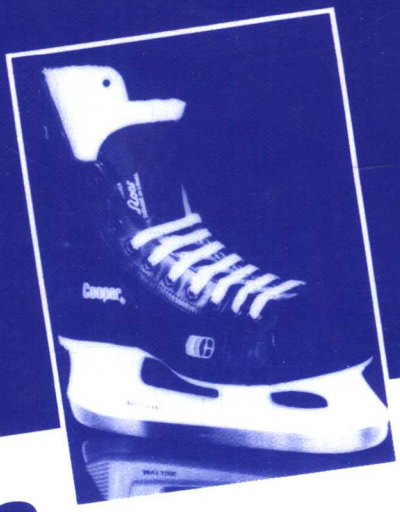

Safety in Ice Hockey

Castaldi/Hoerner, editors

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Each paper published in this volume was evaluated by three peer reviewers. The authors addressed all of the reviewers' comments to the satisfaction of both the technical editor(s) and the ASTM Committee on Publications.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of these peer reviewers. The ASTM Committee on Publications acknowledges with appreciation their dedication and contribution of time and effort on behalf of ASTM.

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Overview

Symposia on safety in the sport of ice hockey are not a recent development. Who organized the first symposium and when may be subjects for debate. In reviewing the extensive reference lists for the papers included in this volume, the editors noted a 1952 publication by E. Mathe entitled "Injuries by Ice Hockey," Sport and Health, Norwegian University of Education, and the State Office for Sport and Youth Work, Oslo, Norway. The wording of the reference suggests the possibility of a seminar or conference. However, since the same author's name is listed in reference to a Conference on Winter Sports, held in Madison, Wisconsin, in 1967, it is tempting to believe that, at some time during that 15-year period, a number of pioneering hockey scientists, including T. Toogood, G. LaCava, G. Nagabods, A. Ryan, E. Hoerner, D. Hayes, E. Mathe, and others whose papers were scattered in various journals, managed to get together for an exchange of views and, more important, to record their views about safety in the game.

There was a recorded presentation at the Wisconsin conference entitled "Protective Equipment in Ice Hockey" by George Nagabods, team physician of the University of Minnesota and later of the 1980 Olympic Gold Medalists, Team U.S.A.; this presentation has a remarkable resemblance to the paper by Clement and Jones on, "Research and Development in Hockey Protective Equipment," which appears in this publication.

The International Ice Hockey Federation included an International Conference on Ice Hockey Injuries in its 1978 meeting in Prague, Czechoslovakia, which included speakers from Canada, Russia, Czechoslovakia, Sweden, and the United States. No doubt there have been numerous other seminars and conferences on hockey safety since that time which our search of the literature did not uncover or, regrettably, for which formal reports were neither prepared nor disseminated.[1] A thorough review of the history of modern hockey science is urgently needed and could be the subject of a thesis by one of the many science-oriented sports therapists now graduating from our universities.

The origins of the symposium on which this publication is based began during the fall of 1986 when Earl Hoerner, president of the Hockey Equipment Certification Council (HECC) of the United States, recognized the need for a conference which would attract international authorities representing ice hockey organizations, academics, health care professionals, and manufacturers of ice hockey equipment, all of whom would be concerned with hockey safety. The fact that authors from Canada, Sweden, and the United States offered to present 25 formal papers ensured the success of the symposium, and more important, made this volume possible.

A concern for safety and the need for hockey standards arose in Canada, Sweden, and the United States soon after hockey injury reports began to appear in the sports literature during the early 1960s. In Canada, the Canadian Standards Association (CSA); in Sweden, the Swedish Ice Hockey Association (SIA); and in the United States, the American Society for Testing and Materials (ASTM) began to address hockey standards. The work at ASTM was carried out by the newly formed ASTM Subcommittee F08.15 on Hockey as part of ASTM's existing Committee F-8 on Sports Equipment and Facilities, which was founded in 1969.

[1] Appreciation is extended to Dr. Allan Ryan, past editor of *The Physician and Sportsmedicine*, who kindly forwarded his entire hockey history file to assist in the preparation of this overview.

CSA, SIA, and ASTM addressed the same major areas of concern, head and facial trauma, and by 1986, three independently developed standards for protective helmets and face guards had been issued. One of the aims of this symposium was to review all existing hockey helmet and face protector standards in an effort to incorporate the most desirable elements of each into an international standard. It is encouraging that the work is in progress under Technical Committee TC83/SC5 of the International Organization for Standardization (ISO).

Cosponsoring the symposium with ASTM was the Hockey Equipment Certification Council (HECC), established in 1978 through the joint efforts of the Amateur Hockey Association of the United States (AHAUS) and a number of interested volunteers from several professional organizations. The purpose of HECC[2] is

> to examine the needs and wishes of the various amateur hockey-governing bodies as they pertain to hockey equipment and safety. HECC seeks out and selects codes and standards, including test methods and other requirements for certifying playing equipment and facilities used in the sport of ice hockey. In addition, HECC promotes the use of certified products and monitors the effectiveness of its certification programs on the sport of ice hockey. It has the responsibility to promote and sponsor research pertaining to prevention and/or reduction of ice hockey injuries. This is accomplished by studying playing rules, attitudes, playing surfaces, officiating, training, conditioning, and administration, among others.

The specific objectives of the symposium were (1) to review and evaluate the effectiveness of factors related to safety, and (2) to determine whether those safety factors could be improved upon to reduce injury rates without, at the same time, adversely affecting the basic nature of the sport. With the exception of head and face trauma, no attempt was made to designate specific areas of concern. Readers may be surprised that catastrophic injuries to the spine, which have increased at an alarming rate in ice hockey since 1975, are represented by only one paper (Bishop and Wells). A conference devoted entirely to that subject had been held earlier in 1987 and insufficient time had elapsed for the accumulation of much additional information.

The subject material, consisting of 25 papers, has been arbitrarily grouped into six categories: epidemiology; rules, officiating, and risk factors; body and knee injuries; playing equipment; playing facilities; and head and face protection. At least one third of the papers could have been included in several of the categories.

Epidemiology

Studies of ice hockey injuries began to appear regularly in sports literature during the early 1970s and led to the introduction of improved protective equipment for the head. As more injury data accumulated, protective equipment for the face was made compulsory for youth players up to the age of 16. Technical standards were introduced to ensure that the protective equipment was safe to use, as well as effective in play. More advanced methods for collecting and evaluating injury information are discussed, and examples are given of the kinds of studies that will identify specific problems more accurately as well as determine the effectiveness of protective equipment and its relative benefits to the sport. The

[2] Rudolph, M., "What is the Hockey Equipment Certification Council?" Amateur Hockey Association of the United States, 2997 Broadmoor Valley Rd., Colorado Springs, CO 80906.

responsibility of organized hockey in the collection and surveillance of injury information is discussed.

Rules, Officiating, and Risk Factors

The methods for the introduction of playing rules concerned with safety are described for United States and Canadian amateur hockey associations. However, the interpretation of such rules by game officials, coaches, equipment personnel, health professionals, and the courts varies widely. Problems involved in the resolution of controversial issues are readily apparent from the views expressed. The high-speed continuous action of the sport and the use of the body as well as the stick for defensive play seem to be almost insurmountable problems for game officials in their efforts to see all the game infractions and judge them fairly. The views of college hockey coaches and those of health professionals and the parents of youth players represent almost opposite ends of the safety spectrum.

This section also includes a description of a governmental agency concerned with the conduct of all sports. Although democratic governments have tended not to interfere with the conduct of amateur sports outside the education system, the increasing costs of health care for the treatment of sports injuries is becoming a concern of the Province of Quebec, Canada, which operates under Canada's national health insurance program. Quebec has set up the Quebec Sports Safety Board (La Régie de la Sécurité dans les Sports du Québec), which has broad powers over the conduct of all sports, amateur as well as professional. It also funds sports research. One of its studies, which is described in the section on body and knee injuries, has led to a rule change banning body checking at the Pee Wee level.

Body and Knee Injuries

Biomechanical studies of a possible relationship between the hockey helmet and spinal cord injuries have revealed no cause-and-effect phenomenon. In head collisions of this type, the head comes to rest before the player's torso does, trapping the neck in between. The neck structures have to absorb the kinetic energy of the torso, and if they are unable to do so, cervical failure results. For helmet padding to be effective in the prevention of cervical spine injuries, it must be capable of uniformly decelerating the head, neck, and torso of the player.

When the age range of Pee Wee hockey players was advanced one year to 12 to 13 in 1985, body checking, which was not previously permitted, was also introduced. A study of two Quebec Pee Wee leagues, one of which did not permit body checking, showed that the league which permitted body checking had a significantly higher injury rate and more penalties judged as "hostile aggression" during regular league and tournament games. Morphological and biomechanical measurements revealed significant differences between a group of smaller and a group of larger Pee Wee players. Whether the increased injury rates were due to the introduction of body checking alone, to the grouping of very small players with very large ones as a result of the age range change, or to a combination of both factors could not be determined. Following these studies in 1986, the Quebec Ice Hockey Federation banned body checking in all Pee Wee leagues, a rule which has remained unchanged up to the present.

Although knee braces are almost always recommended after serious knee injuries, their effectiveness is a controversial issue. A variety of well-known and highly recommended knee braces were tested for their effects on normal function of the knee in hockey players running an obstacle course. All braces were found to have an effect on normal function.

The ultimate goal of this research is the development of a knee brace which has little or no effect on normal function of the knee and which assures optimal protection against knee injuries.

Playing Equipment

This section covers hockey skates, skate blades, ice hockey sticks, and the interrelationship between the design and technical aspects of the manufacture of modern ice hockey protective equipment. Only during the last decade has any great amount of research and development been applied to playing equipment. Hockey skates developed out of combining products of the shoe industry with skate blades, which were used on the frozen ponds and canals of Holland as early as 1900. Those early blades, consisting of a runner supported by a wooden holder, were attached to ordinary walking shoes by leather thongs and are still produced and used in the Netherlands today. They were succeeded by the reliable, solid steel blade, and later by the tubular metal blade, with its low breakage rate and effective safety design. These designs were succeeded by today's popular blades, which consist of a runner supported by a light, but fracture-prone and potentially hazardous, plastic holder. A review of the technology of metal processing, the heat treatment of metals, and the molding of modern polymer plastics provides the reader with an understanding of why blade breakage occurs and how it is possible to assure the user of safer and better quality products. A description of the ASTM Performance Specification for Ice Hockey Skate Blades (F 737-86) is included, as well as why its adoption by hockey organizations would benefit players' safety and convenience.

Until recently, hockey skate boots were developed mostly by trial and error methodology. Unsupported claims were made for the relative skating merits of the so-called stitched boot and the modern, molded plastic boot. Biomechanical studies show that there is no significant difference in the skating characteristics of either type of boot and studies are now under way to design boots which compliment the kinematics of the skating motion. Studies of the protection from injury aspects of hockey boots are long overdue, and anything that can be done to relieve the discomfort of breaking in new boots or the excruciating pain of puck impacts will be well appreciated. A fruitful area of research may be the determination of what combination of boot and blade is the most desirable for skating performance. It is of interest that W. Gretzky and M. Lemieux, considered to be North America's two most prominent professional players, use blades different from those generally recommended by their boot manufacturers.

A description of modern hockey sticks and their evolution from all wood construction to the incorporation of various plastic materials for added strength is included. There is also a review of biomechanical studies of the wrist shot and the slap shot. The potential for greater injury from metal shafted sticks is discussed. A history of the evolution of ice hockey equipment manufacturing from what was essentially a cloth and leather craft to a modern, high-technology industry will serve as a valuable contribution to the sport. The difficulties involved in trying to match an attractive design with effective protection from injury challenge the producer and require highly trained, imaginative, and technically competent design teams, all of which increase the research and development costs.

Playing Facilities

This section describes indoor and outdoor playing facilities. There is great variation in the design and dimensions of indoor facilities. European and North American facilities are compared. While specific dimensions are required for Olympic competition, size and

design requirements are only *recommended* for North American competition. Game officials claim that certain rink designs actually complicate the officiating of games. The design and size of a rink is believed to affect the type of play that occurs and the injury experience of the players, but reliable evidence is not available. Standardization of indoor playing facilities is recommended, not only to reduce hazards to players, officials, and spectators, but equally important, to standardize game conditions. Recommendations are made for the maintenance of outdoor natural ice facilities to reduce the possibility of injury to skaters.

Head and Face Protection

This section includes the history and evolution of the Canadian, the Swedish, and the United States standards for ice hockey helmets and full face protectors. Descriptions of the application of biomechanics and mathematics and the use of modern electronic equipment to simulate the impacts of game conditions emphasize the complexity of modern testing of protective equipment for the head and face. Studies of the protective characteristics of the half face, clear plastic shield reveal that it will not provide the same degree of effective protection for face injuries as the full face protector.

The views expressed are those of the authors of the various papers, and while readers may not agree with the experimental methods or the conclusions drawn, such disagreements will undoubtedly foster additional studies, ultimately to the benefit of the sport. It is the resolution of differing views, as well as new findings, which form the basis of ASTM's consensus standards philosophy and its review process.

Among the important areas not included in this volume are conditioning programs, physiology, nutrition, coaching techniques, psychological factors, improved injury protection for goalkeepers, the unresolved problem of severe shoulder injuries, and funding to support research. These areas deserve attention and are prime subjects for future symposia.

It is the editors' hope that the publication of this volume will serve as a significant catalyst for stimulating the scientific aspects of ice hockey which will promote safety and improve hockey skills through better equipment and facilities, while maintaining the basic nature of the sport.

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Epidemiology

Kenneth S. Clarke[1]

The Critical Role of Epidemiological Studies in Assessing the Frequence and Causative Factors in Sports-Related Injuries

REFERENCE: Clarke, K. S., **"The Critical Role of Epidemiological Studies in Assessing the Frequence and Causative Factors in Sports-Related Injuries,"** *Safety in Ice Hockey, ASTM STP 1050,* C. R. Castaldi and E. F. Hoerner, Eds., American Society for Testing and Materials, Philadelphia, 1989, pp. 9–13.

ABSTRACT: "Calculated risk," as a concept, champions the premise that the benefits of sport both cause and justify the risks of sport. Calculated risk, however, need not be only a concept but a measure that can be derived from a valid epidemiological data base. Such a data base requires the presence of a central registry of uniformly and continuously submitted information concerning whatever injuries are experienced in the sport, whatever scenario data are associated with the injury's onset, and whatever exposure data are associated with those programs and products that are followed by the central registry. Such a central registry would enable hockey leadership to have an inventory of what is being experienced, an evaluation of the need and significance of suggested changes in the sport, an awareness of the change in injury patterns when rules or other practices are modified, and a base for rebuttal or reinforcement of safety concepts circulating within hockey circles.

KEY WORDS: ice hockey, sports injuries, epidemiology, hockey injuries

The only ways to solve the injury problem in a sport are to eliminate the sport, eliminate plaintiff attorneys, or eliminate the attitude that sports injury data are either unnecessary, undesirable, or easily obtained. My role here is to pursue the third of these choices as a preface to the papers that follow—they represent the hockey expertise that exists in the United States and Canada—through the concept of the calculated risk in sport.

"Calculated Risk," as a concept, champions the premise that the benefits of sport both cause and justify the risks of sport. Calculated risk, however, need not be only a concept but a measure that can be derived from a hard data base. By a hard data base, I mean a repository of uniformly submitted data that are representative, descriptive, and meaningful in context and that adhere to the premises of an appropriate statistical design. Hard data brings objectivity to the issues at hand, and if continuous can bring perspective as well.

There already are hard data, for example, on the spinal cord injury problem in hockey, which in epidemiological terms demonstrate a remote risk to the individual athlete but now a persistent risk within the sport. There already are hard data which in epidemiological terms demonstrate that rules can have different effects on different subpopulations in hockey, especially at an age level of mixed maturities. There already are hard data that

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demonstrate the patho-biomechanics of the cervical spine injury that in turn explains and clarifies the mechanism of injury in the context of hockey. And there already are hard data that demonstrate that engineers have made dentists and ophthalmologists who love hockey able to continue to do so.

Yet, hard data has come incidentally, from isolated attacks at a void, by the good fortune of various altruistic people with the foresight, insight, expertise, and resources to collect these data. Incidental data, however, typically is provincial and short-term in meaningfulness. The spinal injury picture in hockey, for illustration, would be much different if one looked only at data from Ontario versus that of Quebec, or if surveillance had stopped in 1975 because no spinal cord injuries were recorded.

The profound love affair within sport for continuous hard data on athlete *performance* has never been extended to the need for continuous surveillance of significant injury patterns in hockey (or virtually any sport). Murphy's Law, unfortunately, remains a subject for jokes, not sports science.

Why an Ongoing Surveillance System?

Housekeeping or Inventory

Those responsible for hockey need to know what actually is going on, both to make informed decisions and to rebut unsubstantiated claims and receommendations. Was "it" an isolated incident or one of a series of similar incidents? Was it associated with a random combination of factors or reflective of a pattern of contributing factors?

The parallel between spinal cord injuries in hockey and American football is striking. Until the mid-1970s, hockey did not experience this injury. Now that it is recognized, perhaps the most common recommendation is to remove the protective headgear that permits a style of play that increased the athletes' exposure to head and neck injury. Football has gone through the same misdirected response to the problem. Until the mid-1960s, football did not know if it was experiencing spinal cord injury; all of its attention was to brain injury and thereby better helmets. By the early 1970s, this injury became recognized, and the most common recommendation was indeed to remove the improved headgear. Further, more sophisticated "solutions" were delaying effective remedial actions by focusing attention on "spearing" (while the vast majority of football quadriplegics came from unintentional spearing), on spearing causing injury to the opponent (while even unintentional spearing led to serious injury of the spearer, not the speared), and on the "karate chop" back of helmet impingement on the spine as the mechanism of cervical injury from spearing (while the back of the helmet cannot impinge at the C_6 level).

Improvement

If one knows what's going on, one can improve the conduct of the sport by pinpointing effective safety countermeasures from clues of patterns revealed by data analysis. Unfortunately for the critical readers of safety articles, safety countermeasures are usually found only in the summary at the end of the article, but not among the data that clarified the problem. Sincerity and "common sense" are not substitutes for curiosity and discipline in the examination of that curiosity.

Back to the football parallel, the principal honorable method of blocking and tackling by the end of the 1960s was "face into the numbers," with head up, eyes forward, and neck bulled. By the mid-1970s, hard data became available that demonstrated that the incidence of quadriplegia in organized football was at least 30 per year out of about 1.3 million at

risk. If the mechanism were as simply determined as the karate chop, 30 would have been much too small a number. With a calculated 2 billion helmet contacts a season in American football, and the face up posture being the football position at contact, the karate chop should have produced thousands of cervical injuries. Some other explanation for these relatively small but persistent occurrences was needed.

Evaluation

When one does something for someone (to improve the situation), one must do something *to* them. Surveillance of sports injuries permits evaluation of the outcome to see if the countermeasure indeed worked.

On the flip side, one must be just as curious to see if the "solution" caused other problems.

In 1976, both high school and college football rules changes to make it illegal (and unethical) to teach "face into the numbers" as a blocking or tackling technique. It was not that this technique caused quadriplegia. By this time, the mechanism called "axial loading" was revealed as the culprit: with the chin slightly tucked, the cervical spine straightens; if one hits the opponent with the crown of the helmet in the same axis of the cervical spine (that is, "spears"), the straight spine cannot tolerate the load and "buckles," usually disrupting the spinal cord. Striking the opponent with "face into the numbers" did not break necks; it was the attempt to do so but without proper execution (for example, the player being off balance or flinching) that produced the *inadvertent* spearing posture and quadriplegia. By forcing coaches and athletes to practice blocking and tackling with the brunt of the impact on the shoulder, chest, and side of head, improper execution at impact would no longer put the athlete in such a vulnerable position. The quadriplegia frequency in 1977 was only 12, a substantive drop from the preceding 30 per year, with no other change to account for it, and the incidence has not only maintained that lower frequency level but is settling in now at a 5 to 7 a year plateau.

Going back to the flip-side concern, the alternative to quadriplegia was thought to be brachial plexus injuries caused by blows to the side of the head that either stretch or impact upon the brachial plexus at the neck. Fortunately, the National Athletic Injury Surveillance System at Penn State University was following nearly 100 schools and colleges during the 1975–77 football seasons and found no increase in brachial plexus injuries when the rules changed to lower the rate of quadriplegia. While the trade-off to brachial plexus injuries was preferred over quadriplegia, it was demonstrated that football did not, in this instance, have to accept a lesser problem to solve its major problem.

Reinforcement

The last "why" of continuous injury surveillance is to have the ammunition to reinforce through rule, standard, education, or all three, the countermeasures that were evaluated as effective. Old habits and opinions change with great difficulty. Without hard data, the challenge is great. Without capitalizing on the the hard data, the challenge is not faced.

In football, the dramatic success of the rule changes led to a National Collegiate Athletic Association (NCAA) "shared responsibility" statement that gave the coach the information to tell the athletes why the blocking and tackling techniques were changed, why the helmets have a National Operating Committee for Safety of Athletic Equipment (NOCSAE) seal, and so forth, and thereby the why and the what of the athlete's share of responsibility in minimizing the potential for spinal cord injury in football. Equally important, coaches began to ask for advice on how to teach techniques to help an athlete who