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A REVIEW OF FIELD HOCKEY INJURIES AND COUNTERMEASURES FOR PREVENTION

by

Shauna Sherker

Erin Cassell

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A Review of Field Hockey Injuries and Countermeasures for Prevention

Author(s)
Shauna Sherker
Erin Cassell

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Abstract:
Hockey is an ancient sport thought to be the forerunner of all 'stick and ball' games. The modern game of hockey is played in 132 countries around the world and is second only in popularity to soccer as a team sport. Epidemiological studies have consistently shown that injuries in hockey are numerous and can be serious. Most serious injuries result from being struck by the stick or the ball. Overuse injuries to the ankles and lower back are also frequently reported. Players aged between 10 and 19 years account for 50% of all Victorian hospital emergency department presentations for hockey injuries. Most injuries presenting to hospitals are to the upper limb (mostly injuries to the hand and forearm), face (mostly struck by stick or ball) and lower limb (mostly ankle, foot and knee injuries). Injuries to the eyes are infrequent, although tend to be severe.

The aim of this report is to critically review both formal research literature and informal sources of information in the context of the available epidemiological data, which describe preventive strategies and countermeasures to hockey injury. Countermeasures for preventing hockey injuries with some evidence to support effectiveness include: enforcing rules aimed at preventing dangerous use of the hockey stick and careless play of the ball; modifying rules for children; use of protective equipment (such as shin guards, eye wear and mouthguards); expert training of coaches and officials; adequate nutrition; pre-season conditioning; pre-game stretch and warm-up; prompt access to professional first aid and medical care; and full rehabilitation before returning to play. Potential countermeasures requiring further investigation include: risk management plans; prophylactic taping and bracing of ankles; altering the stick design to make it safer; the use of protective gloves; extending pre-season screening to include non-elite players; and improving injury data collection, especially for non-elite levels of play. A systematic program of epidemiological and biomechanical research is required to investigate these and other risk and preventive factors.

Key Words:
Field hockey, injury prevention, safety, countermeasures, evaluation

Monash University Accident Research Centre,
Wellington Road, Clayton, Victoria, 3168, Australia.
Telephone: +61 3 9905 4371, Fax: +61 3 9905 4363

Contents

Tables

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EXECUTIVE SUMMARY

Hockey is an ancient sport thought to be the forerunner of all 'stick and ball' games. The modern game of hockey is played in 132 countries around the world and is second only in popularity to soccer as a team sport.

The aim of this report is to critically review both formal research literature and informal sources of information that describe preventive strategies and countermeasures to hockey injury. This review is informed by the analysis of hockey injury data, which provides a context for the identification of potentially effective interventions.

Epidemiological studies in Australia and overseas have consistently shown that injuries in hockey are numerous and can be serious. The available evidence suggests that the majority of serious injuries result from being struck by the stick or the ball. Overuse injuries to the ankles and lower back are also frequently reported.

Victorian emergency department presentation data shows that players aged between 10 and 19 years account for 50% of all hockey injuries. Most injuries presenting to hospital ED are to the face, hands, and lower limb. Being struck by an object, usually the stick or the ball causes most of these injuries. Injuries to the eyes tend to be comparatively serious when they do occur.

There are few controlled evaluations of countermeasures to prevent hockey injury, so recommendations in this report are necessarily tentative. Potential countermeasures to injury are listed in Table 1. Where there is some supporting evidence for effectiveness, countermeasures for preventing hockey injuries include: penalties enforcing rules aimed at preventing dangerous use of the hockey stick and careless play of the ball; modified rules for children; use of protective equipment (such as shin guards and mouthguards); expert training of coaches and officials; pre-season conditioning; adequate nutrition; pre-game stretch and warm-up; prompt access to professional first aid and medical care; and full rehabilitation before returning to play.

Potential countermeasures requiring further investigation include: risk management plans; altering the stick design to make it safer; the use of protective eyewear; the use of protective gloves; prophylactic taping and bracing of ankles; extending pre-season screening to include non-elite players; and improving injury data collection, especially for non-elite levels of play.

Table 1: Potential countermeasures to hockey injury.

Primary countermeasures	• Coaching and expertise of coaches • Pre-participation screening • Pre-season conditioning and fitness program • Adequate nutrition and hydration • Adequate warm-up and pre-game stretch • Officiating and expertise of officials • Prophylactic taping and bracing • Devising rules aimed at preventing dangerous play • Safe playing environment (for example level surfaces) • Cool-down and post-game stretch
Secondary countermeasures	• Wearing of proper footwear • Attention to biomechanics, technique • Control of dangerous play by officials and coach • Wearing protective equipment (for example shin guards, mouthguards)
Tertiary countermeasures	• Prompt access to professional first aid and medical care • Availability of first aid equipment on site • Rest, Ice, Compression, Elevation, Referral (RICER) • Rehabilitation • Taping and bracing to prevent re-injury • Return to play only when fit

HOCKEY INJURY DATA COLLECTION

A review of the current literature for hockey injury indicates a need to improve data collection at the club and association level to gain a more accurate picture of the incidence, pattern and severity of all hockey injuries. The use of consistent definitions of injury and standardised classification systems should be promoted. There is a need to include measures of exposure in hockey research (for example, injuries per 100 hours of match play and practice) so that findings from studies are more easily compared.

Recommendations:

- Hockey injury data should be collected at all levels, including club and association.
- Hockey injury data collection should be standardised to allow for easy comparison of reported findings.

RISK MANAGEMENT PLANS

Risk management plans can assist sporting clubs, associations and facilities to provide a structure for sports safety. Components of a risk management plan may include: pre-participation screening; physical preparation; coaching; officiating; codes of conduct; policy and regulations; standards; equipment; health promotion; education; sports first aid and sports trainers; environmental and playing conditions; injury management and rehabilitation; injury surveillance; and insurance.

The effectiveness of risk management plans has not been formally evaluated. Few centre and clubs report that they have adopted a risk management plan. More formal evaluation of risk management plans is warranted. In addition, identifying and addressing barriers to implementing risk management plans at hockey clubs is needed.

Recommendations:

- More formal evaluation of the effectiveness of risk management plans in the prevention of sports injury is warranted.
- Identifying and addressing barriers to implementing risk management plans at hockey clubs is needed.

PRE PARTICIPATION SCREENING

A person wanting to participate in sport needs to be of a minimum physical, physiological and psychological fitness in order to meet the demands of competition and to reduce the risk of injury (Australian Sports Injury Prevention Taskforce, 1997). The overall goal of pre-participation screening is to identify people with conditions that may predispose them to serious injury and to refer them to appropriate specialists for further evaluation.

- Pre-participation screening has been shown effectiveness in reducing the number of injuries in elite Victorian cricket players. On the basis of this evidence, it is recommended that all hockey players undergo at least a pre-season fitness screening for general strength, flexibility and endurance.

Recommendations:

- All hockey players should undergo at least a pre-season fitness screening for general strength, flexibility and endurance.
- Coaches should be trained to screen players and to refer them on to appropriate professionals if problems are evident.

ATTENTION TO GOOD NUTRITION AND HYDRATION

Hockey requires players to perform multiple work bouts at near maximal effort, punctuated by intervals of low intensity exercise or rest. This type of workload has been associated with a significant loss of water (Burke and Hawley, 1997) and fluid replacement strategies during training and competition should be followed. Given the high-energy demands of training and competition, athletes need also increase their total dietary energy intake.

There is evidence that elite female hockey players demonstrate a high level of body dissatisfaction and an elevated drive for thinness (Marshall and Harber, 1996). Female athletes should be monitored for menstrual irregularities, as these have been associated with risk of osteoporosis which have been linked to an increased risk of stress fractures, especially in the lumbar region of the lower back (Benell et al., 1997).

Although there is evidence to show that diet can affect athletic performance, the link between diet and sports injury is not clear and further research is needed.

Recommendations:

- The impact of diet on the incidence of injury, particularly in women, needs to be determined.
- More research is needed to determine the role of menstrual irregularities and the risk of overuse injuries. In particular, the exact relationship between menstrual health, bone health and stress fractures is yet to be determined.

PRE-SEASON CONDITIONING AND FITNESS PROGRAM

Overuse injuries are common in hockey, affecting predominantly the ankles and lower back. Pre-season screening for pre-existing conditions, or for weaknesses in strength or flexibility is important to reducing the risk of injury.

Pre-season conditioning, with particular attention to improving strength, flexibility and endurance, can help the player prepare for the physical demands of the game. Warming-up and stretching, which are known to improve the range of motion of the joints and improve muscle elasticity, are recommended.

Recommendations:

- All players should undergo at least a pre-season fitness screening for general strength, flexibility and endurance.
- Further research is needed to determine the effectiveness and best methods of warm-up and stretching as injury prevention measures for hockey.
- Players should undergo conditioning for general fitness before the start and throughout the season.
- Players' conditioning programs should be monitored for proper content and technique.
- Coaches should be taught principles of sport-specific conditioning and fitness as part of their training.

- More formal scientific evaluation of periodization training for injury prevention is needed.

ADEQUATE WARM-UP, STRETCH AND COOL-DOWN

On the basis of current clinical and experimental evidence, it is reasonable to accept that warm-up plays a role in the reduction of the incidence and severity of musculoskeletal injuries. Well-controlled epidemiological and experimental studies are needed to fully evaluate the preventative effect of warm-up.

There is no epidemiological evidence to show that cooling down reduces the incidence of injury. However, on the basis of anecdotal evidence it is recommended that all participants should practice a slow gradual cool-down after strenuous activity, which can help to promote optimal recovery from strenuous exercise.

Recommendations:

- Undertake research into the effectiveness and best methods of warm-up, stretching and cool-down as an injury prevention measure for hockey.
- Develop and promote information about warm-up, stretching and cool-down techniques specifically for hockey.
- Identify and address barriers to warm-up, stretching and cool-down among hockey players.

COACHING AND EXPERTISE OF COACHES

The role of the coach is important to injury prevention. Coaches and leaders help to educate players in the fundamental playing techniques of the game, which should include tenets of injury prevention, controlled risk taking and disciplined play.

The National Coaching Accreditation Scheme (NCAS) of the Australian Coaching Council offers progressive hockey coach education programs at four levels of proficiency. It is recommended that all coaches should have at least a NCAS level 1 accreditation from a coaching course.

Sports Medicine Australia also recommends that coaches complete at least a sports medicine awareness course from their Safer Sport program. Coaches are usually present during training and games and are often the first to respond to an injured player. A coach with knowledge of basic sports first aid will ensure that a player receives prompt medical attention in case of an injury.

Recommendations:

- All coaches should be provided with at least NCAS level I accredited coaching and sports medicine awareness training.
- Coaches should be trained to screen players and to refer them on to appropriate professionals if problems are evident.
- Coaches should be taught principles of sport-specific conditioning and fitness as part of their training.

OFFICIATING AND EXPERTISE OF OFFICIALS

Rules, and the way that officials interpret them are a key element in sports injury prevention (Australian Sports Injury Prevention Taskforce, 1997). Determining what constitutes dangerous play is often left to the discretion of the officials, who have a duty of care to participants to ensure their safety during play (National Officiating Program (NOP), 1995).

The National Officiating Accreditation Scheme (NOAS) of the ACC offers umpires educational programs at progressive levels of proficiency. Training includes a module on risk management for sports officials (National Officiating Program (NOP), 1995). The program stresses that the health and safety of the participants is the most important factor to be considered in the official's decision making process (National Officiating Program (NOP), 1995).

Recommendations:

- It is recommended that all officials have at least NOAS level 1 accreditation

RULES AND PENALTIES

To reduce some of the risk of injury, certain rules are applied and conventions observed to reduce dangerous play during a match. Rules that limit the use of the stick and the ball are adopted in order to reduce the risk of stick and ball type injuries, which are frequently reported. The effectiveness of these rules in reducing injury is dependent on the strict and consistent interpretation by the umpires.

Modified hockey rules for children gives younger players a chance to develop basic skills before progressing to a more competitive level of play. By gradually introducing and developing more formal skills, children's entry level playing ability is far greater when they start to play hockey with standard rules.

The FIH has adopted a "no blood rule" which states that *an injured player must leave the pitch in case of an injury that causes bleeding*. Players with bloodstains on body or clothing are not to be allowed to start or continue to play in this condition. Wounds must be covered and the bleeding stopped before the player may re-enter the game.

Recommendations:

- Young children should be progressively introduced to hockey through Minkey and 'half-field' hockey.
- Umpires should be continuously trained so that there is consistent interpretation of rules to minimise unsafe play.
- Strict penalties should be consistently invoked for deliberate fouls and player dissension.
- It is recommended that clubs and organisations adopt and enforce an infectious disease policy.

PROPHYLACTIC TAPING AND BRACING

There is increasing interest in prophylactic taping and bracing as a means of protecting players against ankle sprains which probably account for the greatest loss of playing time of any injury. The effectiveness of taping and bracing in the prevention of ankle injuries in hockey has not been investigated, although it has been shown effective in reducing the incidence of acute ankle injuries in other sports (basketball and US football).

The concept of taping and bracing implies that the ankle joint is inherently 'weak', and requires added support to sustain the forces involved in play. One alternate theory is that these injuries are due to poor tactile sensory cues and not from a lack of mechanical support to the ankle. Further controlled research is needed to determine the exact mechanism of ankle injury and whether taping or bracing can prevent ankle sprains and strains in hockey.

Recommendations:

- Improve ankle stability by including flexibility and strength exercises in the pre-season training
- Ensure full recovery of ankle function before returning to play in order to prevent recurrent ankle injuries
- Investigate the effectiveness of different prophylactic stabilising methods for the ankle in hockey players in controlled studies
- Investigate the relationship between footwear and ankle injuries in hockey.

PROTECTIVE EQUIPMENT

The effectiveness of protective equipment in preventing hockey injuries has not been fully evaluated. Shin guards have been proven effective in preventing kick-type injuries to the lower leg, although the force of a swung hockey stick is much greater than the force of a kick. Nevertheless, shin guards are recommended for use by hockey players.

Mouthguards are effective in protecting the teeth from fracture, preventing lacerations to the lips and cheeks, decreasing the risk of jaw fracture and reducing the risk of concussion. Mouthguards should be worn by all players during games and training.

The use of protective eyewear and gloves to protect against hand and especially finger injuries requires further investigation.

Recommendations:

- Enforce the rule that all goalkeepers wear helmets and other protective gear during games and at training.
- Promote the use of well-fitted shin guards during training and games.
- Undertake further research into the design and effectiveness of shin guards for use in hockey.
- Players are strongly advised to wear mouthguards during training and games.

- Mouthguards should be properly fitted and of good quality in order to maximise player comfort and compliance.
- Mouthguard use should be encouraged at an early age so that it becomes a habit.
- Mouthguards should be replaced at the first sign of wear (cracks or splits) or loss of resilience.
- Undertake controlled studies into the effectiveness of protective gloves in preventing hand and particularly finger injuries in hockey.
- Undertake further research into the effectiveness of protective eyewear in the prevention of hockey eye injuries, with a view to introducing protective eyewear if indicated by research findings.

ENVIRONMENTAL CONDITIONS

There are practical advantages to the use of synthetic surfaces in hockey. The International Hockey Federation (FIH) has developed performance standards for hockey pitches based on ball rebound, ball run and deviation, impact response, surface friction, dimensions, slope, smoothness, colour, gloss, watering, porosity and surface health.

Anecdotal evidence suggests that ankle inversion injuries, meniscal problems and the prevalence of shin soreness, knee pain and lower back problems have increased with the more widespread use of synthetic surfaces. The abrasive nature of synthetic playing surfaces has meant that lacerations are also more frequent.

The natural grass surface contributes to a greater cushioning effect and less strain to the lower limbs by absorbing 10% more energy on impact than synthetic turf (Reilly and Borrie, 1992). The only study to compare the rate of injury on synthetic surface to that of grass is Jamison and Lee (1989). The authors reported that although the overall number of injuries sustained on Astroturf was greater than on grass, the joint injuries to the lower limb were *more prevalent* on grass surfaces (53%) than on Astroturf (37%). More research is needed to determine whether synthetic surfaces put the joints of the lower limb at greater risk of injury.

No specific evidence of preventative measures for climate-related hockey injuries were identified in this review. Injury prevention strategies are based on general thermoregulatory recommendations, such as wearing appropriate clothing, using sunscreen, maintaining hydration and undergoing a process of acclimatisation in extreme temperatures. Coaches, sports trainers and officials should be familiar with the potential dangers of playing or competing under inclement weather conditions, including high heat and humidity, extreme cold, or during electrical storms (National Officiating Program (NOP), 1995, Australian Coaching Council (ACC), 1991). In such situations, practice or competition should be restricted, altered or possibly cancelled to reduce the risk of injury.

Recommendations:

- Testing of new surfaces for hockey pitches should include controlled studies of changes in frequency, pattern and severity of injury.
- The relationship between playing surface, footwear and ankle injuries in hockey needs to be investigated

- Hockey players should maintain adequate fluid intake, especially in hot weather.

- Hockey players should wear a broad-spectrum sunscreen in high ultra-violet conditions.

- Risk management plans should be developed and implemented by hockey associations to control for environmental hazards such as thunderstorms and extreme climatic conditions.

TREATMENT AND REHABILITATION

Emergency care of hockey soft tissue injuries includes immediate rest, ice, compression, elevation and referral (RICER). The RICER method of treatment is believed to reduce the possibility of further damage to the injured soft tissue by reducing the swelling in the area.

The goal of a rehabilitation program is for the athlete to be free from pain and for the muscle strength and joint flexibility to return to pre-injury levels. It is important for a player to undergo a full recovery before returning to play. A premature return to play may exacerbate the injury and result in further time off the field.

Recommendations:

- Players should seek prompt attention for their injuries from a professional with first aid qualifications.
- Organisers of events should ensure that there are qualified professional first aid personnel at all events.
- Players should allow enough time for adequate rehabilitation of injuries, especially full recovery of ankle function, before returning to pre-injury levels of play.
- More controlled research into the effectiveness of different rehabilitation programs should be undertaken.

1. INTRODUCTION

Hockey is an outdoor game played by two opposing teams of 11 players who use sticks curved at the striking end to hit a small, hard ball into their opponent's goal. It is sometimes called field hockey to distinguish it from the similar game played on ice.

The earliest tangible record of hockey is a drawing done in 2050 BCE on a tomb at Beni-Hasan in the Nile Valley in Egypt. One of the six drawings of athletic activities depicted two figures holding sticks with curved ends. Between the sticks is a round object, possibly a hoop or a ball. On the basis of this evidence, historians nominate hockey as the forerunner of all stick and ball games.

There is also evidence that the Greeks, Arabs, Persians and Romans each had their own versions of hockey. Evidence of a stick game played by the Aztec Indians of South America has also been found. The name "hockie" was first recorded in Ireland in 1527 and probably comes from the French word "hoquet" meaning "shepherds crook". Rules have differed and playing surfaces have changed, but the concept of a two-team stick-and-ball game has remained the same.

The modern game of hockey evolved in England in the mid-18th century, primarily in schools. The earliest clubs played on large pieces of open ground with crudely designed sticks. A London club introduced several major variations, including the ban on using hands or lifting sticks above the shoulder, the replacement of a rubber cube by a spherical ball and the adoption of a striking circle. These changes were incorporated into the rules of the newly founded Hockey Association in London in 1886.

Hockey was one of the few early sports that encouraged women to engage in strenuous activity and to compete enthusiastically in a team athletic situation. The women's game developed quickly in many countries. In 1927, the International Federation of Women's Hockey Associations (IFWHA) was formed. The founding members were Australia, Denmark, England, Ireland, Scotland, South Africa, the United States and Wales.

Although hockey was a popular sport in Europe and the Middle East for centuries, it did not make an appearance in the Olympic Games until 1908. England 'ruled the field' in these early Olympic years, but India took over complete domination of the sport from 1928 to 1960. In recent times, Australia has emerged as one of the world leaders in the sport.

2. AIMS

The aim of this report is to critically review both formal and informal research literature describing measures to prevent hockey injury. The report evaluates the extent to which these measures have been demonstrated to be effective.

Unlike other literature describing hockey injuries, this report does not specifically focus on the epidemiology of hockey injury, nor does it provide a detailed description of injury aetiology. Instead, it focuses on a detailed examination of the range of measures to prevent hockey injury. A brief overview of the epidemiology of hockey injury, particularly from an Australian perspective, is given to provide the context for the subsequent discussion of countermeasures.

3. METHOD

The sources of information used to compile this report were:

- Medline CD-ROM search for published medical literature (from 1980 to 1998)
- Sport Discus CD-ROM search for published sports literature (from 1980 to 1998)
- Austrom:Ausport (Sport) CD-ROM search for published Australian sports literature (from 1980 to 1998)
- Population Survey Monitor (PSM) of the Australian Bureau of Statistics
- Brian Sweeney and Associates' market research into Australians and Sport 1996
- Discussions with state, national and international hockey organisations
- Discussions with key Australian hockey injury researchers
- Scanning of internet and world wide web sites
- Expert comment on the draft report

Data from the Victorian Emergency Department Minimum Dataset (VEMD) were analysed to provide information on the nature, severity and circumstances of hockey injuries as a context for the review of preventive measures.

The literature gathered for this review was critically assessed to determine the extent to which the various countermeasures had been fully evaluated and demonstrated to be effective in preventing injuries. A gradation scale for the strength of the evidence presented in the identified literature was developed, and is shown in Table 2.

This review is based largely on English-language material. Non-English language articles with English abstracts have been included where appropriate.

Table 2: Grading scale for assessing the quality of research evidence

Relative strength	TYPES OF EPIDEMIOLOGIC STUDIES
Weaker	**DESCRIPTIVE STUDIES (case series and cross sectional)** • **Case series (small, special registry and population-based)** **What are they?** Case series studies identify, define and describe injury problems and patterns. They classify injury cases into homogenous (like) subsets, count them, measure their severity and may specify their concentrations in specific population groups. There are three types of case series: • *small* for example, cases drawn from a single hospital or a small group of hospitals; • *special registry* for example, the new Victorian Emergency Department Minimum Dataset (VEMD) which holds detailed injury data collected from 25 hospital Emergency Departments; and • *state or national data*, for example, studies based on the Victorian Inpatient (hospital admissions) Database (VIMD) which collects a small amount of data on injury cases from all public and private hospitals. **Example:** *A study of 300 hockey injury cases presenting to VEMD hospital emergency departments 1996-1997.* **Strengths and weaknesses:** Case series can be a rich source of information on injury, especially special registry and follow-up studies. If the injury hazard from the case series is obvious there may be little need to carry out longer term and more costly research. However, case series can’t be used to prove causes of injury. Also, the sample of cases may be biased (particularly when drawn from small and registry-based collections) and may not be representative of all cases, which precludes the calculation of injury rates and trends over time. • **Cross sectional studies (surveys)** **What are they?** These studies determine the status quo of a condition during a specified period of time, *for example*, a survey of injuries among a representative sample of hockey players. Most surveys are cross sectional. **Strengths and weaknesses:** Cross sectional studies examine the relationship between the condition (for example, injury) and other variables of interest (for example, age, sex, skill level, use of protective gear) by comparing the prevalence of the condition in different population subgroups and between those with or without the condition, according to the presence or absence of the variables. They examine a condition at one point in time so cannot determine cause and effect.

Stronger	**ANALYTIC (OBSERVATIONAL) STUDIES (case control and cohort)** **What are they?** These studies test hypotheses (suppositions/conjectures) about the influences that determine that one person is injured while another is not ie. they provide strong evidence on the causes, risk and contributory factors to injury. • **Case-control studies** The researcher assembles a group of persons with the injury of interest (cases) and a comparison group drawn from the same population without the injury under investigation (controls). The history of past (retrospective) exposure of one or more potential risk factors for the injury can then be investigated. *For example,* a group of hockey players with ankle injury (cases) could be compared to a group of players from the same association without ankle injury (controls) in terms of exposure to potential risk factors (for example, playing position, previous ankle injuries). **Strengths and weaknesses:** Case control studies generally require a comparatively short study period, are relatively inexpensive and have the ability to examine association of several risk factors for the given injury. However, the choice and recruitment of appropriate controls can be difficult. Because case control studies investigate retrospectively from the injury event they are subject to recall and other biases which may affect the results and weaken evidence of cause and effect.
	• **Cohort studies** The investigator begins with a group of persons exposed to the factor of interest and a group of persons not exposed (for example, 15 to 19 year-old male hockey players would be a suitable cohort if hockey injury was the factor of interest) and the researcher follows up the cohort and *observes* the association between exposure (hockey) and outcome (injury) over a number of years. **Strengths and weaknesses***:* Because they are generally prospective (forward-looking) the likelihood of collecting reliable and valid data is greater. Consequently, results from a well-designed cohort study carry more weight in establishing a cause than results from a case control study. However, cohort studies often involve large numbers (especially if the factor of interest is rare) and/or a long study period, and are therefore expensive. The other great problem can be the dropout rate ('loss to follow-up') which can result in biased data

Strongest	**EXPERIMENTAL STUDIES** **(RANDOMISED CONTROLLED TRIAL AND COMMUNITY TRIAL)** **What are they?** In experimental epidemiological studies, the investigator controls the conditions under which the study is to be conducted by assigning subjects (preferably randomly) to either an experimental (treatment) group which receives the intervention or a control group that does not receive it. • **Randomised controlled trial (RCT)** In a RCT the investigator randomly allocates similar persons to the treatment and control groups. For example, in a RCT to test whether or not mouth guards prevent dental injuries, subjects would be recruited into the trial and randomly allocated to treatment (mouthguard wearing) and control (non-mouthguard wearing) groups and followed up over time. • **Community trials (quasi-experimental)** In a community trial the group as a whole is collectively studied. The investigator selects two similar communities. The incidence of the disease or condition of interest (for example, dental injuries among hockey players) and prevalence of suspected risk factor/s (for example, non-wearing of mouthguards) for which an intervention has been developed are surveyed in both. The intervention (for example, compulsory wearing of mouthguards) is then carried out in one community and the other does not receive it. The intervention stops and the communities are surveyed again. The net difference in the incidence of the condition and prevalence of the risk factor/s is thereby associated with the intervention. **Strengths and weaknesses:** Well-conducted controlled trials, where the assignment of subjects or communities to the experimental or comparison group is random, are regarded as the strongest epidemiological studies and provide the greatest justification for concluding causation. Obstacles to their use include their great expense and long-time period.

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Robertson L.S. *Injury Epidemiology*. Oxford University Press 1992, New York.

The above scale reflects an epidemiological and rigorous scientific approach to injury prevention that considers demonstration of the effectiveness of a countermeasure's performance in the field to be the highest level of 'proof'. This is particularly important for sports injury countermeasures where any change to the nature of the game is an important factor to be considered. In general, changes to factors such as how the sport is played, the behaviour of the participants and the effectiveness of rule changes can only be proven during "in-the-field" evaluations.

Another important aspect of countermeasure implementation is the extent to which they are accepted or adopted by the users for whom they were intended. Countermeasures should be acceptable to those they were designed to protect. Player consultation and awareness programs must therefore be considered in any implementation process. It is also important to assess barriers towards use of injury countermeasures. An investigation of attitudes, knowledge and behaviours is crucial to this. Studies of these factors can highlight the need for behavioural or educational change at either the individual or organisational level.

Another measure of the success of countermeasures is a demonstration of their benefit/cost ratios. This information is often needed by regulatory bodies and those involved in policy or rule making, to inform and justify their decisions about countermeasures. To date, there have been no studies of the economic benefits of hockey injury countermeasures.

4. PARTICIPATION IN HOCKEY

Hockey is played in 132 countries and is the second most popular team sport after soccer. Men's and women's competitions are played at the Olympic Games and at the Field Hockey World Cup, both of which are played every 4 years. The interest in these competitions is phenomenal: at the 1996 Olympic games, hockey was the 7th most watched event by TV viewers worldwide. Television audiences for the 1998 World Cup reached an estimated 50 million viewers over the 2 week event (World Cup web site).

The international game of hockey is regulated by the International Hockey Federation (FIH), which consists of five Continental associations and 119 member associations. In Australia, the Australian Hockey Association oversees the men's game, while Women's Hockey Australia regulates the women's game. Currently (1997-98), more than 48,000 players are registered with the Australian Hockey Association and approximately 31,000 are registered with Women's Hockey Australia.

The Victorian Hockey Association (VHA) regulates the men's game in the state of Victoria. Their current (1997-98) membership is approximately 4,500 registered players, a participation rate that has been static over the past 3 or 4 years (Joe Hough, Executive Director VHA, personal communication). The Victorian Women's Hockey Association regulates the state women's game. Their current membership is approximately 3,600 registered players, which is a slight increase over 1996-97 enrolment (Michelle Sheehan, Victorian Women's Hockey Association, personal communication).

The number of participants may be significantly higher, because the number of *registered players* does not include recreational players, players who participate in school teams, mixed competitions or who play for clubs which are not affiliated with the Hockey Associations.

Two percent of Australians questioned in a capital city survey said that they currently play hockey, with participation highest in the 16-29 age group (Brian Sweeney and Associates, 1996). A larger national sample reported that approximately 4% of Australians participated in hockey in the previous 12 months, with most participants aged below 20 years (ABS, 1995-96). Both surveys reported that participation is divided evenly between male and female players.

Given the popularity of hockey among younger community members, both surveys would have under-estimated the true number of hockey participants because of the cut-off ages used in their surveys (16 years and 15 years, respectively). Sweeney (1996) reported that participation in hockey has declined compared to previous years, while the Australian Bureau of Statistics reports a slight increase in the number of participants from 1993/94 to 1995/96.

The Centre for Health Promotion and Research estimates that 15% of hockey players are injured during a single season (Egger, 1990). A prospective survey of 50 adult Australian amateur hockey players found that injuries caused players to spend 10.7% of the total hockey season training and playing at less than full capacity (Roberts et al., 1995).

A more recent survey of NSW youth sports injuries reported that 32% of young hockey participants had self-reported sustaining an injury in the past six months. The definition used in this survey included any injury meeting one or more of the following criteria: treatment by a medical person; stoppage of physical activity for at least one day; and, injury resulting in loss of consciousness. The proportion of injured participants for hockey was the fifth highest when compared to other popular sports, even outranking AFL football (Alcock et al., 1997). A longitudinal cohort study is currently underway in Western Australia to determine the incidence and cost of hockey injuries.

5. AN OVERVIEW OF THE EPIDEMIOLOGY OF HOCKEY INJURIES

5.1 VICTORIAN EMERGENCY DEPARTMENT PRESENTATIONS

5.1.1 General overview

The Victorian hospital emergency department database (VEMD) provides information on injuries presenting to the 25 participating Victorian public hospital emergency departments. The data provide information on injury that is weighted towards the acute and more serious hockey injuries. A large proportion of hockey injury may present to GP's, sports medicine clinics, be treated by team physicians or self-treated.

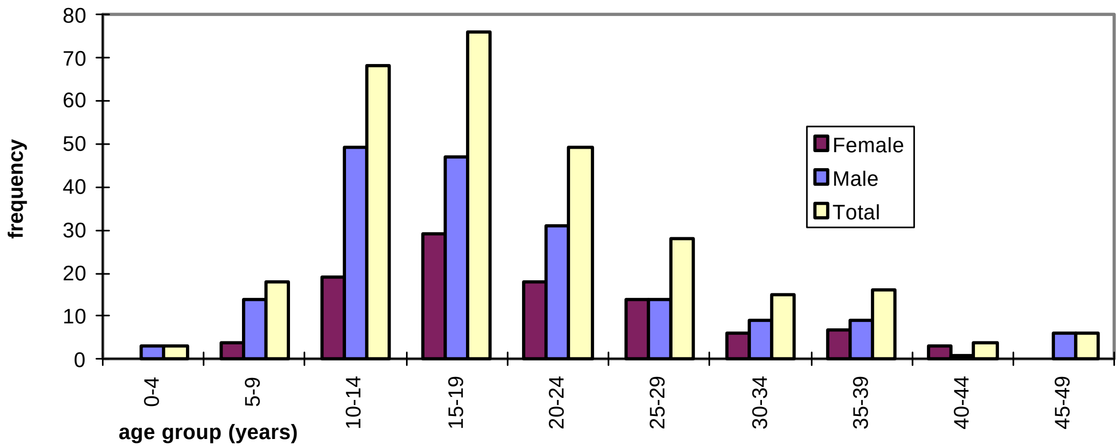
While VEMD data may under-represent the number of hockey injuries presenting to the ED, the data represents the largest case series of hockey injuries to date. In addition, the case narratives for the VEMD data files can provide valuable information on the circumstances of injuries, which can help guide injury prevention initiatives. Validation studies are currently in progress to determine the completeness and accuracy of capture of injury cases presenting to emergency departments of participating hospitals.

5.1.2 VEMD injury data

The data for hockey injury covers a two year period from January 1996 to December 1997, and represents emergency department presentations from the following nineteen hospitals which provided data for all 24 months: Austin and Repatriation Medical Centre, Ballarat Base Hospital, The Bendigo Hospital Campus, Box Hill Hospital, Dandenong Hospital, Echuca Base Hospital, The Geelong Hospital, Goulburn Valley Base Hospital, Latrobe Hospital, Mildura Base Hospital, The Northern Hospital, Royal Children's Hospital, Royal Victorian Eye and Ear Hospital, St Vincent's Public Hospital, Wangaratta Base Hospital, Warrnambool and District Base Hospital, Western Hospital, The Williamstown Hospital and Wimmera Base Hospital.

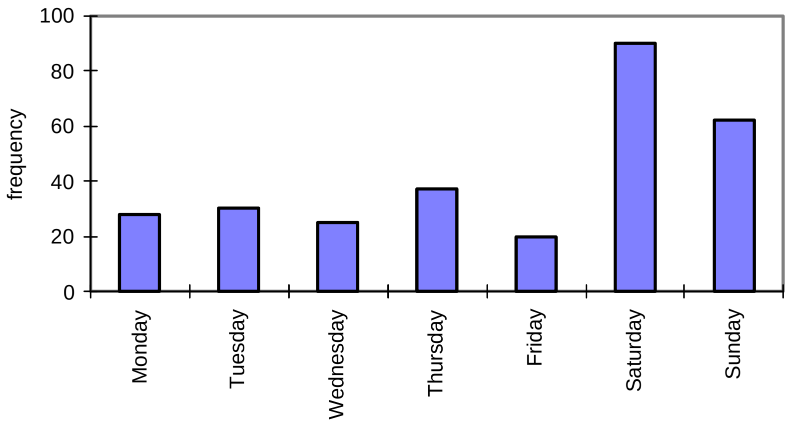
In Victoria, there were 292 VEMD emergency department presentations for hockey injury identified for the period January 1996 to December 1997. Figure 1 displays the sex and age related frequency of hockey emergency hospital presentation data for VEMD hospitals. The injured ranged in age from 2 years to 47 years (including bystanders). Players aged 10 to 19 years accounted for 50% of the injured, mostly in the 15 to 19 year age group (26% of all injured). Sixty-three percent of the injury cases were male and 37% were female, a ratio of 1.7:1. Males appear more at risk to injury than females, however more male than female players (1.25:1) are registered players in Victoria. Detailed exposure data are needed before any conclusions can be made regarding gender and risk of injury.

Figure 1: Age and sex distribution of hockey injuries presenting to Victorian public hospital emergency departments (n=292)



Source: Victorian Emergency Minimum Dataset (VEMD), January 1996 to December 1997

Figure 2: Days of the week of VEMD hockey injury hospital presentations (n=292)

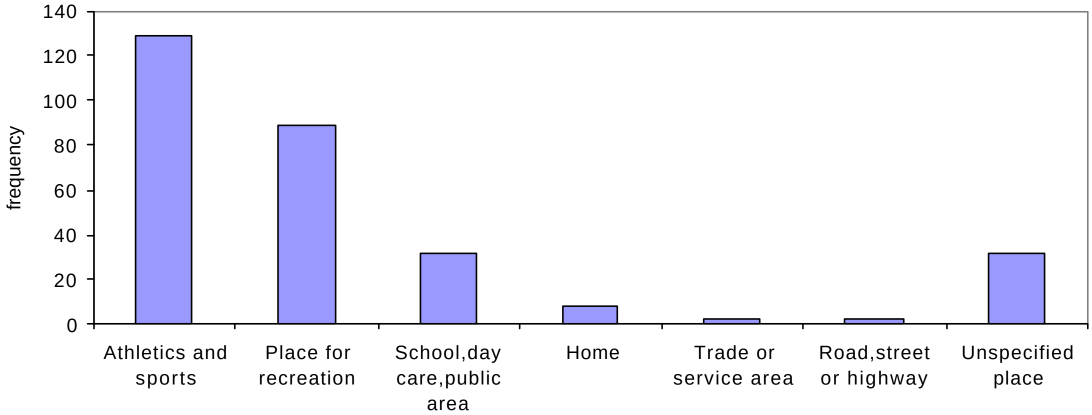


Source: Victorian Emergency Minimum Dataset (VEMD), January 1996 to December 1997

5.1.3 Time and location

Figure 2 illustrates that just over one-half of all hospital emergency department presentations for hockey injuries were on a Saturday (30.8%) or Sunday (21.2%), with the majority on a Saturday afternoon. Both the Victorian Hockey Association (4,500 registered players) and the Victorian Women's Hockey Association (3,600 registered players) hold the majority of their matches on the weekends, which probably explains the high number of weekend hockey injuries. Most hockey injuries occurred at a place used for athletics and sport (44.2%), followed by a place used for recreation (30.5%) or school (10.6%) (Figure 3).

Figure 3: ***Victorian public hospital emergency department hockey injuries by location (n=292)***



Source: Victorian Emergency Minimum Dataset (VEMD), January 1996 to December 1997

5.1.4 Mechanism of injury

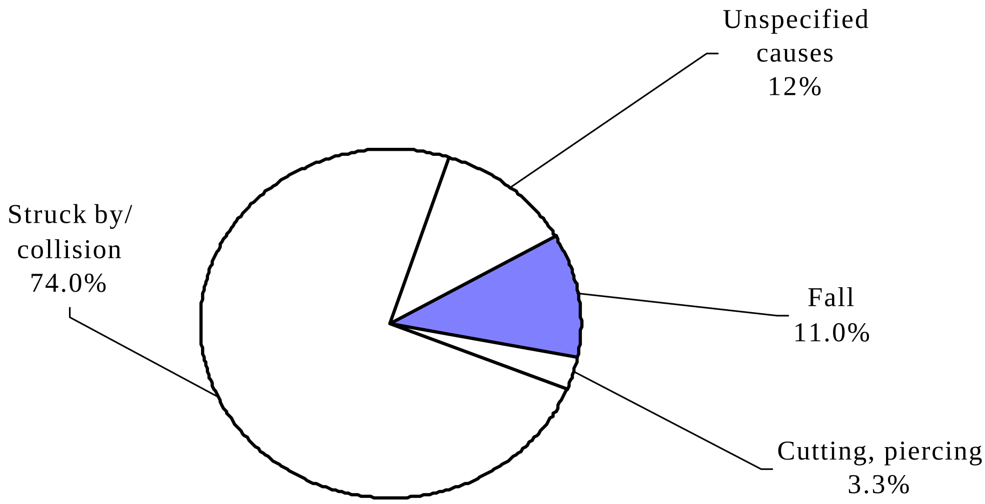
Most injuries (74.0%) requiring hospital emergency department treatment were a result of the player being struck by or colliding with an object (for example, ground, ball or stick) or another player, as shown in Figure 4. The case narratives revealed that the most common of these injuries were struck by a hockey stick (40.8% of all injuries), followed by struck by a ball (23.3% of all injuries).

Eleven percent of ED presentations for hockey injury were a result of falls. A sample of the case narratives for falls include: *"fracture - radius / ulna, fell over playing hockey"; "fall playing hockey, injured knee"* and *"playing hockey fell heavily on right shoulder"*.

5.1.5 Nature of injury

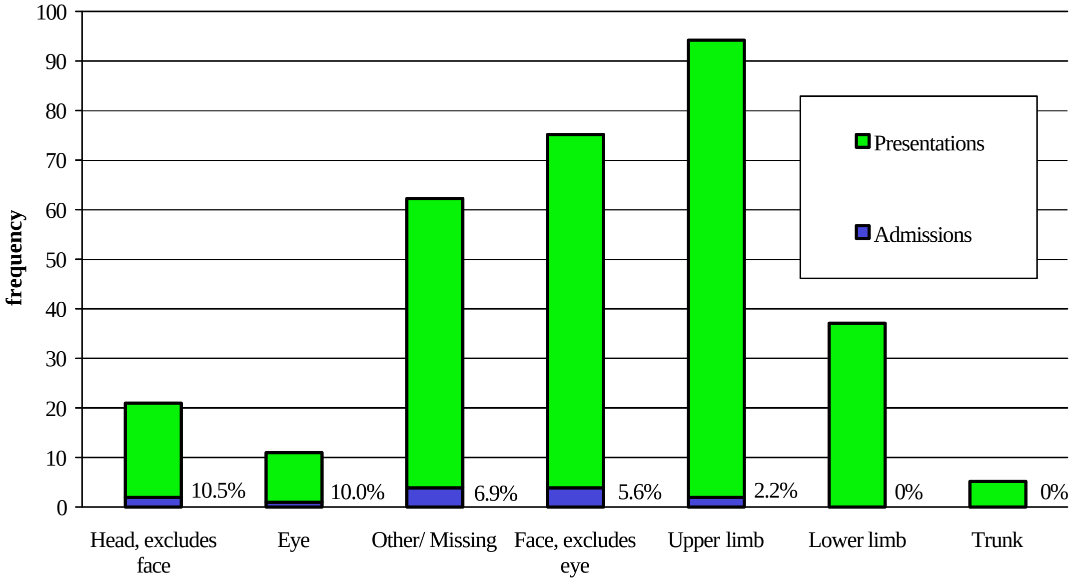
Overall, the most common injuries presenting to hospital emergency were open wounds (20.5%), fractures (16.4%), sprains and strains (14.7%) and superficial wounds (12.0%). Collision and 'struck-by' injuries, were mostly open wounds (24.4%), superficial wounds (14.5%), fractures (14.1%) or sprains and strains (11.5%). The most frequent fall injuries were sprains and strains (39.5%), fractures (23.7%) and dislocations (7.9%).

Figure 4: Primary causes of hockey injuries resulting in emergency department presentations (n=292)



Source: Victorian Emergency Minimum Dataset (VEMD), January 1996 to December 1997

Figure 5: Severity of VEMD presentations for hockey injuries by body region (n=292)



Source: Victorian Emergency Minimum Dataset (VEMD), January 1996 to December 1997

5.1.6 Body sites injured

Figure 5 summarises the site and severity of VEMD presentations for hockey injuries. The body site most frequently injured was the upper limb (31.7%). This includes injuries to hand, including fingers (19.2%); forearm (4.5%); wrist (3.8%); elbow (2.1%) and shoulder (2.1%). Text narratives describing injuries to the upper limb include for example, *"hit across fingers by hockey stick"* and *"playing hockey, hit to arm by hockey ball"*. Although upper limb injuries were frequent, only 2.2% of these were admitted to hospital for treatment.

Injuries to the face were also frequently reported and comprised 24.3% of hockey injuries presenting to hospital ED and 5.6% of admissions. Injuries to the face do not include eye injuries, which are coded separately. Text narratives describing injuries to the face include for example, *"hit in face with hockey stick, fractured nose lacerated lip, hit by hockey ball"*.

Injuries to the lower limb represent 12.7% of hockey injuries in hospital ED data, with no cases of admission. Injuries to the lower limb include injuries to the ankle (4.5%); foot (3.1%); knee (2.7%); lower leg (1.4%); and thigh (1.0%). Text narratives describing lower limb injuries include for example, "*rolled on right ankle playing hockey*", "*twisted knee playing hockey today*" and "*struck by hockey ball on ankle*".

The number of head injuries presenting to emergency departments is relatively low (5.1%). However these injuries are frequently serious. Intracranial injuries sustained during hockey play had a 25% admission rate on the VEMD database, while head injuries in general had a 10.5% admission rate. The mean admission rate for all hockey injuries for the same period was 4.5%. Examples of text narratives describing head injuries are "*struck on head with hockey stick*" and "*hit in forehead by hockey ball at school*".

Eye injuries are also comparatively infrequent but are more likely than other injuries to warrant hospital admission. Eye injuries represent 3.4% of hockey injuries in hospital ED data, yet have a 10.0% admission rate (Figure 5). An analysis of the available text narrative data for eye injuries revealed that the stick was involved in over two-thirds (67.7%) of eye injuries and the ball almost one quarter (22.6%). Other causes of eye injury included foreign body in the eye. Examples of text narratives describing eye injuries include *"hit under right eye by hockey ball"* and *"hit in left eye by hockey stick"*.

5.2 GENERAL OVERVIEW OF REPORTED HOCKEY INJURIES

There have been several descriptive studies on the epidemiology of hockey injuries since the early 1980s (Freke and Dalgleish, 1994b, Fuller, 1990, Jamison and Lee, 1989, Lindgren and Maguire, 1985, Rose, 1981). Most of these studies are small scale and exploratory in nature. It is difficult to compare their results due to methodological limitations, including: differences in the age, sex and ability level of the subjects; the definition of injury used; the surface played on; the exposure time; the length of the survey period; and the method of reporting results. A summary table of these studies can be found in the Appendix. It is clearly important that a systematic approach be developed for reporting hockey and other sports injuries in a reliable and comparable form. Despite these limitations, the studies show that, at both elite and amateur levels of play, injuries in hockey are numerous and can be serious.

In one of the earlier studies, Rose (1981) investigated the incidence of injury in one team of elite varsity-level female hockey players. Eighty-one injuries were reported over a four-year period. The number of players and their playing hours were not reported. Most injuries (82.7%) were ‘minor’. First-degree ankle sprains were the most common minor injury, accounting for 19.8% of all injuries. Other minor injuries reported include quadriceps strain (8.6%) and contusion to the leg and foot (8.6% each).

Seventeen percent (17.3%) of the injuries were classified as ‘major’ (defined as requiring the attention of the team physician, producing a definite disability and needing follow-up care). The most common major injuries were second-degree ankle sprains (4.9% of all reported injuries), ligament or cartilage damage to the knee (4.9%) and cerebral concussion (3.7%).

Rose commented that ‘several’ injuries were a result of contact from the hockey stick, but did not report the number and type of stick injuries. The major injuries in the Rose study were severe enough for the author to conclude that hockey is a hazardous sport. This study had methodological limitations, such as the non-reporting of the number and ages of subjects, making comparisons with later studies difficult.

The first study to compare the incidence and patterns of injury by gender was that of Lindgren and Maguire (1985). They reviewed the injuries of a small group of elite Australian Institute of Sport hockey players over a 12-month period (16 males and 12 females). Male players sustained an average of 3.1 injuries per player compared to 5.0 injuries per female player. The authors concluded that female hockey players had a higher rate of injury than their male counterparts. This finding is not consistent with the VEMD data, which shows a higher frequency of injury for males compared to females of 1.7:1. It is important to bear in mind some limitations of the Lindgren and Maguire study: the sample size was very small; exposure to play was not taken into account; and injury severity was not reported. Acute versus chronic injury was also not indicated and no statistical analysis was performed.

Only injuries treated by the team physiotherapist were included in the Lindgren and Maguire study. Forty-nine injuries were reported for male players, the most common being leg contusions (10%), ankle sprains (8%), knee sprains (8%), lumbar vertebral injuries (8%) and quadriceps strain (6%). Sixty injuries were reported for female players. These included shin soreness (22%), lumbar vertebral injuries (10%), leg contusions (8%), foot contusions (7%), ankle sprains (7%), and groin strains (7%).

Lindgren and Maguire classified hockey injuries as external, internal, and overuse. Male players reported 26.5% external, 55.1% internal and 18.4% overuse injuries. Female players reported 18.3% external, 50.0% internal and 31.7% overuse injuries. The authors concluded that male players were more prone to external injuries and female players to overuse injuries. This finding was subject to the same methodological problems outlined above. The types of injuries will be discussed in more detail in the following section (5.3).

Jamison and Lee (1989) investigated injury among ‘elite’ Australian female hockey players, comparing the incidence of injury in two successive national championships, the first played on a grass playing surface and the second on Astroturf. During the tournament played on grass surface, 110 players reported 86 injuries (0.78 injuries per player), while 95 players on Astroturf reported 92 injuries (0.97 injuries per player). The authors concluded that injury rates on Astroturf were significantly higher than those on grass ($p<0.0001$). One limitation to this finding is that exposure (number of hours of training and play) was not reported and may have influenced the number of injuries sustained.

Jamison and Lee found that the types of injury sustained on grass and on Astroturf were similar. The most common types of injury were contusions (64.0% grass vs 48.9% Astroturf), abrasions (14.0% grass vs 13.0% Astroturf), lacerations (2.3% grass vs 12.0% Astroturf) and strains (4.7% grass vs 12.0% Astroturf). Injuries to the lower limb were the most frequent on both surfaces, although there was a significantly higher incidence of knee and ankle injuries on grass (53.0% of lower limb injuries) than on Astroturf (37.0%) ($p<0.01$).

Most epidemiological studies done after Jamison and Lee (1989), report on hockey played on synthetic surfaces. Fuller (1990) studied the epidemiology of hockey injuries in elite British female hockey players playing on three different types of synthetic surfaces. Fuller reported 135 injuries in the 100 hours of play that was observed over two seasons. The average rate of injury was 1.34 injuries per hour of play. This is one of the earliest studies to report on the rate of injury by exposure to the game. No significant differences in the rates of injury on the three types of synthetic surface were found. It is not possible to compare the rate of injury reported by Fuller to that reported by Jamison and Lee, as the total number of participants in the Fuller study was not revealed. Like Jamison and Lee, Fuller reported that injuries to the lower limb predominated (60% of all reported injuries).

The studies employed different methods of collecting injury data and different definitions of injury. The Jamison and Lee study relied on self-reported data on injuries, and players were instructed to report all injuries regardless of severity. In the Fuller study, an injury was defined as one requiring treatment by the attending team physiotherapist during or because of play. Fuller reports that the most common types of injuries sustained on synthetic playing surfaces were contusions (38.5%) and overuse injuries (29.6%). Injuries to the lower limb were frequent (60.7%) and included injuries to the knee (24.4% of all injuries) and to the thigh (17.0%). Injuries to the upper body were dominated by injuries to the hands and fingers (17.8% of all reported injuries) and facial injuries (10.4%). Fuller also reported that 90% of all injuries sustained on synthetic playing surfaces were minor while the remaining 10% of injuries were severe enough for the player to be unable to play or practise for more than two days.

Freke and Dalgleish (1994a) investigated the history of injury in an ‘elite’ squad of female hockey players from the Queensland Academy of Sport (QAS). A total of 40 hockey players (mean age = 21.6 years) were surveyed about injuries sustained throughout their playing careers. An injury was recorded if it was sustained during hockey and required hospital admission, medical attention or absence from play for more than seven days. The forty players suffered 95 injuries, an average of 2.37 injuries per player. Only two players or five percent reported never having been injured.

They found that sixty-seven percent of all previous severe injuries to the sample of ‘elite’ Australian female hockey players involved the lower limb. The most common injuries were ankle sprains (21% of all injuries), followed by low back pain (18%), knee injuries (14%), miscellaneous fractures (12%) and tibial stress syndrome (7%). Strains (32%) were the most common type of injury, followed by sprains (24%), overuse injuries (18%), fractures (11%) and contusions (3%). The body area most commonly injured was the ankle (23%), followed by back (21%), knee (16%), thigh (13%), upper extremity (12%), shin (8%) and groin (2%).

This study relied on self-reported data collected retrospectively and was confined to severe injuries. Because it relied on players' memory of injury events, which may have happened years earlier, the study was subject to recall bias. It is unclear whether the authors used medical records of previous injuries to validate recall, however less severe injuries which still may have affected the playing capacity of the athletes were not included.

Freke and Dalgleish (1994b) continued their research with a prospective study of acute injuries sustained by the same squad of ‘elite’ female players on tour at four Australian Women’s National Hockey Championships. Seven teams each played approximately 8 games in 10 days (Matt Freke, QAS Physiotherapist, personal communication). Sixty-two players developed or exacerbated 116 conditions and required treatment by the team physiotherapist. Sixty-six injuries were acute (56.9%) and 50 injuries (43.1%) were chronic conditions. Most of the acute injuries were caused by impact with the ball or the turf resulting in haematomas (23% of all acute injuries) or fractures to various parts of the body (3%), most often the lower limb.

The team physiotherapist frequently treated spinal pain (21% of all acute injuries divided evenly between neck and lower back pain), foot problems (11%), muscle strains to the calf and hamstring (11%), abrasions and lacerations from the turf (9%) and ligament sprains of the knee, ankle and thumb (11% combined). Lower limb injuries were more common (50%) than upper limb injuries (13%). Of the chronic injuries reported, the most frequent complaint was exacerbation of spinal conditions (28% low back, 8% neck) followed by ankle conditions (16%), and shin pain (10%).

Roberts et al. (1995) undertook a prospective survey of 50 Australian amateur hockey players and found that 2.36 injuries per player were sustained over a 5-month playing period (dates not reported). This rate is high compared to that reported by Freke and Dalgleish (1994a) for elite athletes. They found a *career* total of 2.37 injuries per elite Australian female player, although Freke and Dalgleish employed a very narrow definition of injury. The Roberts et al. (1995) study reported one injury for every 37.5 hours of amateur hockey training and competition. They also found that injuries caused amateur players to spend 10.7% of the total hockey season training and playing at less than full capacity (Roberts et al, 1995).

Two recent studies compare the frequency and patterns of injury in hockey to other sports. In 1994, Cunningham and Cunningham (1996) conducted injury surveillance at the Australian University Games. Hockey had the second highest incidence of injury by participation (33.5%) as well as the highest frequency of injury of all 19 represented sports (Cunningham and Cunningham, 1996). Exposure data was not collected. The authors reported that hockey injuries were mostly haematoma and bruising (28%), muscle-tendon injuries (19%) and abrasions (14%). Extrinsic injuries (contact with person, object or ground) made up 59.7% of all hockey injuries (Cunningham and Cunningham, 1996).

A recent NSW youth sports injury survey (Alcock et al, 1997) reported that 32% of the young hockey participants had sustained an injury in the past six months. The proportion of injured participants for hockey was the fifth highest when compared to other popular sports, and outranked AFL football (Alcock et al, 1997). The majority of self-reported injuries to the 254 hockey players were bruising (60%) and muscle strains (24%). The body parts most frequently reported as injured were the knee (33%) and the ankle (30%), followed by the finger (18%), lower leg (14%) and head (13%) (Alcock et al, 1997).

Taken together, these studies reveal that there is a predominance of injuries to the lower limb, especially the ankle. Extrinsic injuries resulting from being struck by the stick or the ball are also common. At an elite level of play, overuse injuries are a concern. The effect of playing on different surfaces is unclear. A standardised methodology would make future studies easier to compare.

5.3 TYPES OF INJURIES

One method of classifying hockey injuries is to group them as extrinsic, intrinsic, or overuse injuries (Kannus, 1993). Extrinsic injuries are injuries due to external forces and can result from being struck by a ball or stick, by colliding with another player, a goal post or the ground. Intrinsic injuries are injuries due to internal forces acting upon muscle, tendon, ligament or joint. Constant overuse may result in an accumulation of stresses to the involved tissue (bone, ligaments or tendons) and result in an overuse-type injury.

5.3.1 Extrinsic injuries

Several studies report a high incidence of extrinsic injuries in hockey, ranging from 60% to 88% of all reported injuries (Fuller, 1990, Jamison and Lee, 1989, Cunningham and Cunningham, 1996, Crompton and Tubbs, 1977) (Table 3). Lindgren and Maguire (1985) reported a lower incidence of extrinsic injuries (22% overall) than most studies, with male players being more prone to extrinsic injuries (27%) than their female counterparts (18%). However, the sample size in the Lindgren and Maguire study was comparatively smaller and only more serious injuries were recorded.

Most extrinsic injuries reportedly result from being struck by the hockey stick or ball. In an early study, Crompton and Tubbs reported that ball and stick injuries make up 72.2% of all hockey injuries on grass (*n*=54). This is slightly higher than the 65% incidence of ball and stick injuries for play on grass reported by Jamison and Lee (1989), and much higher than the 47% reported by Fuller (1990). Fuller's study reported on synthetic playing surfaces, and compares more closely to Jamison and Lee's findings of 59% ball and stick injuries on Astroturf. These results are consistent with the case series of hockey injuries from the VEMD data, where 41% of case narratives refer to the hockey stick as the cause of injury.

The quality of both the hockey stick and the ball are constantly improving, resulting in the ball being hit more powerfully. Players may be struck by a vigorously swung stick weighing between 480 and 650 grams or hit by a hard ball weighing 156 to 163 grams travelling at a high velocity (Fox, 1981). Fuller (1990) and Jamison and Lee (1989) both report more injuries caused by the ball (30% - 32% on synthetic surface, 42% on grass) than the stick (17% - 27% on synthetic surface, 23% on grass) (Table 3). There were also fewer ball-related hockey injuries (23%) in the VEMD data than stick-related injuries (41%).

Extrinsic injuries can occur to any part of the body and may result in laceration requiring suture, contusion, oedema and inflammation, with accompanying pain and acute or sustained incapacity. Spedding commented that the most serious injuries in hockey include blows to the head, throat or genitals from a deflected ball or stick and collisions with the goalkeeper (Spedding, 1986).

Contusions are by far the most commonly reported types of extrinsic injury in hockey. The reported incidence of contusion-type injuries varies greatly between studies from 3% to as high as 64% of all reported hockey injuries (Roberts et al, 1995, Freke and Dalgleish, 1994b, Jamison and Lee, 1989, Lindgren and Maguire, 1985, Rose, 1981, Freke and

Dalgleish, 1994a). The methodologies of these studies differ in terms of the sex, age and ability level of the subjects. Also, the large variation in results may be due to differences in: the method of collecting injury data; the definition of "injury" used and the level of severity; and the surface played on.

Body contact or collisions between players are relatively uncommon and account for 2% - 11% of all reported injuries (Fuller, 1990, Jamison and Lee, 1989, Crompton and Tubbs, 1977). Jamison and Lee (1989) report that fall injuries on synthetic turf may be more frequent and severe than those on grass. However, the difference in the proportion of fall injuries was not statistically significant (11% vs 9%).

Jamison and Lee (1989) also report a slightly higher proportion of extrinsic injuries on grass (88%) than on Astroturf (82%). The authors hypothesise that the introduction of the synthetic surfaces has led to more control of the ball and could account for fewer ball-related injuries (32% on turf vs 42% on grass). In addition, greater control of the ball on synthetic surfaces has led to longer offensive possessions and harder and more indiscriminate tackles by defenders, which could account for the higher reported collision related extrinsic injuries on synthetic turf (11% on turf vs 9% on grass).

Table 3: Summary of reported extrinsic hockey injuries

STUDY	EXTRINSIC INJURIES	BALL	STICK	GROUND	PLAYER
Crompton and Tubbs, 1977 (*n*= 54)	**80% grass**	**72.2% combined ball and stick**			**7.4%**
Jamison and Lee, 1989 * (*n*= 95)	**82% Astroturf**	**32%**	**27%**	**14%**	**11%**
Jamison and Lee, 1989 * (*n*= 110)	**88% grass**	**42%**	**23%**	**12%**	**9%**
Fuller, 1990 † (*n*=not reported)	**60% synthetic surface**	**30.4%**	**17.0%**	**10.4%**	**2.2%**
Freke and Dalgleish, 1994c) (*n*= 62)	**Synthetic surface**	**-**	**23% combined stick and ground**		**-**
VEMD hospital data †† (*n*= 292)	**surface type not reported**	**22.9%**	**40.8%**	-	-

* includes all injuries, including minor injuries
† includes only injuries requiring team physiotherapists' treatment, advice or handling
†† includes all injuries presenting to Victorian hospital EDs from Jan. 1996 to Dec. 1997

5.3.2 Intrinsic injuries

Intrinsic injuries are due to internal forces acting on the muscle, tendon, ligament or joint. Intrinsic injuries can result in tearing muscle fibres (strain); tearing ligament (sprain); and tearing cartilage. Localised bleeding and ensuing swelling often result.

Intrinsic injuries are reported to account for 11% to 18.5% of all hockey injuries (Fuller, 1990, Jamison and Lee, 1989). Rate (1988) states that the most common non-contact injuries in hockey are ankle sprains, back strains and thigh strain (no statistics reported). In some studies, cramps are included as intrinsic-type injury and account for a small number of hockey injuries (Fuller, 1990, Cunningham and Cunningham, 1996).

Sprains and strains are often classified as intrinsic in nature. However they can also result from extrinsic forces or from overuse. Table 4 summarises the studies that report on the incidence of sprains and strains in hockey. The variation in the reported proportion of sprains and strains may be due to the definitions used in each study. Jamison and Lee (1989) and Fuller (1990) appear to report on only *intrinsic* sprains and strains, while the remaining studies report on *all* (intrinsic, extrinsic and overuse) sprains and strains, resulting in a higher incidence of these injuries.

Freke and Dalgleish (1994b) reported a different pattern of chronic and acute sprains and strains. For the purpose of their study, sprains included ankle and knee ligament sprains, and strains included spinal pain and muscle tears. In one championship tour, elite female players suffered more exacerbated chronic sprains and strains than acute sprains and strains (see Table 4). No statistical comparison was reported, however the authors concluded that chronic injuries are a problem for elite hockey players.

Players keeping a prospective injury diary over a 5-month period reported 23.7% sprains and 15.3% strains (Roberts et al, 1995). Jamison and Lee (1989) reported that eighteen percent of injuries sustained while playing on Astroturf were of intrinsic origin, compared to 12% intrinsic injuries sustained on grass, though this difference was based on small numbers and did not prove statistically significant.

Hospital ED presentation data (VEMD) indicates that 20.2% of all presentations are sprain or strain type injuries. The VEMD does not separate sprains and strains, hence these injuries are listed together.

Table 4: Summary of reported sprain and strain injuries for hockey

STUDY	SPRAINS	STRAINS
Jamison and Lee, 1989		
Astroturf (*n*= 95)	**2%**	**12%**
Grass (*n*= 110)	**2%**	**5%**
Freke and Dalgleish, 1994		
a) Past injuries (*n*= 40)	**24%**	**32%**
b) 'Chronic' injuries (*n*= 62)	**20%**	**42%**
c) 'Acute' injuries (*n*= 62)	**8%**	**32%**
Cunningham, Cunningham 1994 (*n*= not reported)	**19%**	**15%**
Roberts, et al., 1995 (*n*= 50)	**24%**	**15%**
VEMD hospital data (*n*= 292)	**20.2% combined**	

5.3.3 Overuse injuries

Repetitive episodes of trauma can overwhelm the body's ability to repair itself, and result in overuse injuries (Herring and Nilson, 1987). Typical examples of this type of injury in hockey include tibial stress syndrome (shin soreness), iliotibial band pain, low back dysfunction, tendonitis, patellofemoral pain, plantarfasciitis, and stress fractures of the foot and leg (Freke and Dalgleish, 1994a). Overuse injuries are variously reported to account for 18% to 32% of hockey injuries (Fuller, 1990, Lindgren and Maguire, 1985, Freke and Dalgleish, 1994a). Lindgren (1985) reported that females are more prone to overuse injuries (32%) than their male counterparts (18%), although sample sizes were small. Overuse injuries to specific body regions will be discussed in the following section.

5.4 BODY SITES INJURED

Hockey players are exposed to various injuries during running, turning, twisting and stretching, with vulnerability at many body sites. At each site, injuries can include lacerations, haematomas, miscellaneous other soft tissue injuries, fractures and dislocations.

It is reported that the majority of injuries reported for elite players are to the lower limb and to the back (Freke and Dalgleish, 1994b, Jamison and Lee, 1989, Freke and Dalgleish, 1994c). This is not consistent with the pattern of injury seen in the Victorian hospital ED (VEMD) data, where injuries to the face and upper limb are more commonly reported. It appears that the hospital ED data is weighted to the more severe and possibly acute end of the injury scale. Thus, minor contusions, strains and chronic injuries may be under-reported. In addition, several of the injuries at the elite level of play are treated by the team physicians and physiotherapists and may not present to hospital ED. Finally, it is possible that the injuries sustained at a recreational level of play are different to those sustained by elite players. For example, it appears that overuse-type injuries (especially to the lower limb) are a concern for the elite player, while they may not figure as prominently at a recreational level where exposure is not as great.

5.4.1 Lower limb injuries

Frequent lower limb injury sites include the ankle, shin, knee and thigh. Jamison and Lee (1989) report that injuries to the lower limb are the most commonly reported injury amongst elite female hockey players playing on grass and synthetic surfaces. Injuries to the lower limb represent 12.7% of all hockey injuries presenting to Victorian hospital EDs.

It has been suggested that women may be predisposed to a greater incidence of lower limb joint injuries than men because of anatomical differences (Egger, 1990). When compared to men, women have a greater angle at the knee, a higher rate of ankle pronation, and greater joint mobility (for review, see (Beck and Wildermuth, 1985)). The relationship between anatomical differences and the patterns of injury in male and female hockey players requires further investigation.

Lower limb injuries can result from extrinsic forces (for example, being hit in the leg by a stick or ball), intrinsic forces (for example ankle sprain), and overuse (for example 'shin splints' or exertional shin pain). Another factor in the aetiology of lower limb injuries may be the playing surface. The natural grass surface absorbs 10% more energy on impact than the synthetic turf, contributing to a greater cushioning effect and less strain to the lower limbs (Reilly and Borrie, 1992). Playing on harder synthetic surfaces is widely believed to increase the incidence of lower limb injuries, however this is not supported by the findings from the Jamison and Lee (1989) study, the only one to compare injuries on synthetic and grass surfaces.

5.4.2 Ankle and foot injuries

The ankle is a particularly vulnerable part of the human anatomy and it has been estimated that ankle injuries account for up to 19% of *all* sporting injuries (Giltrow, 1988). It has also been reported that there is a high recurrence rate (or failure to reach full recovery of function) in up to 64% of all ankle sprain injuries (Peters et al., 1991).

Several studies report a prevalence of ankle and foot injuries in hockey, ranging from 4% to 27% (Lindgren and Maguire, 1985, Rose, 1981, Freke and Dalgleish, 1994a). Rate (1988) reports that the most common ankle injury in hockey is to the anterior section of the lateral ligament, generally occurring when the foot is forced into inversion. Victorian hospital ED presentations for hockey injury include 4.5% injuries to the ankle and 3.1% injuries to the foot. Again, minor ankle injuries and chronic ankle injuries may be under-reported in the VEMD data.

A four year study by Rose (1981) revealed that ankle injuries accounted for 27% of all injuries in one team of American female varsity hockey players and foot injuries accounted for another 14% of reported injuries. Freke & Dalgleish (1994b) found that the ankle was the most commonly injured body site, accounting for 23% of all injuries reported during one season of play by the Australian national women's team. These findings indicate that ankle injuries in elite female hockey players are common.

It appears that ankle injuries are also common in male players. Lindgren and Maguire (1985) reported no significant difference in the number of ankle injuries in elite female players (16.7%) compared to their male counterparts (14.3%). The number of subjects in this study was small (n=28). Roberts et al. (1995) studied 50 Australian amateur hockey players (23 male, 27 female) and reported that 23% of injuries to male players and 18% of injuries to female players were to the ankle and foot region. The difference was not significant and the authors concluded that the number of ankle and foot injuries in male and female amateur hockey players is equivalent.

Jamison and Lee (1989) studied 110 female hockey players playing on grass and 95 playing on Astroturf in successive tournaments. They found a lower proportion of ankle and foot injuries on Astroturf compared to grass (ankle: 7.3% on grass vs. 3.2% on Astroturf; foot: 10.9% on grass vs. 1.1% on Astroturf). Fuller (1990) also reported a relatively low proportion of ankle and foot injuries for play on synthetic turf (5.2% ankle and 8.9% foot). Jamison and Lee (1989) encouraged players to report all injuries, which resulted in over-reporting of minor injuries. The result was a large number of reported minor contusions and a comparatively lower proportion of moderately severe injuries, such as ankle sprains. Fuller (1990) also captured a high number of minor injuries by recording all injuries that required the "treatment, advice or handling" of the physiotherapist.

5.4.3 Knee injuries

The knee, like the ankle, is particularly vulnerable to injury in hockey. In studies of female hockey players playing on artificial turf, Fuller (1985) and Jamison and Lee (1989) respectively, reported 24% and 17% of all injuries were to the knee. Freke and Dalgleish (1994b) found that injuries to the knee were common (14%) amongst elite female players, while knee pain was reported by 30% of players surveyed.

Relatively fewer knee-related injuries presented to Victorian hospital EDs (2.7%). It is possible that knee injuries are less common among community level rather than elite players and that chronic injuries are being treated outside of the hospital ED, such as by the team physician or physiotherapist, by the player's GP, at a sports medicine clinic or self-treated.

Lindgren and Maguire (1985) studied a small group of elite players and found that 24.5% of injuries to the male squad were knee-related, compared to 11.7% in the female squad members. The biggest difference between the two squads was the number of knee sprains (12.2% male vs 1.7% female). This contrasts with the pattern reported for ankle sprains. The number of subjects was too small for any statistical comparisons between the sexes to be made.

Some sports medicine professionals believe that synthetic playing surfaces have decreased the playing life of the modern hockey player by increasing the prevalence of shin soreness, knee pain and lower backs problems. However, the only study to compare injury patterns on the two surfaces found that knee injuries were more frequent on natural grass than on synthetic turf (24.5% versus 17.9%) (Jamison and Lee, 1989).

5.4.4 Shin injuries

Injuries to the shin can be debilitating. Problems in sport associated with the shin are sometimes called shin splints or shin soreness. Injuries to the shin in hockey can be of extrinsic origin (for example, lacerations and contusions from a stick or ball strike) but are more often due to overuse.

Shin injuries in hockey are variously reported as comprising: 1.4% of all Victorian hospital ED presentations; 4.1% of all injuries in male players vs 21.7% in female players (Lindgren and Maguire, 1985); 5.5% of all injuries on grass and 12.6% on Astroturf (Jamison and Lee, 1989); 13.8% of acute injuries and 16.0% of chronic injuries (Freke and Dalgleish, 1994c). None of the reported differences were subjected to tests of statistical significance.

As with running, shin splints may be aggravated by improper footwear and irregular surfaces. The unyielding nature of synthetic playing surface may also be a factor. The hard synthetic surface appears to cause more shin injuries than the softer natural grass (Jamison and Lee, 1989).

5.4.5 Back injuries

Cannon and James report that 8% of all athletes referred to a back pain clinic over a four-year period were hockey players (Cannon and James, 1984). Reilly and Seaton found in a small survey of male ‘club’ hockey players in England that 53% reported low back pain problems at sometime in their hockey careers (Reilly and Seaton, 1990). The prevalence of low back pain in ‘elite’ hockey players is reportedly as high as 78% to 80% (Freke and Dalgleish, 1994c, McRoberts, 1988). The evidence suggests that elite players, who have more exposure to play, have a greater prevalence of low back pain than amateur hockey players do. It also suggests that chronic back pain is highly prevalent among hockey players, even at a young age.

By contrast, Rose (1981) reported a low occurrence of low back pain for a small group of female varsity players, representing only 1.5% of all injuries. Chronic injuries may be under-reported for a variety of reasons. Some chronic back pain may be self-managed by the players and injuries of this nature would not require ‘active treatment by the team physician’, as required in the Rose study. Also, some players could get used to playing with a certain amount of chronic pain and not seek treatment or seek it outside the clubs. Lastly, elite players may be reluctant to report injuries for fear of being omitted from the team selection.

Fuller (1988) reported that the incidence of *acute* low back injury observed in hockey players over 100 hours of match play made up 9% of the total injuries sustained. This is consistent with Jamison and Lee (1989), who reported that back pain contributed to 8% of all injuries sustained by elite women players over two national tournaments. Back injuries sustained on Astroturf were slightly more common than on grass, however no statistically comparison was made.

The crouched playing position in hockey combined with side flexion and rotation may be contributing factors in the high incidence of low back problems (Freke and Dalgleish, 1994a). Compressive loading of intervertebral discs causes them to lose height, resulting in a change in total body length known as shrinkage (Reilly and Seaton, 1990). Shrinkage induced during experimental dribbling of a hockey ball on a motorised treadmill occurred at a rate of 0.4 mm/min (n=7 males) (Reilly and Seaton, 1990). The rate of shrinkage during dribbling was about 4 times that observed in running, indicating that spinal loading during dribbling of a hockey ball is greater than during normal locomotion (Reilly and Seaton, 1990). The flexed playing position in hockey continually stresses the neural tissue networks of the lower limb and back, resulting in pain and dysfunction in most hockey players (Freke and Dalgleish, 1994a).

5.4.6 Hand injuries

Hands can be seriously injured when struck by the stick, the ball or when players fall to the ground or collide with each other. They can be subjected to abrasions, lacerations, strains, fractures and finger amputations.

Injuries to the hand (including fingers) accounted for 19.2% of all hockey injuries presenting to Victorian hospital EDs. This is higher than the proportion of injuries to the hand reported from other studies (between 2% and 17.8% of all hockey injuries) (Fuller, 1990, Jamison and Lee, 1989, Lindgren and Maguire, 1985).

Lindgren and Maguire (1985) found that 2% of injuries to elite male players were finger lacerations. Jamison and Lee (1989) reported that injuries to the hand were more common on Astroturf (14.7%) than on grass (4.5%). Fuller (1990) found that injuries to the hand were the second most reported injury in their study of elite British female players, accounting for 17.8% of all injuries. Of the 24 hand and finger injuries reported over 100 hours of play, 50% were caused by the stick, 33% by the ball and 12.5% by the synthetic playing surface (Fuller, 1990).

5.4.7 Head injuries

Head injuries in hockey are relatively infrequent. Head and eye injuries presenting to Victorian hospital emergency departments accounted for 5.1% and 3.4% of all injuries, respectively. However, these injuries are often serious. Intracranial injuries sustained during hockey play had a 25% admission rate on the VEMD database, while eye injuries had a 12.5% admission rate. The mean admission rate for all hockey injuries for the same period was 4.5%.

The reported number of head injuries varies according to the definition of injury used. Some studies count all injuries to the head region, including injuries to the skull, cheek, ear, eye, jaw, teeth, and lip, while others count only concussion. Head injuries, including concussion are variously reported to comprise between 2% and 13% of all hockey injuries (Jamison and Lee, 1989, Lindgren and Maguire, 1985, Rose, 1981). Concussion is reported at between 1% and 3.9% of all injuries to hockey players (Jamison and Lee, 1989, Rose, 1981, Cunningham and Cunningham, 1996).

Lindgren and Maguire (1985) reported that elite male players had a higher proportion of head injuries than their female counterparts, with 6% of all injuries being to the head for male players and only 2% for female players. For amateur hockey players, Roberts et al. (1995) reported opposite findings. Female players were more at risk of head injuries than male players (10% vs 4%). The latter study may have included facial injuries in the total, and neither study reported any statistical comparisons. It is noteworthy that the official rules of men's and women's hockey are identical.

Head injuries are reportedly sustained more frequently on Astroturf (13%, including 3% concussion) than on grass (8%, including 1% concussion), possibly because of the increased speed of play, as well as the harder landing surface (Jamison and Lee, 1989). In the same report, the authors hypothesised that the uniform synthetic surface makes the ball run predictably, causing players to throw themselves on the ground more readily than on grass, consequently causing more head and upper limb injuries. Jamison and Lee counted injuries to the skull, cheekbone, lower jaw, eye, ear, teeth and lip as “head

5.4.8 Dental-facial injury

Dental injury includes injury to the teeth, upper jaw, lower jaw, and alveolar arch (Bolhuis et al., 1987) and can occur when the ball rises abruptly in the air or a stick is swung carelessly. Running into a raised stick can inflict severe injuries to the nose, face, eyes and teeth. Dental damage is mostly severe and, in contrast to other physical damage, mostly irreversible (Bolhuis et al, 1987).

Very few epidemiological studies have reported separately on facial injuries. They are usually grouped with other head injuries. Facial injuries are reported to comprise between 2.7% and 10.4% of all hockey injuries (Fuller, 1990, Jamison and Lee, 1989, Lindgren and Maguire, 1985, Rose, 1981). Rose (1981) reported that 6.2% of all injuries sustained over a 4-year period in female U.S. college hockey players were to the face, while Lindgren and Maguire (1985) reported 3% facial injuries in a small survey of elite Australian players. Fuller (1990) reported the highest incidence of facial injuries (10.4%), although these appear to include dental injuries as well. Jamison and Lee (1989) reported slightly more facial injuries on Astroturf (7.4%) than on grass (2.7%), perhaps caused by the comparative hardness of the synthetic surface.

In a survey of the 279 elite international hockey players at three international tournaments in 1984-85, 62% reported having sustained a serious facial injury at least once in their careers (Bolhuis et al, 1987). Unfortunately, Freke and Dalgleish (1994a), who studied the injury history of elite female players, did not present data on facial or dental injuries.

Dental injuries are not consistently reported, but are believed to comprise approximately 1% of all hockey injuries (Jamison and Lee, 1989, Rose, 1981, Lee-Knight et al., 1992). Although this is a relatively small proportion, unlike other injuries, damage to the teeth is often painful and irreversible. Mouthguards as a countermeasure for prevention of dental and facial injuries will be discussed in detail in section 7.11.3.

6. AN OVERVIEW OF INJURY COUNTERMEASURES FOR HOCKEY

Injuries result from a cumulation of a set of circumstances and pre-existing conditions that may best be understood as a chain of events: pre-event, event and post-event (Robertson, 1983). Injury countermeasures are measures that "counter" the risk of injury. A number of researchers have described how countermeasures should be targeted at different links in the chain of events leading to injury (Haddon, 1972, Ozanne-Smith and Vulcan, 1990, Watt and Finch, 1996).

Many factors contribute to the risk of injury in hockey players. Generally, more than one factor is involved in the chain of events leading to injury. Consequently, several countermeasures should be considered when planning interventions to prevent or minimise hockey injuries.

6.1 PRIMARY, SECONDARY AND TERTIARY COUNTERMEASURES

Injury countermeasures can be classified as primary (pre-event), secondary (event) and tertiary (post-event). Primary countermeasures are preventive actions taken before an event or incident that could potentially lead to injury. These countermeasures are designed to prevent the injury from occurring in the first place. Secondary countermeasures act during the event or incident to prevent the injury occurring or to reduce the severity of the injury. Tertiary countermeasures act after the injury has occurred and help to minimise the consequences of injury. Table 5 lists some of the major countermeasures to hockey injury, and categorises their action in the chain of events leading to injury.

Table 5: Potential countermeasures to hockey injury

Primary countermeasures	• Coaching and expertise of coaches • Pre-participation screening • Pre-season conditioning and fitness program • Adequate nutrition and hydration • Adequate warm-up and pre-game stretch • Officiating and expertise of officials • Prophylactic taping and bracing • Devising rules aimed at preventing dangerous play • Safe playing environment (for example level surfaces) • Cool-down and post-game stretch
Secondary countermeasures	• Wearing of proper footwear • Attention to biomechanics, technique • Control of dangerous play by officials and coach • Wearing protective equipment (for example shin guards, mouthguards)
Tertiary countermeasures	• Prompt access to professional first aid and medical care • Availability of first aid equipment on site • Rest, Ice, Compression, Elevation, Referral (RICER) • Rehabilitation • Taping and bracing to prevent re-injury • Return to play only when fit

7. COUNTERMEASURES IN DETAIL

7.1 RISK MANAGEMENT PLANS

The purpose of a risk management plan is to reduce the potential for injury by improving the safety of the sport (Australian Sports Injury Prevention Taskforce, 1997). Risk management plans assist sporting clubs, associations and facilities to provide a structure for sports safety. Risk management plans may cover: pre-participation screening; physical preparation of players; coaching; officiating; codes of conduct; policy and regulations; relevant standards for equipment and facilities; equipment; health promotion; education; sports first aid and sports trainers; environmental and playing conditions; injury management and rehabilitation; injury surveillance; and insurance (Australian Sports Injury Prevention Taskforce, 1997).

An effective risk management plan should include the establishment of a safety committee and a detailed safety plan (Coalition of Americans to Protect Sports (CAPS), 1990). A safety committee usually is comprised of representatives from all aspects of a particular sport, including coaches, officials, managers, staff, players and sports trainers. In order to be effective, risk management plans should also incorporate the following elements: risk identification; risk assessment; risk management; implementation; evaluation and consequent modification (Coalition of Americans to Protect Sports (CAPS), 1990).

Risk management plans are not common at club level in Victoria. Only 52% of clubs and centres in the City of Hume reported that they had a policy or written objective that recognised the health and welfare of their participants (Finch, 1996). By comparison, 62% of sporting organisations in Queensland were found to have adopted a risk management plan (Sports Insurance Safety Advisory Committee (SICAC), 1995). The effectiveness of the development and implementation of risk management plans as an injury prevention measure has not been formally evaluated. It has not known how many hockey clubs in Victoria have risk management plans and this needs to be researched by the Hockey Associations. In addition, any barriers to the development and implementation of risk management plans need to be identified and addressed.

Recommendations:

- Identify and address barriers to implementing risk management plans at hockey clubs.

- Formally evaluate the effectiveness of risk management plans in the prevention of sports injury.

7.2 PRE-PARTICIPATION SCREENING

A person wanting to participate in sport needs to be of a minimum physical, physiological and psychological fitness in order to meet the demands of competition and to reduce the risk of injury (Australian Sports Injury Prevention Taskforce, 1997). The overall goal of pre-participation screening is to identify people with conditions that may predispose them to serious injury and to refer them to appropriate specialists for further evaluation. Pre-participation screening aims to evaluate participants posture, joint integrity, muscular strength, flexibility, muscle balance and the analysis of normal movement and technique (Brukner and Khan, 1993).

The effectiveness of pre-participation screening for cricket has been reviewed by McGrath and Finch (1996b). During the period 1986-1989, it was found that 47% of the Victorian under age state cricket squad had their careers affected by injury (McGrath and Finch, 1996b). Since implementation of a pre-participation screening program in Victoria, the injury rate for fast bowlers has decreased to 36% in the state team, 11% in the U19 level and is non-existent in the Victorian Institute of Sport cricketers and U17 level (McGrath and Finch, 1996b).

In 1995, a committee was established to address the inconsistent approach of sporting bodies to pre-participation screening (Australian Sports Injury Prevention Taskforce, 1997). The aim of the committee, in consultation with the Australian Institute of Sport, sports medicine practitioners and stakeholders, was to develop a screening program for elite Australian athletes to reduce the incidence and severity of sports related injury. This screening program is currently being trialed and injuries monitored to measure the effectiveness of the program (Australian Sports Injury Prevention Taskforce, 1997).

The Queensland Academy of Sport (QAS) women's hockey team undergoes an annual assessment in order to screen for changes in postural control, range of motion (flexibility), strength and cardiovascular fitness (Matt Freke, QAS Physiotherapist, personal communication). A team comprising a physiotherapist, a podiatrist, an exercise physiologist and a doctor (who checks general health) assess the players. Identified weaknesses in flexibility, strength or endurance can then be addressed via a specific training program. Follow-up routine screening is undertaken to ensure that the prescribed training program is beneficial or whether it needs to be modified.

The QAS is an elite Australian sporting facility and has more resources than the average recreational club, which generally rely on coaches to implement pre-season screening of players. As a minimum, all coaches should be able to screen players for general strength, flexibility and endurance before each season. Coaches should be taught screening criteria and exercise prescription as part of their coaching preparation.

Recommendations:

- All hockey players should undergo at least a pre-season fitness screening for general strength, flexibility and endurance.
- Coaches should be trained to screen players and to refer them on to appropriate professionals if problems are evident.

7.3 ATTENTION TO GOOD NUTRITION AND HYDRATION

Hockey requires players to perform multiple work bouts at near maximal effort, punctuated by intervals of low intensity exercise or rest. This type of workload has been associated with a significant loss of water (Burke and Hawley, 1997) and fluid replacement strategies during training and competition should be followed.

Rate (1988) recommends that hockey players follow these guidelines for fluid replacement, especially when playing in hot weather:

1. Water is the best fluid replacement.

2. The fluid should be at a temperature between 8-13°C.
3. No more than 2.5 grams of sugar per 100ml of water should be added, if any.
4. Drink 400-600ml of fluid 30 minutes prior to training or competition.
5. Fluid should be consumed in 100-400ml volumes.
6. During exercise, 150-250ml of fluid should be taken every 10-15 minutes.
7. A glass of orange or tomato juice will replace electrolyte loss after exercise.
8. In cases of high fluid loss, athletes should drink beyond the feeling of adequate thirst quenching.

Although there is evidence to show that diet can affect athletic performance (Hargreaves et al., 1985), the link between diet and sports injury is not well known. Given the high-energy demands of training and competition, athletes need to increase their total dietary energy intake. Monitoring body weight and body composition can assess the balance between energy intake and energy output. High levels of training combined with inadequate caloric intake can lead to loss of weight and body fat. Very low levels of body fat can cause hormonal imbalances and especially low oestrogen levels, which have been linked to athletic amenorrhoea (absence of the menses) in female runners (Larkins, 1990).

The clinical significance of athletic amenorrhoea depends on a number of factors, including the type of sport, genetic background, body composition and calcium intake (Benell et al, 1997). Bennell et al. (1997) reported a higher prevalence of current and past menstrual disturbances in female athletes with stress fractures than in those without. The authors report that amenorrhoea may be associated with a risk of osteoporosis and has been associated with an increased risk of stress fractures, especially in the lumbar region of the lower back (Benell et al, 1997). Lower bone density in the lumbar region has been demonstrated in athletes with amenorrhoea, illustrating the susceptibility of the lumbar spine to alterations in menstrual status despite high levels of mechanical loading (Benell et al, 1997).

Reducing training intensity and increasing weight can treat some menstrual irregularities (Benell et al, 1997). Special care should be taken in any intervention strategy, as elite athletes may be reluctant to reduce training or to put on weight. One survey of 111 elite female hockey players reported that 17% demonstrated a high level of body dissatisfaction and 4% an elevated drive for thinness (Marshall and Harber, 1996). The authors concluded that these athletes might be more prone to initiating and sustaining eating disorders (Marshall and Harber, 1996).

Recommendations:

- The impact of diet on the incidence of injury, particularly in female athletes, needs to be determined.

- More research is needed to determine whether menstrual irregularities elevate the risk of overuse injuries. In particular, the exact relationship between menstrual health, bone health and stress fractures is yet to be determined.

7.4 PRE-SEASON CONDITIONING AND FITNESS PROGRAM

An effective training and conditioning program is essential to maintain fitness in the pre-season, during competition and in the off-season. Players require a certain degree of strength and flexibility, particularly in those regions directly involved in their activity. Adequate training requires advanced planning of the time and length of each session and activity.

Training should prepare the participant for activity and should not in itself present a risk of injury to the participant. Inappropriately designed training programs have been linked to injury in runners (McGrath and Finch, 1996a) and cricketers (McGrath and Finch, 1996b). Best and Garrett (1993) have identified several "training errors" which may contribute to injury, including persistent high intensity training without sufficient recovery; sudden increases in training volume or intensity; a single severe training or competitive session; and inadequate warm-up.

Training needs to encompass the development of skills specific to that sport. Each position on the hockey field has its own distinct physical demands (for review see (Reilly and Borrie, 1992). The goalkeeper, for example, requires good anaerobic power and moderate aerobic fitness, while the striker requires the greatest aerobic capacity. A pre-season conditioning and fitness program should be prescribed bearing in mind the skills required for each position. Hockey demands a high endurance component from all players and training must emphasise the development of aerobic capacity for endurance (Reilly and Borrie, 1992). In addition to high levels of endurance, players must also possess significant anaerobic power to keep up with the frequent high intensity bursts of activity involving acceleration, deceleration and turning movements (Reilly and Borrie, 1992).

Many authors have proposed that strength imbalances or specific muscle weaknesses might be a factor predisposing players to muscle strain (for review, see (Safran et al., 1989). A stronger muscle will absorb more energy than a weak muscle prior to failure, therefore reducing the likelihood of muscle strain (Safran et al, 1989). Strength must also be balanced between antagonistic muscle groups. If quadriceps muscles, for example, are over 10% stronger than the hamstrings, there exists an increased risk of hamstring muscle strain under maximal load (Safran et al, 1989).

In pre-season screening, Freke (physiotherapist to the QAS) found that many of the elite female players for QAS had a poor range of motion in their hips and ankles, as well as inadequate strength in their postural muscles (Matt Freke, QAS Physiotherapist, personal communication). The team of physiotherapists at QAS set out to improve the range of motion and strength in those specific areas in the hope of reducing the problems the team was having with lower back dysfunction and shin splints. The training program for the team included stretching of the deep muscles of the hip, as well as flexibility exercises for the ankle. The strength work focused on improving core postural strength, including the abdominal muscles; gluteal muscles; and muscles of the lower back. Resistance training was prescribed, implemented and reviewed for content and technique by a qualified strength and conditioning specialist.

In order to improve the alignment of the lower limb, it has been recommended that players include *single leg* weight training exercises in their resistance training programs to improve the efficiency of movement by correcting the alignment of the leg (Mike Dalgleish, QAS Physiotherapist, personal communication). Players were instructed to move through the entire range of motion of their resistance exercise with minimal rotation in the ankle and foot, and with the hip correctly aligned with the knee and the ankle. The principle is to minimise the rotation in the lower limb and reduce the chance of injury due to poor lower limb alignment. This technique should ensure that stability and good alignment are maintained in any position (Mike Dalgleish, QAS Physiotherapist, personal communication).

It is too early to tell if these countermeasures have been effective in reducing the incidence of hip, back and ankle injuries in the QAS team. Anecdotal evidence from the physiotherapists suggests that the program has been effective in reducing these injuries. However there were still a significant number of these problems reported for players training intensively (Matt Freke, QAS Physiotherapist, personal communication). These countermeasures require scientific evaluation in order to determine their effectiveness in preventing injury in hockey players.

Another important training principle is that of progression and periodization, which imply gradual increases in workload and training cycles that emphasise programmed rest (Matt Freke, QAS Physiotherapist, personal communication). By *gradually* increasing the intensity of the training program and scheduling periods of rest and muscle recovery, injuries due to overtraining can be minimised (Matt Freke, QAS Physiotherapist, personal communication). The physiotherapist team of the QAS believes that this is one of the most important components of an effective injury prevention strategy (Matt Freke, QAS Physiotherapist, personal communication). However, all evidence at this stage is anecdotal and from only one team. Clearly, more formal evaluation of periodization training for injury prevention is needed.

It may not be feasible for the average Australian club to run a hockey specific conditioning and fitness program of the calibre of the QAS team. Most coaches, however, should at least be capable of prescribing a conditioning program aimed at improving general strength, flexibility and endurance (aerobic capacity) in their players.

Recommendations:

- Players should undergo conditioning for general fitness before the start and throughout the season.
- Players' conditioning programs should be monitored for proper content and technique.
- Coaches should be taught principles of sport-specific conditioning and fitness as part of their training.
- More formal scientific evaluation of periodization training for injury prevention is needed.

7.5 ADEQUATE WARM-UP, STRETCH AND COOL-DOWN

The Australian Sports Commission, in association with Sports Medicine Australia, recommends warming-up, stretching and cooling down to help prevent musculoskeletal injuries during physical activity.

"Warm-up" is a term which covers the light exercise, stretching and psychological activities that are undertaken just prior to sporting activity to increase 'readiness to perform' (Best and Garrett, 1993). Warm-up to a light sweat followed by slow and relaxed stretching, immediately prior to exercise, is generally recommended as a means of enhancing performance and reducing the risk of musculotendinous injury, particularly muscle tears (Safran et al, 1989).

Safran et al (1989) and Best and Garrett (1993) concluded from their respective literature reviews, that there is a body of physiological evidence that shows that warming-up reduces some of the physical stresses associated with exercise. Warm-up and stretching have been shown in laboratory studies to increase the temperature of the muscle, improve the range of motion of the joints and increase muscle and tendon elasticity (thus requiring a greater degree of lengthening and force to tear the muscle) (Safran et al, 1989, Best and Garrett, 1993).

On the basis of current clinical and experimental evidence, Safran and his colleagues were prepared to recommend that warm-up and stretching routines were essential to the prevention of muscle injuries in sport. Best and Garret (1993) were more guarded. They concluded that it was ‘reasonable to accept’ that warm-up plays a role in the reduction of the incidence and severity of musculoskeletal injuries. Both groups of researchers recommend that well-controlled epidemiological and experimental studies were needed to fully evaluate whether warming-up prevents injury.

McGrath and Finch (1996) recently reviewed published studies on the effectiveness of warm-up and stretching as a countermeasure to running injuries and found that the epidemiological evidence of a protective effect was inconclusive. In fact, the weight of research evidence suggested that warm-up and stretching had either no effect or a negative effect on the risk of sustaining a running injury (McGrath and Finch, 1996a). However, the authors identified a number of methodological weaknesses in the studies they reviewed, particularly the lack of information on the type and duration of the routines used by participants. They suggested that a possible explanation for the inconsistent findings is that some warm-up, cool-down and stretching regimes protect against injury while others do not (or may even cause injury).

The type of warm-up is thought to be an important consideration in injury prevention (Safran et al, 1989, Best and Garrett, 1993). Best and Garrett (1993) suggest that most modern athletes and coaches favour ‘specific’ warm-up, that is a warm-up involving moving through the paces of a playing situation, because this type of activity allows for rehearsal of the event. A shift in hockey coaching towards a ‘specific’ warm-up has also been noted (Mike Dalgleish, QAS Physiotherapist, personal communication). This type of warm-up emphasises ‘hockey specific’ movements, such as running, ball handling (passing) and shooting. There is anecdotal evidence that this type of warm-up improves a player’s reaction time early in the hockey game, when it can sometimes be lacking (Mike Dalgleish, QAS Physiotherapist, personal communication).

The physiotherapy team of the QAS have observed that elite female players tend to develop an uneven degree of flexibility to each side of the body (Mike Dalgleish, QAS Physiotherapist, personal communication). Hockey is asymmetric by nature, as all players shoot and dribble the ball with a right-handed hockey stick. The loss of symmetric flexibility is thought to result from asymmetric movements that are used in a game situation and which are reinforced in the warm-up component of a match (Mike Dalgleish, QAS Physiotherapist, personal communication).

In order to counter this asymmetry, the physiotherapy team recommends that a thorough warm-up should include a static component (including stretching for symmetric flexibility) as well as a dynamic component (including hockey specific drills to improve early game reaction time) (Mike Dalgleish, QAS Physiotherapist, personal communication). This is similar to the warm-up program used by the gold medal National women's hockey team in the Atlanta Olympic games in 1996 (Mike Dalgleish, QAS Physiotherapist, personal communication). Controlled scientific research is required to determine whether 'specific' warm-up is exacerbating the problem of asymmetry in hockey players.

Anecdotal evidence suggests that stretching exercises for ankles, hips and back helps to prevent overuse-type injuries to the lower extremities and back in some hockey players (Matt Freke, QAS Physiotherapist, personal communication). However, sound experimental evidence of an injury prevention effect in hockey players has not been determined. Rigorous controlled trials are required to determine whether warm-up and stretching routines are effective injury countermeasures. Other issues such as optimal type and duration, individualised routines for players of different sex and age groups, and customised warm-up for different sports should also be investigated.

Stretching and 'cool-down' after exercise may have physiological benefits similar to warm-up. Gibbons et al (1989) suggest that cooling down activities may reduce the risk of exercise-related cardiovascular complications in older people. They reported that only 6 exercise-related cardiovascular complications occurred during a total of 71,914 exercise tests in 34,295 participants (mostly healthy, young and very fit adults) but that the majority of the complications were during the recovery period from exercise (Gibbons et al., 1989).

The authors recommended that all participants practice a slow gradual cool-down after strenuous activity. Cooling down may promote optimal recovery from strenuous exercise but there is little research evidence to show that cooling down reduces the incidence of injury (Best and Garrett, 1993).

Recommendations:

- Undertake research into the effectiveness and best methods of warm-up, stretching and cool-down as an injury prevention measure for hockey.
- Develop and promote information about warm-up, stretching and cool-down techniques specifically for hockey.
- Identify and address barriers to warm-up, stretching and cool-down among hockey players.

7.6 COACHING AND EXPERTISE OF COACHES

The Australian Coaching Council (ACC) identifies the role of the coach as essential to injury prevention. Coaches help to educate players in the fundamental playing techniques of the game, including tenets of injury prevention, controlled risk taking and disciplined play. Appropriately trained and accredited coaches are especially important to injury prevention at junior levels, where young players are first exposed to the game. One of the most important duties of the coach is to ensure that the playing environment does not predispose the participant to any unnecessary injury (Australian Coaching Council (ACC), 1991).

The National Coaching Accreditation Scheme (NCAS) of the ACC offers progressive hockey coach education programs at four levels of proficiency. Each NCAS level emphasises appropriate methods of analysing athletic performance, and correcting faulty techniques and training. Coaches are also taught how to instruct their players to avoid potentially unsafe and dangerous practices. It is recommended that all coaches should have at least a NCAS level 1 accreditation.

For hockey, special emphasis should be placed on the proper use of the hockey stick and correct hitting technique. The well-coached player should be taught how to maximise control of the ball and minimise the risk of injury.

Sports Medicine Australia also recommends that coaches complete at least a sports medicine awareness course from their Safer Sport program. Coaches are usually present during training and games and are often the first to respond to an injured player. A coach with knowledge of basic sports first aid will ensure that a player receives prompt medical attention in case of injury.

Recommendations:

- All coaches should be provided with at least NCAS level I accredited coaching and sports medicine awareness training.
- Coaches should be trained to screen players and to refer them on to appropriate professionals if problems are evident.
- Coaches should be taught principles of sport-specific conditioning and fitness as part of their training.

7.7 OFFICIATING AND EXPERTISE OF OFFICIALS

Rules, and the way that they are interpreted by officials are a key element in sports injury prevention (Australian Sports Injury Prevention Taskforce, 1997). Determining what constitutes dangerous play is often left to the discretion of the officials.

The National Officiating Accreditation Scheme (NOAS) of the ACC offers umpires educational programs at progressive levels of proficiency. Training includes a module on risk management for sports officials (National Officiating Program (NOP), 1995). The program stresses that the health and safety of the participants is the most important factor to be considered in the decision making process of officials (National Officiating Program (NOP), 1995).

Officials have a duty of care to participants to ensure their safety during play (National Officiating Program (NOP), 1995). The duty of care of an umpire has been identified by the NOP as: to enforce rules; protect participants; warn of possible dangers; anticipate foreseeable dangers; and control and supervise the game (National Officiating Program (NOP), 1995).

Recommendations:

- It is recommended that all officials have at least NOAS level 1 accreditation

7.8 RULES AIMED AT PREVENTING DANGEROUS PLAY

To eliminate some of the risks of injury in hockey, certain rules are applied and conventions observed to reduce dangerous play. All hockey associations affiliated with the International Hockey Federation (FIH) adopt the official FIH rulebook. The rules for women's hockey are identical to those of the men's game. The FIH rulebook lists all measurements in imperial (non-metric) values.

It is important that the officials consistently interpret the rules of the game of hockey. Deliberate physical contact is not permitted and should not be tolerated. The officials should also strictly adhere to rules that are specially designed to minimise the risk of injury from a high stick.

7.8.1 Use of stick

The high swing of a stick can cause severe injuries to the sensitive areas of the head and face. Improper use of the hockey stick can also result in contusions and lacerations. In order to prevent these types of injuries, the FIH rulebook states that *1) the players shall not play the ball above shoulder height with any part of the stick,* and *2) the players shall not lift their sticks over the heads of others.*

Because of the number of serious eye injuries in hockey, it has been suggested that the design of the hockey stick be changed. The hook of the stick can be altered to produce a shape that makes it impossible for the end of the stick to enter the eye socket (Spedding, 1986). This would make the blade of the stick into more of a closed circle, thus reducing the sharpness of the end. This suggestion to reduce eye injuries requires further investigation, although the high stick rule should remain regardless of the design of the blade.

7.8.2 Raised ball

There are a number of rules to protect players from a dangerously raised ball. The rulebook states that *players shall not intentionally raise the ball from a hit except for a shot on goal*, and *players shall not intentionally raise the ball over a long distance so that it lands directly in the circle*. According to the rules, a hit must be judged solely on risk of injury and penalised if dangerous. An offence should be penalised where the danger occurs and not where the ball is originally played.

Any player receiving a lofted ball must be given the opportunity to play it safely. If the receiving player is clear of other players at the time the ball is lofted, the rules state that no opposing players can approach within 5 yards until the ball has been received and is under control on the ground. Any flick or scoop made with an oncoming opponent within five yards is almost certainly dangerous and should be penalised.

Not every ball entering the circle off the ground is forbidden. It is permissible to raise the ball over an opponent's stick or grounded body, if it is not dangerous. Also, any pass into the circle is judged on risk. Umpires should be especially strict about these passes, for example, the cross from the wing into the circle may be dangerous even if only slightly off the ground.

7.8.3 Rules to protect the goalkeeper

Rules have changed to reduce the risk of catastrophic injury to the goalkeeper. The rule for the raised penalty corner shot now requires the ball to hit the low backboard in the net to count as a goal. One unexpected outcome of this rule change is that goalkeepers now pad up and lie down to block the shot that they anticipate will be kept low. A watching brief should be kept on this development and action taken if it has resulted in an increase in head injuries to goalkeepers.

There have been other developments from this rule change. If a goalkeeper falls to the ground on a penalty corner shot, it is now legal to flick or scoop (not hit) the ball over the keeper to any area of the goal (which is seven feet in height). In addition, the rule for the number of players in the goal crease has been reduced in order to lessen the risk of a deflection and improve the vision and safety of the goalkeeper.

7.8.4 Communicable disease control

Bloodborne pathogens are carried in body fluids and the blood stream. Of greatest concern in sport are transmission of Hepatitis B and C viruses and Human Immunodeficiency Virus (HIV) (Skaros, 1993, Australian National Council of AIDS, 1994). Avoidance of exposure to blood is the best means of preventing transmission of these viruses. This can be challenging in a sporting environment where open wound injuries occur during play. Despite the theoretical risk of exposure, there are no documented cases of HIV transmission during sport in Australia or elsewhere in the world (Australian National Council of AIDS, 1994).

Sports Medicine Australia (SMA) state that it is the responsibility of the sporting organisation and the infected player themselves to prevent the spread of disease and to limit exposure to risk (their own and others) (Australian National Council of AIDS, 1994). The FIH has adopted a "no blood rule" which states that *an injured player must leave the pitch in case of an injury that causes bleeding*. Umpires may have to stop time and remove the player. Players with bloodstains on body or clothing are not to be allowed to start or continue to play in this condition. Wounds must be covered and the bleeding stopped before the player may re-enter the game.

The prevention of transmission of bloodborne pathogens is an important concern in both the general and sporting communities. Any risk management plan must take into account strategies for prevention of communicable disease. Finally, the frequent occurrence of lacerations and abrasions in hockey illustrates the need for all players to ensure regular tetanus boost updates (Fuller, 1990).

Recommendations:

- It is recommended that clubs and organisations adopt and enforce an infectious disease policy.

7.8.5 Modified rules for children

The Australian Sports Commission (AUSSIE SPORT Program) has developed a modified version of hockey in order to develop hockey proficiency in younger players. The game, named Minkey, is designed for mixed teams of girls and boys at primary school level. It gives younger players a chance to develop basic skills before progressing to more competitive levels.

Minkey is played on a field one-quarter the size of a regular hockey field, and there are only six players on each side. Young players have much more contact with the ball because of the smaller field and modified rules. Minkey players often progress to Half-Field hockey, which has seven players, and plays on half the field only (Aussie Sports, 1991).

By gradually introducing and developing more formal skills, children's entry level playing ability is far greater when they start to play hockey with standard rules. There is strong evidence from Australian Rules football that modified games for juniors reduce the risk of injury (McMahon et al., 1993).

In a case-control study comparing injury rates in AFL football using conventional rules and modified rules, significantly fewer injuries at all levels of severity in the under-15 years and under-10 years age groups were reported with modified rules (McMahon et al, 1993). The modified game, called Vickick, had a significantly lower rate of injury (3.49 injuries per 1000 player hours) than the conventional under-10 age group (8.29 injuries per 1000 player hours) and the conventional under-15 age group (9.79 injuries per 1000 player hours) ($p < 0.05$) (McMahon et al, 1993). Vickick includes fewer players, a smaller playing field, reduced ball size and reduced body contact. The authors concluded that all sports should consider rule modification as an effective method of injury control.

7.9 ENFORCEMENT OF PENALTIES

Penalties for fouls vary depending on whether the fouls are personal or technical, made by the defensive or offensive team or committed inside or outside the striking circle. Determining what constitutes dangerous play is often left to the discretion of the umpires.

7.9.1 Deliberate fouls

Deliberate fouls include a defender approaching within 5 yards during the taking of a free hit or hit-in; playing the ball with the stick above the shoulder (except a goalkeeper stopping a shot); and inappropriate use of the stick and/or body.

Diving or sliding tackles can cause injury as well as unnecessary interruptions to the game. An illegal tackle, which intentionally grounds the player with the ball, should be penalised. Umpires should be trained to deal with deliberate fouls swiftly and consistently. Progressive penalties and appropriate use of cards maintain the umpires' control throughout the game, minimising unsafe play and reducing the risk of injury.

7.9.2 Penalty cards

Players who breach the rules may be cautioned, warned or suspended when circumstances justify. Players are "carded" for penalties, in a similar way to soccer. When a player deliberately fouls an opponent, the umpire issues that player with a card, the colour depending on the seriousness of the offence. The player's number is written down and the card is raised high to stand as a warning to all that this conduct will not tolerated.

A green card is issued as a first warning to a player, for relatively minor offences. A second warning or a relatively serious first offence will result in the umpire serving a yellow card. When a yellow card is awarded, a minimum 5 minutes send off is required. For physical offences, the suspension can be lengthened, although this it at the discretion of the umpire. In the time that a penalty is being served, the offending player's team must play short-handed, giving the opposing team a definite playing advantage.

For more serious offences, a player can be served a red card. Offences punishable with a red card include loud swearing, repeated breaches of the rules, misconduct, dissent and counselling misconduct (loudly encouraging a team mate to manufacture a foul). A red card will send the offending player off the field for the remainder of the game and could result in further disciplinary action being taken against the player.

Recommendations:

- Young children should be progressively introduced to hockey through Minkey and 'half-field' hockey.
- Umpires should be continuously trained so that there is consistent interpretation of rules to minimise unsafe play.
- Strict penalties should be consistently invoked for deliberate fouls and player dissension.

7.10 PROPHYLACTIC TAPING AND BRACING

Sports involving running, sudden changes of direction or landing from a jump can pose a risk for ankle inversions and result in a loss of playing time (Hume and Gerrard, 1998). Ankle taping and bracing is generally considered a valuable component of the management and rehabilitation process for ligament injuries. However, prophylactic (preventive) taping and bracing is becoming more common in sports that have high rates of ankle inversion injury.

The effectiveness of taping and bracing in the prevention of ankle injuries in hockey has been the subject of only one small study. Firer (1980) studied six South African provincial (state) level hockey players with a history of recurrent ankle sprains. The subjects had a minimum of three inversion injuries per season over at least two seasons. The injuries resulted in the players missing at least two or more practices or matches in the season. For the whole next season (which included approximately 120 practices and games), the six players taped their ankles with an elastic adhesive tape (Gibney basket weave). There was only one inversion injury throughout the season, and that player missed only one practice session. All players reported an increased feeling of stability and confidence in the taped ankle (Firer, 1980). This study was small and had no control group but it suggests that the role of ankle taping in reducing recurrent ankle injury in hockey warrants further investigation.

There is some debate on the best method of stabilising the ankle joint. Research into the effectiveness of taping in US football players indicates that there is a statistically significant reduction in ankle movement just after taping, though the reduction in movement is lessened after exercise (Firer, 1990). These findings indicate that the tape can stretch under active conditions and lose its stabilising qualities. For this reason, there is a growing interest in bracing as a means of stabilising the joint.

Hume and Gerrard (1998) reported on several controlled studies that have shown that ankle braces protect against ankle re-injury. The strongest study, a large prospective randomised controlled trial on the effectiveness of a semi-rigid ankle stabilisers (involving 1,601 healthy US Military Academy cadets playing basketball) was conducted over two seasons by Sitler et al. (1994). The study found that semi-rigid ankle stabilisers significantly reduced the frequency, but not the severity, of acute ankle injuries in both the non-injured ankle group and previously injured ankle group (Sitler et al., 1994).

Studies of soccer players also report that ankle orthosis (braces) when used by players with previous ankle injury protected against re-injury. A randomised controlled trial of the effectiveness of a particular brand of semi-rigid orthosis that involved 258 senior soccer players with previously injured ankles and 246 uninjured players, found a fivefold reduction in the incidence of recurrent ankle sprains in soccer players using the orthosis (Surve et al., 1994).

These studies consistently showed that the effectiveness of the external ankle support is dependent on the material properties and application method of the tape or brace and the innate stability and previous injury status of the athlete's ankle (Hume and Gerrard, 1998). Also, players with previous ankle injury were shown to be more at risk of re-injury than players with no prior history of ankle injury irrespective of whether they taped and/or braced their vulnerable ankle/s (Hume and Gerrard, 1998).

Of note is a contrary view on the value of taping and bracing put forward in recent review by Robbins and Waked (1998). The concept of taping and bracing implies that the ankle joint is inherently 'weak', and requires added support to sustain the forces involved in play. Robbins and Waked (1998) reviewed ankle injuries in several sports (not including hockey) and concluded that most ankle injuries occur when landing from a height (for example landing from a jump), and involve no significant lateral movement. These authors believe that the main risk factor for ankle injury is not a lack of mechanical support but rather the lack of effective proprioception (the precision of the estimated position and orientation of the plantar surface with respect to the leg), exacerbated by poor footwear (Robbins and Waked, 1998). In addition, they attribute the effectiveness of taping reported in other studies to the restoration of poor tactile sensory cues (because taping improves the relationship of the proprioceptive receptors to the playing surface), rather than the extra mechanical support taping gives to the ankle.

The weight of current evidence suggests that hockey players who have a history of ankle sprain injuries should seek a sports medicine professional's advice on a suitable ankle orthosis (brace) or taping. The disadvantages of taping include the expense, inconvenience and the diminution of support for the ankle after 20-40 minutes of active movement. One advantage of taping over bracing is that taping seems to interfere least with normal movements.

Recommendations:

- Improve ankle stability by including flexibility and strength exercises in the pre-season training
- Ensure full recovery of ankle function before returning to play in order to prevent recurrent ankle injuries
- Investigate the effectiveness of different prophylactic stabilising methods for the ankle in hockey players in controlled studies
- Investigate the relationship between footwear and ankle injuries in hockey.

7.11 PROTECTIVE EQUIPMENT

Aside from the goalkeeper, hockey players are not formally required to wear any protective equipment while playing. The Victorian Hockey Association (VHA) makes it compulsory for their junior players (under 17 years old) to wear mouthguards and shin guards, however their state players (the goalkeeper excepted) are not required to wear any protective equipment. The VHA highly recommends that older players also wear shin guards and mouthguards (Joe Hough, Executive Director VHA, personal communication). The Victorian Women's Hockey Association has no written policy on shin guard and mouthguard wearing, however it is compulsory for the goalkeeper to wear a helmet (Michelle Sheehan, VWHA, personal communication).

7.11.1 Goalkeeper gear

Field hockey goalkeepers dress like ice hockey goalies with facemask, throat guard, chest protector, mouthguards, large thigh pads, extra-thick shin guards and large gloves to prevent serious injury. It is mandatory for goalkeepers to wear secured protective headgear, pads, kickers and hand protectors; no rough edges or protrusions are permissible.

Goalkeepers must wear protective headgear at all times. A match cannot start nor continue without a goalkeeper wearing a helmet. This includes during a penalty stroke, unless the goalie is the stroke taker.

It is important that the Goalkeeper wear a throat guard to protect against injury due to a ball or stick strike to the Adam's apple. A throat guard that hangs from the helmet grill may not always be in the correct position to cover the throat - especially when the goalie is lying on the ground. A wrap-type collar guard is preferable so that the throat is always protected. The manufacturers have provided most of the evidence on the effectiveness of throat guards and independent evaluation is warranted.

Recommendations:

- Enforce the rule that goalkeepers wear helmets and other protective gear during games and at training at all levels of play.

7.11.2 Shin guards

Shin guards can act to protect the shin from forces that may lead to lower extremity injuries. Shin guards, similar to those worn by soccer players, can be slipped into the socks. These guards may protect the shin region from extrinsic injuries from being struck by the stick or ball.

Bir et al. (1995) used a Hybrid III female dummy (similar in size to a ten-year-old child) to evaluate the effectiveness of shin guards during impact forces delivered to the shin region. A pendulum impact apparatus simulated one player being kicked by another. It was found that load forces to the leg were reduced by between 41% and 77% with the use of shin guards (Bir et al., 1995). The authors concluded that the use of shin guards attenuated the force of impact to the tibia and thus reduced the risk of injury (Bir et al, 1995). Epidemiological evidence to support this claim is lacking.

Unlike soccer, lower leg injuries in hockey are primarily caused by contact with the hockey stick and ball. The effectiveness of shin guards in attenuating the forces of this type of impact has not been evaluated. It is uncertain whether shin guards, which meet protective standards for soccer, sufficiently protect against the strong forces of being hit by a swung hockey stick or a fully hit hockey ball. However, in light of the study by Bir and her colleagues, hockey players are strongly advised to wear shin guards during games and training.

It is important for players to wear properly fitted guards that do not slip out of place during running. The weight of the guards is another important consideration, because shin guards should be comfortable to wear and light enough not to impede play.

Recommendations:

- Promote the use of well-fitted shin guards during training and games.
- Undertake further research into the design and effectiveness of shin guards for use in hockey.

7.11.3 Mouthguards

Running into a raised stick can inflict severe injuries to the teeth. Dental damage is usually severe and, in contrast to other physical damage, mostly irreversible (Bolhuis et al, 1987). At three international tournaments in 1984-85, 62% of the 279 elite international hockey players surveyed report having sustained a serious facial injury at least once (Bolhuis et al, 1987). Participants in hockey should be aware of the importance of mouth protection and the availability of well-designed mouthguards (Rate, 1988). A properly fitted mouthguard is light, comfortable, strong and durable and should not inhibit breathing or speech.

The Dental Health Services of Victoria have indicated that a *properly fitted* mouthguard provides protection by:

- decreasing the risk of injury to the front teeth, especially the upper front teeth, which can be reduced by 90% when a mouthguard is worn;
- preventing laceration to jaws, lips and cheeks from the sharp edges of teeth;
- decreasing the risk of jaw fracture, especially in the area of the temporal-mandibular joint; and
- reducing the risk of concussion by absorbing and dispersing the force of a blow to the jaw.

As early as 1964, there was evidence that mouthguards were protective against dental, head and neck injuries in US football (Stenger et al., 1964). Stenger et al. (1964) studied one college football team's injuries for a one-season and found that there were no reported dental injuries for players who wore a mouthguard (the four players who reported dental injuries did not wear a mouthguard). In addition, there was only one report of a (minor) concussion in a mouthguard-wearing player. Nine players who did not wear mouthguards reported concussion. None of the four players who had previously worn a neck brace for cervical traction found it necessary to wear a brace once adopting the use of a mouthguard. The authors concluded that mouthguards provide direct protection to the teeth, jaw and surrounding tissue, and evidence that they safeguard against concussion and injuries to the head and neck (Stenger et al, 1964).

More recently, Chalmers (1998) reviewed the current evidence for the protective effects of mouthguards, particularly for Rugby Union players. He found that the weight of evidence clearly indicates that the use of mouthguards should be highly recommended, especially in contact sports [for review, see (Chalmers, 1998)]. Moreover, he concluded that there was a high level of evidence that mouthguards are effective in protecting against concussion and injuries to the cervical spine, through the repositioning of anatomical structures in the head and neck (Chalmers, 1998).

In a survey of 279 elite hockey players at three international tournaments in 1984 and 1985, Bolhuis (1987) found that female players were twice as likely to possess a mouthguard than their male counterparts (67% vs 27%). Overall, 43% of players reported owning a mouthguard. Possessing and wearing a mouthguard were not synonymous, as 70% of male owners and 80% of female owners reported wearing their mouthguards during matches. Only 20% of the total number of players reported wearing a mouthguard consistently during training *and* matches. Australian male and female players reported a high wearing rate of 100% and 94% respectively during matches**,** although the wearing rate was not as high for training (83% and 27% respectively) (Bolhuis et al, 1987).

Interestingly, most players in the Bolhuis survey who had sustained a dental injury (96%) went out and bought a mouthguard following their injury. The main excuse used for not wearing a mouth guard by elite international players was that it was felt to be unnecessary (65%) (Bolhuis et al, 1987). Other reasons given for not wearing a guard were that it caused nausea (15%) and it interfered with the athletes breathing (3%) (Bolhuis et al, 1987). Among players who obtained their protectors from a dentist (correctly fitted) the answer “disturbs my breathing” and “uncomfortable” were given less often than among players who had obtained protectors in a sport shop or elsewhere (Bolhuis et al, 1987). Knowledge of the importance of dental protection and access to mouthguards (for example, cost and comfort) has improved over the past decade, and these results may now be outdated.

Interestingly, Fuller (1990) cites 12 out of 14 incidents of facial/dental injuries where the players were wearing gumsheilds (mouthguards). Fuller does not comment on whether the mouthguards were properly fitted, nor does he differentiate between facial injuries and dental injuries. The wearing of a mouthguard will not protect against all facial injuries (for example, fractured nose) and its evaluation as a countermeasure should consider that.

Recommendations:

- Players are strongly advised to wear mouthguards during training and games.
- Mouthguards should be properly fitted and of good quality in order to maximise player comfort and compliance.
- Mouthguard use should be encouraged at an early age so that it becomes a habit.
- Mouthguards should be replaced at the first sign of wear (cracks or splits) or loss of resilience.

7.11.4 Protective eyewear

The total number of patients hospitalised for eye injury in Victoria from July 1989 to June 1991 was 1 289, or 645 patients per year, an incidence of 15.2 per 100 000 population (Fong, 1995). Sports-related eye injuries accounted for 5% of all eye injuries presenting to the ED of the Royal Victorian Eye and Ear Hospital in Melbourne from November 1989 to October 1990 (Fong, 1994). Although sports-related eye injuries were relatively rare, they represented a disproportionately high number of hospital admissions (22%) (Fong, 1994). Hockey accounted for 1.5% of the 709 eye injuries presenting to that hospital during the same period (Fong, 1994).

On the basis of evidence from the analysis of Victorian hospital ED data (VEMD, see section 5), most eye injuries in hockey appear to be a result of being struck in the eye with a hockey stick or the ball. These injuries are particularly serious. VEMD data show that hockey eye injuries result in a 12.5% hospital admission rate, which is much higher than the overall rate of admission for all hockey injuries (4.5%). Given the seriousness of eye injuries in hockey, the use of protective eyewear needs to be investigated.

The effectiveness of protective eyewear in preventing eye injury in field hockey players requires controlled evaluation. Hockey Associations should seriously consider the introduction of good eye protective devices in order to reduce the number of serious eye injuries in the sport.

Because of compelling evidence on the number and severity of eye injuries in the United States and Canada, protective eyewear was made compulsory for ice hockey, squash and racquetball. Protective eyewear has proven effective in greatly reducing serious eye injuries in ice hockey (Pashby, 1979) and racket sports (Easterbrook, 1987).

Canadian injury surveillance indicates that the introduction of a mandatory facemask for eye protection in ice hockey has reduced the number of facial injuries by 70% (Pashby, 1979). By 1988, not one eye injury had been reported by any ice hockey player wearing a Canadian Standards Association approved face protector (Pashby, 1989).

The effectiveness of eye protectors for squash and racquetball were evaluated in laboratory tests (Pashby et al., 1982). Balls were fired on an anthropometric head form at incremental velocities ranging from 50 to 100 miles per hour. Polycarbonate protective eyewear was found to prevent the ball impacting on the eye in all but one (100mph) trial (Pashby et al, 1982). This study also showed that lensless eye protectors afforded virtually no eye protection against ball impact (Pashby et al, 1982). The authors concluded that the use of approved polycarbonate eye protectors should be made mandatory in racquet sports in order to prevent serious eye injury. In epidemiological studies, no serious eye injury has been reported in racquet sports participants who wear eye protective devices that meet American Society for Testing and Materials (ASTM) standards (Easterbrook, 1987).

The earlier research into the design of protective eyewear was instrumental in helping to develop a standard for squash eye protectors overseas and eventually in Australia. A four-year campaign to progressively introduce protective eyewear for squash players in Victoria and Australia provides a good model for engendering Association and player acceptance of eyewear in hockey.

Recommendations:

- Undertake further research into the effectiveness of protective eyewear in the prevention of hockey eye injuries, with a view to introducing protective eyewear if indicated by research findings.

7.11.5 Gloves

Goalkeepers wear protective gloves, which act as a gauntlet to protect the hand and fingers from injury. The use of gloves by fielders is less commonplace, despite the high number of hand and especially finger injuries to these players. Hands and fingers can be injured when struck by the stick, the ball or when players collide with the ground or each other.

Gloves may offer some physical protection, especially from ball and stick injuries. Fuller (1990) found that the hands were not protected in 80% of cases of hand injury. Jamison and Lee (1989) advocate protection for the right hand, which is held lower down on the stick and is possibly more vulnerable to extrinsic injury than the left hand. The use of gloves as a countermeasure to hand injury in hockey clearly requires evaluation.

Recommendations:

- Undertake controlled studies into the effectiveness of protective gloves in preventing hand and, particularly, finger injuries in hockey.

7.12 ENVIRONMENTAL CONDITIONS

7.12.1 Surface

There are practical advantages to the use of synthetic sport surfaces in hockey. The synthetic surface is consistent over the entire playing field and the ball travels at a faster pace and in a truer trajectory (Reilly and Borrie, 1992). Adoption of synthetic surfaces for hockey (first introduced at the Montreal Olympics in 1976) helped to increase the playing time and decrease the number of interruptions in the game (Reilly and Borrie, 1992).

The International Hockey Federation (FIH) has developed performance standards for hockey pitches based on ball rebound, ball run and deviation, impact response, surface friction, dimensions, slope, smoothness, colour, gloss, watering, porosity and surface health (Yeend, 1990). Modern pitches can be sand-filled or water-filled, however to reduce friction and the risk of injuries, it is important that synthetic pitches are well maintained (Verow, 1989). The major advantage of the sand-filled pitch is that it is available for about half the price of the wet pitch, although the price differential is said to be shrinking (Yeend, 1990). The disadvantage of the sand-filled pitch is the comparatively harder surface which has brought with it faster ball run and rebound, increased severity of body damage in a fall and an increased strain upon lower limbs resulting from high surface friction and low energy absorption (Yeend, 1990).

Natural grass surfaces are believed to provide a greater cushioning effect and cause less strain to the lower limbs by absorbing 10% more energy on impact than synthetic turf (Reilly and Borrie, 1992). The only study to compare the rate of injury on synthetic surface and grass is Jamison and Lee (1989). The authors reported that although the overall number of injuries sustained was greater on Astroturf than on grass, the joint injuries to the lower limb were *more prevalent* on grass surfaces (53%) than on Astroturf (37%). More research is needed to determine whether synthetic surfaces increase the risk of injury to the joints of the lower limb.

Spedding (1986) comments that the introduction of artificial surfaces has reduced the opportunity for injury by bringing more possession and control to the game, but does not offer supporting evidence to his assertion. He contends that the movement of the ball is more accurate and predictable and opportunities for close-in deflections are fewer, thereby reducing the risk of extrinsic injury.

Anecdotal evidence suggests that ankle inversion injuries and meniscal problems have increased with the more widespread use of synthetic surfaces (Verow, 1989). There are reports that longer playing times coupled with the faster pace of play on synthetic fields have increased the physiological demands placed on elite players (Reilly and Borrie, 1992). Expert opinion has stated that the advent of synthetic playing surfaces has resulted in an increase in the prevalence of shin soreness, knee pain and lower back problems (Mike Dalgleish, QAS Physiotherapist, personal communication). It is thought that the synthetic surface results in a lower body position for players. This in turn results in more flexion in the hips and in the lumbar spine during play. The overall result is believed to be an increase in the number of intrinsic injuries, especially lower back complications (Mike Dalgleish, QAS Physiotherapist, personal communication).

The abrasive nature of synthetic playing surfaces has meant that lacerations are more frequent. Freke and Dalgleish (1994b) reported that 9% of acute injuries sustained on turf are lacerations, primarily to the lower limb, while Jamison and Lee (1989) found a higher number of lacerations on Astroturf (12.0%) compared to grass (2.3%). Sand-filled pitches are implicated in a large number of abrasions and “carpet burns” (Verow, 1989), although no specific data were reported.

Jamison and Lee (1989) reported that injuries to the head were slightly more frequent on Astroturf (13%) than on grass (8%), while Fuller (1990) found a high number of facial injuries (10.4%) on synthetic surfaces, but did not provide comparative data for facial injuries on grass. Fuller suggests that the high incidence of facial injuries results from the faster speed of play, as well as the greater bounce of the ball on the turf.

7.12.2 Weather

Hockey is an outdoor sport that can be played all year round in Australia. Therefore, extremes in temperature and the weather can become factors in the risk of injury. Extreme temperatures can affect bodily function, as well as environmental factors such as playing surface.

No specific evidence of preventative measures for climate-related hockey injuries were identified in this review. Injury prevention strategies have been based on general thermoregulatory recommendations, such as wearing appropriate clothing, using sunscreen, maintaining hydration and undergoing a process of acclimatisation in extreme temperatures.

Summer in Australia means high levels of ultra-violet radiation and high risk of sunburn, dehydration, heat exhaustion and heat stroke. Players are advised to wear a broad-spectrum sunscreen, as hockey uniforms generally leave the skin of their arms, legs and faces exposed to the sun. Hockey coaches should be made aware of the symptoms of heat stress and rest a player displaying these warning signs in hot conditions: cramps, headache, dizziness and uncharacteristic lack of co-ordination.

Coaches, sports trainers and officials should be familiar with the potential dangers of playing or competing under inclement weather conditions, including high heat and humidity, extreme cold, or during electrical storms (National Officiating Program (NOP), 1995, Australian Coaching Council (ACC), 1991). In such situations, practice or competition should be restricted, altered or possibly cancelled to reduce the risk of injury.

7.12.3 Other environmental issues

Footwear

When playing on grass surfaces, boots with moulded cleats are ideal, however they are not suitable for playing on synthetic surfaces. When playing on artificial surfaces, like Astroturf, shoes with non-slip grips are preferred. It has been suggested that the choice of footwear is important for good proprioceptive function in the foot, which may be a factor in the prevention of ankle sprains and strains (Robbins and Waked, 1998).

Water, which is applied to synthetic surfaces before games, increases the wear and tear on the shoes and can result in poor traction and a loss of foot support. Proper footwear is important in the prevention of overuse-type running injuries (see review in (McGrath and Finch, 1996a). Since running is an integral part of the game of hockey, it is important that players choose the correct footwear to match the conditions of the pitch.

Recommendations:

- Risk management plans should be developed and implemented by hockey associations to control for environmental hazards such as thunderstorms and extreme climatic conditions.
- Testing of new surfaces for hockey pitches should include controlled studies of risk and protective factors for injury.
- Hockey players should maintain adequate fluid intake, especially in hot weather.
- Hockey players should wear a broad-spectrum sunscreen in high ultra-violet conditions.
- Further research needs to be conducted into the relationship between footwear and ankle injuries in hockey

7.13 TREATMENT AND REHABILITATION

7.13.1 Rationale and background

An athlete with a previous injury may be more susceptible to re-injuring the affected body part. It is possible that the repaired tissue may not function as well, may be less protective than the original tissue, or may not have healed completely (Powell et al., 1986). It is important that the injured player is completely rehabilitated before returning to play.

Early treatment of injury reduces inflammation, decreases pain and improves range of motion, enabling players to return to competition as soon as possible (Seto and Brewster, 1993). A delay in treatment may result in a loss of performance, which may not be noticed by those playing recreational hockey, but could effect the fitness of elite players.

Initial treatment may involve rest, ice, compression, elevation, and referral (RICER). In addition, general rehabilitation and a combination of preventative measures may need to be administered. The overall treatment goals are pain relief, promotion of healing, decreased inflammation and a return to play as soon as possible.

7.13.2 Sports first aid

The high number of serious soft tissue injuries in hockey highlights the need for early and appropriate intervention. In order to minimise the time delay in treating an injury, it is essential that there is first aid equipment available at the location where games and training are held. It is also important that someone with knowledge of emergency care of athletic injuries is present at all times. Since coaches are most often present at training and matches, they should undergo at least a basic first aid course as part of their training.

Emergency treatment of hockey injuries includes immediate rest, ice, compression, elevation and referral (RICER). The RICER method is believed to reduce the possibility of further damage to the injured soft tissue (Knight, 1985), but has not been formally evaluated. Sports Medicine Australia identifies the benefits of the RICER method of treatment to include the reduction in the severity of injury by minimising swelling and the amount of tissue damage, resulting in a reduction in recovery time (National Sports Trainers Scheme, 1994).

7.13.2 Rehabilitation

The goal of a rehabilitation program is for the athlete to be free from pain and for muscle strength and joint flexibility to return to pre-injury level. Often rehabilitation of an injury needs to include the complete cessation of playing for a given period of recovery. Alternately, it may include a reduction in the intensity and/or duration of training sessions. This is necessary in order to allow the injury time to heal.

In hockey, early and complete treatment of minor injuries, such as ankle strains, may prevent such problems becoming chronic (Verow, 1989). Active early care of minor injuries is essential in order to prevent escalation into major or chronic injuries (Freke and Dalgleish, 1994a).

It is important that the rehabilitation process be supervised by a trained specialist (for example, sports medicine physician, physiotherapist, kinesiologist) in order to ensure that a full recovery is reached. A player may ‘feel’ ready to return to action, when in fact they have not regained full strength and flexibility. A premature return to play can put a player at risk of exacerbating an injury.

Recommendations:

- Players should seek prompt attention for their injuries from a professional with first aid qualifications.

- Organisers of events should ensure that there are qualified first aid professionals at all events.
- Players should allow enough time for adequate rehabilitation of injuries before returning to pre-injury levels of play.
- More controlled research into the effectiveness of different rehabilitation programs should be undertaken.

SUMMARY AND CONCLUSIONS

In general, the evidence on the incidence, patterns and causes of injury in hockey is mostly drawn from injury surveillance and descriptive studies involving small samples of elite players, typically a club or a team. Information is retrospectively and/or prospectively collected over a limited period in a particular location. The data may be subject to a number of biases and may be unrepresentative of the general population of hockey players.

The available evidence suggests impact injuries from the ball and stick and sprains and strains, predominantly to the ankle and lower back, are the most prevalent injuries. VEMD hospital data indicates that 'collision' injuries and 'struck by' injuries, particularly to the hand and face, are frequent and can be severe.

There are few controlled evaluations of countermeasures to sports injury, so recommendations in this report are necessarily tentative. Countermeasures for preventing hockey injuries where there is some supporting evidence for effectiveness include: penalties enforcing rules aimed at preventing dangerous use of the hockey stick and careless play of the ball; modified rules for children; use of protective equipment (such as shin guards, eye protection and mouthguards); expert training of coaches; pre-season conditioning; pre-game stretch and warm-up; prompt access to professional first aid and medical care; and full rehabilitation before returning to play.

Countermeasures requiring further investigation include altering the stick design to make it safer; the use of protective eyewear; the use of protective gloves; prophylactic taping and bracing of ankles; extending pre-season screening to include non-elite players; playing surface materials; footwear design; and standardising and improving injury data collection, especially for non-elite levels of play.

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APPENDIX 1

VEMD hospitals with hockey presentations
(2 years, 1996-1997)

Hospital	Frequency	Percent
Box Hill Hospital	44	15.1
Royal Children's Hospital	31	10.6
Ballarat Base Hospital	27	9.2
Dandenong Hospital	26	8.9
LaTrobe Hospital	26	8.9
Warrnambool Base Hospital	21	7.2
Williamstown Hospital	19	6.5
Austin Hospital	15	5.1
St Vincent`s Hospital	14	4.8
Mildura Base Hospital	12	4.1
Western Hospital	11	3.8
The Northern Hospital	11	3.8
Royal Eye & Ear Hospital	10	3.4
Echuca Base Hospital	7	2.4
Geelong Hospital	6	2.1
Wangaratta Base Hospital	4	1.4
Bendigo Base Hospital	3	1
Goulburn Valley	3	1
Wimmera Base Hospital	2	0.7

APPENDIX 2

Authors	**Study design and population**	**Definitions and methods**	**Outcomes**	**Results**	**Conclusions, recommendations and study limitations**
Rose, C.P. 1981	Four-year prospective observational study. **Population:** Elite collegiate women's field hockey team, California State University, Long Beach Time period: 1976-1979	**Definition of injury:** *Major injury* is one that required the attention of the team physician and produced definite disability needing follow-up care *Minor injury* is one that was handled by the sports trainer and produced no or limited disability	Number, type and severity of injuries during hockey play.	Eighty-one injuries were reported during a four-year period. Sixteen percent were major, most were minor. Most minor injuries were contusions (39%) and first degree ankle sprains (24%). Most major injuries were second degree ankle sprains (29%) and concussion (21%).	Most women's hockey injuries were minor, though major injuries were serious and reveal a hazard in the sport. Several injuries resulted from contact with the hockey stick. **Recommendations:** Emphasise safety precautions re use of stick and protective devices. Ensure adequate physical conditioning of players. Encourage competent officiating. Well-trained personnel must spot and treat minor injuries before they become disabling. **Limitations:** Small sample of elite athletes (not representative of general population). It is not clear whether it is the same team of players for the duration of the four-year study. No exposure data were collected.

Authors	Study design and population	Definitions and methods	Outcomes	Results	Conclusions, recommendations and study limitations
Lindgren, S. and K. Maguire, 1985	Retrospective survey from medical records **Population**: Mixed elite (AIS) scholarship hockey players. n = 16 males n = 12 females	All injuries in AIS scholarship players presenting to the WAIT physiotherapy clinic in WA in 1984 were reviewed. Injuries sustained prior to playing for the AIS were excluded from this review. All remaining cases were classified as external, internal and overuse type injuries. Injuries were also categorised for severity, although this data was not reported.	Comparison of men's and women's hockey injuries.	Lower limb injuries predominated. Female players had a higher rate of injury for the one year under investigation (5.0 injuries per female player vs 3.1 injuries per male player). Males reported 26.5% external injuries vs 18.3% for females. The incidence of internal injury was similar for both (55.1% males vs 50.0% females). The incidence of overuse injuries was higher in females (31.7%) than in males (18.4%).	External injury is more common in male players than female. Overuse injuries were more common in female players. Internal injuries were most common, with no difference in frequency between the two groups. **Recommendations:** Treatment and rehabilitation of injuries and modification of training is recommended. Players should be gradually introduced to new training surfaces. Players should be educated re first aid, strapping and warm-up. There needs to be good communication between the coach, the players and the physiotherapist. **Limitations:** Small sample of elite athletes (not representative of general population). Injury severity was not reported, which may explain the different rates of injury reported for men and women. Exposure data not collected.

Authors	Study design and population	Definitions and methods	Outcomes	Results	Conclusions, recommendations and study limitations
Jamison, S, and C. Lee 1989	Cross sectional survey. **Population:** Elite women's state teams participating in the Australian National Women's Hockey Championships 1984, n=110 1985, n=95 Time period: 1984 (on grass) and 1985 (on Astroturf)	Players were asked to complete a pre-tournament questionnaire to establish a baseline of injury status. Players sustaining injuries completed a second questionnaire during the tournament. Details of the injury (type, location, aetiology, position on field, footwear and weather conditions) were gathered. **Definition of injury:** Players were asked to report any injury, no matter how slight.	Number and type of injuries sustained during two hockey tournaments played on different surfaces were recorded. Injuries sustained while playing on grass were compared to injuries sustained while playing on synthetic Astroturf.	Overall, the 110 players on the grass surface reported 86 injuries (0.78 injuries per player), while the 95 players on Astroturf reported 92 (0.97 injuries per player). These differences were statistically significantly ($p<0.0001$). Injuries to the lower limb were the most common injuries reported on both surfaces. Thirty five (53%) of lower limb injuries to the knee and ankle joints were on grass compared to 20 (37%) on Astroturf ($p<0.01$). Although 18% of the injuries on Astroturf were of intrinsic origin, compared to 12% on grass, the difference was not statistically significant.	Injury rates were higher on Astroturf. Soft tissue injuries were more frequent on Astroturf and joint injuries were more frequent on grass. **Recommendations:** Coaches and players should be aware of the effects of different surfaces on playing style and on risk of injury. Protective equipment, including mouthguards, shin guards, protection of the right hand and adequate shoes are highly recommended. Educate players to recognise the early signs of injury. **Limitations:** Sample of elite athletes (not representative of general population).

Authors	Study design and population	Definitions and methods	Outcomes	Results	Conclusions, recommendations and study limitations
Fuller, M.I., 1990	Prospective observational study. **Population:** British County and Territorial level women hockey players. Just over 100 hours of match play were observed in the 1987/88 and 1988/89 seasons. Matches were played on three different types of synthetic surfaces.	An injury was recorded as the presence of pain, discomfort or disability, arising during or because of playing in a hockey match and for which physiotherapy treatment was given. *Major injury:* Injuries where the player was unable to play or practice for more than two days from the time of injury. All other injuries were classified as *Minor injury*.	The injury type, severity and rate, along with the players' positions on the field were recorded.	A total of 135 injuries were documented during 100 hours of observation, representing an overall injury rate of 1.34 injuries per hour of play. There were no significant differences in the rate of injury on each type of synthetic surface. Most (60.7%) injuries were to the lower limb, 20.0% to the upper limb, 10.4% to the face, and 8.9% to the back. Of the 10% Major injuries reported, the majority were soft tissue injuries. The remaining 90% of injuries were of Minor severity. Being struck by the ball (30%) or the stick (17%) caused most injuries. The stick caused most injuries to the hand, while the ball caused most to the face. The Forward and Midfield positions each accounted for 37% of injuries, while Defenders had 16%, Goalkeepers 4% and Umpires 6%.	This exploratory study found that the pattern of injury in women's hockey is: of minor severity; occurring at a rate of 1.34 injuries per hour of play; inflicted to the lower limbs, hands and fingers; mostly due to over-use and contusion; often a result of being struck by the ball or stick. **Recommendations:** High number of recorded lacerations on artificial turf indicates a need for all players to ensure regular tetanus boost updates. Additional body protection should be worn on the hands and fingers (ie in the form of protective gloves or padding). The total number of players is not reported. A control group observed playing on grass would have been useful. **Limitations:** Exploratory study-only 100 hours of play observed. The total number of players was not reported. No

					control group was observed.
Authors	**Study design and population**	**Definitions and methods**	**Outcomes**	**Results**	**Conclusions, recommendations and study limitations**
Freke, M. and M. Dalgleish, 1994a	Retrospective medical study **Population:** Forty players drawn from four touring teams of elite Queensland state women's hockey (two U21 and two open sides). Time period: Career prevalence	Medical records were reviewed and injuries were tabulated. Definition of injury: *Past injury* is any injury sustained during hockey that required admission to hospital, medical attention, or absence from practice or games for more than seven days.	Number and type of past injuries during hockey career.	Forty players sustained 95 injuries, or 2.37 injuries per player. Only two players (5%) had never been injured. A greater number of injuries were reported by the open team players (2.6 injuries per player) than by the under 21 team (2.1 injuries per player). Sixty-seven percent of all injuries involved the lower limb. The most common previous injuries were ankle sprains (21%), followed by low back pain (18%), injuries to the knee (14%), miscellaneous fractures (12%) and tibial stress syndrome (7% of all injuries).	Ankle and low back pain dominate injuries in elite women's hockey. **Recommendations:** Educate players on prophylactic mobilisation of lower back and nervous system. Emphasise active care of minor ankle injuries and controlled rehabilitation, strapping of ankles, ankle specific warm-ups and improved athlete proprioception. **Limitations:** This is a small sample size, and is not representative of general playing population. The reporting of injuries may be subject to recall bias.

Authors	Study design and population	Definitions and methods	Outcomes	Results	Conclusions, recommendations and study limitations
Freke, M. and M. Dalgleish, 1994b	Small prospective observational study **Population:** Sixty-two players comprising four touring teams of elite Queensland state women's hockey (two U21 and two open sides). Time period: Four Australian Women's Hockey National Championships: each a two-week tour of at least 8 elite level games.	An injury record was kept via treatment notes during tours and results were tabulated.	Number and nature (pre-existing or acute) of injuries were recorded for the duration of four hockey championships.	Sixty-two players developed or exacerbated 116 injuries (1.9 injuries per player over 4 tournaments). Sixty-six injuries (56.9%) were acute and fifty (43.1%) were chronic conditions. The most common acute injuries were haematomas caused by either a ball strike or impact with the ground, followed by neck or back injuries, muscle strains to the lower limb and lacerations from the abrasive synthetic surface. The body sites most cited for acute injuries were the thigh (17%) and the back and neck (12% each). The most frequently reported chronic injuries were for exacerbation of spinal conditions low back (28%), neck problems (8%), ankle conditions (16%) and shin pain (10%). Strains made up 42% of all chronic conditions requiring treatment, while 26% were a	The touring physiotherapist must be prepared for treatment of contusions in acute situations and for treatment of exacerbated chronic and acute spinal pain. **Recommendations**: Warm up and cool down to reduce chance of acute muscle strain. Educate players on lower back care and mobilisation. **Limitations:** Elite sample is not representative of general population.

				result of overuse.	
Authors	**Study design and population**	**Definitions and methods**	**Outcomes**	**Results**	**Conclusions, recommendations and study limitations**
Freke, M. and M. Dalgleish, 1994c	Small survey study. **Population:** Twenty elite U21 women hockey players from the Queensland Academy of Sport (QAS).	Subjects underwent a physical screening test for lumbar spine joint range, pelvic muscle and neural extensibility. Subjects also completed a questionnaire on injury history, knowledge of warm-ups and training regimes.	Tests for lumbar dysfunction were deemed positive if the athlete had pain on active movement, restriction in ROM, or palpable tenderness in lumbar spine. Tests for neural extensibility were positive if the athlete was restricted in slump or straight leg raise (SLR), or a difference of more than 15 degrees between limbs was found. Muscle extensibility tests around the pelvis included Ober and Thomas tests for ITB, hip flexors and rectus femoris.	Sixteen players (80%) had positive findings of low back dysfunction. Most commonly, pain was on palpitation. Only three of the sixteen had reported low back pain on the pre-examination questionnaire. Results from the questionnaire revealed that only one player out of 20 reported consistently mobilising their back in three directions and performing mobilisation exercises for the nervous system during warm-ups.	The incidence of lower back dysfunction is high among elite women hockey players, even at a young age. Ignorance of techniques to mobilise the lumbar spine and nervous system may be an important factor. **Recommendations:** Players should be educated in proper techniques for stretching and for exercises designed to improve mobility and support of the lumbar spine. **Limitations:** This is a very small sample of elite players, however, the results very clearly indicate a consistent pattern of injury that requires more research and preventive action.

Authors	Study design and population	Definitions and methods	Outcomes	Results	Conclusions, recommendations and study limitations
Roberts, P.D.T., Geljon, A.C., and G.S. Kolt, 1995	Retrospective and prospective cross-sectional study. **Population**: Fifty (23 male and 27 female) amateur (club-level) hockey players and 40 male Australian Rules Football players.	Players were surveyed retrospectively at the start of the season for injuries over past 12 months. The same players were asked to complete a weekly injury diary throughout a 5-month season. Data collection included information on the number, type and site of injuries, as well as the severity (the number of training sessions and games missed or modified as a result of each injury).	The retrospective and prospective data collection methods were compared. The injuries for hockey were compared to those sustained during football.	Football players reported a rate of 1.98 injuries per player (prospective 5 months). Hockey players reported a rate of 2.36 injuries per player (prospective 5 months). Hockey injuries occurred at a rate of one injury per 37.5 hours (training and competition). Injuries caused football players to miss 15.2% of the season, while hockey players missed 10.7% of the season. Body sites injured during prospective hockey survey include: knee and shin (30.5%); ankle and foot (20.3%); hip and thigh (8.5%). Types of injury for hockey includes: contusions (26.3%); sprains (23.7%); and strains (15.3%).	Football and hockey have different rates and severity of injuries, possibly due to the amount of contact in each game. **Limitations:** This report is only a summary, and the available data on hockey injuries were not reported. The method used to group body sites injured made comparisons to other studies difficult. The different surfaces played on are not reported and may be a factor. Also, the different injuries sustained by male and female hockey players are not discussed and this information could be useful.