Children's winter sports injuries & protective equipment: a surveillance system based study

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Abstract

Sports injuries that could be prevented by protective equipment are a serious cause of morbidity among children. The objectives of this study were to: determine the frequency of protective equipment use among children participating in winter sports, identify the reasons for non-use of equipment, explore whether an injury prompted an intended change in the use of protective equipment, and compare an open-ended and a categorical method for collecting data on sports injuries. Data was collected about children who visited the emergency rooms of the Montreal Children's Hospital and L'Hôpital Ste. Justine, from the Canadian Hospitals Injury Reporting and Prevention Program, and from a follow-up telephone interview. There were 691 injuries. Protective equipment was used in 2% of sledding injuries, 6% basketball, 11% snowboarding, 29% skiing, 40% ice skating, and 75% ice hockey. With regards to intended use of protective equipment, 40% of respondents stated they will not require its use and 5% will no longer permit participation in the sport.

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Résumé

Les blessures reliées aux sports qui pourraient être prévenues par l'équipement de protection sont une des plus importantes causes de morbidité chez les enfants. Les objectifs de cette étude sont de: déterminer la fréquence de l'emploi de l'équipement de protection chez les enfants qui participent aux sports d'hiver, identifier les raisons pour lesquelles l'équipement de protection n'est pas utilisé, déterminer si une blessure a incité un changement intentionnel dans l'utilisation d'équipement de protection, et comparer un méthode non-déterminé avec un méthode catégorique pour ramasser l'information sur les blessures reliées aux sports. L'information sur les enfants qui ont visité les salles d'urgence de l'Hôpital de Montréal pour Enfants et l'Hôpital St. Justine a été ramassé en utilisant le Système Canadien Hospitalier d'Information et de Recherche en Prévention des Traumatismes (SCHIRPT) et en rappelant les parents d'enfants blessés. Il y avait 691 blessures. De l'équipement de protection a été utilisé dans 2% des cas de blessures de glissade sur traîneau, dans 6% de basket-ball, dans 11 de planche à neige, dans 29% de ski alpin, dans 40% de patin sur glace, et dans 75 de hockey sur glace. Par rapport à l'intention d'utiliser de l'équipement de protection, 40% des parents ont déclaré que leurs enfants n'avaient pas besoin d'utiliser cet équipement et 5% ont décidé de ne plus permettre leurs enfants de participer dans le sport.

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1 INTRODUCTION

Sports and recreational activities impart numerous benefits to children and adolescents: improved fitness, increased motor development, and interaction with other children and adults. However, with more children than ever involved in sports, there has recently been a surge in the number of pediatric sports injuries. Gallagher et al., in a surveillance system based analysis, found that participation in sports was the most common cause of injury among 13- to 19-year olds.[40] Similarly, in its first year of data collection, one-fourth of all injuries reported by the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP) were sports-related.[38] Because children's sports injuries are associated with a high fracture rate-- that requires the cost of both treatment and follow-up--, sports injuries are also the second largest health care expenditure for injuries.[6]

Many of these childhood injuries could be averted by the use of protective equipment. For instance, although bicycle helmets have been found to reduce the incidence of head injury by 85% and brain injury by 88%[125, 128], children are less likely to wear helmets than adults and, consequently, suffer a disproportionate number of head injuries.[30, 133, 134] In one year of data collection, the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP) recorded over 9000 sports-related injuries for children aged 5-19 with only 7% reporting the use of any protective equipment (PE).[38]

The recognition of the preventability of sports injuries lead the World Health Organization to launch a coordinated research project, "Sport for All: Sports Injuries and Their Prevention" to improve on the current understanding of these injuries and to encourage the development of prevention strategies grounded in a scientific framework.[130]

Because of the recently recognized role that protective sports equipment can play in preventing sports injury, there is increasing interest in understanding the determinants and frequency of PE use. Indeed, if its use is better understood, appropriately tailored prevention interventions can be provided to the population. However, there is little research either on the methodology of collecting information on protective equipment or on the descriptive characteristics of PE users.[3, 5, 15, 37,77,90,118,120] Although several studies have been conducted on bicycle helmets[124,125,128] and rollerblading equipment[36,114,126,135], studies are scarce on PE use in other sports and recreational activities; this is especially true for winter sports and activities (See Appendix 2).

Injury surveillance -- the ongoing collection of data describing the occurrence of, and factors associated with, injuries has been viewed as an effective way to study injury in general, and sports injury in particular. Sports medicine specialists have recently called upon the academic community to help in designing, or improving, sports injury surveillance systems that deal not only with elite level participants but also with novice and recreational participants, the latter who are often neglected in sports injury studies.[63,130] The present report describes a series of studies on protective equipment use during winter sports and recreational activities based on data collected by the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP), hereafter.

CHIRPP is an emergency room based surveillance system organized by the

Laboratory Centre for Disease Control in Ottawa, Canada. The CHIRPP database was not designed solely to collect data on sports injuries, but it is, nevertheless, a critical resource for sports injury epidemiologists because it specifically gleans information on several patient variables associated with sports injuries. These include: what the child was doing when the injury occurred, what went wrong, and what safety devices were in use at the time of injury.

This thesis addresses three major issues in the field of protective equipment and sports injury epidemiology: how should we collect data on sports equipment, who is wearing equipment, and why? To this end, four studies were conducted:

Study one explored whether the free-field safety equipment question on the CHIRPP form was reliable when compared with a follow-up phone call.

Study two explored whether a free-field question or closed-ended questions is more appropriate for obtaining information on safety equipment.

Study three described injuries commonly associated with winter sports: an attempt was made to estimate the use of equipment by children injured while participating in winter sports and to describe the characteristics of non-users of PE by age, sex, and ownership of equipment.

Study four examined whether a sports-related injury prompted a change in reported behavior with regards to the use of safety equipment during future sporting activities.

2 BACKGROUND & LITERATURE REVIEW

This section reviews literature germane to the study of children's sports injuries with an emphasis on surveillance system research. Section one describes the methodology used in selecting appropriate literature; section two presents a historical perspective of injury surveillance systems and highlights both the benefits and deficits of this modality of study design: section three provides insight into studies that have been conducted on PE and section four examines the unique perspective that must be considered when discussing children and PE.

2.1 METHODS OF LITERATURE REVIEW

A computer search of the bibliographic databases of MEDLINE (1981-onwards), Social Sciences Index (1984-onwards), and Applied Science and Technology (1983-onwards) were used to identify relevant publications. Keyword headings included pediatric or children's sports injuries, injury surveillance, safety or protective equipment, eye guard or protector, helmet, elbow pads, knee pads, wrist guards, ice hockey, basketball, skiing, sledding, snowboarding, ice skating, and ringuette. Only English publications were used, and all articles -- including, review articles, editorials, and original publications -- were considered. Numerous papers that pertained to children's sports injuries in general could not be included in this review. Rather, only those articles that provided information relevant to protective equipment were included.

2.2 INJURY SURVEILLANCE SYSTEMS

In the industrialized world, injuries are recognized as the leading cause of mortality and morbidity among children, and they have been identified as the principal reason for potential years of life lost.[74] Despite the significant impact of injury, the study of injuries, in general, and injury prevention, in particular, is still on the periphery of public health. With most countries lacking systems to monitor injuries, the causes of injuries have not been effectively delineated[71] and, consequently, efforts to eliminate injury over the last few decades have typically been unsuccessful.[67] Recently, injury surveillance has emerged as a potential modality for understanding the antecedents of injury and as a possible method for decreasing incidence. England, New Zealand, the USA, and Canada have all undertaken the organization of surveillance systems to monitor injuries.

The Necessity of Injury Surveillance

For the past several decades, injury has been identified as the leading cause of death among individuals between 1 and 35 years.[67] In 1993, 60% of deaths among Canadian children were caused by injury. Among pre-school children choking is the most common cause of death while among other age groups it is motor vehicle fatalities. Despite a lack of comprehensive or complete information on the frequency of morbidity due to injuries, data that do exist indicate that injury is a leading cause of morbidity.[51] Although injuries are a paramount public health problem, there is a common misperception among health care workers, policy-makers, and the general population that injuries are accidents -- that is, inevitable and unforeseeable events and therefore not amenable to prevention. As Gordon, the forefather of injury epidemiology remarked: "It is not so generally appreciated that injuries, as distinguished from disease, are equally susceptible to the epidemiological approach".[47] Moreover, even when epidemiological studies confirm the effectiveness of an injury prevention initiative, politicians who view personal freedom as a pre-eminent value often oppose legislation designed to reduce injury.

In the 1940s, injuries were described as non-random events that could be examined using the infectious disease framework of host, agent, and environment.[47] Although in 1966 the National Academy of the Sciences recognized the continued subordinate position of injury research compared to other health problems, it accurately conceded that injury was "the neglected disease" of modern society. In the 1970s, Haddon provided a framework to study injury prevention and developed various strategies to reduce injury, including decreasing the amount of hazard or preventing creation of hazards.[51] In epidemiological terms, these schemes are often equivalent to reducing exposure to injury risk factors. With the advent of computers and the successes of surveillance programs for the control of infectious disease, surveillance systems have been identified as an important part of the process for lessening the burden of injury.

Surveillance, as defined by the Centre for Disease Control (CDC) is "the ongoing systematic collection, analysis, and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know. The final link in the surveillance chain is the application of these data to prevention and control. A surveillance program includes a functional capacity for data collection, analysis, and dissemination linked to public health programs".[18] The initial impetus for health surveillance was the control of communicable diseases, including cholera, smallpox, and yellow fever. The utility of surveillance has now been extended beyond infectious diseases, and surveillance systems have been designated as appropriate and essential for a broad range of non-infectious diseases and health-related issues, including disability, risk factors, injury, and sports injuries.[99]

Injury surveillance involves the continual monitoring of injuries, including their antecedents and consequences in a defined population. Injury surveillance monitors not only injury-related death and morbidity, but also agents, events, and situations that predispose to injury.[59] The data gleaned from injury surveillance can be used to document the magnitude of injury problems, characterize populations at risk for injuries, and identify emerging problems in injury prevention.[59] Periodically collected data can measure trends, detect geographic clusters, determine the effectiveness of previously implemented injury control programmes, and serve as a catalyst for future epidemiological research by generating hypotheses about risk factors.[49]

Epidemiological research is crucial to the success of injury prevention methods. It is only through research that the actual protective effect of an intervention can be determined. Injury surveillance is a useful method for determining what equipment is needed for sports and then monitoring the effect of this equipment. For instance, the Scottish Karate Injury Register recorded all injuries during karate competitions. After one year of surveillance, it was determined that protective clothing and padding would help reduce the high rate of injury. After appropriate PE was introduced the surveillance system was then able to monitor the decline in injury rate.[106]

Describing and Quantifying Injury via Injury Surveillance

Before plans to prevent injuries are devised it is necessary to determine which groups of persons are at high risk for injuries, what types of injuries occur, and under what circumstances these injuries occur. This would include estimating the burden of injury in a population as it would include information about the causal pathway. Thus, the intent of injury surveillance is clear -- to identify, quantify, and provide insight into the etiology of injury. The success of an injury surveillance system in classifying, counting, measuring severity, and specifying the population in which injuries occur is contingent on data that is of a high quality: representative, sensitive, and specific.[49]

Before determining whether a system has these features, a clear case definition of injury is required. It is difficult to assess whether an injury surveillance system correctly identifies all cases in the population being surveyed or if it minimizes misclassification of non-cases as cases, unless it includes a coherent and established definition of what an injury is. The term "injury" has been defined as damage to the body resulting from transfer of physical energy, that is, mechanical, thermal, electrical, radiant, or chemical energy, or from the absence of essential energy, such as heat.[51] However, because the spectrum of injury severity is endless, ranging from a pin prick to death, the salient question is whether to survey all injuries or simply severe injuries? This prompts the question: what constitutes a severe injury?

Most data collection has been either on injury mortality or on injury leading to hospitalization, as opposed to morbidity. Whether death or hospitalization is a sufficient measure of burden of illness is questionable. First, many minor injuries have a substantial associated morbidity but do not lead to hospitalization. Gallagher et al.[40] reported on the Massachusetts Department of Health statewide childhood injury prevention program that included a comprehensive injury surveillance program. The data on injury were obtained from death certificates, injury hospitalizations, a sample of hospital ER visits, and a random-digit survey of 1200 households. This study concluded that for every death due to injury, there are 45 hospital admissions, and 1300 ER visits. This study probably under-estimated the number of injuries because patients treated at a primary care office and private clinics were not included in the survey. Thus, a main question that arises in injury research is: what is the appropriate scope of an injury surveillance system?[107]

The universal system for classifying all medical conditions is the International Classification of Diseases (ICD) which codes an injury event by both External cause --

the E-code, (ex. fall) and Nature of injury -- the N-code, (ex. head injury). This method of definition does not help in identifying the type of energy transfer -- a requisite for injury prevention initiatives. For instance the ICD does not discriminate between a motor vehicle death due to impact or electrical burn. The lack of internationally standardized definitions of injury causality have resulted in dissimilar definitions around the world and have lead to difficulties in international comparisons. Moreover, changing categories of injuries within the ICD have lead to inaccurate reports. In 1968 a new E-code was introduced which resulted in an artefactual decrease in the trend in infant homicides.[63] To accurately study injury trends, injury definitions are required not to change during the study period.

The National Safety Council attempted to categorize injuries into groups relevant to injury prevention and thereby overcome problems associated with the ICD. Broad categories include: work, motor-vehicle, public, home, and farm injuries. This categorization violates a major principle of classification which requires that groups be mutually exclusive. Under this system, a professional athlete may report an occupational injury although a sports injury would also be an appropriate response.[106]

One of the main purposes of an injury surveillance system is to determine incidence rates; this necessitates identifying all injury events in a geographically defined population of individuals.[71] It is crucial that numerators and denominators used in the calculation of injury rates be compatible. That is, individuals counted as injured in the numerator must be from the same study base as those who make-up the denominator. This epidemiological requirement generates two potential sources of errors in the calculation of incidence rates. First, individuals in the numerator may be from outside the study base. For example, in a study attempting to identify injury rates on the island of Montreal, the emergency rooms in the downtown area may treat people who live in Northern Quebec for injuries, but those same individuals may not visit that hospital for other illnesses. These individuals must be readily identifiable so that they can be excluded from the numerator when the incidence rate of the island of Montreal is being estimated. Similarly, personal factors like age and sex must be compatible with categories used for census-based population estimates.[68]

Second, the identification of the study base, that is, the denominator is a complex process. Risk is the probability that the injury will occur during use of a given product or participation in a given activity. It is typically derived from rates assuming that the previous relative frequency of injury will continue, adjusting for death. In order to study factors that are correlated to injury the study base must be grounded in a system that is relevant to injury control.[106] For instance, in an analysis of sports injuries, by examining the number of injuries per total population, soccer would emerge as the most common source of injury. Because soccer is a commonly played sport it may have a higher crude number of injuries although other sports may have a higher risk of injury. In a risk per participant analysis, many confounding variables are controlled for and more accurate estimates are calculated. An even more sophisticated method of analysis, although somewhat more costly, is risk per time exposed.[31] Thus, total populations may be an inappropriate denominator; use of denominator other than population is an attempt to obtain a more refined estimate of rate.

Biases in Injury Surveillance

Because injuries are often treated in emergency rooms these settings emerge as a logical place for surveillance. Consequently, injury surveillance is often based in large trauma centers through trauma registries. This is particularly useful in ensuring good clinical detail and access to trained research personnel and facilities. Trauma registries are effective at identifying the majority of severe injury cases with comprehensive patient data on the nature and cause of injury, as well as on outcome.

There are several selection biases that accompany the use of trauma registries or emergency room data. Many non-life threatening injuries are treated in local emergency rooms or in a primary care office, and trauma centers usually only capture patients with serious injuries from further geographic regions but not with minor injuries. With an increasing proximity between home and emergency department there is an increasing propensity to seek medical care for an injury at that emergency room. Thus, there is an uncertain catchment area of a trauma centre for injuries of different severity, and it is difficult to link injuries to a defined population so as to both calculate incidence rates and to estimate other measures of effect.[18] In communities with several hospitals, data are only available from hospitals that have registries, and patients in the other hospitals may not be representative of all injured patients. Moreover, attendance at emergency departments may be influenced by patient perceptions of their problems and access to their doctors, socio-economic status, or proximity to an accident department. A unique issue associated with pediatric injury reporting is that data are often obtained from parents or guardians who serve as proxies. However, Macarthur et al. found a kappa of 0.79-1.00 in test-retest reliability and 0.4-1.00 for validity in a study of proxy responses from the Canadian Hospitals Injury Reporting and Prevention Program.[75]

Macarthur noted that the database may be unreliable for the reporting of protective equipment. Thus, if this database is used to conduct research on the efficacy of protective equipment in sports, the under-reporting of equipment could result in inappropriate prevention strategies. For example, if there is a high head injury rate among ice skaters who have reported the non-use of helmets, attempts may be made to promote helmet use. However, if these head injury victims have actually been wearing helmets, then further investigation would be required regarding the fitting of the helmet or the condition of the helmet to determine the actual etiologic factors of the injuries.

A number of methods other than trauma registries can be used to survey injuries. Police reports, vital statistics, and newspapers have been suggested as injury surveillance methods.[68] In order to formulate hypotheses that explain the distributions of injury, data are needed that are more sophisticated than that provided through medical records or vital statistics. That is, although demographic characteristics are necessary to understand the etiology of injury, they are not sufficient; they must be supplemented with data on activity at the time of injury, type of energy transfer, and mechanism of injury. According to Rainey et al.[102] newspapers covered 96% of fire fatalities and 78% of drownings, with more information provided than medical examiners regarding the presence of a smoke detector, pool fences, warning signs, and supervision, although the validity and reliability of this information was not confirmed.

An effective method for overcoming the inadequacies of the individual sources of injury data is through combining data obtained from several sources. For instance, a surveillance system could combine the use of death certificates, census estimates, and hospital discharge summaries. Although this will increase representativeness, sensitivity, and specificity, it would also increase cost.[45] By employing capture-recapture analysis to injury monitoring, certain combinations of sources for ascertainment could provide better estimates of numbers of injuries occurring in populations.[69] In a school injury study the frequency of capture of injury events was evaluated and Boyce et al.[13] discovered that with an expanded reporting system there was an increased reporting rate when compared to the routine conditions of surveillance.

According to van Machlen[130,131], the sequence of preventing sports injuries cannot be accomplished without an injury surveillance program. The goals of the system would be: firstly, determine the incidence and severity of sports injuries; secondly, identify factors that play a role in the occurrence of the injuries; thirdly, introduce measures that are likely to reduce severity; and finally, evaluate the effect of the countermeasure.

There also exists a tension between the desired breadth of injury surveillance systems versus the specificity of programs to local needs. The CDC is interested in nationwide statistics on causes and severity of injury so that particular classes of injuries can be targeted for research. On the other hand, data must be detailed enough so that injury patterns in small communities can be studied and local priorities established.[67] Injury problems and trends vary greatly between communities and specific information is needed to characterize priority problems and target injury control measures.

Geographical clustering is of central importance for injury research. For instance, in New York city, epidemiologists tried to discern the circumstances surrounding fatal falls in young children. They determined that 66% of these injuries were attributable to children falling out of high-rise windows and isolated a geographic cluster that coincided with these deaths.[106] Subsequently, the health department mandated the use of window barriers and there was a concomitant decrease in fatal falls from 30 to 50/year in the 1960s to only 4 in 1980. This exemplar of a successful injury prevention initiative, sparked by a surveillance system, illustrates the need for local injury surveillance. According to Robertson[106], every community should have a comprehensive injury surveillance system. Although he recognizes the importance of a national system, he believes that local communities should take the initiative before a comprehensive national system is instituted.

The key to establishing a national injury reporting system would include defining an essential set of data elements, database linkage elements, and universal agreement of injury codes.[107] Information from local surveillance systems should be standardized so that surveillance systems are useful both in local areas and in national injury prevention initiatives. In the United States, there are several national datasets that survey unintentional injury: the National Electronic Injury Surveillance System organized by the Consumer Product Safety Commission, the Fatal Accident Reporting System, and the National Accident Sampling System maintained by the National Traffic Safety Commission. These systems have yet to be evaluated. In Canada, the main sources of data on injury are provided by CHIRPP, Statistics Canada, and the Transport Canada Motor Vehicle Accident Program.

Surveillance systems need to reflect the different categories of injury. For example, data collected on sports injuries should differ from data about occupational injuries. Consequently, a pertinent issue in injury surveillance is whether general injury or specialized registries are needed, and whether different methods of data collection should be used for the various categories of injuries. Spinal cord, head injury, and burn injury registries have been established due to the severity of these outcomes. However, the representativeness of this type of registry is plagued with the above-noted biases.

2.3 PROTECTIVE EQUIPMENT FOR SPORTS: AN OVERVIEW

Protective equipment is designed to provide protection from major injuries and to prevent or minimize injuries that are routinely associated with a given sport. For example, helmets function to prevent catastrophic life-threatening head injuries in bicycling, shin guards protect against tibia fractures caused by direct blows common in soccer, and helmets and face masks in ice hockey prevent concussions, facial lacerations, and eye injuries. The prevention, or reduction in severity, of sports injuries by such equipment is accomplished by a variety of mechanisms: increasing the area of impact, transferring the area of impact, limiting the relative motion of certain body parts, increasing the mass of a body part to limit deformation, reducing friction between contacting surfaces, or absorbing energy.[83]

The success of such equipment in reducing injury is well documented. For example, since the Hockey Equipment Certification Council set standards for hockey face masks, and mandated their use, no ice-hockey eye injuries have led to the loss of sight[136] Widespread face guard use in the United States is estimated to have prevented more than 70 000 projected eye and facial injuries in 120 000 ice hockey players, with the additional benefit of savings in medical expenses of about $10 million.[50] Bicycle helmets have been found to reduce the risk of head injury by 85% and of brain injury by 88%.[125] Minor head injuries, even without loss of consciousness, which may initially seem innocuous, may have long-term consequences,[2] and the use of bicycle helmets has, thus, also pre-empted enormous hospital costs and reduced mortality and morbidity.

Mouth guards protect against dental fractures, lip lacerations, neck injury, and concussion.[20, 78] Through force dispersion over its surface area, a professionally-fitted mouth guard can prevent the majority of dental injuries caused by participation in sport.[19] In a study conducted by McNutt et al., it was found that 56% of all concussions, and 75% of all orofacial injuries, occurred in sporting participants wearing no mouth protection.[78]

Protective equipment must function to prevent an anticipated injury but, at the same time, it must not predispose the user to other injuries, nor be harmful to other participants. Many head and facial (mouth and eye) ice hockey injuries are prevented by the mandatory use of helmets, face masks, and throat protectors. However, when the requirement came into effect there was a concomitant increase in spinal injuries.

> The introduction of mandatory head and facial protection has been effective in virtually eliminating ocular, facial, and dental injuries...but, it has also been problematically linked with an increase in catastrophic spinal injuries. Players adopt a false sense of security...leading them to take excessive risks...The addition of these protective devices has also altered how officials perceive the game, leading them to be more lenient in administering penalties. The net result has been an increase in illegal and injurious behaviours, such as checking from behind.[20]

Similarly, the use of the hard-shelled helmet in football decreased the incidence of cranial haemorrhage and concussion, and the cage caused a decline in facial lacerations. But, players began using their helmeted heads as battering rams, and the face mask became a common place to tackle opponents, with a consequent increase in neck and spinal injuries. Fortunately, a 1976 rule that prevented spearing resulted in a decline in such, often-devastating, injuries.[3]

A well-designed piece of equipment may be useless in protecting against injury if it is not fitted properly. In New Zealand, Plumridge et al., discovered that one reason the number of head injuries had not decreased as bike helmet use had increased was that the helmets may not have been worn properly.[101] They suggested that one way to improve this situation would be to improve advice about helmet fitting at the time of purchase.

Any argument in support of protective equipment should not be construed as negating the importance of rule changes, appropriate education, proper coaching and training, or a safer environment. As Rome suggested, in ice hockey by introducing "stricter penalties or eviction of players" the incidence of spinal cord injury may be reduced.[108] A study of soccer injuries revealed a 75% decrease in injuries by combining a variety of prevention methods, including protective equipment, education, and a safer environment.[84]

Thus, there are clearly many routes for intervention in the prevention of sports injuries; in the modern technological era, the development of effective protective equipment deserves attention. Importantly, proper testing is needed to ensure that protective equipment functions as intended and does not cause harm to other body parts. Testing must establish the minimum standards to produce effective and reasonably priced equipment. Equipment must also be based on the biomechanics of the sport and the durability, shock absorption, and ease of cleaning.[105]

The innovation of a PE prototype, however, must rest on a need for a given piece of equipment. This underlying need can be determined by epidemiological studies that identify the risks of participating in a selected sport, determine the common nature and mechanisms of injury, classify the different etiologies of sports-related injury by age and sex, and conclude whether equipment that is being used is reducing the injury rate.

The present study will examine the use of PE among children injured during several winter sports and recreational activities. For a description of the studies completed up to the present on PE and winter sports injuries, see Appendix II.

2.4 PROTECTIVE EQUIPMENT FOR CHILDREN PARTICIPATING IN SPORTS

The psycho-social and physical development of children predisposes them to injury and makes their use of protective equipment especially important. It has been demonstrated that children younger than nine do not have adequate motor-skills, muscle strength, or coordination to be proficient cyclists. Moreover, their sense of judgement is not sufficiently well developed to appreciate safety rules.[29] This may explain why 68% of severe head injuries in the biking population occurred in riders under 15 years old.[125] The inverse relationship between age and injury rates among cyclists can be extrapolated to other sporting activities, reinforcing the need for children to wear protective equipment. The propensity towards sports-related injuries in children is compounded by the fact that children are beginners at every sport and thus are at increased risk because of inexperience, lack of awareness of risks, and lack of skills.[104]

Children and adolescents are also more susceptible to these injuries due to their immature skeleton. As bone growth occurs, the muscle-tendon units spanning bones and joints become progressively tighter and flexibility is lost, increasing the likelihood of injury. Additionally, due to the biochemical changes that occur during the growth spurt of adolescence, this population tends to be highly susceptible to musculoskeletal injuries.[73] Indeed, the temporal independence of bone growth and mineralization in the adolescent means his/her bones are temporarily weakened.

Children are especially predisposed to injury in the epiphyseal and apophyseal areas. An impact that would likely cause a ligamentous injury in an adult may cause a physeal fracture in a skeletally immature individual. For example, injury to the wrist in children often results in a distal radial epiphyseal fracture rather than the less debilitating wrist sprain seen in adults.[73] Similarly, what would result in a medial collateral ligament injury in an adult may result in an epiphyseal fracture of the distal femoral epiphysis in a child.

Skiing injuries exemplify the n~ed for child-tailored equipment. Although skiing injuries, in general, have decreased over the last thirty years, the number of such injuries among children has increased. This increase is partially a function of the growing participation by children in the sport. However, the lack of a decline in the injury rate among children can also be partly attributed to their anatomy. Children sustain three times more lower leg injuries than adults, with spiral oblique and transverse boot top fractures of the tibia and fibula being the most prevalent. As children approach adulthood, there is an increase in the number of ligamentous injuries and a corresponding decrease in fractures. It would be useful to take into account the predisposition of children to leg fractures when designing ski boots and release bindings.[12]

In general, it seems that better equipment is needed to protect children at those epiphyseal areas most likely to be injured. This is especially important because injury to the epiphysis can lead to growth disturbances, such as limb-length discrepancies and joint angle deformities.[73]

The epidemiology of children's sports injuries demonstrates that even within the category of "child", different types of protective equipment may be needed for different age groups. For instance, during one eight year period, 20 children (aged 5-13) died from being hit in the chest with a batted or thrown baseball.[104] Older children do not face this risk because their bones tend to be firmer and they are more skilled at being able to bring their gloves up to stop the ball thus preventing their bones from breaking.[102] Thus, chest pads that are recommended for young children may not be required for older children.

Children and adolescents are not miniature adults; they have a different biochemistry, physiology, and psychology. Consequently, protective equipment must be tailored to the biomechanics of their sports and to their specific constitution.

Despite all the need for such equipment, few studies have been undertaken on this subject.[84] Even where studies have confirmed the efficacy of protective equipment, its use tends to be low.[30,36,72,82,92,132,133,135] For instance, in a study conducted by Cushman, the frequency of bicycle helmet use was found to be 3% among university students, 1.9% among high school students, and 0.8% among elementary students.[30]

The lack of use of equipment by children may be a function of cost. A report by SAFEKIDS CANADA (June 1994) indicated that:

> Over two-in-ten parents indicated that they could not buy certain protective equipment due to cost. These were more likely to be low income mothers. The types of protective equipment too expensive to purchase included bike helmets (55%), elbow/knee pads (29%), car seats (11%), and hockey equipment (10%).[111]

Of paramount importance is the fact that many individuals who own a piece of equipment do not consistently wear it. "Despite the fact that three-quarters of children who ride bikes are said to own a helmet, parents reported only 57% of them wear it at all times".[111] Similarly, a study of injuries on small-wheel skates reported that although 59% of patients who owned protective equipment, only 25% were using it at the time of injury.[93]

Resistance to wearing protective equipment by children is due to many factors: Children often perceive themselves as being at low risk for injury[94]; the use of protective equipment may be viewed as succumbing to parental pressure; or children may fear ridicule. Moreover, protective equipment may make the wearer uncomfortable. Condie et al. found that equestrians were well informed about the need for helmet use but didn't wear them because of their cost or discomfort. Thus, "while safety education was an important component, changing the cost and style of the helmet was imperative" to increasing the use of helmets.[25] Even an injury does not seem to encourage the use of protective equipment. In a study by Nakayama, even though 2/3 of the children he surveyed had experienced head injuries, fewer than 1/4 were sufficiently impressed by their experience to subsequently begin wearing helmets.[86] The present study will explore how intentions regarding use of PE change after an injury event.

3 METHODS

3.1 BACKGROUND

The Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP), organized by the Laboratory Centre for Disease Control in Ottawa, Canada, was initiated on April 1, 1990 with the intent of reducing the number and severity of injuries in Canada.

CHIRPP uses a standardized data collection form to gather information on children who present to a participating emergency room with an injury. The CHIRPP form provides information on the pre-injury and injury event. Data are collected on the circumstances leading to an injury by having the patient or adult accompanying the child fill out a short standardized questionnaire (see Appendix 1A & 1B). This includes questions about the date and place of the injury, what the injured person was doing when the injury occurred, what went wrong, what caused the injury, and what safety devices were in use. Information about the body part involved, the nature of the injury, intent, and disposition are provided by the attending physician.

3.2 SUBJECTS & DATA COLLECTION

STUDY 1:

The objective of this study was to explore whether the safety equipment question on the pre-1997 CHIRPP form was reliable when compared to information obtained at a follow-up phone call.

Eligible subjects included children presenting to the emergency rooms of Montreal's two paediatric hospitals (The Montreal Children's Hospital and L'Hôpital Ste. Justine) for a sports or recreational injury, and for whom a CHIRPP form was completed. Subjects were identified by reviewing the forms weekly from January 1997 to April 1997. Children who resided outside the province of Quebec were excluded. Parents were telephoned 7-21 days after the emergency room visit. The interviewer asked to speak to the person who completed the CHIRPP sheet on the day of the visit. Questions identical to those written on the form were then asked of the respondent, with the interviewer blinded to the original answers. In the second part of the interview the interviewer asked probing questions about the activity and use of protective equipment. Of particular interest was whether equipment designed to prevent the injury was used at the time of injury.

Of 915 eligible respondents, 691(76%) completed the interview. Reasons for not including eligible respondents in the study were: 169 could not be reached, 23 were untraced, 18 had language difficulties, and 12 refused.

STUDY 2:

The objective of this study was to explore whether a free-field question or a closed-ended set of questions is more appropriate for obtaining information on safety equipment.

The data from study one was used if it related to an ice hockey or skiing injury. As well, a second set of data pertains to the period January 1998-March 1998 when CHIRPP forms were collected for ice hockey and skiing injuries. In 1997 the CHIRPP questionnaire was changed, with the new form differing most notably in its efforts to ascertain information related to sports activities. (Compare Appendix 1A to Appendix 1B). Skiing and ice hockey injuries were chosen because it seemed reasonable to assume that there had not been a true increase in equipment use between the two winter seasons. Therefore, comparing the proportions of PE use from the new CHIRPP form (from the 1997-1998 season) to the old CHIRPP form and to phone-reported equipment use from the 1996-1997 season would indicate whether the new form was more effective at capturing the true rate of equipment use.

For this study, eligible subjects included children who were Quebec residents presenting to the emergency rooms of Montreal's two pediatric hospitals (The Montreal Children's Hospital and L'Hôpital Ste. Justine) for an ice hockey or skiing injury, and for whom a CHIRPP form was completed. Subjects were identified by having the CHIRPP co-ordinators from the two hospitals review the forms weekly from January

1998 to April 1998.

The phone number and family name of the injured child is located on each CHIRPP form. Parents who did not refuse consent were telephoned 7-21 days after the emergency room visit. The interviewer asked to speak to the person who completed the CHIRPP sheet on the day of the visit. Questions identical to those written on the form were then asked of the respondent but with the interviewer blinded to the original answers. In the second part of the interview, the interviewer asked probing questions about the activity and use of protective equipment.

STUDY 3:

The objective was to describe injuries commonly associated with winter sports in order to identify areas in the field of equipment design that deserve attention; to do so, an attempt was made to estimate the use of equipment by children injured while participating in winter sports and to describe the characteristics of non-users of PE by age, sex, and ownership of equipment. This information was provided by the data collected from the CHIRPP forms from study 1.

All analyses regarding PE were based on phone-reported equipment use. Equipment users were compared to non-equipment users according to sport, age, sex, and place. Because the mechanism of injury is relevant to future PE innovation the common mechanism of injury for each sport was reported as well.

STUDY 4:

The objective was to examine whether a sports-related injury prompted a change in reported parental behavior with regards to the use of safety equipment by their children during future sporting activities.

The subjects for this study were identical to those used in study 1. Information regarding future behavior was gleaned by asking parents what their intentions were regarding the prevention of injury in future sports activities. This included use of already owned equipment and purchase of new equipment.

The follow-up phone interview was done within two weeks post-ER visit. This extended was selected because a longer period gives parents more opportunity to purchase protective equipment.

BOX 1: STUDY OBJECTIVES AND DATA SOURCES

	OBJECTIVE	DATA SOURCE
STUDY 1	Compare open-ended protective equipment question with a follow-up phone interview	January 1997-April 1997 CHIRPP forms and follow-up phone interviews
STUDY 2	Compare open-ended question on protective equipment with close-ended question	January 1997-April 1997 CHIRPP forms and follow-up phone interviews for ice hockey and skiing & January 1998-March 1998 CHIRPP forms for ice hockey and skiing
STUDY 3	Describe injuries commonly associated with winter sports	January 1997-April 1997 CHIRPP forms and follow-up phone interviews
STUDY 4	Examine whether a sports-related injury prompted an intended change in behaviour with regards to the use of protective equipment during future sporting activities	January 1997-April 1997 CHIRPP forms and follow-up phone interviews

4 RESULTS

STUDIES 1 & 2

Tables 1 & 2

Seventy-eight percent of respondents reported the same response on the form and the phone with regards to the use of PE. One hundred and fifty-three (22%) respondents provided different responses regarding safety equipment when the open-ended CHIRPP form was compared to the phone interview. The majority of divergent responses can be attributed to respondents claiming the use of equipment on the phone, although they had not reported use on the original form (20%), as compared to 2% who had initially reported the use of equipment and later claimed there had been no such use.

TABLE 1: Equipment use: CHIRPP form vs. follow-up phone interview

Telephone / CHIRPP Form	Equipment	No Equipment	TOTAL
Equipment	66	12	78
No Equipment	141	472	613
TOTAL	207	484	691

Simple Agreement: $\frac{472 + 66}{691} = 78\%$

As presented in Figure 1, when the data are compared for ice hockey, the under-reporting of equipment on the original CHIRPP form seems pronounced. On the original CHIRPP form 28% reported the use of equipment, while on the phone 76% reported wearing equipment. Similarly, there was a significant difference in reported equipment use in skiers, with 11% reporting equipment use on the original CHIRPP form and 30% reporting equipment on the phone. However, in basketball, where the use of equipment is less common, there is less divergence in data after re-test, with 0% reporting equipment use on the CHIRPP form and 6% reporting equipment use during the telephone interview.

The kappa coefficient is commonly the statistic of choice when measuring agreement in nominal scales. Thus, for the data provided in Figure 1, the kappa coefficient is calculated:

$$K = (p_0 - p_e)/(1 - p_e)$$
$$p_e = [(a+b)(a+c)+(c+d)(b+d)]/N^2$$
$$p_o = (a+d)/N$$

(where p_0 represents observed agreement and p_e represents expected agreement)

The numerator measures the observed agreement beyond chance, and the denominator measures the maximum possible agreement beyond chance. With complete agreement, the kappa coefficient would be 1. (Table 2)

TABLE 2: Level of agreement (Kappa) between CHIRPP form reporting and follow-up phone interview reporting for different sports

Sport	Kappa-Coefficient	Agreement
All Sports	0.36	Fair
Ice Hockey	0.09	Slight
Basketball	0	Poor
Snowboarding	0.23	Fair
Sledding	0	Poor
Skating	0.59	Moderate
Skiing	0.27	Fair

Figure 1: Test-Retest of CHIRPP Safety Question

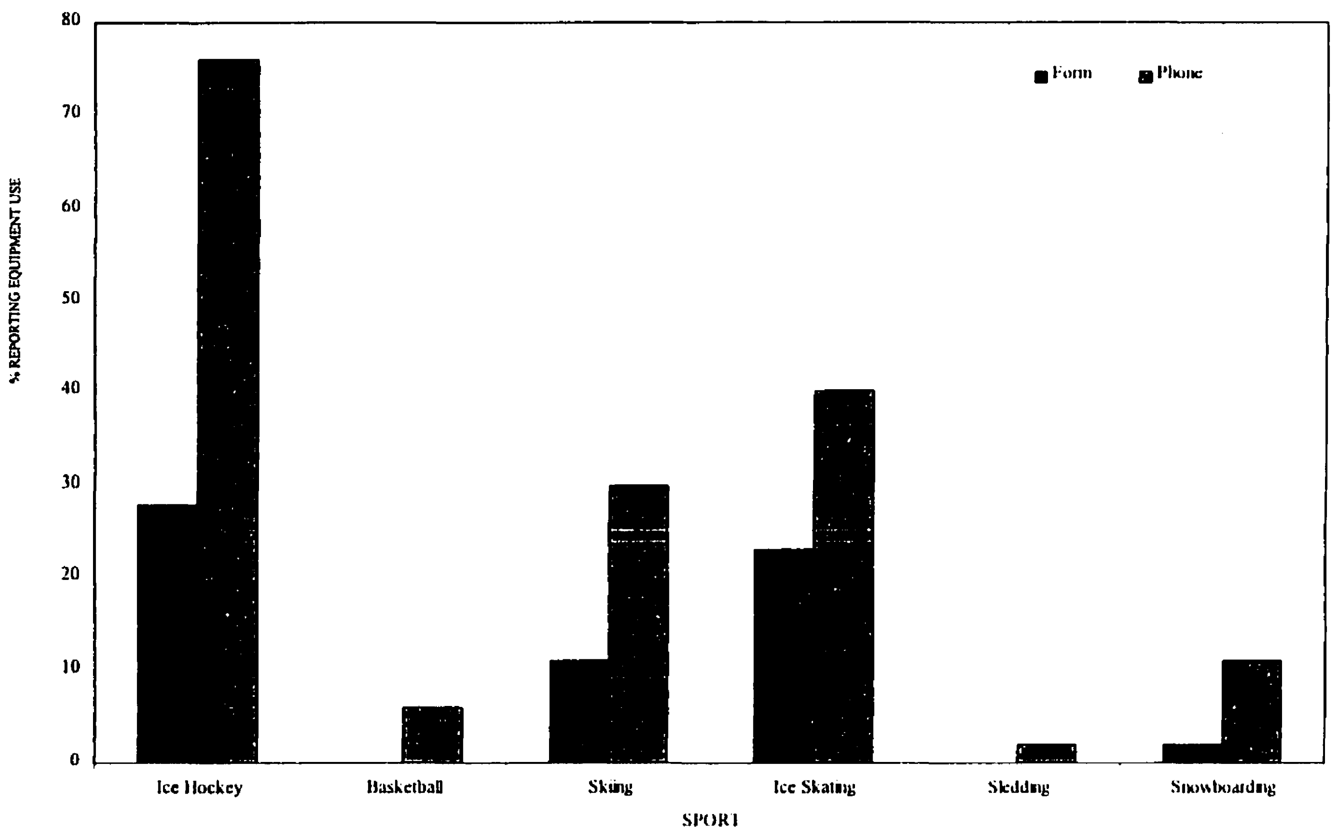

Table 3

According to Table 3, the phone interview provided the highest rates of equipment use. The new form, with its categorical responses, reveals a reported use of equipment closer to the phone report than to the open-ended form for both sports.

TABLE 3: Reported equipment use for specific pieces of protective equipment for Ice Hockey and Skiing

	Data Source	Any (%)	Helmet (%)	Elbow Pads (%)	Knee Pads (%)	Full Hockey (%)	Other (%)
Ice Hockey	Old Form (n=130)	28	26	21	21	21	—
	Phone (n=130)	75	73	71	72	68	—
	New Form (n=110)	62	47	—	—	10	Non-specified padding = **55**
Skiing	Old Form (n=107)	10	9	0	0	—	—
	Phone (n=107)	29	23	2	1	—	—
	New Form (n= 90)	26	17	—	—	—	Non-specified padding = **26**

STUDY 3

Tables 4 & 5

The sport that caused the most injuries was ice hockey, followed closely by basketball, and skiing. These three sports, combined with skating, sledding, and snowboarding, accounted for 77% of all sports injuries seen at the two hospitals during the study period. Because this study only covered the winter and spring months, however, the results do not reflect the array of injuries sustained through a full year.

The mean age of the children was 12 years old. The majority of injuries involved 10-14 year olds. However, the most common age of injury was sport dependent; although few basketball injuries occurred in the 5-9 age group, almost half of all sledding injuries occurred in this population. The majority of all injuries were to boys. Again, however, the sex-related frequency of injury was sport dependent; boys accounted for most of ice hockey injuries but only 1/4 of ice skating injuries. Most of all injuries occurred during recreational activities.

The type of injury and the body part injured also reflected the sport involved. In ice hockey, head and facial injuries, fractured clavicles, and sprained knees, were the most common. The mechanism of these injuries was typically a child being checked or hitting the boards. In basketball, the finger and ankle were particularly susceptible, and the ball was usually implicated as the cause of injury. Skiers suffered from fractures and sprains, often of the lower extremity caused by falling or hitting a stationary object. In ice skating, head/facial injuries and fractured forearm/wrists were the two most common outcomes. Sledding was characterized by head or facial injuries and lower leg fractures, with all of the fractures caused by hitting a stationary object. Finally, forearm/wrist fractures constituted 36% of all injuries among snowboarders.

Because the nature of injury was sport dependent, so was disposition. Only 1% of ice skating injuries required admission whereas the admission rate was 5% for both skiing and snowboarding injuries.

TABLE 4: Characteristics of Sports Injuries reported on CHIRPP form (n=691) (%)

	ALL INJURIES¶ (N=691)	HOCKEY (N=130)	BASKETBALL (N=116)	SKIING (N=107)	SKATING (N=62)	SLEDDING (N=61)	SNOWBOARDING (N=55)
Sex(%)							
Boys	65	93	59	53	27	57	76
Girls	35	7	41	47	73	43	24
Age(%)							
1-4	4	0	1	4	5	16	2
5-9	20	7	2	33	40	48	0
10-14	51	62	58	43	47	33	51
15-18	25	31	39	20	8	3	47
Type of Activity(%)							
Recreational	61	27	22	94	79	98	91
Organized Competition	24	71	28	5	8	0	2
Physical Education Class	15	2	50	1	13	2	7
Type of Injury(%)							
Sprain	31	25	51	37	16	16	27
Fracture	31	20	29	36	44	46	51
Bruise, Contusion	20	28	16	18	21	13	9
Head Injury	8	10	1	5	13	16	6
Cuts, Lacerations	7	13	1	4	6	7	2
Other	3	4	2	0	0	2	5
Body Part(%)							
finger	15	8	41	13	5	7	7
forearm/wrist	14	10	2	6	35	8	47
shoulder	6	11	4	3	7	7	5
hand	3	6	6	1	0	3	7
elbow,upper arm	2	1	5	2	2	2	7
ankle	11	5	23	9	8	11	4
knee	11	17	3	21	11	5	2
lower leg	6	2	1	22	6	10	0
foot	3	3	2	2	2	2	6
upper leg, hip	2	1	2	3	0	3	4
Head, face, neck	14	23	5	8	23	30	9
Lower back, abdomen,oth	13	13	6	10	1	12	2
Disposition(%)							
Advice only	60	68	70	53	74	51	43
Follow-up	37	32	29	42	25	44	52
Admission	3	0	1	5	1	5	5

TABLE 5: Mechanisms of common injuries & potential methods for prevention

	Common Injuries	Mechanism	Potential Prevention Strategies
Ice Hockey	23% head & face injuries 20% fractures; 27% to shoulder 25% sprains, 36% to knee	80% hit boards hit against board, fell, checked fall, checked, hit boards, twisting, stopping	HELMET/FACE MASK NO CHECKING
Basketball	13% fractured finger 24% sprained finger 4% fractured ankle 18% sprained ankle	94% hit solid object (ball) 92% hit solid object (ball) fall, twisted, landing twisting, fall, landing, collision	CHANGE BALL SIZE ANKLE STRENGTHENING EXERCISES
Ice Skating	23% head & face 44% fractures, 59% to forearm/wrist	----------------------	HELMET/FACE MASK HOCKEY GLOVES
Skiing	36% fractures/53% lower leg 37% sprains/ 43% to knee	80% fall; 20% hit stat object 70% fall; 18% hit stat object	BOOT REDESIGNING
Sledding	30% head & face 46% fractures, 21% to lower leg	human collision, fell out of sled, hit stat object 100% hit tree or wall	HELMET
Snowboarding	36% fractured forearm/wrist	Falling on outstretched arms	WRIST GUARDS/REINFORCED GLOVES

Equipment use & Injuries (Tables 6 & 7)

The use of **hockey** equipment was much more common in arenas than on outdoor rinks ($p < 0.01$). The proportion of fractures was greater among individuals not wearing full hockey equipment than among full hockey equipment users, with a 17% frequency of fractures among full equipment users compared with 27% among non-users (OR=1.72, CI [0.71, 4.16]). The non-use of a helmet was significantly associated with an increased proportion of head injury (OR=4.15, 95%[1.77, 9.75]).

The use of protective equipment in **basketball** was very low. The most common protective measure was a high-top shoe, followed by knee pads and ankle supports.

For **ice skating**, helmet use was more frequent among girls than boys and among younger patients than older ones. Those wearing helmets had an 8% risk of head injury, while those not wearing a helmet had a 27% risk. This result was non-significant (OR=10.9, 95% CI [0.14, 804.2]).

The PE used by **skiers** included helmets, elbow pads, and knee pads. Helmet use was inversely related to age, with 46% use among 1-9 year olds, 13% among 10-14 year olds, and 4% among 15-18 year olds. Twenty-eight percent of skiers reported that their skis and boots were rented. In this group, 63% of injuries were to the lower extremity, whereas of the 72% of skiers who used their own equipment, 53% of injuries were to the lower extremity.

Few **snowboarders** and **sledders** reported using PE. Although the result was non-significant, it is of interest to note that of the 7 head injuries to **snowboarders**, none were wearing helmets, while among the 3 helmeted snowboarders, there were no head injuries.

TABLE 6: Phone reported equipment use in various sports (%)

	Any	Helmet	Elbow Pads	Knee Pads	Other Equipment
Ice Hockey	75	73	71	72	FH= 68
Basketball	6	NR	1	3	KB=2; MG= 1; WG=1; AS= 3; HT= 7
Ice Skating	40	34	6	10	---
Skiing	29	23	2	1	---
Sledding	2	2	0	0	0
Snowboarding	11	5	2	5	0

FH=full hockey equipment, KB=knee brace, MG=mouth guard, AS=ankle supports, HT=high-top running shoes, WG= wrist guards

TABLE 7: Reported equipment use in ice hockey and skating according to place, age, and gender

		ICE HOCKEY		SKATING	
		Full Hockey Equipment(%)	Helmet(%)		Helmet(%)
PLACE					
Arena	(n=91)	96	98	(n=20)	40
Outdoor Rink	(n=38)	0	10	(n=38)	35
AGE					
1-4		--	--	(n=3)	67
5-9	(n=9)	44	67	(n=25)	48
10-14	(n=81)	66	70	(n=29)	17
15-18	(n=40)	78	80	(n=5)	40
GENDER					
Male	(n=93)	69	73	(n=17)	24
Female	(n=7)	66	78	(n=45)	38

STUDY 4

Future intentions Regarding Protective Equipment Use

Two hundred and seventy-eight (40%) respondents stated they would **not** ask their child to wear PE in the near future and 23% said the same equipment would be used. Twenty-one percent said they **would** ask the child to wear equipment in the future; this group included those who were not wearing equipment at the time of injury, and those who were wearing safety equipment when injured and who would now wear additional pieces of equipment. Eleven percent said they would consider the use of PE in the future, and 5% reported that the child would no longer be permitted to participate in the sport. At the time of interview, 4% of respondents stated that they intended to purchase new equipment but only 2% stated that they had done so since the time of injury.

The reasons for not requiring the use of equipment differed between age groups. In the 1-4 age group, future non-use was mostly because equipment was not viewed as necessary. However, as age increased, respondents' increasingly reported that non-use was because the child refused, or because it was the school's responsibility to enforce its use. Among 10-14 year olds, 11% responded that the child would not obey when asked to wear equipment, and for 15-18 year olds 31% provided this response.

For all sports, the injury event prompted an increased reported intent to use equipment in future participation of the given sport. The increase varied by sport: ice hockey (5 %), basketball (9%), skating (15%), skiing (6%), sledding (26%), and snowboarding (18%).

5 DISCUSSION

This investigation is one of the only surveillance system based studies regarding children's sports injuries. Moreover, few studies have focused specifically on methodological aspects of gathering data on sports injuries. In this section, sport specific injury patterns, equipment use, and data gathering methods from the four studies are discussed. The implications of these findings for public health in Canada are described. The results have major implications for the prevention of children's sports injuries.

5.1 MEASURING PROTECTIVE EQUIPMENT USE (STUDIES 1& 2)

A key finding is the unreliability of the safety question on the initial open-ended CHIRPP form. Macarthur et al. investigated the reliability and validity of the CHIRPP data and determined that all items on the pre-1997 CHIRPP injury surveillance form were valid and reliable. However, the question on safety precautions showed a low level of agreement, with an item kappa=0.4.[75] Macarthur[56] also noted that the safety question was not as reliable upon re-test when compared to other CHIRPP questions, but claimed that this unreliability was insignificant. However, the present study demonstrates that by adjusting for confounding by sport, the safety question proves to be unreliable.

Injuries reported by CHIRPP may occur during activities for which there is no appropriate safety device (fall while walking, being bit by a dog). In such cases, it is unlikely that a respondent would provide a different response regarding the use of safety devices upon re-test because the use of safety devices in these activities is uncommon. As prevalence of equipment use declines, the positive predictive value of the test would tend to increase. Thus, sports for which equipment use is rare, or does not exist, probably contribute minimally to any unreliability in the safety devices question. For instance, if a child was injured while playing badminton, it is unlikely that a respondent would report the use of equipment either on the form or during the phone conversation, because the use of protective equipment in this sport is uncommon. On the other hand, the use of hockey equipment is mandatory in organised ice hockey and widely recommended for unorganised play. Thus, ice hockey, with a higher prevalence of equipment use, would have different results regarding reliability.

As shown in Figure 1, certain sports are characterised by a low use of equipment on both the form and during the follow-up phone call. On the other hand, sports like ice hockey have a larger discrepancy between equipment reported on the form and during the follow-up phone call. If sports where the use of equipment is commonly high are examined, agreement between the form and the follow-up phone interview appears less congruent. Our findings demonstrate that, indeed, the safety devices question is somewhat unreliable upon re-test for sports where the use of equipment is more prevalent. However, one of the limitations of this study is that during the phone conversation parents may over-report the use of equipment because of guilt or embarrassment.

Nevertheless, this finding is extremely significant for injury prevention. If the CHIRPP database is being used to conduct research on the efficacy of protective equipment in sports, the under-reporting of equipment could result in inappropriate prevention strategies. If there is a high head injury rate among ice skaters who have reported the non-use of helmets, attempts should be made to promote helmet use. If, however, these head injury victims have actually been wearing helmets, then further investigation would be required regarding the design of the helmet, its fitting, the condition of the helmet, etc. to determine the appropriate countermeasure.

The new CHIRPP form (appendix IB), which provides categorical response options, appears to ascertain information more closely in line with phone-reported equipment use. By using categorical response options, however, some of the detail regarding what equipment was in use at the time of injury is lost. For instance, on the open-ended form the parent may report the use of elbow pads, whereas on the close-ended form the data obtained is more general ie., the parent will check the box "sports padding". It is virtually impossible to include categories on the form for all types of PE, but the categories provided must, at the very least, be useful in terms of their relevance to injury prevention. It is questionable whether "sports padding" is detailed enough to aid in injury prevention strategies; for instance, if a child suffers a knee injury and the CHIRPP form reports that "sports padding" was in use, it is unclear as to whether the child was wearing knee pads or elbow pads.

Because CHIRPP was designed not only for the prevention of sports injuries we recognize that the form cannot include all types of PE and must include categories that are relevant for other sources of injury. Nevertheless, given that sports injuries are a major cause of morbidity and comprise at least 25% of all ER visits by children, the categories on the new CHIRPP form should be more specific with regards to what equipment was in use at the time of injury.

After comparing the three methods of ascertaining information on protective equipment, it is evident that the highest reported use of equipment is by phone interviewing. For both ice hockey and skiing, the reported use of equipment on the new form is closer to that reported on the phone than to the old form. While the categorical questions on the new CHIRPP form are more useful than the open-ended questions, categories could be more specific: for example, helmets, full hockey equipment, wrist guards, etc.

5.2 WINTER SPORTS INJURIES & PROTECTIVE EQUIPMENT (STUDIES 3 & 4)

The major findings about sports injuries show that: injuries are almost twice as frequent among boys than girls; injuries during recreational activities and physical education classes account for more than twice as many injuries as in organized competition; over half of all those injured are 10-14 year olds; the use of protective equipment is typically low; there is a common perception that equipment is not necessary; finally and crucially, these findings varied according to the sport under consideration.

The finding that the risk of injury is higher among males than females is consistent with the results from other sports-related studies.[44] Ten to 14 year olds seem particularly susceptible to injury, and the use of PE needs to be emphasized for this age group. The finding that more injuries occur during non-competitive activity confirms Zaricznyj's results and reinforces concerns about the dangers associated with recreational skiing and sledding, physical education classes, and unorganized team sports.[138] Although the aim of physical education is to promote fitness, 50% of all basketball injuries occurred in gym class. However, we recognize that fewer children participate in organized competition and that these children may be at increased risk when participation rates are taken into account.

Intuitively, basketball appears to be a relatively safe sport -- one that does not require the use of equipment. Nevertheless, 29% of all basketball injuries were fractures. Although large-scale studies on basketball are scarce[17], the ankle[2,3,18] and finger[18] have been consistently recognized to be at increased risk for injury. This suggests the need to investigate the effectiveness of ankle supports or better running shoes, as well as a possible change in ball size.[17]

There was also an alarmingly high fracture rate among skiers, skaters, sledders, and snowboarders. Interestingly, the sport with the highest rate of equipment use was ice hockey and it had the lowest fracture rate.

In ice hockey there was a high incidence of head or face injuries and this raises concerns given that a helmet and face-mask are required in organized hockey. The high incidence of fractures to the shoulder, even when shoulder pads were in use, suggests that the design of shoulder pads needs re-examination. Shoulder injuries are typically the result of being checked and this prompts us to ask whether checking should be forbidden in youth hockey.[7,8] Knee injuries were also common and studies are needed to determine if they can be prevented by equipment.

We found a high rate of lower leg fractures among younger skiers, as well as among users of rented skis. This is consistent with Blitzer's et al.[5] study that found the use of hand-me-down equipment to be dangerous. Moreover, as Ekeland noted, ski injuries in children are often caused by the inappropriateness of the system used in determining tensions for children's bindings and boots. Such equipment must be designed taking the child's anatomy into consideration.[15] In fact, although thermoplastic boots are known to increase the incidence of fibular fractures, this material is often still used in children's ski boots.[6]

Our findings support Nguyen's[30] conclusion that 10-14 year olds are the most commonly injured ice skaters. Ice skaters had high rates of fractures and head injuries. The use of helmets is far too low in light of their proven efficacy[125, 128] -- albeit for bicyclists. The high rate of forearm fractures among ice skaters indicates that wrist guards or hockey gloves may be needed, especially for beginners.

We found a disturbingly high risk of head injury among sledders and this too may reflect a failure to use helmets. Although no studies have yet shown the effectiveness of helmet use among sledders this is largely due to their low rate of use. Nevertheless, several studies recommend their use, particularly among young sledders.[30] Another important finding is that the common mechanism of all lower leg fractures is sliding into stationary objects which suggests that attempts must be made to curtail this occurrence.

The high frequency of forearm and wrist fractures among snowboarders is consistent with other studies.[1,4,10,36] The susceptibility of the wrist is especially high among children and other beginners.[1,36] Although wrist guards have been recommended for snowboarders, especially for beginners,[2,3] not one injured snowboarder in our study was wearing wrist guards at the time of injury.

5.3 LIMITATIONS

There are several limitations to studying sports and recreational injuries using a surveillance database. The capture rate, reliability and validity of the data are always critical, although the acceptability of these elements for CHIRPP were confirmed in the study by Macarthur et al.[56] However, as Macarthur et al.[56] noted, the safety device question proved least reliable upon re-test and we, similarly, found a discrepancy between the form and phone reported use of equipment.

As is common in most sports-related studies, exposure, or participation rates in the population are unknown. We established the frequency of equipment use only among injured children seen at our hospitals and not in the general population. Do low rates in injured patients suggest that those who do not wear equipment are more likely to get injured? Or, is the low use of equipment by injured children simply a reflection of low equipment use by children, in general. Also, this would suggest that equipment is not, in fact, preventing injury. However many items of PE have been found to be effective in reducing the incidence and severity of injury.[9,11,16,17,19,20,22,24,33,35,38,39,42]

As with all surveillance based studies some cases are missed eg., non-emergency cases, older children who go to adult hospitals, those who do not receive or refuse to fill out the form. Another limitation is the possibility of a selection bias in respondents unable to be reached by telephone. They may be unable to afford a phone and, perhaps, equipment as well. Consequently, this study may underestimate the proportion of people who were not wearing equipment at the time of injury. This only serves to underscore the low use of PE by children seen at Montreal's two pediatric hospitals.

5.4 CONCLUSIONS & IMPLICATIONS FOR PUBLIC HEALTH

This study attempted to evaluate the CHIRPP database as a method for studying children's sports injuries. Although there are some limitations to the CHIRPP database, it appears to be a valuable resource for sports injury epidemiologists. It could improve upon the quality of its data by having more specific categories on PE in its safety devices question. While the switch from an open-ended safety devices question to a categorical question was a step in the right direction for CHIRPP, it needs to re-work the categories it has selected. Nevertheless, this study confirms the value of a surveillance system for studying sports injuries. Surveillance systems, like CHIRRP, enable the identification of injury clusters, the implementing of an appropriate countermeasure, and the monitoring of such an intervention.

Our findings, when combined with those from other studies, reveal that the use of PE intended to protect children from injury in sports and recreational activities is low. The results demonstrate that there are certain body parts at increased risk of injury depending on the sport. This supports the need for further innovation, testing, and use of equipment.

In the end, however, the key is having children wear equipment proven to prevent injury. This may require regulatory measures that are justifiable by the impact they may have on reducing the incidence of injury or on preventing long-term sequelae and thereby decreasing health care costs.

Given the above-mentioned necessity and benefits of certain pieces of protective equipment, and the reluctance of children to wearing them, one solution to increase use is for children to be required to use equipment under specified circumstances, eg. organized sports. Rights advocates argue that even though equipment may reduce the incidence of injury, it violates the individual's right to decide for himself or herself. However, even John Stuart Mill, the forefather of individualism, acknowledged that "the conduct of children must be regulated by others". Our study suggests that one reason for the low use of PE is that it is not viewed as necessary by parents. Another is that some parents have trouble enforcing its use, or feel that, in the case of injuries occurring at school, it is the schools responsibility to do so. Mandatory enforcement of the use of protective equipment, that has been found to reduce the incidence of injury, would not only effectively decrease the rate of morbidity associated with sports but would also reduce the burden on parents to persuade their children to wear equipment.

The innovation of protective equipment requires insight into the epidemiology of sports injuries, the biomechanical properties of the sport, and the psychology of PE use. This study has provided some understanding into children's winter sports injuries and PE although there is a lot more research that needs to be conducted on this often neglected field.

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APPENDIX 1A:

CHIRPP Form from the pre-1997 period

HC PROTECTED (WHEN COMPLETED)

MONTREAL CHILDREN'S HOSPITAL

INJURY/POISONINGS FORM

- COMPLETE ONLY AT FIRST VISIT FOR THIS INJURY
- PLEASE GIVE AS MUCH DETAIL AS POSSIBLE
- PLEASE PRINT CLEARLY

1. When did the injury happen? DATE: day ___ month ___ year 19___ TIME: ________ ☐ A.M. ☐ P.M.

1A. Did you see the injury happen? ☐ YES ☐ NO

2. Where did the injury happen?

OWN HOME - WHICH ROOM? ________________ OTHER HOME - WHICH ROOM? ________________

OTHER PLACE ________________________________

ON ROAD ________________________________

(e.g., intersection of First Avenue and Main Street, at side of road)

3. What was the injured person doing when the injury happened? (e.g., Playing hockey, crossing road, taking a bath, etc.)

4. Did the injury happen at work? ☐ Yes ☐ No If "Yes", give occupation:

5. What went wrong? (e.g., Chased by dog and lost control of bike, toy broke, hot coffee spilled, etc.)

6. What actually caused the injury? (e.g., Landed on concrete, cut by sharp toy, burned by hot coffee, etc.)

7. If a specific PRODUCT or ARTICLE other than a motor vehicle was involved, please give details:

Product:	Brand or Make:	Type or Model:

8. If the injured person was in or hit by a MOTOR VEHICLE, please give details:

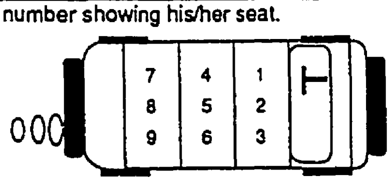
Make and Model (e.g., Honda Civic)	Year	Type of vehicle (e.g., sedan, hatchback, 4x4, motorcycle, snowmobile)
	19___	

9. What SAFETY DEVICES were in use when the injury occurred? (e.g., seat belt, child car seat, child-proof cap, helmet, etc.)

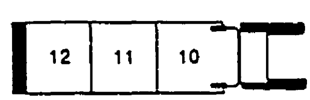
10. If the injured person was in a motor vehicle, circle the number showing his/her seat.

NOTE: 1 = DRIVER

If in another position in / on motor vehicle (not shown), check here ☐



CAR / VAN



MOTORCYCLE / SNOWMOBILE / ATV

11. What LANGUAGE is most often spoken at the injured person's home?

SOMETIMES WE NEED TO CONTACT PATIENTS (OR THEIR PARENTS) FOR MORE INFORMATION ABOUT AN INJURY

If you do not wish to be contacted, please place an "X" here ☐

IMPORTANT: GIVE THIS FORM TO THE DOCTOR WHEN YOUR CHILD IS SEEN

HC/SC AAA 4006E\05

PROTÉGÉ PAR SC (UNE FOIS REMPLI)

HÔPITAL DE MONTRÉAL POUR ENFANTS

Déclaration de traumatisme ou d'empoisonnement

- **REMPLIR SEULEMENT À LA PREMIÈRE VISITE RELATIVE AU PRÉSENT TRAUMATISME**
- **FOURNIR LE PLUS DE DÉTAILS POSSIBLE**
- **ÉCRIRE LISIBLEMENT EN LETTRES MOULÉES**

1. Quand l'accident est-il survenu? jour mois année

DATE: __ __ 19__ HEURE: ______ ☐ A.M. ☐ P.M.

1A. Avez-vous été témoin de l'accident? ☐ Oui ☐ Non

2. Où l'accident s'est-il produit?

DOMICILE PERSONNEL-QUELLE PIÈCE? ______ AUTRE DOMICILE-QUELLE PIÈCE? ______

AUTRE ENDROIT ______

SUR LA ROUTE ______
(par ex., à l'angle du boulevard St.Laurent et de la rue Notre Dame)

3. Activité de la personne blessée au moment de l'accident (par ex., jouait au hockey, traversait la rue, prenait un bain, etc.)

4. L'accident est-il survenu au travail? ☐ Oui ☐ Non Si oui, indiquer l'emploi:

5. Circonstances de l'accident (par ex., un chien l'a poursuivi et il a perdu la maîtrise de sa bicyclette; son jouet s'est brisé; il a été éclaboussé par du café chaud, etc.)

6. Cause réelle du traumatisme (par ex., il a fait une chute sur le ciment; il s'est coupé sur son jouet; il a été brulé par du café chaud, etc.)

7. Si un PRODUIT ou un ARTICLE précis (autre qu'un véhicule motorisé) est en cause, veuillez l'indiquer:

Produit:	Marque ou Modèle:	Type ou Modèle:

8. Dans le cas d'un accident de voiture, veuillez préciser:

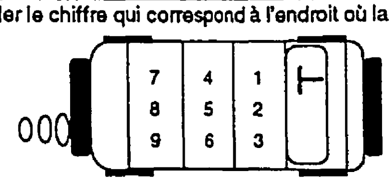
Marque ou Modèle (par ex., Honda Civic)	Année	Genre de véhicule (par ex., sedan, hatchback, 4x4, motocyclette, motoneige, etc)
	19	

9. MESURE DE SÉCURITÉ utilisées au moment de l'accident (par ex., ceinture de sécurité, siège d'auto, bouchon à l'épreuve des enfants, casque de sécurité pour bicyclette, etc.)

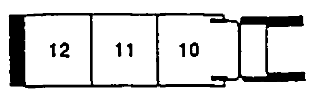
10. Dans le cas d'un accident de voiture, veuillez encercler le chiffre qui correspond à l'endroit où la personne était assis.

NOTA: 1 = CONDUCTEUR

Autre position, non illustrée (cocher s'il y a lieu) ☐



AUTOMOBILE OU VAGONNETTE



MOTOCYCLETTE, MOTONEIGE, VTT

11. LANGUE parlée le plus souvent à la maison?

NOUS DEVONS PARFOIS COMMUNIQUER AVEC LES PATIENTS (OU LES PARENTS) POUR OBTENIR PLUS DE DÉTAILS AU SUJET D'UN TRAUMATISME
Si vous vous y opposez, inscrivez un «X» ici ☐

IMPORTANT: REMETTRE CETTE FEUILLE AU MÉDECIN AU MOMENT DE LA CONSULTATION

HC\SC AAA 4006 F\05 (9-93)

APPENDIX 1B:

CHIRPP Form from the post-1997 period

Montreal Children's Hospital

Injury/Poisonings Reporting Form

- **Complete only at first visit for this injury**
- **Please give as much detail as possible**
- **Please print clearly**

1. When did the injury happen?
   TIME____________ ☐ A.M. ☐ P.M. day | month | year

1A. Date of visit to this hospital (if different from date of injury) day | month | year

2. Where did the injury happen?
   Own home (which room) or yard | Other home (which room) or yard | Other place (e.g. school, shop, park)
   On road (e.g., intersection of First Avenue and Main Street, at side of road)

3. What was the injured person doing when the injury happened? (e.g., playing hockey, crossing road, taking a bath)

4. Did the injury happen while working for income?
   ☐ No ☐ Yes → Describe kind of work | Describe industry or type of business

5. Did the injury happen while participating in sports or recreation?
   ☐ No ☐ Yes → If "Yes" ☐ organized league or activity ☐ informal game or activity → Specify ____________

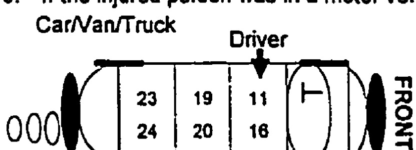
6. What went wrong? (e.g., chased by dog and lost control of bike, toy broke, hot coffee spilled)

7. What actually caused the injury? (e.g., landed on concrete, cut by sharp toy, burned by hot coffee)

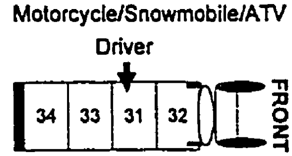
8. List all SAFETY DEVICES in use when the injury occurred.
   ☐ None ☐ Sports padding ☐ Seat belt ☐ Inflated air bag
   ☐ Helmet or hard hat ☐ Protective boots or clothing ☐ Protective eye wear ☐ Child car seat
   ☐ Other safety device - specify or describe → ____________

9. If the injured person was in a motor vehicle, circle the number showing his/her seat.
   ☐ Being towed ☐ In a non seating area

Car/Van/Truck



Motorcycle/Snowmobile/ATV



10. What LANGUAGE is most often spoken at the injured person's home?

SOMETIMES WE NEED TO CONTACT PATIENTS (OR THEIR PARENTS) FOR MORE INFORMATION ABOUT AN INJURY
If you do not wish to be contacted, please place an "X" here ☐

IMPORTANT: GIVE THIS FORM TO THE DOCTOR WHEN YOU OR YOUR CHILD IS SEEN

Hôpital de Montréal pour enfants

Déclaration de blessure ou d'empoisonnement

- **Remplir seulement à la première visite relative à la présente blessure**
- **Fournir le plus de détails possible**
- **Écrire lisiblement en lettres moulées**

1. Quand la blessure est-elle survenue (p. ex., 13 h 00)? jour | mois | année

HEURE ____________

1A. Date de la visite à cet hôpital (si différente) jour | mois | année

2. Endroit où s'est produit la blessure.

Domicile personnel (quel endroit ou pièce) ou la cour	Autre domicile (quel endroit ou pièce) ou la cour	Autre endroit (p. ex., magasin, école)

Sur la voie publique (p. ex., à l'angle du boulevard Saint-Laurent et de la rue Notre Dame)

3. Qu'est-ce que le blessé faisait au moment de la blessure (p. ex., jouait au hockey, traversait la rue, prenait un bain)?

4. La blessure est-elle survenue en faisant un travail rémunéré?

☐ Non ☐ Oui → Genre de travail | Genre d'industrie ou d'entreprise

5. La blessure est-elle survenue pendant des activités récréatives ou sportives?

☐ Non ☐ Oui → Si «Oui» ☐ organisées ☐ informelles → Préciser ____________

6. Que s'est-il passé? (p. ex., un chien l'a poursuivi et il a perdu la maîtrise de sa bicyclette, son jouet s'est brisé, il a été éclaboussé par du café chaud)

7. Qu'est-ce qui a causé la blessure (p. ex., il a fait une chute sur le ciment, il s'est coupé sur son jouet, il a été brulé par du café chaud)

8. Énumérer tous les DISPOSITIFS DE SÉCURITÉ utilisés au moment de la blessure.

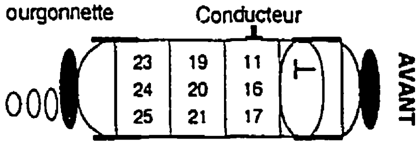
☐ Aucun ☐ Équipement de protection rembourré pour le sport ☐ Ceinture de sécurité ☐ Coussin gonflable

☐ Casque protecteur ☐ Bottes ou vêtements protecteurs ☐ Lunettes protectrices ☐ Siège d'auto pour enfant

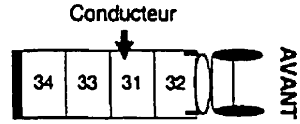
☐ Autre dispositif de sécurité (préciser) → ____________

9. Dans le cas d'une blessure en véhicule moteur, veuillez encercler le chiffre qui correspond à l'endroit où la personne était assise.

Voiture/camion/fourgonnette



Motocyclette, motoneige, VTT



☐ Ailleurs que dans un siège ☐ Pendant le remorquage

10. LANGUE parlée le plus souvent à la maison du blessé?

NOUS DEVONS PARFOIS COMMUNIQUER AVEC LES PATIENTS (OU LES PARENTS) POUR OBTENIR PLUS DE DÉTAILS AU SUJET D'UNE BLESSURE - Si vous ne voulez pas être contacté, inscrivez un «X» ici ☐

IMPORTANT : REMETTRE CETTE FEUILLE AU MÉDECIN AU MOMENT DE LA CONSULTATION

HC/SC4006F/05 (06-97)

APPENDIX 2 : HIGHLIGHTS FROM STUDIES ON WINTER SPORTS INJURIES & PROTECTIVE EQUIPMENT

BASKETBALL

STUDIES ARE SCARCE:

Ellison[37]: * epidemiological studies of basketball are scarce, large-scale studies are rare

Barrett[5]: *taping, ankle braces, and **high top shoes** theoretically provide external mechanical support to the ankle joint by preventing extremes in range of motion, thereby reducing the risks of injuries. Few studies have been done to evaluate whether these methods actually prevent ankle sprain.

American Academy of Pediatrics[3]:
* little information exists regarding injury experience of preadolescent players

OROFACIAL INJURIES COMMON; MOUTH GUARD AND EYE PROTECTORS RECOMMENDED

Nelson[88]:
* basketball -- has second highest incidence of eye injuries among sports
* **protective eye wear** would prevent these injuries

Flanders[39]:
* 18.3 orofacial injuries/ 10, 000 in basketball (1.4/ 10,000 in football)
* orofacial injuries account for 30% of total
* recommends a **mouth guard**

Morrow et. Al[82]:
* study of female athletes
* 69% wore **mouth guard**, 2.8% injury rate, 31% no **mouth guard**, 30.3% injury rate
* recommends a **mouth guard**

Lee-Knight et al.[72]:
* basketball players had the highest incidence of orofacial injury; no **mouth guard** in use at time of injury.

ANKLE INJURIES COMMON; ANKLE PROTECTION NEEDED:

Bernhardt[6]:
* ankle injuries comprise 40% of all basketball injuries
* more than 80% of ankle sprains are from an inversion

Ellison[37]:
* fingers and ankles were most common site of injury
* there is an increase in ankle injury with increasing age
* suggested prevention: **prophylactic taping, muscle strengthening, high-tops**

Barrett[5]:
* there is no difference between **high-tops** and **low-tops** despite other studies which suggest a difference

Shapiro[115]:
* study on cadaveric ankles showed that **high-top** shoes required a greater force to cause ankle inversion
* there is a benefit from **high-tops** that is further increased by **taping**

RECOMMENDED EQUIPMENT:

mouth guard, eye protectors, research needed on: ankle supports, high-top shoes, shin guards, change in ball size

ICE HOCKEY

FEW STUDIES ON YOUTH HOCKEY:

Brust[5]:
* risk of injury at youth levels has received little study; concern is growing
* Squirts experienced the fewest injuries -- supports age association

Björkehheim[9]:
* epidemiological studies of junior ice hockey are rare
* early teenagers are most vulnerable group with injuries typically caused by direct trauma; 55% of injuries to lower extremity

Stuart[120]:
* further research in youth hockey is needed to determine whether injuries can be reduced by **equipment**, rule changes, etc.

NECK AND HEAD INJURIES ARE COMMON; MUST WEAR HELMET AND FACE MASK

Grin[50]:
* estimated that hockey **face masks** prevented more than 70,000 projected eye injuries -- resulting in $10 million savings in medical expenses.
* minor head and neck injury may be precursor to serious injury

Brust[15]:
* 1987 study at high school level: 75 injuries per 100 players with 22% of injuries to the neck and head
* programs should be geared to children with information on strengthening neck muscles

Brunelle[14]:
* in last few decades there has been an improvement in use of hockey **equipment** for various parts of the body
* l'Association canadienne de hockey amateur(ACHA) mandated use of **helmet** and **face mask**; in 1988, the RSSQ mandated use of **helmet, facial protector, and throat guard**

Sim[119]:
* Hornof and Napravnik: head and neck injuries are largest single group
* Biener and Muller: head and face are largest single group
* AMHAUS: very small % of players would use face masks if it was optional

Laprade[70]:
* mandatory use of **face masks** in intercollegiate ice hockey resulted in a reduction in facial lacerations and no increase in overall head and neck injuries

Björkehheim[9]:
* need stricter rule enforcement because 1/3 of all injuries are the result of foul play

Murray[85]:
* the institution of **face mask, helmet** led to an increase in cervical spine injuries because players perceived themselves to be immune to injury -- increase incidence of illegal use of the stick.
* may overestimate the protection of their own **equipment** and dive into the boards in interest of winning the game.
* **helmet, face mask** are a passive solution to players mishandling their sticks. However, increase in neck and spinal injuries can not only be attributed to **helmet, face mask** because it has been on a gradual increase. Other factors: player size, attitudes, role models.

PUSHING AND CHECKING ARE MOST COMMON CAUSES OF INJURY:

Murray[85]:
* leading cause of spinal cord injuries is a push or a check into the boards.

Brust[5]: * Regnier: risk of injury in youth hockey is high and major contributor is body checking; 88% of fractures were related to body checking; 12 times more injuries in checking leagues as compared to non-contact leagues.
* body contact accounted for 86% of all injuries that occurred during games
* checking and illegal infractions accounted for 86% of all injuries

Brunelle[14]: * being checked, hit with a stick or projectile are major cause of injury
* 1988 study -- risks in pee-wee hockey (12-13 y. old): twelve times more fractures in contact leagues compared to non-contact leagues. Quebec outlawed checking in the pee-wee category

RECOMMENDED EQUIPMENT:

Required: helmet, full face mask, throat protector

Recommended: shoulder pads, elbow pads, hockey gloves, hockey pants with genital protectors [athletic support and cup (male) and athletic jill strap (female)], shin guards, garter belt or equivalent, mouth guard

SKIING

CHILDREN HAVE UNIQUE INJURY PATTERN:

Shorter[117]:

* study on 18 year olds and younger
* major ski injuries to children, most involve collision with stationary objects.

There has been a decrease in extremity injuries over the past three decades as a result of improved equipment. However, there has been no corresponding decrease in rate of upper extremities or injuries to the head, neck, and trunk.

* Children and beginners seem to be more prone to collisions. 20 to 40 % of injuries occur in children under the age of 16 and the injury rate is higher in children, with boys 11 to 14 most prone to injury. The types and patterns of injury seen in children differ in some respects from those seen in adults and there are different injury patterns in different pediatric age groups (should have age specific equipment)
* excessive speed and loss of control are the most life-threatening and should be targeted - more adult supervision.

Garrick[42]:

* younger children do not have more fractures they simply have fewer non-fracture injuries.
* females sustain more injuries
* children and adolescents should not be considered as a single group; the skiing population could be considered as 3 distinct sub-groups:

<10: low injury rate, however, concern because 22% of injuries are fractures
11-14: highest injury rate
>15: mid-way

Blitzer[11]:

* compares adult and children
* adolescents usually have sufficient skill to ski rapidly, yet show bad judgement, recklessness; use **old, obsolete, poorly maintained equipment**; distinctly increased risk of injury compared to adults or younger children
* providing children with inexpensive, **hand-me-down equipment** is dangerous
* overall incidence of knee injuries in all age groups was similar; older children sustain more severe injuries
* thumb injuries are less prevalent in children under 10

Macnab[77]:

* proportion of females injuring their knees is about 20 times that of males in all groups above 7 years old; need **gender specific equipment**

Brunelle[14]:

* knee sprains are most common type of injury
* need a study of real causes of ski injuries

BOOTS AND BINDINGS:

Bouter[12]:

* use of modern **ski binding** has had preventive effect. **Thermoplastic boot** increases chance of fibular fractures because of impaired binding function; this material still used in the manufacturing of many children **ski boots**.
* development and use of modern equipment, especially of **release bindings** and **plastic ski boots** has contributed to decline in incidence.
* risk for LE injury compared to non-LE injury is elevated when no **binding** release occurs.

Ekeland[34,35]:

* the most common **binding system** used is based on body weight; this system results in higher values than tibia head diameter system; this may explain why only

43% of injured skiers under 10, skis released as compared with the release of skis of 73% of 10-14 year olds.
* lower extremity **equipment** related injuries (binding release problems) are most significant injury group in alpine skiing
* knee sprains (56%), lower leg fractures (14%) with no or late **binding release**
* children below 10 years old had 9x risk of lower leg fractures when compared to skiers beyond 20 years

Brunelle[12]: * decrease in injuries over last decades, a result of improved **bindings, ski boots**

Blitzer[10]: * tibia fracture decreases as age increases due to weaker tibias of younger children and the use of old, **poor equipment**.

EVIDENCE ON HELMET USE IS LACKING

Shorter[91]: * 27/38 injuries were to the head
* Oh and Schmmid recommended compulsory **helmet** use by all child recreational skiers, but studies of **helmet** effectiveness have not been done. Design problems still exist concerning sight and hearing.
* **helmets** would be of value in decreasing the severity of head injury to young recreational skiers

Macnab[58]: * no studies report on the efficacy of **helmets** in young skiers

RECOMMENDED EQUIPMENT:

helmet, proper fitting skis, ski boots for children based on proper weight system

ICE SKATING:

FEW STUDIES ON ICE SKATING

Nguyen[90]:
* there is little literature on ice skating
* 10-14 year olds most likely to be injured

RECOMMENDED EQUIPMENT:

helmet, wrist guards, elbow pads, knee pads

SNOWBOARDING

UPPER EXTREMITY INJURIES AND WRIST GUARDS

Chow[21]: * majority of snowboards have non-releasable binding systems and, thus fix the lower limbs preventing this area from absorbing energy during a fall. Consequently, the outstretched arm is used to break the fall, often resulting in distal radius fractures
* fractures to upper extremities comprised 35.9% of snowboarding injuries as compared with 12% for skiers
* wrist guards may increase injury to areas proximal to the wrist: 21 snowboarders wearing wrist guards sustained no wrist injuries, 6 injuries to the shoulder, 4 radial shaft fractures (does not address manner in which snowboarder fell)
* wrist guards may be most helpful to the beginner because most predisposed to injury

Abu-Laban[1]: * children are at increased risk for wrist injuries
* injuries more common among beginners: 36% to first time snowboarders, 25% to first year snowboarders

Shealy[116]: * distal radius of children is relatively weak because it is a metaphyseal bone that has not been remodeled; fractures are potentially serious because they can result in interrupted bone growth

Calle[17]: * all participants should wear **protective wrist and upper extremity pads** due to wrist fractures and upper extremity soft tissue injuries.

Bladin[10]: * novice riders were more likely to have upper limb fractures, particularly to wrist and forearm
* falling with clenched fists may reduce fractures
* gloves are being manufactured with wrist reinforcement

USE OF EQUIPMENT

Chow[21]: * 86% of snowboarders used soft shelled boots, 14%used **knee pads**, 3% used **elbow pads**

LOWER EXTREMITY INJURIES AND BOOTS

Abu-Laban[1]: * majority of snowboards to do not have a releasable binding system and no ski poles are used. In Canada, most snowboarders wear soft boots.
* Snowboarding injuries usually involve young well-conditioned males.
* Accidents are characterized by wrist, spinal, and ankle injuries, a significant propensity toward injuries to the left rather than the right leg and a low rate of lacerations and thumb injuries.
* manner of riding probably puts snowboarders at greater risk for falling backward and thus for axial-loading injuries.
* soft boots likely prevent the significant stress on the leg that causes contusions or fractures. The fixed binding of both feet to a snowboard likely decreases the possibility of valgus stress on the knee, a frequent cause of ligamentous injuries in skiing.
* many studies show the shifting nature of skiing injuries over the last 50 years: related to a move from soft boots and fixed bindings to stiff boots and releasable bindings: drop in foot and ankle injuries, tibial fractures increased and then decreased. Same level of knee injuries but a propensity toward complete ligamentous tears.

Bladin[10]:

* ankle injuries were more common with soft-shelled boots than hard-shelled
* hard shelled boots -- more distal tibial boot top fractures
* 4 times more ankle injuries than in skiing, 2 times as many upper limb injuries, and half as many knee injuries
* soft-shelled boots for beginners

RECOMMENDED EQUIPMENT:

helmet, wrist guards, knee pads, elbow pads
to be investigated: soft-shelled vs. hard shelled boots

SLEDDING/TOBOGGANING

FEW STUDIES RELATED TO SLEDDING

Shugerman[118]: * there are few studies related to sledding injuries despite the fact that sledding is often associated with serious injuries (recreational activities are not seen as threatening as organized sports).

Nguyen[90]: * there are few studies related to sledding

HELMET

Shugerman[92]: * Case control study: children who sledded while wearing a bicycle **helmet** did not show a decreased risk of injury. The number of children who sledded with a **helmet** was not large enough to analyze their risk for head injury alone. Samples with larger sample sizes should provide more info.
* Preventive strategies should be organized around sledding in streets as opposed to parks and sledding without adult supervision.

Nguyen[90]:
* 33,000 sledding injuries in U.S.
* sleds can obtain speeds of 16-32km/hr
* head injuries are usually seen in young children while extremity injuries are more often seen in older adolescents; younger children have larger heads and higher center of gravity

Sudbury study (in Nguyen)[90]:
* males are more often injured
* most accidents occurred when it is not light outside
* 17% are spinal injuries, 25% are head and facial injuries
* few people wore **helmets**
* **helmet** should be worn

Kim[65]:
* only 1/22 was wearing **protective head gear**
* 59% has head as initial sight of impact
* need awareness of dangers and safety guidelines

TYPES OF EQUIPMENT RECOMMENDED:

elbow pads, knee pads, protective helmets