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Cerebral Concussion: Causes, Effects, and Risks in Sports

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Objective: To characterize the causes, effects, and risks associated with concussion in sports.

Background: Concussion is an injury associated with sports and is most often identified with boxing, football, ice hockey, and the martial arts. In addition, recent research has shown that concussion occurs in many different sports. In the decade of the 1990s, concussion became a primary issue for discussion among the media, sports sponsors, sports medicine professionals, and athletes.

Description: Concussion is an injury that results from a wide variety of mechanisms and has numerous signs and symptoms that are common to different types of injury. Continued improvement in prevention and management strategies for concussion

requires a strong body of research from a variety of different disciplines. It is essential that research efforts focus on both prevention and management and that researchers and clinicians work closely toward their common goals.

Conclusions/Recommendations: Until the research community is able to provide sound recommendations for the prevention and management of the concussion, the care of the injured player falls squarely on the clinician. It is important for sports medicine professionals to continue to stay up to date on the advances in understanding concussions and how to care individually for each player who sustains a concussion.

Key Words: mild traumatic brain injury, head injury, injury prevention

In today's competitive sports environment, large numbers of athletes participate in a wide variety of youth, high school, collegiate, professional, and recreational sports. Whereas some sports (eg, football) have maintained a consistent number of participants, others have increasing participation.¹ For the younger participants, the sport experience provides an environment in which they can grow and develop physically, mentally, and socially. For college and professional athletes, sports offer an opportunity for personal success and future employment. For recreational athletes, sports provide opportunities for maintaining a healthier lifestyle and an outlet for relieving the tensions of modern life. As sports programs continue to flourish, it is the responsibility of the sponsors of these programs to provide an environment that minimizes the risk of injury.

Risk of injury is inherent in sports participation. This risk stems from the nature of the game and the specific activities of the participants, both during their participation and during events that surround their participation. For example, collision sports such as football and ice hockey characteristically have more acute traumatic injuries than sports such as swimming and track. Boxing has more head-related trauma because of the focus of the sport. Within each sport, a general injury pattern and specific types of injury are unique to the sport. One type of injury that can occur in any sport or physical activity is concussion. This injury represents the most common type of acute brain injury in sports and is most often associated with boxing, football, ice hockey, and martial arts.² As with other types of injury, the frequency and severity of concussion

that is associated with a sport is a function of the nature of the game, specifically, the rules and regulations, the specific physical activities of participants, and the environmental conditions associated with the game.

HISTORICAL PERSPECTIVE

Concussion has been associated with a range of definitions that generally focus on the nature of the medical signs and symptoms present at the time of injury. Concussion has been described as a clinical syndrome characterized by immediate and transient posttraumatic impairment of neural function, such as alteration of consciousness or disturbance of vision or equilibrium, and other signs and symptoms due to brain stem involvement.³ This approach includes the classic "ding" associated with head injury in sports. Some authors have indicated that concussion must be associated with a loss of consciousness, either short term or long term. Concussion has been defined as a "trauma-induced alteration in mental status that may or may not involve a loss of consciousness."^{4,5} If surveyed, the public would probably associate concussion with boxing, football, and ice hockey and would not consider the injury a real problem for other sports. This perception is most likely related to the visibility of boxing, football, and ice hockey at the professional level. The current thinking among sports medicine clinicians is that concussion occurs in all sports but with varying frequencies. In reality, concussions have always been a part of competitive athletics.

The study of Gerberich et al⁶ published in 1983 was one of the first widely cited articles to deal with concussions in high



school football and spanned the years 1978–1982. They found that 20% of the reported injuries in high school football were concussions and that 14% of the high school football players included in their study reported a history of concussion associated with a loss of consciousness. From this work, other authors have projected a frequency of 200 000 concussions per year in high school football. It is important to consider the era for the data collection in this article. In the early 1970s, emphasis was on the use of the head and the face mask as the initial points of contact for blocking and tackling. Risks associated with this technique were documented, and in 1976, the National Federation of State High School Associations Football Rules Committee banned the use of the face mask as the initial point of contact. The players surveyed by Gerberich et al⁶ had participated before the ban. In addition, football players in the 1970s wore a variety of helmets that are no longer in use or manufactured. Therefore, these data may not accurately reflect the magnitude of the problem for today's high school football player.

In the early 1980s, the discussion of concussion took a giant leap forward with the work of Rimel et al⁷ and Barth et al.⁸ Their research efforts identified neuropsychological effects associated with the injury. During the decade that followed, a great deal of discussion flourished among members of the neuroscience community regarding the description, classification, and management of concussions and guidelines for the return to competition after concussion.^{4,5,9–12} As the medical community learned more about the natural history of concussion, the importance of the injury, regardless of the sport, was recognized.

The discussion of concussions related to sports received very little attention until the early 1990s. The media and fans fostered a heightened awareness for sport concussion as they learned of high-profile professional athletes who attributed their retirements to repetitive concussions. Additionally, post-concussion syndrome was identified in players who retired for other reasons in the months and years after their injuries. As a result, the current research concerned with the identification, management, and long-term effects of concussion is adding new and exciting information to the professional body of knowledge required to reduce the risk of injury.

In 1994, the National Athletic Trainers' Association (NATA) Research and Education Foundation conducted the Mild Brain Injury Summit.¹³ The program brought together professionals from neurosurgery, neuropsychology, neurology, sports medicine, and athletic training. The objective was to examine the current knowledge regarding the risk of concussion in sports. Panel members discussed the definition of concussion and the various types of programs designed to provide medical care and management for concussion, examined the status of existing research, and made recommendations for future research.¹³

During the past few years, a plethora of articles, papers, and symposia have discussed the concussion. Much of the discussion has focused on refinements of the grading and management systems identified during the 1980s and early 1990s.^{5,10,14} Many in the medical professions and media have encouraged the use of the consensus practice option identified by the American Academy of Neurology, but there is still no consensus on which concussion grading system is the best.⁴ Another issue that has received much discussion and been the focus of numerous papers and several research projects is the role of neuropsychological screening and follow-up as a tool

for managing concussion. Within the many articles are a number of common points as well as continuing points of disagreement, especially regarding the grading and management of the injury. It is important for us to be able to integrate the new knowledge regarding concussion with the past knowledge to move forward in the area of prevention.

One of the most challenging issues facing medical and paramedical professionals is the identification of concussions. The main problem with identification is the variety of signs and symptoms that may or may not be present. For example, headache, dizziness, nausea, or memory alterations may be symptoms of concussion, or they may be symptoms of other injury. The injury may result in short-term or long-term unconsciousness or no loss of consciousness. The signs and symptoms present at the time of injury may disappear very quickly, or they may linger for long periods. In some rare cases, the initial signs and symptoms may disappear and then reappear with dramatic consequences. Some of the common symptoms result from different types of injury; for example, dizziness may result from brain injury or from vestibular injury (W. Meeuwisse, oral communication, 2000).

Once a concussion has been identified in a player, it warrants professional evaluation by clinicians who are trained and up to date on the management of concussion. Team physicians and athletic trainers must realize that concussions occur in every sport and that, although the injury may have occurred in volleyball, its proper management is just as important as if the concussion had occurred in football.

After the identification and management of concussion, the question of return to participation becomes most important. How long should the athlete wait to return to collision sports? How long should he or she wait to return to noncollision sports? What is the potential for the player to sustain a second concussion? And, does this second injury create more significant damage than the first one? How can the player be sure that the brain has truly "returned to normal"? Current research is focusing directly on the answers to these questions. Until that research is complete, the clinician should treat the players who sustain concussions on an individual basis. Decisions regarding return to play should be based on the signs and symptoms associated with the player's injury and not simply grouped into one of the many current classification and injury management systems. Among the new tools being placed in the hands of clinicians is the ability to compare baseline brain function parameters with the same parameters after a concussion. The research in this area is most promising and will be an asset to the management of concussions.^{15–18}

The sponsors of sports programs have challenges of their own to face. They must design and maintain injury prevention programs that minimize the risk of injury, including concussion. They must take into consideration the nature of the sport and the activities of the players as they make decisions that affect the injury risk pattern. Specific areas that require attention are facilities and equipment, player protective equipment, and competition rules and regulations. Combining and using information from medicine, program sponsors, athletic trainers, coaches, and players is essential to improving player safety.

RESEARCH ISSUES

As concussion became the sports injury "issue" of the 1990s, numerous researchers began projects regarding concussions. It became apparent from the findings of the earlier pro-



jects that a variety of different methods of identifying a concussion exist. Some clinicians described a concussion as a loss of consciousness. Others identified a concussion only if memory problems were associated with the injury. Still other clinicians considered a very minor impact to the head, often called a "ding," to be a concussion. The confusion over the definition created problems for multicenter research programs. To be comfortable with the consistency of data coming from different locations, researchers' projects began to identify mild traumatic brain injury (MTBI) as a synonym for concussion.¹⁹ MTBI represents an injury that meets specific criteria regarding the presence of signs and symptoms, and when these minimum conditions exist, the injury is considered reportable for the research project.¹⁹ In general, the MTBI approach to injury identification encompasses all of the qualities that have been associated with concussion. The use of an operational definition of a reportable MTBI allows researchers and clinicians to begin their analysis from a common reference point for injury.

EPIDEMIOLOGY OF CONCUSSION

Among a wide variety of sports, the potential for concussion is related to the number of opportunities within the sport for activities that produce collisions. For example, in football, the number of collisions involving the head is very high. Some players on the field experience a head impact on every play. In other sports such as ice hockey, impacts with the head are expected but not inherent in the design of the sport. Sports such as tennis and swimming have little potential for collision, although falls on the court or collisions with walls may occur. The frequency of collisions associated with a specific sport is a function of the opportunity for collision to occur within the context of the sport. The number of collisions in a practice or game is directly related to the potential for concussion.

To evaluate the potential for injury, we must have a general understanding of the likelihood that injury will occur. In the case of concussion, the likelihood of injury is a function of the number of times a player's head sustains an impact within the context of participation. These impacts may be incidental (unintentional) and occur as a result of the nature of the game, or they may be impacts that result from intentional acts (eg, fighting). There may be head impacts from objects associated with the game, such as sticks, surfaces, boundary obstructions, or game operations equipment. These impacts may be frequent and considered a part of the game, as in football, or very unusual, as in tennis. The important consideration is that the concussion can occur in any activity, regardless of the nature of the activity, and that when the injury occurs, it has the potential for a lasting effect on the player. Since high school football has the largest number of participants and is most often associated with concussion, an estimate of the number of head impacts would provide perspective on the risk of injury.

CONCUSSION IN HIGH SCHOOL SPORTS

The NATA conducted a study of the frequency, type, and severity of injury in high school football for the 1995 through 1997 seasons. The purpose of the study was to examine the frequency patterns associated with participation in 10 high school sports: football, boys' and girls' basketball, boys' and girls' soccer, wrestling, field hockey, baseball, softball, and girls' volleyball.¹⁹

The subjects in the NATA study were athletes on the varsity sports rosters at the study schools. Athletic trainers certified by the NATA Board of Certification recorded data from 236 high schools over the 3-year study period. Before the project began, the operational definitions and reporting requirements were included in a user's manual and distributed to all data recorders. The definition of *reportable injury* included injuries necessitating removal of athletes from participation for the remainder of the current practice or game or longer. Additionally, all fractures, dental injuries, and MTBIs were reportable, regardless of time lost. Because of the variations in the definition, classification, and management of concussion that exist among the different classification systems, it was important that the study employ a definition for concussion that could be used by all study participants. Rather than ask the athletic trainers to report a "concussion," the study identified a definition for a reportable MTBI. An MTBI represented an event identified by the athletic trainer as an incident that required the cessation of a player's participation for initial observation and evaluation of the injury signs and symptoms before returning to play, either in the current session or subsequent sessions.¹⁹

In the NATA study, data were collected for 23 566 reportable injuries in 3 years, of which 1291 (5.5%) were MTBIs.¹⁹ The injury rates per 100 player-seasons for each sport were 3.66 for football, 1.58 for wrestling, 1.14 for girls' soccer, 0.92 for boys' soccer, 1.04 for girls' basketball, 0.75 for boys' basketball, 0.46 for softball, 0.23 for baseball, 0.46 for field hockey, and 0.14 for volleyball. Among the players with MTBI, 76.1% missed fewer than 8 days, with a median time lost for all MTBIs of 3 days. Rates of MTBI were higher in a game than in a practice for all sports except volleyball.

Based on this study, the rates of MTBI varied among sports, and no sport was without the occurrence of an MTBI. The prevention of MTBI, given its close association with a variety of different types of collisions, may be most successful using interventions aimed at controlling the participation environment. Decision makers in sports safety should focus their prevention efforts on programs that minimize the potential for head impacts from collisions, both intentional and unintentional. The continued cooperation of sports sponsors, researchers, medical professionals, and sports participants is essential to help minimize the risk of concussion.

CONCUSSION PREVENTION

The foundation for developing a sports injury prevention program is that regardless of the preventive steps taken to avert sports injuries, including concussion, some players will continue to be injured. It becomes the task of the injury prevention team to work toward limiting the numbers of injuries by using regulatory controls, educating participants, designing specialized protective products, and monitoring the injury frequency patterns through ongoing surveillance programs.²⁰ First, the program must emphasize prevention by focusing on decisions relevant to the rules and regulations of the games. Continual review of this area allows the governing agency to require that the sport meet the current standards of injury prevention. Second, the coaches must continue to review the up-to-date techniques for teaching appropriate skills that facilitate player performance and, at the same time, provide consistent protection from injury. In addition, coaches need to be sensitive to both general and sport-specific conditioning to properly prepare the



Countermeasures: Concussion in Sports²¹

Factors	Phase		
	Pre-event	Event	Postevent
Host (player)	Preparticipation evaluation of concussion history	Properly designed and maintained player head protection, when appropriate	Recognition and management of players evaluated for concussion
Agent (sport)	Rules and regulations relating to minimizing the risk of injury	Maintenance of standards related to the safety issues for the sport (eg, rule enforcement)	Evaluation of injury incidents to establish procedures for preventing future injury
Environment (ambient conditions)	Playing facilities free of inherent hazards (eg, padded sideline equipment for collision games)	Resources (personnel) immediately available to evaluate and manage the injured	Availability of emergency medical services and medical support for injury management

athletes for the rigors of competition. Continuing investigation of the products that are used to protect players from the inherent hazards associated with the sport should occur. The continued monitoring of the injury patterns associated with sports will go a long way in providing the safety decision makers with up-to-date information regarding the status of injury prevention programs.

The early recognition of concussion provides for the implementation of proper management for even the least severe injury. This early identification and management minimizes the risk of a negative outcome and maximizes the probability of the player's returning to competition without an increased risk of reinjury. The process of monitoring concussion in players should include player-reported symptoms, apparent signs of incomplete recovery, and the development of protocols for assessing brain function (ie, neuropsychological assessment).

A DECISION MODEL FOR PREVENTION

Injuries in sports occur in a specific moment when a wide variety of internal (player-related) and external (sport-related) risk factors converge. To begin the process of developing an injury prevention or injury control program, including programs specifically aimed at concussion, the decision maker must bring order to the variables that exist at the time of injury. William Haddon Jr²¹ developed a model for categorizing some of the complexity and diversity of the variables that exist at the time of an injury. His model addresses the conditions that are present before the injury occurs (pre-event), at the time that the injury occurs (event), and after the injury occurs (postevent).²¹

In Haddon's model, the 3 time phases are coupled with the variables associated with the host (player), agent (sport), and environment (ambient conditions) to produce a matrix for planning intervention strategies.²¹ For example, a model for developing intervention programs for preventing sports concussion might resemble the model shown in the Table. The items in this table represent a general approach to concussion. Because of the varying nature of each sport, a specific approach that considers the qualities and conditions for the sport must be developed.

RECOMMENDATIONS FOR CONCUSSION MANAGEMENT

The management and prevention of concussion have become paramount issues among sports medicine professionals. Until we have a better understanding of exactly what constitutes a concussion, especially regarding the amount of force

associated with specific levels of injury, it is difficult to focus on the most important strategies for preventing the initial injury. We must focus our attention on preventing reinjury by enhancing our management of injured players. Clinicians associated with sports may have a variety of ideas regarding the prevention and management of concussion; the management recommendations identified by the NATA summit¹³ seem to capture the essence of most of the more common ideas:

1. The injured player should be managed as an individual case.
2. Clinicians should familiarize themselves with current standards for the evaluation of concussion on the sideline as well as in the office.
3. Consistent and routine follow-up procedures should be implemented to monitor the individual's progress.
4. Clinicians should provide accurate and consistent information to the patient's "supporters" regarding danger signals associated with concussion.
5. Accurate documentation of the injury event, findings on evaluation, and decisions to return to participation should be encouraged.

Another important area examined by the NATA summit panel members¹³ was the question of the current state of knowledge regarding the research that must be done to better understand the risks of concussion both in the short term and in the long term. The following recommendations provide direction for the research programs associated with concussion:

1. Research requires a multidisciplinary team of professionals. The team represents the neuroscience community, the rehabilitation professions, and sports medicine team physicians and athletic trainers.
2. Important areas for consideration are the effects of multiple injuries and the relative risks associated with continued participation.
3. Emphasis should be placed on developing procedures for acquiring neuropsychological baselines to evaluate the effect of concussion over time.
4. Research efforts that focus on pharmacologic intervention for prevention and management are encouraged.
5. Specific programs must address the recovery time for concussion and its relationship to reinjury and the long-term effects.

SUMMARY

The problem of concussion in sports is one that has moved to the forefront in the past few years. The retirement of high-



profile professional athletes as a result of repetitive concussion and postconcussion syndrome has heightened the awareness of the sports community to the importance of these injuries. The potential for serious effects of brain injury on the individual player's physical and mental status is generally accepted. The ability to provide objective information regarding the exact nature of the effects of concussion, both in the short term and over time, has been lacking. The unpredictability of concussion and the inability to identify cases in the general population have made large-scale research projects impossible. Thus, the focus of research and education regarding brain injury has been centered on the more serious cases. Recently, the research community has begun to implement programs for the in-depth study of concussion in the sports arena. Under these conditions, head injury risks can be identified and patients with concussion can be followed to assess long-term effects. Today's computer technology has made the uniform documentation of injuries among multiple institutions a reality. The ability to coordinate information from multiple sites, multiple professions, and a wide variety of athletes will provide the foundation for developing intervention programs for preventing and managing cases of concussion, both for the athlete and the nonathlete. The potential is bright for the future success of programs that will minimize the risk of concussion and techniques to manage the concussions that continue to occur. The intensity of the light cast depends directly on the continued cooperation of the sponsors of sports programs, the sports medicine community, the coaching community, and the consumers of the sport, the players.

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