those with no history of concussion, with the exception of offensive tackles with a history having significantly fewer than expected concussions and quarterbacks with a history having more than expected (based on the distribution by player position among those with no history of concussion).

DISCUSSION

Cerebral concussion is a common problem that in the past has received little attention from those in the general population or from athletes,[23,24] despite growing concerns in the medical community. Among the concerns is the presumed increased risk for those with a history of concussion. However, the existence and magnitude of this risk have not been adequately defined. The data presented here do indicate there is an increased risk, and the risk is about 5.8 times higher for those with a previous concussion in this sample population of football players. Because this sample included only young male athletes, in the strictest sense, a statistical generalization is not possible to young females or older adults. However, regardless of the extrinsic risk of the activity that causes a concussion (playing football or falling off a chair), within the brain, the pathophysiologic mechanism of concussion presumably will be the same for everyone, including young female individuals and older individuals. Therefore, it should be reasonable to make the logical projection that this increased intrinsic risk of a second concussion will be similar for the

general population as well. These results replicate and extend previously reported results from data collected by this project from a smaller national sample of college football teams during the 1988–90 seasons,[5] which showed a relative risk of 5.95.

McCrory et al.[2] suggested that there may not be an actual increased risk, but it is rather a reflection of cumulative time in risky activity (playing in a contact sport). This can be addressed by looking at the relative risk for high school and collegiate football players. If their suggestion is correct, it would be expected that collegiate players, who have been involved in the sport for a longer period, will have a higher relative risk than high school players. Because the calculated relative risk for the high school players is greater than for collegiate players, these data do not support their premise.

Currently there is a great deal of discussion among sports medicine practitioners regarding when it is appropriate to return an individual to participation in a sport after a concussion, with no complete agreement on specific criteria.[7–11] The results of this study, indicating there is indeed a greater risk of repeat concussions among those who have incurred a concussion, may have an impact on such on-the-field clinical decisions. At the very least, these results should highlight the need for team physicians and athletic trainers to reconsider the common tendency to send a player back in as soon as they can "see straight."

This study did not collect information on the number of previous concussions incurred by those with a history of concussion or when they occurred (other than within the previous 5 yr). Therefore, it is not possible to determine whether there is a dose-response relationship between number of previous concussions, or the time since the previous concussion, and the risk of a new concussion. These are factors that should be investigated in the future.

A study of this nature is dependent on the accuracy of the reported histories of previous concussions. Although the individuals in college programs are under continuous medical surveillance while participating in football and their medical records are presumably accurate, the reported histories of concussion from the high school level could be open to more question. Realistically, at the high school level, the trainers are reporting only what is in the individual's medical record while attending that school and participating in sports; the trainers were not asked to get self-reports from the athletes. If some of these athletes had actual histories of nonsport concussion or concussion during the year or two before entering high school that did not get recorded, they would be counted among those with no history. If such an individual incurred a concussion and it was tallied among those with no history instead of among those with a history, the result would be to artificially raise the numbers of concussions among those with no history and reduce the numbers among those with a history. This results in a calculated relative risk that is lower than it should be. Therefore, the results presented here of a relative risk of 5.8 should be considered a conservative number that is a minimum relative risk.

CONCLUSION

The data presented here from a large prospective cohort study, utilizing a subpopulation of individuals involved in an activity with high extrinsic risk for concussion (football players), indicate that there is an increased intrinsic risk of a second concussion among those with history of concussion during the previous 5 yr. These individuals are 5.8 times more likely to experience a new concussion than those with no history of concussion.

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Announcement

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