

Sports and Recreation Injury
Prevention Strategies:
Systematic Review
and Best Practices

EXECUTIVE SUMMARY

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The British Columbia Injury Research and Prevention Unit (BCIRPU) directed by Dr. Parminder Raina, was established by the Minister of Health and the Minister's Injury Prevention Advisory Committee in August 1997. BCIRPU opened its doors in January 1998. It is housed within the Centre for Community Health & Health Evaluation Research (CCHHER) at Children's & Women's Health Centre of British Columbia and supported by BC Research Institute for Children's & Women's Health. The primary purpose of the Unit includes "The reduction of unintentional injuries among children and youth in BC, through the support and evaluation of effective prevention measures, and the establishment of ongoing injury surveillance across the province."

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INTRODUCTION

Canadian children and youth spend a considerable amount of time participating in sports and recreation activities. On average, children between the ages of 5 and 12 spend 18 hours engaged in physical activity every week, while those between 13 and 17 spend 15 hours (Canadian Fitness and Lifestyle Research Institute, 1998). The benefits of sport and recreation activity for children and youth are numerous, including: physical fitness, motor skill acquisition, improved self-esteem and development of teamwork and leadership skills. Participation in these activities does carry some risk however, particularly the danger of suffering an injury. Sports and recreational injuries, both organized and informal, account for relatively few deaths (~6% of deaths to those under age 20). However, these activities are associated with 17% of all hospitalized injuries and 19% of emergency room visits to hospitals participating in the Canadian Hospital Injury Reporting and Prevention Program (CHIRPP) (Canadian Hospital Injury Reporting and Prevention Program, 2000).

Unintentional injuries are the leading cause of death in children and adolescents in Canada and a major cause of morbidity (Canadian Institute of Child Health, 1994). Evidence has shown that these injuries are not the unlucky “accidents” we tend to dismiss them as. Rather, they are predictable events that are in most cases preventable (Rivara & Grossman, 1996). In Canada, \$4.2 billion was spent on treating unintentional injury in 1995 (SMARTRISK, 1998). Thus in addition to saving lives, injury prevention has great potential to save money.

Very little data on sport and recreation injuries in Canadian children and youth has been previously published. An initial perusal of the literature found only a few studies. A school-based study of elementary and second-

ary students in Vancouver, British Columbia found that sports injuries were the most frequent cause of injuries among secondary school students (Sheps & Evans, 1987). In a 1998 telephone survey using random digit dialing in Alberta, authors estimated that there were 11 sports and recreational injuries per 100 people annually (Mummery, Spence, Vincenten & Voaklander, 1998). More than half of the total estimated injuries were attributed to seven activities: ice hockey, baseball, basketball, soccer, jogging, cycling, and volleyball.

Even based on the limited data available, it is obvious that the prevention of sports injuries has merit on two fronts. First, increasing physical activity holds promise for reducing the risk of cardiovascular disease as well as having other health benefits; thus the reduction of injuries related to sport and recreational activities has significant implications for public health. Secondly, although the majority of sports injuries are not severe enough to require hospitalization, they are frequent and have a major economic impact in terms of both direct medical costs (treatment and rehabilitation) and indirect costs (lost productivity by parents taking time off to care for injured offspring).

Assessing the best prevention strategies for a sports or recreational injury requires a full understanding of the factors that contribute to both the occurrence of these injuries and the uptake of, or compliance with, potential prevention strategies. One of the challenges in current injury prevention is the gap that exists between what is known about these factors and the use of that information in developing and evaluating prevention strategies and/or policies. Prevention strategies can take the form of education and awareness raising activities, engineering modifications or setting and enforcement of policy.

Strategies can be targeted at the sports participant, a potential hazard or the surrounding playing environment. Thus when discussing sports and recreational injuries and the circumstances surrounding them, it appears clear that we should be able to prevent the majority of these injuries from occurring by:

1. Ensuring that design, development and maintenance of sports and recreation equipment and facilities meet safety standards;
2. Promoting the wearing of protective gear in both informal and organized sports and recreational activities;
3. Adapting playing rules to the participants with respect to age, etc.

However, the views on what environmental modifications, standards, protective equipment and playing rules are needed are mixed and vary between participants, parents, coaches and officials. Further, much of what exists in the way of standards, equipment and rules for children and youth is based on studies of adults. If we want to encourage evidence-based practice, we must also ask where is the evidence to suggest what the standards, protective equipment and playing rules for children and youth should be? Further, before promoting these strategies widely, what is the evidence that they will be effective?

To answer these questions, researchers at Plan-it Safe, the Child and Youth Injury Prevention Centre at the Children's Hospital of Eastern Ontario and the British Columbia Injury Research and Prevention Unit conducted a systematic review. The review examined published and unpublished Canadian and international literature related to injury prevention strategies in select sports and recreational activities. This method was selected over other approaches due to its rigor. Key aspects of systematic reviews include a well-formu-

lated review question; explicit inclusion criteria; identification and inclusion of all relevant evidence, description of the methodology used to conduct the review, and an effort to explicitly link resulting recommendations to the evidence.

The goal of this project had three components: to examine existing evidence on the effectiveness of current prevention strategies in selected sports and recreational activities; to determine the applicability of this evidence to children and youth and to the Canadian setting; and to make recommendations related to best practice (policy and programming) and future research needs in this area. The specific objectives were to:

1. Describe the evidence and quality of evidence on the effectiveness of strategies used to prevent injury during sports and recreational activities;
2. Develop and widely disseminate two reports – a Technical Report and a Best Practices Guide providing evidence-based practice and policy recommendations.

METHODS

The protocol for this review was developed from previously tested “systematic review” methods, including explicit and reproducible procedures for systematically identifying and selecting studies, grading the strength of evidence, and extracting information. Adaptations to the protocol were made, in consultation with experts, to suit the particular needs of this project.

Sports and recreational activities for this review were selected by two methods: 1) an analysis of the incidence and severity of pediatric sports and recreational injuries presenting to emergency rooms at the Children’s Hospitals in Vancouver and Ottawa and 2) discussions with a panel of experts from injury prevention, epidemiology and sports medicine. The Canadian Hospital Injury Reporting and Prevention Program (CHIRPP) database analyzed sport and recreation injuries in children and youth. A list of the most frequent and severe injuries was generated from this data. In total, the search identified the twenty-five most common sport and recreation activities resulting in injury in Canadian youth and children. Bicycling and general sport and recreation activities were also included to ensure that non-sport specific prevention strategies would be identified in the selection stage.

Literature search procedures included searches on eight electronic databases to identify potentially relevant documents. The databases were: Medline, Psycinfo, CINAHL, Current Contents, HealthSTAR, Sportdiscus, the Cochrane database for Systematic and Complete Reviews, the Cochrane Controlled Trials Registry and EMBASE. All databases were searched from the earliest records, for all languages and for all age groups. Hand-searching of additional sources was also conducted to identify potentially relevant studies not cap-

tured in the electronic database search. Sources for hand-searching included the reference lists of: a) all relevant articles; b) all “review” articles identified; c) sport injury textbooks published after 1990; d) a series of sport injury systematic reviews published by the MONASH Injury Prevention Centre in Australia; and e) the table of contents from the American Journal of Sports Medicine. A strict inclusion criterion was developed and the abstract from each document was critiqued. Documents were included in the review if they:

- Addressed sport and/or recreation unintentional injury prevention (IP) in one of the 27 specific sport areas or multiple sport areas (cycling papers were limited to those published after 1996);
- Evaluated the effectiveness of either (a) an educational IP program/strategy (b) a policy/regulation/legislative change (c) a community organization effort (d) environmental, equipment or product modifications;
- Contained either (a) injury incidence (b) injury severity (c) uptake of risk reducing behaviors (d) uptake or compliance with IP measures;
- Contained a control group in its methodological design or used other comparative measures.

Additionally, biomechanical studies were excluded from the review for two reasons; because they were not specifically included in the search filter, and the research team and the expert panel determined that many biomechanics articles would not be identified with the search strategy employed. Finally, only sports with three or more relevant articles were included in the review.

Data extraction and quality assessment tools were de-

veloped to review each of the relevant articles. The data extraction tools were developed by the researchers to record all of the pertinent information from each article including publication data, populations studied, interventions, results and conclusions. For Randomized Controlled Trials (RCTs), a tool developed by Moher, Jadad et al., was used to rate quality (Moher et al., 1995). For all other study designs, the research team consulted with the expert panel and methodology experts to develop a unique set of quality assessment tools, tailored to each study design.

For each relevant study, reviewers attempted to abstract the primary outcome, the intervention and relevant results. If the primary outcome was unclear, an objective selection of the outcome to report was made by determining which outcome seemed to be the most telling or serious. The data extraction and quality assessment was completed independently by two members of the research team. Any disagreements were resolved by discussion between the two reviewers and when necessary, a third reviewer made the final decision.

The quality or strength of reporting for each relevant study was assessed to determine the strength of evidence it provided. Articles were first grouped by study design as per data extraction. Since no practical tools existed to evaluate the remaining study designs, quality assessment forms were developed by the research staff with input from the expert panel.

Each study was rated on internal validity and quality of reporting. From these values a total score for each article was calculated. This score was converted to a percentage value and the quality of each study was rated using the following three-point scale:

- 0% - 49% = Poor;
- 50% - 89% = Moderate;
- 90% and greater = Good.

Post-hoc statistical analysis was calculated to determine the inter-rater reliability of the quality assessment.

- 0% - 49% = Poor;

RESULTS

The detailed searches of the eight electronic databases identified 21,499 articles meeting the initial search criteria. A review of the abstracts from each article identified 740 potentially relevant articles. An additional 124 articles were identified through hand-searching. Eventually, 117 of the articles met the inclusion criteria and were judged to be relevant to this review. The three primary reasons for articles to be excluded were: a study did not address sport and/or recreation unintentional injury prevention; a study did not evaluate the effectiveness of an injury prevention strategy, intervention or program; or the article focused on biomechanical study/interventions.

All of the relevant studies were published in English. Relevant articles were only found for 17 of the original 27 sport and recreational activities (a breakdown by sport is included in Table I). Only eight of the original sports/activities had three or more relevant articles and were included in this systematic review: Alpine Skiing, Baseball, Basketball, Bicycling, Football, Ice Hockey,

Rugby and Soccer. Overall the quality of the relevant studies was found to be low with approximately 52% rated as poor, 47% as moderate and only 1% as good. One of the objectives of this review was to assess injury prevention interventions among Canadian youth and children. However, only seven of the articles (6%) were of Canadian origin. Therefore, wherever possible a Canadian perspective is presented on injury prevention but most of the research is based on populations from other countries. The remainder of this report consists of the individual reports for each of the eight sports with three or more relevant articles.

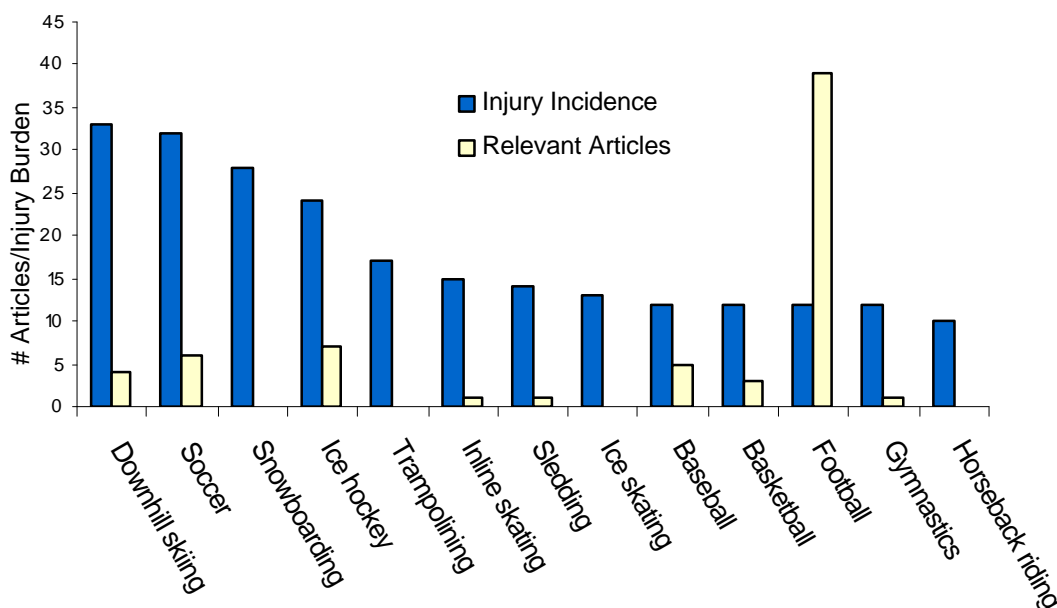
Table 2: Study Quality by Sport

	<i>Poor</i>	<i>Moderate</i>	<i>Good</i>
Alpine Skiing	8	2	0
Baseball	1	3	0
Basketball	2	1	0
Bicycling	5	7	0
Football	23	23	1
Ice Hockey	4	4	0
Rugby	1	4	0
Soccer	1	3	0

Table 1: Total Potentially Relevant & Relevant Articles & Number of Canadian Articles

	<i>Potentially Relevant</i>	<i>Relevant</i>	<i>Potentially Relevant Canadian</i>	<i>Relevant Canadian</i>
Alpine Skiing	91	10	1	0
Baseball	39	4	2	0
Basketball	14	3	0	0
Bicycling	31	12	11	0
Football	159	47	5	1
General Sport	189	2	12	0
Gymnastics	10	1	2	1
Horseback Riding	20	1	0	0
Ice Hockey	68	8	27	5
Inline Skating	17	2	1	0
Martial Arts	13	2	1	0
Rugby	40	5	1	0
Skating	23	2	1	0
Soccer	44	4	1	0
Swimming	28	1	0	0
Volleyball	9	1	0	0

Figure I. Burden of Injury vs. Number of Published Injury Prevention Articles



CONCLUSIONS

A systematic review of the sports and recreation literature retrieved surprisingly few well-designed and controlled studies investigating strategies to prevent injuries. An even smaller number of papers evaluated strategies to reduce injury in children and youth. Of the approximately twenty-one thousand articles identified through database and manual searching, only 740 were judged to be potentially relevant and only 117 met all the inclusion criteria.

For included studies, the majority had quality ratings of poor to moderate with only a small fraction achieving a good rating. Perhaps even more concerning is the lack of studies examining preventive strategies for the majority of sports and recreational activities examined. As governments in Canada continue to focus on increasing physical activity among children and youth, thought must be given to the issue of risk of injury and the relative lack of evidence of effective preventive measures.

The lack of good evaluative studies is disappointing given the magnitude of sport and recreational related injuries among children and youth. Undoubtedly, further research is required to: ascertain the scope of sport and recreation injuries in children and youth; evaluate existing prevention strategies among this age group; and develop interventions specific to the population where none exist. Future studies should also employ more rigorous study protocols. Where possible, studies should apply a randomized control group design. In circumstances where randomization is not possible, studies should attempt to match subjects on factors including: age, sex, size, playing position, experience, etc. Further, a consistent definition of injury is essential to allow a comparison of results across studies, and stronger measures of exposure would further elucidate the true magnitude of the issue. Many of the studies included in this review failed to apply these basic research stand-

ards. Consequently, the validity of results is called into question and they cannot be generalized to other populations.

Despite the lack of abundant studies, the synthesis of the existing research does provide some direction for current practice, although the majority of our recommendations are for further research. In the absence of

strong evidence to the contrary, we do not recommend cessation of existing practices not previously tested among children and youth. Rather, we advocate that the evaluation of these strategies be given priority so that evidence is produced as to their effectiveness, and evidence-based practice recommendations for these activities can be developed.

RECOMMENDATIONS

Research

- Develop an injury surveillance system that allows the monitoring of injury exposure and incidence in child and youth sports and recreational activities and assess injury trends in activities when new equipment or regulations are introduced;
- Develop consistent operational definitions of injury for all future research so that the results of independent studies can be compared;
- Evaluate gender differences in injury rates among various sport and recreation activities;
- Evaluate contemporary artificial and natural turf surfaces to determine if injury rate, type and severity differ between the surfaces;
- Test modern shoe and cleat designs to ascertain which models offer the best balance of improved athletic performance and reduced risk of lower extremity injury;
- Evaluate the benefit of modern safety equipment (helmets, pads, mouthguards, etc.) preventing injury or reducing injury severity;
- Further evaluate helmets and helmet use, fit and design in reducing head injury in non-contact sports such as skiing, cycling and snowboarding;
- Evaluate the effectiveness of lights and reflectors at improving driver awareness and reducing injury among cyclists and runners;
- Evaluate the impact of strength and conditioning, proprioception, and skill and coordination development programs on reducing injury in children and youth;
- Assess the effect of having an increased number of, or better trained, game officials on reducing injury in child and youth sports;
- Ascertain if a coach's experience and/or training has an effect on athlete injury rate in child and youth sports;
- Determine appropriate pre-season training programs for children and youth to prevent the occurrence of injury;
- Evaluate the effect of modified rules and equipment at reducing injury in children and youth;
- Assess the effect of an increased penalty severity for rule infraction at improving fair-play and reducing sport injury in children and youth;
- Further evaluate the effectiveness of prophylactic bracing and taping at reducing sport injuries among children and youth.

Practice

- In all sports, but especially contact sports, ensure that athletes have perfected basic tackling/checking skills prior to moving to more advanced leagues and introducing body contact;
- Ensure that all athletes complete a thorough warm-up and stretch routine prior to beginning practice or play and following game intermission;
- Offer safety equipment at a discount or by donation to encourage its use among children and youth;
- Teach young athletes and their parents to test and check their equipment prior to participation in sport and recreation activities to ensure it is functioning properly;
- Develop and run safety awareness campaigns to educate children and youth, parents, coaches and officials on proper injury prevention knowledge and techniques;
- Encourage lessons for beginners to ensure that basic skills are mastered before children and youth are allowed to participate in unsupervised sport and recreation activities.

ALPINE SKIING INJURY PREVENTION STRATEGIES FOR CHILDREN AND YOUTH

Alpine skiing is one of Canada's most popular sports, a result of our long winters and the abundance of snow and mountains. Due to the nature of skiing, injury risk is related to the high speeds and potential for impact with immovable objects, level of ski ability (due to the typical mixed abilities of skiers on a ski slope), equipment and the environment (Faelker, Pickett & Brison, 2000). Downhill ski injuries tend to be related to a twisting fall, impact with an obstacle or collision with another skier (Faelker et al., 2000). The

types of injuries seen are typically lower extremity injuries with a historic trend suggesting a shift from ankle fractures and sprains to severe knee injuries because of changes in skiing equipment in the last two decades (Faelker et al., 2000).

Lower extremity injuries tend to be the result of twisting falls, while upper extremity and head injuries, are due to impact (Soma, Mandelbaum, Watanabe & Hanft, 1996). Upper extremity injuries are estimated to account for between 13% and 36% of all downhill-related injuries (Soma et al., 1996). Thumb sprains account for the largest proportion of upper extremity injuries followed by fractures and dislocations of the shoulder as the result of either a fall or a pole becoming entangled in bushes (Soma et al., 1996).

Skiing Injury Research

The searches of computerized databases found 1,500 downhill skiing-related studies, of which 70 were found to be potentially relevant. Twenty-one additional potentially relevant studies were identified as a result of hand searching. Eleven of the 91 potentially relevant articles (12%) met the relevance criteria.

- *Ski Lessons* – studies on ski lessons found no overall association between the risk of injury and ski lessons (Bouter, Knipschild & Volovics, 1989a; Shealy, 1993).
- *Binding Adjustment Education* – education strategies designed to teach people how and why to check and adjust their ski bindings prior to skiing have had mixed results. One study that played a video on a bus trip to a ski hill found a reduction in injury at the end of the day. A second study that employed a broad-based pamphlet and cassette education program failed to find any change in behavior (Damoiseaux, de Jongh, Bouter &

Hospers, 1991; Jorgensen, Fredensborg, Haraszuk & Crone, 1998).

- *Ski Equipment* – one study found that skiers with non-release bindings were 3.3 times more likely to sustain a lower extremity injury than those with release bindings (Bouter, Knipschild & Volovics, 1989b), and two found that skiers who performed binding release self-tests were less likely to sustain an injury than those who did not (Ekeland, Holtmoen, & Lystad, 1989; Lystad, 1989). Two of the case-controls found that skiers with bindings at higher than recommended settings were at greater risk of injury (Hauser, Asang & Muller, 1985; Ungerholm & Gustavsson, 1985). Hauser went on to discuss the need for and importance of developing standard binding settings for children and youth (Hauser et al., 1985). A second study by Hauser found that the actual number of falls, injury events and lower extremity injuries were significantly lower in the group whose skis had been adjusted than among the control group (Hauser, 1989). They also examined thumb injuries using a special bow grip pole in a sub-set of skiers, and found that 2.8% of those using the special pole reported thumb injuries as compared to 4.0% of controls (Hauser, 1989).

Research Recommendations

- Develop a set of ski equipment standards for children and youth (e.g., appropriate binding settings for children);
- Conduct a prospective evaluation of the impact of

ski lessons for children and youth, and in particular, quantifying the number of hours of skiing needed or skill level to no longer be considered “a beginner”;

- Evaluate the impact of ski helmets (particularly for children and youth) in preventing injury;
- Further evaluate public awareness campaigns designed to increase awareness of the importance of properly adjusted bindings;
- Evaluate policy requiring separation of skiers by level of ski ability;
- Conduct a study examining the relationship of hill environment to injury.

Practice Recommendations

- Ski equipment should be appropriate to the level of ability of the skier;
- Ski bindings should be adjusted by a professional at the beginning of each ski season;
- Children and youth should be taught how to conduct a ski binding self-test and should conduct these tests at the beginning of each ski day;
- Parents should consider enrolling beginning skiers in lessons and restricting them to beginner ski hills until a reasonable number of ski hours have been completed;
- Inexperienced skiers should be supervised and should wear a helmet at least until they have mastered basic skills (e.g., a controlled snow plow).
- Until such time as a rigorous evaluation of ski lessons is conducted, ski lessons should continue

to be recommended by ski hill management and school boards supporting ski trips - in particular for beginning skiers;

- Until such time as a rigorous

Table 3: Skiing Studies Quality Rating

	<i>Poor</i>	<i>Moderate</i>	<i>Good</i>
Ski Lessons	2	0	0
Binding Adjustment Education	2	0	0
Ski Equipment	4	2	0

evaluation of ski helmets is conducted, the use of helmets specifically designed for skiing should continue to be required by ski hill management for children taking lessons, *and* be required/recommended by school boards supporting ski trips (especially for beginning skiers).

BASEBALL INJURY PREVENTION STRATEGIES FOR CHILDREN AND YOUTH

In Canada, both baseball and softball are very popular sports. According to Softball Canada, there are 400,000 players in registered leagues and an estimated 3 million people playing in Canada. Baseball is one of the four most popular sports for children between the ages of 6 and 14. Results from the 1992 General Social Survey indicate that 14% of children (20% of males) aged 6-10 years old and 16% of children (25% of males) aged 11-14 years old play baseball (Sport Canada, 1994). Injuries among youth baseball players were found to most frequently involve abrasions and sprains as well as a high incidence of fractures (Walk, Clark & Seefeldt, 1996). Injuries occurred most frequently in the upper extremity, followed by the spine and trunk (Walk et al., 1996). Overuse injuries to elbows and shoulders among youth baseball players is also very prevalent (Walk et al., 1996). Eye injuries among youth in baseball are reported as frequent and often severe (Larrison, Hersh, Kunzweiler & Shingleton, 1990).

Baseball Injury Research

A search of electronic databases identified 37 potentially relevant articles and 2 additional articles were identified through hand-searching. Of the 39 articles, 4

were deemed relevant and included in this review. Three of the included studies investigated the benefit of breakaway bases. The remaining study researched the effect of modified safety equipment.

- *Break-Away Bases* – the use of break-away bases has been tested with male and female athletes at recreational, collegiate and professional levels. Break-away bases have been shown to reduce sliding injuries by 80% to 98% (Janda et al., 1993; Janda, Wojtys, Hankin, Benedict & Hensinger, 1990; Sendre, Keating, Hornak & Newitt, 1994);
- *Batting Helmets with Face Masks* – one study investigated the benefit of face-masks on batting helmets for children. No reduction in facial injuries was found by using the face-masks (Pasternack, Veenema & Callahan, 1996);
- *Reduced Impact Balls* – no reduction in batter injury was found in children using reduced impact balls compared to regular baseballs (Pasternack et al., 1996).

Research Recommendations

- Better surveillance of baseball injuries in children and youth, particularly in softball, where there has been very little research on the patterns of injury among children and youth. Conduct longitudinal studies to document overuse injuries frequencies in youth and children;
- Additional analyses of injury patterns in younger players. Particularly injuries occurring at different levels of play and differences between position played;

Table 4: Baseball Studies Quality Rating

	<i>Poor</i>	<i>Moderate</i>	<i>Good</i>
Break-away Bases	0	3	0
Batting Helmets w/ Face Masks	1*	0	0
Reduced Impact Balls	1*	0	0

(* one study investigated two interventions)

- Evaluate interventions such as modified playing rules or equipment (e.g., modified bases to prevent sliding injuries or reduced pitching schedules to prevent overuse injuries) aimed at younger players;
- Ascertain the frequency of pitchers/in-fielders being struck by a hit ball or the bat (or pieces of it) to determine if rule or equipment changes are necessary to prevent injury in specific positions;
- Investigate the effectiveness of educational strategies such as modified rules and skills, and sport-specific training programs for younger players, for example safe sliding techniques or training programs to prevent overuse injuries.

Practice Recommendations

- Break-away bases should be used in competitive softball and baseball play at all levels.

BASKETBALL INJURY PREVENTION STRATEGIES FOR CHILDREN AND YOUTH

Basketball is one of the most popular sports among young people in Canada today. It is also the highest contributor to sport and recreation related injuries, according to a recent analysis of data from two Canadian pediatric hospitals. Among children and youth seen in emergency departments for sports and recreation related injuries, basketball was ranked as the number one reason for visits (Canadian Hospital Injury Reporting and Prevention Program, 2000). Among 10 to 19 year-olds, basketball was the leading cause of injuries, the majority of which occurred during organized events (Goulet & Regnier, 1997). The most frequent injuries were sprains (40%) and fractures or dislocations (26.5%) (Goulet & Regnier, 1997). The upper limb (50%) was most often affected, followed by the lower limb (36%). Twelve percent of the injuries were su-

perficial, 8% open wounds, 13% fractures, 20% sprains and strains and nearly 8% were head injuries (Canadian Hospital Injury Reporting and Prevention Program, 2000). The fingers were the body part most often involved in the injury (33.7%). Most of these injuries were the result of improper passes and receptions. Falls and collisions were involved in 74.3% of injuries (Canadian Hospital Injury Reporting and Prevention Program, 2000).

Basketball has the second highest percentage of sports and recreation injury (20%) by age, sex and type of activity (Canadian Hospital Injury Reporting and Prevention Program, 2000). In an informal context, basketball has the highest percentage of sports and recreation injury (15.9%) by age, sex and type of activity. Broken down by gender, boys in the 15-19 age group had the highest injury rate; for girls, those in the age group 10-14 were most frequently injured (32%).

Basketball Injury Research

Fourteen potentially relevant articles were identified, of which three met the inclusion criteria for this review. All three were written in English. All of the studies examined equipment-related interventions designed to reduce injury to the ankle and one also examined knee sprains.

Research Findings

- *Shoe Design* - There were no differences in the incidence or severity of ankle sprains in athletes wearing either a low top shoe, a high top shoe or a high top shoe with an inflatable air chamber (Barrett et al., 1993);
- *Ankle Taping* - The lowest incidence of ankle sprains was reported among athletes with taped ankles and high-top shoes (6.5/1000 games), followed by the low-top shoes and ankle tape (17.6/

1000 games). Injury incidence among players with no taping was considerably higher (low-top shoes/no tape (33.4/1000 games) and hi-top shoe/no tape groups (30.4/1000 games)(Garrick & Requa, 1973);

- *Ankle Braces* - Use of ankle stabilizers significantly reduced the frequency of ankle injuries across all player positions. Severity of ankle injury and frequency of knee injuries were not reduced with ankle stabilizer use (Sitler et al., 1994).

Research Recommendations

- Future studies must clarify findings on a broader range of basketball players, specifically younger players participating both recreationally and competitively;
- A large part of the published research literature on the prevention of sport injuries is aimed at organized athletics as opposed to the casual participant, which is how many children participate in sports and recreational activities. Research is needed in these areas to gain a better understanding of how children are injured in non-organized settings and what can be done to effectively reduce these types of injuries;
- Sport injuries will never be totally eliminated. However, sports injury research has already resulted in rule changes, equipment standards and improved coaching techniques and better conditioning of the athletes. If continued progress in sports injury prevention is to be made, reliable data is a must. Persistent surveillance of sports injury data is essential;
- Assess the impact of rule changes (i.e., limiting which players can attempt to gain

possession of a rebounded ball) at reducing acute injuries in children and youth;

- Determine if any basketball injuries are the result of an unsafe playing surface and assess the effect of court and facility maintenance on injury rate;
- Investigate the effect of equipment modifications, such as lighter basketballs, in reducing the force and injury potential of ball-player contact in children and youth;
- Research effectiveness of protective eye-wear to prevent eye injury;
- Sample size required for clinical study should be determined a priori.

Practice Recommendations

- The use of ankle stabilizers or high-top shoes and ankle taping can reduce the incidence of ankle injuries in basketball players;
- Encourage pre-season conditioning to prepare the athlete for competition and reduce the possibility of injury;
- Playing surfaces must be well-maintained and kept clear of debris or obstructions and conditions should be monitored;
- Ensure that the design, development and maintenance of sports and recreation equipment and facilities meet recognized safety standards, and monitor the effects on injury reduction.

Table 5: Basketball Studies Quality Rating

	<i>Poor</i>	<i>Moderate</i>	<i>Good</i>
Shoe Design	0	1	0
Ankle Taping	1	0	0
Ankle Braces	1	0	0

BICYCLING INJURY PREVENTION STRATEGIES FOR CHILDREN AND YOUTH

Bicycling is a very popular activity among Canadian children and youth. In the 1994 National Population Health Survey, 62% of parents with a child aged 14 years or younger and 49% of parents with a youth aged 15-19 reported that their child rode either a bicycle or tricycle (Pless & Millar, 2000). The causes of bicycle-related injuries tend to be a fall, collision with an immovable object, collision with a moving object, or malfunction of the bicycle (Health Canada, 1997). In 1993, 76% of CHIRPP bicycle-related cases were described as a fall or loss of control (Canadian Hospital Injury Reporting and Prevention Program, 2000). Eight percent were the result of a collision with a motor vehicle, 5% a collision with something other than a motor vehicle and just over 2% involved equipment failure (Health Canada, 1997).

Minor injuries such as lacerations and abrasions are the most common type of injury, while head injuries are the most severe. Emergency room data from CHIRPP indicate that 53% of bicycling injuries reported in 1993 were abrasions or lacerations, 26% were fractures and 7% were head injuries (Canadian Hospital Injury Reporting and Prevention Program, 2000). Data from the United States estimate that head injuries account for 33% of bicycle-related emergency room visits, 67% of bicycle-related hospital admissions and 62% of bicycle-related deaths (Centers for Disease Control, 1995). The 1988 Canadian General Social Survey identified bicycle injuries as the second leading cause, after hockey injuries, of restricted-activity days due to sports activities in persons older than 15 years (Milburn & Barry, 1998).

Bicycling Injury Research

Our search for studies subsequent to 1996 found 393 articles, of which 28 were identified as potentially relevant. In addition, three more potentially relevant studies were identified through hand searching. Of these 31 articles, only 12 met relevance criteria.

Research Findings

- *Bicycle Skills Education* – Two studies tested the benefit of bicycling safety courses including safe rider skills, traffic knowledge and basic bicycle mechanics (Carlin, Taylor & Nolan, 1998; Macarthur, Parkin, Sidky & Wallace, 1998). No improvement in safe bicycling behavior was detected between research groups. In one study, the research findings suggested that education actually increased risk of injury;
- *Helmet Education Campaigns* – Several studies investigated the effect of helmet education programs on their adoption rate (Britt, Silver & Rivara, 1988; Ekman, Schelp, Welander & Svanström, 1997; Hendrickson & Becker, 1998; Kim, Rivara & Koepsell, 1997; Logan et al., 1998; Ressler & Toledo, 1998; Watts et al., 1997). The results were mixed, depending on the type of interventions employed. Studies that provided free or reduced-cost helmets and education demonstrated only limited or temporary increases in helmet use among children. Other studies that used multi-component strategies including school and home-based education, educational video, helmet fitting and distribution etc., have demonstrated improvements in helmet usage rates. Further study is required to determine which strategies are most effective at changing children's attitudes about helmet usage;

- *Helmet Legislation* – Two studies on the impact of legislating helmet use found significant increases in the number of people, both adults and children, wearing helmets (Ni, Sacks, Curtis, Cieslak & Hedberg, 1997; Shafi et al., 1998). The overall number of people wearing helmets was still relatively low, however, and both studies suggested further interventions to increase helmet usage;
- *Helmet Education and Legislation* – One study that tested both educational and legislation strategies found better adoption rates among people that had both education and legislation compared to those with just legislation (Abularrage, DeLuca & Abularrage, 1997).

Research Recommendations

- Develop a surveillance system to ascertain where and when bicycling injuries are occurring;
- Evaluate the role of bicycle lights and reflectors in decreasing bicycle collisions;
- Evaluate the role of bicycle/rider fit in injuries resulting from a loss of control;
- Evaluate environmental modifications designed to separate cyclist from motor vehicle traffic (e.g., bicycle lanes, bicycle pathways);
- Further evaluate bicycle skills training, with stronger designs and thought to frequency and duration of interventions;
- Evaluate the effectiveness of helmets in different age groups of cyclists (e.g., small children);
- Develop age-specific guidelines for children and youth and suggest appropriate environments for them to cycle in;
- Evaluate the role of helmet fit and helmet retention in overall protection;

- Evaluate the feasibility, acceptability and effectiveness of enhanced helmet designs to protect the lower face, jaw, mouth and teeth;
- Investigate the impact of bicycle lanes on injury rates;
- Evaluate the role of handlebars as a cause of injury.

Practice Recommendations

- Bicyclists should wear a CSA approved helmet;
- Bicyclists should ride only proper-fitting bicycles to prevent overuse injuries and decrease injuries resulting from loss of control of the bicycle;
- Bicyclists wishing to increase performance should consider that with regard to their type of cycling (e.g., mountain biking versus road racing), bicycle fit, stretching and strengthening exercises, use of padded gloves and handle bars, properly-fitting and padded bicycle pants all contribute to increased performance;
- Community campaigns should be based on research data, focus on carefully selected target age groups, include the use of bicycle helmets (through discounts or donation) in addition to other strategies and have a built-in evaluation component (including a control group where possible);
- Community awareness and educational campaigns should be part of the pre-law phase when helmet legislation is introduced;
- Long-term awareness campaigns are necessary to move helmet use into the realm of social norm.

Table 6: Bicycling Studies Quality Rating

	<i>Poor</i>	<i>Moderate</i>	<i>Good</i>
Bicycle Skills Education	1	1	0
Helmet Education Campaigns	4	3	0
Helmet Legislation	0	2	0
Helmet Education & Legislation	0	1	0

FOOTBALL INJURY PREVENTION STRATEGIES FOR CHILDREN AND YOUTH

Football is a very popular sport among children and youth throughout Canada and the U.S. Injury in football is not uncommon, with ligament sprains and muscular strains being the most frequently reported (Andrish, Bergfeld & Romo, 1977; Mueller, Zemper & Peters, 1996). Concussions, bruises and abrasions are also regular football injuries (Mueller, Zemper & Peters, 1996). In Canada, the upper limb is the most common site of injury with the leg frequently hurt as well. Injury has been reported to occur in between 12% and 81% of high-school aged athletes involved with the sport (Andrish et al., 1977; Mueller, Zemper & Peters, 1996). In Canadian athletes, the percentage of football injuries reported by body region was: upper limb 52%; lower limb 25%; head, face & neck 17%; trunk & spine 6%.

Football Injury Research

There has been considerable research on interventions to reduce or prevent injury in competitive football. A review of electronic databases identified 131 potentially relevant articles. A manual search of reference lists discovered an additional 28 potentially relevant articles. A total of 47 studies met the inclusion criteria. All but one of the studies were conducted in the U.S.A. The remaining study was from Canada. Some of this research has resulted in regulation and equipment changes being implemented to prevent injury or reduce its severity in football.

Research Findings

- *Shoe & Cleat Design* – There appears to be a relationship between cleat design and knee injury. Cleats which develop higher foot fixation are associated with an increased rate of knee injury. Further research is required to determine the cleat design for each playing position that maximizes athletic performance while minimizing the risk of injury (Blyth & Mueller, 1974b; Cameron & Davis, 1973; Lambson, Barnhill & Higgins, 1996; Rowe, 1969; Torg & Quedenfeld, 1973);
- *Preventative Knee Braces* – The medial collateral ligament (on the inside of the knee) is very susceptible to injury in football players. Consequently, knee braces have been developed in an attempt to prevent these injuries. The research results are mixed with some studies finding reduced rate of injury and reduced injury severity (Albright et al., 1994; Brodersen & Symanowski, 1993; Hansen, Ward & Diehl, 1985; Quillian, Simms & Cooper, 1987; Schriener, 1987; Shaw & Brubaker, 1987; Sitler, et al., 1990), while others have found an increase in injury severity and rate (Deppen & Landfried, 1994; Grace et al., 1988; Hewson, Mendini & Wang, 1986; Rovere, Haupt & Yates, 1987; Teitz, Hermanson, Kronmal & Diehr, 1987; Zemper, 1990). Further research is required before conclusions on preventative knee braces can be determined;
- *Preventative Ankle Braces* – Research indicates that ankle braces are more effective at maintaining ankle stability and preventing injuries than taping (Rovere, Clarke, Yates & Burley, 1988);
- *Football Helmets & Equipment* – Football equipment has changed considerably over the past 3 decades. However, the one consistent finding across studies is that all equipment must be well-maintained, fit properly, be appropriate to the player position and meet NOCSAE and/or CSA specifications (Andrish et al., 1977; Blyth & Mueller, 1974a; Mueller & Blyth, 1974; Robey, 1972; Zemper, 1994);
- *Playing Surface* – Higher rates of minor injuries

such as abrasions have been reported on artificial surfaces. The research has not clearly determined if more severe injuries occur on natural or artificial turf. Further research is required to evaluate the injury rates on modern artificial turf compared to natural turf. Regardless of the playing surface, all fields must be well-maintained and free of obstacles to reduce the possibility of injury (Adkison, Requa & Garrick, 1974; Bramwell, Requa & Garrick, 1972; Keene, Narechania, Sachtjen & Clancy, 1980; Larson & Osternig, 1974; Powell & Schootman, 1992; Powell, 1987; Stevenson & Anderson, 1981);

- *Pre-Season Training* – Pre-season training programs that emphasize aerobic and anaerobic endurance, muscular strength, flexibility and agility have been demonstrated to reduce injury. Training regimes that alternate between running drills and cross-training activities such as cycling, swimming or water running have been shown to decrease pre-season overuse injuries while still increasing the fitness levels of the athletes (Cahill, Griffith, Sunderlin, Madden & Weltman, 1984; Cahill & Griffith, 1978; Gorse, Mickey & Bierhals, 1997; Heiser, Weber, Sullivan, Clare & Jacobs, 1984);
- *Warm-up & stretching* – Most athletes perform a warm-up session prior to beginning either a practice or game. Research has demonstrated a reduced rate of third quarter injuries when the athletes complete a second warm-up and stretch following the half-time break (Bixler & Jones, 1992);
- *Rules & Regulations* – regulations that have made spearing, face tackling and butt blocking illegal have

significantly reduced the number of head and neck injuries. Enforcement of these regulations by officials and the instruction of proper technique by coaches will help to further reduce these injuries (Mueller & Blyth, 1986; Mueller & Blyth, 1987; Torg et al., 1979; Torg, Vegso & Sennett, 1987);

- *Coaches* – Older coaches (> 30 years), those with an advanced degree, and those with experience playing football at the college level have been found to have teams with lower injury rates. Increasing the number of assistant coaches per team, and the use of limited-contact training programs also reduced injury rate (Blyth & Mueller, 1974b);
- *Game Officials* – While most coaches, officials and players would intuitively agree that increasing the number and experience of the referees would reduce the number of injuries suffered by the football players, there is no research evidence to support this theory (Kraus, Anderson & Mueller, 1971).

Research Recommendations

- Determine which cleat design provides the best combination of surface friction and foot fixation, and enhances athletic performance while reducing injury rates;
- Determine what differences in shoe-surface

Table 7: Football Studies Quality Rating

	<i>Poor</i>	<i>Moderate</i>	<i>Good</i>
Shoe & Cleat Design	3	2	0
Preventative Knee Braces	7	5	1
Preventative Ankle Braces	0	1	0
Football Helmets & Equipment	4	1	0
Playing Surface	3	4	0
Pre-season Training	0	4	0
Warm-up & Stretching	1	0	0
Rules & Regulations	2	2	0
Coaches	1	0	0
Game Officials	1	0	0
Miscellaneous	1	4	0

interface exists between artificial and natural turf and its impact on injury incidence;

- Test contemporary artificial turf designs to determine if injury rates differ between artificial and natural turf;
- Test the effectiveness of modern prophylactic braces in a randomized and controlled subject population;
- Evaluate modern football equipment to determine which models are most effective at reducing injury, and provide recommendations for future designs;
- Investigate the benefit of cross-training activities at reducing pre-season injury and maintaining or even improving fitness levels;
- Determine the most appropriate pre-season training regime for different levels of play and player positions;
- Research the effect of proprioceptive training programs at preventing specific types of injuries such as ACL ruptures;
- Evaluate pre- and mid-game warm-up protocols to determine the appropriate activity, intensity and duration to reduce the incidence of injury;
- Determine the relationship between stress and football injuries and develop appropriate measures to reduce the incidence of injury;
- Evaluate the effect of more and/or better trained officials at reducing the number of football injuries;
- Determine the effect of better-educated or experienced coaches at reducing injury;
- Examine the incidence of football injury in children to determine if similar injuries are occurring and at the same rates as older athletes;
- Develop appropriate training and competition guidelines for children based on age, size and/or

physical/skeletal maturity of the athletes;

- Determine the appropriate amount of contact for children and the safest method to introduce and teach the physical skills of football;
- Investigate the effect of regulation changes on injury rate.

Practice Recommendations

- All players should have equipment that is the safest available. Helmets must meet National Operating Committee on Standards for Athletic Equipment (NOCSAE) safety requirements. All equipment must be properly maintained and fitted for each individual athlete. The equipment must also be appropriate for the athlete's playing position;
- Playing surfaces must be well-maintained and athletes should wear shoes appropriate to the playing surface. Athletes playing on artificial turf should use knee and elbow pads to reduce abrasion injuries;
- Pre-season and off-season training is essential for injury prevention in competitive football. Pre-season training should gradually increase in intensity, duration and frequency to prevent overuse injuries. Pre-season training must emphasize all the components of fitness required in football including: aerobic and anaerobic endurance; muscular strength, especially in the neck and upper back; and overall flexibility. Cross-training should be incorporated into pre-season training to reduce the risk of developing overuse injuries;
- Until future research provides conclusive evidence for or against prophylactic braces, they should be available for athletes requiring them. Care must be taken to ensure that the braces meet quality standards and are upgraded when needed;
- Athletes should complete a warm-up consisting of light aerobic exercise and stretching prior to a game

or practice and should also perform a warm-up following the halftime break to reduce the possibility of sprain or strain injuries;

- Further regulations that reduce the roughness of football and prevent athletes from using the helmet as a weapon should be introduced. Current regulations need to be strictly enforced by game officials;
- Certification and continuing education should be essential for all coaches and officials to inform them of new injury prevention information.

ICE HOCKEY INJURY PREVENTION STRATEGIES FOR CHILDREN AND YOUTH

Canada is the birthplace of ice hockey. From the backyard rink to the National Hockey League, players and fans have made ice hockey one of Canada’s most popular sports. In this fast-paced game, the players of each team risk contact with a hockey stick or the puck, the surrounding boards, goal posts and the ice surface on which they play.

An analysis of CHIRPP data found that hockey injuries ranked third, after basketball and soccer, for emergency room visits related to sport and recreational activities (Canadian Hospital Injury Reporting and Prevention Program, 2000). In a measure of injury severity, hockey ranked fourth for frequency of hospitalization (Canadian Hospital Injury Reporting and Prevention Program, 2000). Hockey-related injury accounted for 8% of children and youth presenting at emergency rooms that were subsequently admitted (Canadian Hospital Injury Reporting and Prevention Program, 2000). When examining hockey-related injuries, the pediatric emergency room physician attends most fre-

quently to males between 10 and 14 years of age (Canadian Hospital Injury Reporting and Prevention Program, 2000). Injury rates in the studies reviewed ranged from 1.4 injuries/1000 athlete exposures during an elite team’s practices to 119 injuries/1000 athlete exposures for university athletes during game play (Montelpare, 1996). Contusions and sprains were the most frequently reported injury types with lacerations also being very common (Montelpare, 1996).

Ice Hockey Injury Research

A database search identified 58 potentially relevant articles. Eight additional potentially relevant English language articles were identified through hand searching, four of which were Canadian. Of the total of 65 identified, eight articles met relevance criteria, and are included for review.

Research Findings

- *Rules* – Fair play rules that encourage athletes to play clean hockey were demonstrated to reduce injury almost five-fold in one study. Rules that made checking from behind illegal significantly reduced the incidence of head/neck and back injuries (Roberts, Brust, Leonard & Hebert, 1996; Watson, Singer & Sproule, 1996);
- *Face Masks & Helmets* – The introduction of rules mandating the use of face masks in youth hockey in conjunction with high-sticking rules significantly reduced the number of eye injuries, and the number of athletes declared blind from their injuries (Downs, 1979; Kraus, Anderson & Mueller, 1970; Pashby, 1985; Pashby, 1977; Pashby, 1979);

Table 8: Ice Hockey Studies Quality Rating

	Poor	Moderate	Good
Rules	0	2	0
Face Mask & Helmets	4	1	0
Playing Surface	0	1	0

- *Playing surface* – There was an association noted between ice surface size and injury rate in hockey games. As the surface size increased, the number of injuries decreased (Watson, Nystrom & Buckolz (1997).

Research Recommendations

- Obtain child-specific injury data;
- Develop and use a consistent definition of injury in future research studies;
- Studies must employ designs that use matched-control groups and include exposure measures;
- Further research is required to assess injury rates in the contemporary game of hockey which requires helmets and face masks, safety equipment and has significant rule changes;
- Investigate the effect of increased penalty severity for rule infraction;
- Determine if injury rates differ in women's hockey compared to their male counterparts;
- Examine the effect of increasing the safety of environmental targets, for example, by making rink boards impact absorbing;
- Determine the effectiveness of modern equipment including mouthguards, neck-guards, pads etc., at reducing injury severity and rate;
- Explore other measures to reduce contact injuries with objects e.g., uniform fabric design to reduce sliding speed into boards, or development of force-absorbing puck materials;
- Establish the benefit of training and conditioning programs to prevent injury;
- Investigate increased training for coaches/officials to recognize hazards, and introduce injury prevention best practices as a means of increasing player safety.

Practice Recommendations

- Develop a surveillance/reporting system that is standardized across leagues;
- Strictly enforce current safety standards and rules such as high-sticking and fighting and checking from behind;
- Develop rules of “fair play” in addition to regular rules;
- Ensure coaches are certified and qualified to teach players to recognize & prevent injurious situations, and maintain equipment;
- Head and facial protective equipment should be mandatory for all levels of play. Further, the equipment must be properly fitted and of the highest standard;
- Development of new safety standards such as mandatory facial protection for all players, regardless of league;
- Correct helmet fit must also be made mandatory (snug fit with straps done up).

RUGBY INJURY PREVENTION STRATEGIES FOR CHILDREN AND YOUTH

Rugby is a fast-moving and high-intensity team sport. Although historically dominated by males, the sport is gaining popularity among female athletes, particularly at the high school and collegiate levels. Studies of injury in rugby have previously reported rates of injury higher than for many other team sports (Gerrard, 1998). An analysis of the CHIRPP database conducted in 1995 revealed that the majority of rugby-related injuries presenting at Canadian Emergency Departments were to those 15-19 years old, and that 83% of all the injuries were to boys. The injuries were most commonly associated with tackling (32%) or with a hit (unknown

or unintentional contact 20%) (Canadian Hospital Injury Reporting and Prevention Program, 2000). Slips, trips or falls accounted for 9% of the rugby injuries, collision between players for 8%, and injury from player being stepped on or kicked also accounted for 8% (Canadian Hospital Injury Reporting and Prevention Program, 2000). The nature of the injuries included abrasion/ bruising/ inflammation (28%), fractures (26%), and sprains and strains (25%) (Canadian Hospital Injury Reporting and Prevention Program, 2000). Concussion accounted for 4% and minor head injury for 3% of these injuries. Protective equipment was used by approximately 7% of those injured in this analysis (Canadian Hospital Injury Reporting and Prevention Program, 2000).

Shoulder injuries, particularly dislocation are an extremely common injury resulting from a tackle followed by a fall. The leg is one of the most frequently injured parts of the body generally caused by the excessive loads being placed on the ankle or knee joints. These injuries usually occur through unexpected contact with the playing surface or a second person. Face/mouth injuries are also common in the sport.

Rugby Injury Research

There is very little published research on injury prevention interventions in competitive rugby, especially in child and youth leagues. From a search of computerized databases, 30 articles were identified to be potentially relevant for this review, and five additional articles were identified through hand-searching. Only 5 studies met the inclusion criteria and were included in this review; four on the effect of mouthguards and one study of the impact of changing the season of play.

Research Findings

- *Mouthguards* - Players (both senior and mini levels) who wore mouthguards tended to report fewer mouth injuries as well as fewer concussions and loss of consciousness than non-wearers (Jennings,1990). There was no difference in the number of fractured or missing teeth in players wearing either “mouth-fitted” or “laboratory-made” mouthguards. It would be reasonable to accept that both types of mouthguards had a preventive effect against damage to the teeth. Although players reported some problems with dryness of the mouth and nausea, they agreed that fitted mouthguards were far superior to the stock types of guard that they had previously worn (de Wet, Badenhorst & Rossouw, 1981; Upson, 1985).
- *Playing Season* - The effect of changing the season of play from fall and winter to spring and summer was investigated. Both forwards and backs experienced an increased risk of bruises, fractures, dislocations and joint injuries in the spring/summer league (Gerrard, 1998).

Research Recommendations

- Line judges on the field in addition to the referee should be investigated to determine whether safer play is enforced, particularly in amateur leagues;
- Rigorous study needs to determine if prophylactic taping, helmet use, shoulder pads and other common types of protective equipment are effective in reducing injuries in rugby;
- Rule changes directed at preventing injuries in the scrum have been made. Studies need to determine if scrum-related injury rates have decreased.

Table 9: Rugby Studies Quality Rating

	<i>Poor</i>	<i>Moderate</i>	<i>Good</i>
Mouthguards	1	3	0
Playing Season	0	1	0

Practice Recommendations

- All players should wear mouthguards to prevent mouth/face injuries;
- Players should wear mouthguards during practice as well as games in order to increase comfort and familiarity;
- Accreditation of coaches at the appropriate levels. Coaching manuals and programs should include information on: pre-season fitness; management of injury; and issues regarding foul play and tackle;
- Priority should be placed on correcting foul play. Fair play should be reinforced;
- Parents of children playing junior rugby need to be informed about the benefits of mouthguards;
- Efforts should be made to custom-fit mouthguards.

SOCCER INJURY PREVENTION STRATEGIES FOR CHILDREN AND YOUTH

Soccer is the most popular sport in the world, with approximately 200 million players in 186 countries registered with FIFA (the International Federation of Football Association). In Canada, interest in soccer has increased considerably over the last few decades. The Canadian Soccer Association reports the total registration in the sport for 1999 to be over 700,000 with participation increasing yearly. Registration increased 13% from 1997 to 1998 and 10% from 1998 to 1999. Of registered players in Canada, 36% are female and 87% are youth under 19 years.

Injury in soccer is not uncommon with rates reported between 2.6% and 5.2% of players per year. Eighty-five percent of injuries occur in athletes under age 23 and 45% in those under age 15. The male:female injury ratio has been reported at 1:2. Lower extremity injury account for 61% to 80.9% of all soccer injuries.

The upper extremity between 2.7% and 7.7% and the head and face account for 4.9% to 22% of injuries (Canadian Hospital Injury Reporting and Prevention Program, 2000). An analysis of recent CHIRPP data found that soccer ranked second after basketball for emergency room visits related to sport and recreational activities (Canadian Hospital Injury Reporting and Prevention Program, 2000). Soccer-related injury accounted for 9% of children and youth presenting at emergency rooms who were subsequently admitted to hospital (Canadian Hospital Injury Reporting and Prevention Program, 2000).

Soccer Injury Research

Despite soccer's popularity throughout the world, there is surprisingly little research on interventions to prevent injuries in soccer. Of the total 44 articles identified through database and hand searches, only four articles met the inclusion criteria and are included in this review. The research that met the inclusion criteria investigated the following topics:

- *Injury Prevention through Conditioning Programs* – One study assessed the benefit of a proprioceptive training program to reduce the incidence of ACL injury in semi-professional and amateur soccer players (Caraffa, Cerulli, Progetti, Aisa & Rizzo, 1996). All teams were followed for three seasons and the incidence of ACL injuries among teams following the program was 0.15 per team per season as compared to 1.15 per team per season among the control teams. A second study investigated the effect of a strength training program on the incidence of injuries among a male college soccer team (Lehnhard, Lehnhard, Young & Butterfield, 1996). The team was monitored for four years with a strength training regimen incorporated into the non-season and the pre-

season during the third and fourth years. The injury rate during the years without the strength training was 15.15 injuries per 1,000 exposures as compared to 7.99 per 1,000 exposures for the two years with the strength training.

- **Multi-Component Training/Education Programs**
A seven-part program to reduce injury incidence among 17-36 year old males was tested in a Swedish community soccer league (Ekstrand & Gillquist, 1984). The program, delivered by doctors and physiotherapists, consisted of the following: correction of training; equipment and shin guards; prophylactic ankle taping; controlled rehabilitation; exclusion of players with knee instability; information to coaches and players; correction and supervision. After a six-month follow-up, the intervention teams had 75% fewer injuries than the control teams.
- A second multi-component intervention study was conducted to assess the effects of emergency preventive measures to prevent heat exhaustion during the tournament (Elias, Roberts & Thorson, 1991). The intervention included provision of heat stroke prevention information to staff, coaches, officials and referees; as well as emergency measures with game modifications and hydration techniques. The rate of heat exhaustion per 1,000 player hours decreased after the implementation of the emergency measures from 21 cases in the first two days to 13 cases in the last four days.

Research Recommendations

- Conduct a surveillance study to assess patterns of soccer injuries among children and youth;
- Modify training regimens for children – such as

proprioceptive and strength training strategies;

- Replicate the proprioceptive training program, particularly with younger age groups and female players;
- Investigate whether strength training or other conditioning programs have been appropriately modified for children;
- Test the effect of modified training in child and youth settings;
- Conduct evaluation studies to assess the effectiveness of modified strategies to reduce injuries;
- Design and evaluate a multi-component strategy for injury prevention for child and youth soccer;
- Further evaluate heat illness prevention measures in youth soccer tournament settings;
- Assess the importance of other environmental factors or play conditions (such as goal post safety, playing surfaces) and how these influence injuries in children and youth.

Practice Recommendations

- Ensure that environmental concerns such as heat exhaustion are addressed during soccer play in hot weather. Include tracking of injuries and prevention measures at large events;
- Develop training protocols (i.e., on-season and off-season conditioning programs, proprioceptive and strength/flexibility programs) with appropriate modifications for children;
- Develop guidelines related to the prevention of heat exhaustion for young players.

Table 10: Soccer Studies Quality Rating

	<i>Poor</i>	<i>Moderate</i>	<i>Good</i>
Conditioning Programs	0	2	0
Multi-Component Strategies	1	1	0

STUDY OVERVIEWS

Table 11: Alpine Skiing Study Overview

First Author	Quality Rating	Study Aim	Conclusion
Bouter	Poor (6.5/18)	Determine whether binding adjustment on both skis among injured skiers differs from non-injured skiers and whether binding release is less frequent during incidents leading to LEER.	Non-release of bindings during an injury incident was associated with a higher risk of lower extremity injury. For males, the risk of LE injury was 3.2X higher in non-release and for females, 3.3X.
Bouter	Poor (5/18)	Determine the relation of ability & physical condition to injury risk in downhill skiing.	No evidence could be demonstrated for a preventive effect of a pre-holiday course in ski gymnastics, training on an artificial ski slope or good physical conditioning.
Damoiseaux	Poor (5.5/14)	Evaluate the effectiveness of an educational message targeting skiers binding adjustments (compared eight ways of delivering the message).	A fear-arousing approach to the message increased adjustment behavior score irrespective of timing of message or medium of delivery.
Ekeland	Moderate (8/18)	Identify risk factors in alpine skiing to generate data for preventive measures.	Skiing instruction seemed to protect against injuries and all beginners ought to attend ski school classes. Prior release testing of bindings reduced the risk of sustaining a LEER injury.
Hauser	Poor (1/5)	Estimate the injury risk difference in skiers with a correct binding setting compared to skiers with an average binding setting.	Significant differences between skiers with proper binding setting and improperly set bindings.
Hauser	Poor (3/18)	Identify special risk groups among skiers (of interest to this systematic review, those related to equipment & binding settings).	Binding settings of skiers with sprained knees were distinctly higher than those with non-LEER injuries or controls, and lower than those with fractured tibias.
Jorgensen	Poor (0/5)	Investigate the effect of an instructional video on skiers' behavior, injury risk and type and severity of injury.	Injuries were seen in 16% of skiers in the video group versus 23% of skiers in the control group –The video group was less likely to have to seek medical attention and/or reduce their amount of skiing.
Lystad	Poor (5/18)	Not stated by authors.	During the timeframe of this study skiers became less aware of the importance of performing self-test of bindings. This suggests the need for continuous information about skiing safety and the role of self-test of bindings.
Shealy	Poor (5/18)	Explore protective factors in downhill skiing & snowboarding (for this systematic review we examined the results for downhill skiers).	There was no evidence that taking a skiing lesson is associated with a reduced risk of injury.
Ungerholm	Moderate (12.5/18)	Explore risk factors related to lower extremity injury in skiers \leq 16 years, including binding adjustment.	The release force of the toe mechanism deviated markedly for both groups. The deviation was even more pronounced for the injury group. The heel mechanism showed a moderate deviation in both groups. Recommend toe release be set as loosely as possible.

Table 12: Baseball and Softball Study Overview

First Author	Quality Score	Study aim	Conclusion
Janda (1990)	Moderate (11.5/17)	Compare injury rates focusing in softball games using breakaway bases vs. those using stationary bases.	Ankle injuries predominated – 24/45 injuries. For each sliding injury on breakaway base, there were 22.7 injuries on stationary bases.
Janda (1993)	Moderate (12.5/17)	Study the effects of break-away bases within collegiate & professional baseball teams (on sliding-related injuries).	80% reduction in number of sliding-related injuries among teams using breakaway bases.
Pasternack	Poor (5/17)	Determine injury patterns among youth baseball players & assess the value of 2 types of safety equipment.	Batting helmet with face mask – 4 ball-related facial injuries. Batting helmet only – 3 ball-related facial injuries.
Sendre	Moderate (12.5/17)	Compare the frequency of base-running injuries associated with the Hollywood Impact Base (HIB) with those of the standard stationary base. Looks at both softball and baseball.	Use of HIB significantly reduced injury rates.

Table 13: Basketball Study Overview

First Author	Quality Score	Study Aim	Conclusion
Barrett	Moderate 3/5	Examine whether wearing high-top & inflatable air chamber or high top shoe results in fewer ankle sprains compared with wearing low top shoes.	There was no difference between high and low top basketball shoes in the prevention of ankle sprains.
Garrick	Poor 0/5	Attempt to define the relationship between ankle and knee sprains to the practice of prophylactic taping and strapping.	Prophylactic taping plus a high-topped shoe exhibited the lowest incidence of ankle sprains.
Sitler	Poor 1/5	Determine the efficacy of a semi-rigid ankle stabilizer in reducing the frequency and severity of acute ankle injuries occurring during basketball.	The relative risk of sustaining an ankle injury was approximately three times as great for control subjects as for braced subjects. Severity of injury, however, was not reduced with ankle stabilizer use.

Table 14: Bicycling Study Overview

First Author	Quality Score	Study Aim	Conclusion
Abularrage	Moderate (7/14)	Measure the effect of an organized bicycle helmet educational campaign in a multiracial population. Timed to coincide with the introduction of a statewide bicycle helmet law.	A significant increase in helmet use above legislation alone was demonstrated after a campaign and distribution of educational material.
Britt	Moderate (7.5/14)	Evaluate the effectiveness of a multifaceted bicycle helmet promotion program for low-income children attending Head Start preschool enrichment programs throughout Washington state.	The provision of a multifaceted educational program and distribution of individually fitted free helmets by Head Start staff to preschool children resulted in a doubling of observed helmet use.
Carlin	Moderate (13/18)	Evaluate possible benefits of a school-based bike safety education program ("Bike Ed") on the risk of bicycle injury in children.	There was no evidence that the Bike Ed bicycle safety education program decreases the risk of bicycle injury in children. It may increase risk in some children (perhaps due to inadvertent encouragement of risk-taking or bicycling with inadequate supervision).
Ekman	Poor (4.5/14)	Examine the effectiveness of the combination of local, regional & national information on helmet use & bicycle injury in 5 Swedish communities.	Percent annual change in mean incidence/1000 children did not change significantly as compared to other countries or Sweden as a whole. During the timeframe of the study, bicycle-related hospitalization decreased to the level of the remainder of the country.
Hendrickson	Poor (1/5)	Determine relationships among PRECEDE model prediction and self-reported helmet use among fourth graders from low income non-urban schools.	72% of the variance in predicting helmet use for the fourth graders was explained by helmet ownership ($p = 0.000$), belief that helmets protect your head ($p = 0.000$), being in either intervention group ($p = 0.019$) or being in the parental intervention group ($p = 0.039$).
Kim	Poor (1/5)	Determine whether asking for a \$5 donation for bicycle helmets, compared with distribution free of charge, and an educational package from public health clinics would affect helmet use among children receiving helmets.	Helmet use was not significantly different among children whose parents were asked for a small co-payment compared to those who received helmets free. Use of co-payments can increase helmet use by increasing the number of helmets available to give to low-income children.
Logan	Moderate (10/14)	Determine the effect of a bicycle helmet give-away program on helmet use among children.	The bicycle helmet giveaway increased helmet use temporarily in the Grades K-6 but was not enough to sustain it. The program had no impact on Grades 7-8.
Macarthur	Moderate (2/5)	Evaluate the effectiveness of a skills training program (Can Bike Festival) in improving safe cycling behavior knowledge & attitudes in young children.	The skills training program was not effective in improving safe cycling behavior.
Ni	Moderate (9/14)	Evaluate an Oregon law requiring bicyclists younger than 16 years of age to wear a helmet & to compare methods of measuring helmet use.	Although the law has increased helmet use, half of Oregon's child bicyclists are still not wearing helmets, indicating a need for additional promotion of helmet wearing.
Ressler	Poor (5/14)	Use functional theory to develop, pilot and implement a nationwide social marketing campaign aimed at increasing children's bicycle helmet use.	Exposure to the full campaign was associated with an increase in helmet use in the target age groups. The increase in helmet use by adults was only 3%.
Shafi	Moderate (12/17)	Assess the impact of state legislation on helmet use in children admitted to a trauma center following bicycle crashes.	Legislation is an effective way of increasing helmet use in children. There was evidence that helmet use reduces the severity of head injury. A higher proportion of HC suffered concussions alone. Helmets appeared to be protective against skull fractures and showed a trend toward reducing intracranial hemorrhages, cerebral contusions and diffuse cerebral edema.
Watts	Poor (5/14)	Determine whether: 1) bicycle safety programs increase helmet use 2) children who are given a free helmet use their helmets more than children who receive their helmet from another source and 3) free helmet distribution with a bicycle safety program is more effective in increasing helmet use than a safety program alone.	Bicycle safety programs and free helmet distribution may increase the consistent use of helmets in elementary school children. However, the authors caution that increases reported were collected only one month after the bicycle safety program and there may have been a lapse back to previous behavior with a longer follow-up period.

Table 15: Football Study Overview

First Author	Quality Score	Study aim	Conclusion
Adkison	Poor (7.5/17)	Study the effect on injury rates of both synthetic & natural playing surfaces.	Astroturf fields had significantly higher injury rates than did grass or tartan turf. Grass had an intermediate injury rate & tartan turf had the lowest injury rate.
Albright	Moderate (9/17)	Assess the effectiveness of prophylactic knee braces in NCAA Division I college football players.	MCL injury rate for braced players is 0.065 vs. 0.077 for unbraced players.
Andrish	Poor (8/17)	Test the efficacy of the “neck strap” to prevent flexion cervical sprains in football.	The following trends were apparent: Previous neck injury increases the likelihood of another injury (5 times more than one who has never had a neck sprain).
Blyth	Poor (4/17)	Investigate the training and experience of coaches, and the relationship of these to injury.	Coaches with a specific type of background and training are associated with a lower injury rate. Important considerations are coach’s age, college playing experience, coaching experience and advanced degrees.
Blyth	Poor (4.5/17)	Assess the association of injury rates by brand of protective equipment (for helmets, shoulder pads), or by type of equipment (cleats vs. soccer shoes).	It was also found that players wearing new pads had a higher injury rate than those wearing used pads (an explanation that football players who wear new pads are also the ones who are exposed to more contact in practice than in games). There is a higher incidence of injury to players wearing soccer shoes than those wearing regular football cleats. However, conditions of the playing fields are influential since it was found that rate of knee and ankle injuries was reduced when soccer shoes were worn on well-maintained fields.
Bramwell	Poor (8.5/17)	Compare the injury rates between natural and artificial turf.	Injury rate for grass turf is much less than that of synthetic turf. Injury rate for dry artificial turf is much higher than all other surfaces & conditions.
Brixler	Poor (5/17)	Assess whether completing a warm up and stretching routine during half time reduces the incidence of 3 rd quarter injuries in high school football players.	Athletes performing a warm-up prior to the 3 rd quarter had reduced injuries in the 3 rd quarter.
Brodersen	Poor (7/17)	Assess the efficacy of double upright hinged knee brace in reducing the frequency of knee injuries in football players.	26% of braced group suffered knee injury vs. 44% of non-braced group – significant difference at $p < 0.001$.
Cahill	Moderate (7/14)	Assess whether the reduction in knee injuries associated with supervised pre-season conditioning is maintained after conditioning is less supervised.	There was a decrease in injury rate for the supervised conditioning groups as well as fewer days lost. Pre-season conditioning program was also effective in reducing the number of early season knee injuries.
Cahill	Moderate (10/14)	Compare the effect of pre-season conditioning on knee injuries of high school football players.	Injury incidence: pre-season conditioning decreases early season knee injuries, decreases the total number of knee injuries throughout the season, and decreases the severity of those injuries that occur.

Football Study Overview continued...

Cameron	Poor (6/14)	Compare injuries in high school football players wearing swivel shoes with those wearing conventional shoes.	Swivel shoes had the lowest incidence of knee injury with soccer shoes having the second lowest injury rate.
Davis	Poor (5/14)	Assess whether progressive relaxation & sports-related imagery during team workouts would lead to reduced number of injuries.	Both competition and injury data support the effectiveness of the sport psychology program.
Deppen	Moderate (12/17)	Investigate the injury rate of high school football players who utilized preventive knee braces vs. those who did not by comparing the number of contact exposures with the number and type of injuries sustained by the players.	No difference in injury rates occurred for those who did & did not wear braces. In addition, there was no statistically significant difference between contact and non-contact mechanisms of injury between the braced and non-braced groups.
Fine	Moderate (8/14)	Examine trends in cervical spine injuries before & after the NCAA banned "spearing" with football helmets (head-first tackling & blocking).	Cervical spine injuries declined from ~ 100 per year in 1975-76 to ~ 55 per year from 1978-87. The 1976 NCAA rule banning spearing has resulted in dramatic decrease of fractures, subluxations, and dislocations of the c-spine.
Gorse	Moderate (8.5/17)	Compare the occurrence of pre-season football conditioning injuries in traditional and crossover training programs over 5 seasons.	There are significantly fewer pre-season conditioning injuries in the turf & swim group than in the turf group. Running and swimming may decrease the number of overuse injuries associated with repetitive running on artificial turf.
Grace	Good (13/14)	Determine the effect of prophylactic knee braces on injuries of the knee & lower extremity in high school football players.	An increase was seen in the number of knee injuries in the braced group, especially for mild to moderate injuries. There was also an increase in ankle and foot injuries in braced athletes.
Hansen	Poor (5.5/17)	Assess knee injuries in USC football players between those wearing the Anderson Knee Stabler brace and those not using it.	11% injury rate for those without brace vs. 5% injury rate for those with brace. 1.4% of those with brace required surgery vs. 5.2% of those without brace.
Heiser	Moderate (8/14)	Compare the effect of isokinetic testing and rehabilitation of muscle imbalances. Looked at use against non-use of the Cybex II isokinetic dynamometer on prevention of hamstring strains and recurrence of injury.	The group that received supervised winter running programs and staff-designed stretching, running, and weight-lifting programs, combined with treatment of injuries with isokinetic rehabilitation showed fewer hamstring injuries and no recurrences.
Hewson	Moderate (11.5/17)	Evaluation of the effectiveness of the Anderson Knee Stabler in preventing knee injuries.	Total number of knee injuries for both groups are very similar. Prophylactic knee bracing does not improve knee injury prevention.
Jackson	Moderate (12/14)	Assess the incidence & severity of knee injuries in a professional football team with regards to risk factors (i.e., games, practice, experience, position) and the role of prophylactic knee bracing over a 12 year period.	For overall knee injuries, no difference in 2 time periods. Major injuries dropped from 31.7% (77-83) to 14.7% (84-88), highly significant $p < 0.001$.
Kaufman	Moderate (3/5)	Test the effects of a Mandibular Orthopedic Repositioning Appliance (MORA) on performance, injury (number, type & severity), physical fitness & satisfaction with the mouthpiece.	Players with MORA had significantly less severe injuries than those with the conventional mouthpiece. There is no significant difference between the groups on the number of injuries.

Football Study Overview continued...

Keene	Moderate (8/14)	Compare college football injuries occurring on grass with those occurring on tartan turf at the University of Wisconsin.	The number of injuries on each playing field were not significantly different, but the type and severity of injuries were significantly different. More serious sprains and torn ligaments occurred on grass than on Tartan Turf. More scrapes (minor injuries) occurred on Tartan Turf than on grass.
Kraus	Poor (0/5)	Determine whether a helmet could significantly reduce the incidence of head injuries in college intramural touch football games.	The risk of head concussion was about 3 1/2 times greater for un-helmeted than for helmeted exposures.
Kraus	Poor (2/5)	Test whether or not well-trained & experienced officials could significantly reduce the incidence of injuries in college intramural touch football games.	There was no significant difference in overall injury rates. There was also no significant difference in serious injury rates.
Lambson	Moderate (11.5/17)	Evaluate torsional resistance of modern football cleat designs & the incidence of surgically documented tears in high school football players wearing different cleat types.	The edge cleat group had a much higher ACL injury rate than the other three shoe types combined. The edge shoe design also produced significantly higher resistance.
Larson	Poor (6/17)	Compare the incidence of prepatellar & olecranon bursitis on both grass & artificial turf fields.	There is an apparent increase in the incidence of prepatellar and olecranon bursitis among football players since the installation of an artificial turf.
Mueller	Poor (6/17)	Present information in four areas: (1) the injury rate associated with different brand name football helmets & shoulder pads; (2) reduction of knee & ankle injuries by improving playing surfaces & changing cleat type; (3) reduction of injuries by a limited contact program and (4) the incidence of re-injury to participants.	There are specific brand name football equipment that are associated with significantly higher injury rates. Knee and ankle injuries are reduced when players wear soccer type shoes and when fields are properly maintained. A limited contact program during practice will reduce injuries, and full recovery is important to prevent re-injury.
Mueller	Moderate (7/14)	Assess trends in head & cervical spine fatalities in football with respect to rule changes (spearing) & national helmet standards.	The decade with the highest incidence of head and cervical spine fatalities was 1965-74 while a dramatic reduction was seen from 1975-84 largely due to rules that prohibit initial contact with the helmet or face mask.
Powell	Moderate (10.5/17)	Examine injury risk patterns for NFL games on different playing surfaces.	Over the six seasons of NFL, the incidence of injury per game was higher for Astro turf than grass.
Powell	Moderate (10.5/17)	Assess football knee injury rates for natural grass & Astro turf surfaces & the risk factors of game position & type of play.	There is a statistically significant difference between the higher Astro turf injury rates for knee sprains.
Quillian	Poor (1/5)	Assess the effectiveness of preventive knee braces in high school football players to reduce knee injuries.	Players wearing knee braces sustained fewer and less significant injuries than players who did not wear knee braces.
Robey	Poor (5/17)	Assess the concussion injury rates for helmets with different mounting systems, and different categories of conditions and fit in high school football players.	There is no difference in injury rate for suspension helmets by fit or condition as long as it is adjusted correctly. Combined suspension/padded helmets have higher injury rates if the helmet is too small.

Football Study Overview continued...

Rovere	Moderate (8/14)	Retrospectively assess the effectiveness of taping compared to wearing a laced stabilizer in preventing ankle injuries & re-injuries.	The results show that players wearing stabilizers had half of the risk of injury of the players wearing tape. The rates of injury differed by position.
Rovere	Moderate (8/14)	Compare knee injury rates when college football players in one team wore braces for 2 seasons with a previous 2 year period when no braces were worn.	Number of injuries/100 players of ACL knee injuries wearing no brace is 4.0, vs. 4.8 wearing a brace. For MCL grade 1, 6.1 vs. 7.5 respectively. Therefore, greater overall injury rate & MCL injury rate during the brace period.
Rowe	Poor (5.5/17)	Determine the effect of different types of cleats on knee & ankle injury incidence in high school football.	The LC group had the highest injury rates & percentage. The LD group had the lowest, indicating that it is the safest shoe-cleat equipment combination.
Schriner	Moderate (9/17)	Determine the effectiveness of knee braces in preventing knee injuries in non-injured high school football players.	The difference in % of players injured from lateral forces was statistically significant, $p < 0.01$. While the % of injuries in the medial posterior forces was not significant.
Shaw	Poor (3/17)	Assess whether use of McDavid Knee Guard is associated with the incidence of knee injuries in football players at one Texas high school.	There are fewer injuries to athletes wearing the (MKG) than those not wearing the knee guard. In addition, there are fewer days lost to injury.
Sitler	Poor (2/5)	Determine the efficacy of a prophylactic knee brace to reduce the frequency & severity of acute knee injuries in football.	There is a significant reduction in the frequency of knee injuries with use of prophylactic knee braces, both in the total number of subjects injured and total number of MCL injuries.
Stevenson	Poor (1/5)	Compare injury rates in touch football played on synthetic Tartan turf & natural grass.	It was found that significantly more injuries occur on Tartan turf than on natural grass. However, there were no significant differences in the number of major injuries on Tartan turf vs. grass.
Teitz	Poor (6.5/17)	Compare incidence & severity of knee injuries in college football players wearing knee braces with those not wearing braces.	Overall, players who wore knee braces had significantly more injuries than players who did not wear braces. There was no difference in the severity of the injuries in the two groups.
Torg	Moderate (8/14)	Describe how the rule change banning spearing in 1976 resulted in a significant reduction of cervical spine injuries associated with quadriplegia.	There was an increasing incidence of intracranial hemorrhage, due to the advent of widespread CAT scans rather than increasing number. There was a dramatic decrease in the number of cervical spine injuries.
Torg	Moderate (9/14)	Head and neck injuries sustained playing football from 1971 through and including the 1977 season, presented in 4 groups: (1) 1971 – 1975; (2) 1975; (3) 1976 and (4) 1977.	The apparent decrease in serious head injuries has been attributed to the protective capabilities of the helmet-face mask unit. However, the number of cervical spine injuries has been shown to increase.
Torg	Moderate (10/14)	Assess whether changing from conventional football cleats to soccer-type shoes has an affect on knee and ankle injuries.	Results show a significant reduction in both the incidence and severity of knee injuries after players began wearing the soccer-type shoe.
Torg	Poor (5/14)	Assess whether changing from conventional football cleats to soccer-type shoes has an effect on knee & ankle injuries.	Results show a significant reduction in both the incidence and severity of knee injuries after players began wearing the soccer-type shoe.
Zemper	Moderate (9.5/17)	Assess the rate of cerebral concussion injury with different models of football helmets, and assess the effect of concussion history on concussion rates.	Analysis of residuals shows Bike Air Power & Pro Air helmets to be associated with greater concussion rate.
Zemper	Poor (6/17)	Assess the efficacy of prophylactic knee braces in reducing the incidence and/or severity of knee injuries in football players.	Players wearing prophylactic knee braces experienced a significantly greater incidence of knee injuries than those who did not wear braces.

Table 16: Hockey Study Overview

First Author	Quality Rating	Study Aim	Conclusion
Downs	Poor (4.5/14)	Assess the relative value of mandatory facial protection.	Protective facial masks reduced facial injuries.
Kraus	Moderate (7/14)	Determine the effect of introducing a new helmet on head injuries in college intramural hockey.	In the non-helmeted season, the head injury rate was 8.3/100 games and only 3.8 in the helmeted season. The game injury rate was 16.1/100 games and 8.8 respectively.
Pashby	Poor (5/14)	Determine the efficacy of face protectors and whether new high sticking rules have an effect on eye-injury incidence.	Eye injuries, except ruptured globes, decreased after the high sticking rule induction. The rate of blindness for eye injury decreased.
Pashby	Poor (6/14)	Determine if the number of eye injuries continued to decline in the two hockey seasons following the 1976-77 season.	Eye injury incidence has continued to decline except for ruptured globes. Blinding injuries are still occurring; however they mainly affect those not wearing optional face protectors.
Pashby	Poor (6/14)	Determine the influence of face protectors on the incidence of eye injury in minor hockey players.	The incidence of eye injury has declined sharply from the 74-75 season to the 83-84 season. No reported case of injury in the latter season in players wearing a face protector.
Roberts	Moderate (9/14)	Determine the rate, type and severity of injuries incurred and penalties assessed during fair play and "regular" rules.	The ratio of regular rule injury rate to fair play rule injury rate for notable injuries was nearly 5:1.
Watson	Moderate (11/17)	Determine whether injuries decrease as ice surface size increases. Determine whether aggressive player behavior as reflected by penalties is associated with any change in injury rate.	There is a highly significant association between ice surface size and injury rate for all injuries. Neurotrauma showed no significant relationship with ice size.
Watson	Moderate (8/14)	Evaluate the impact of the 1989-90 checking from behind (CFB) rule on injury rates and on player's behavior as indicated by penalty rates.	The CFB rule induction resulted in a pre-post rule decrease in two of three categories of injury and increased CFB penalty rates. There is not a significant association between the CFB rule and decreases in body contact or stick-related infractions.

Table 17: Rugby Study Overview

First Author	Quality Score	Study Aim	Conclusion
De Wet	Moderate (7.5/14)	Determine acceptance of a custom-made mouthguard by primary school boys; investigate problems & complaints & evaluate their effectiveness.	Injuries were reduced significantly when using mouthguards.
Gissanne	Moderate (11.5/17)	Examine whether or not the movement of the playing season from fall & winter to spring & summer would alter risk of injury to players.	Summer rugby may have resulted in a shift of injury risk factors.
Jennings	Poor (6.5/17)	Retrospectively examine orofacial injuries & concussions sustained among rugby players at senior and mini levels, & their use and attitudes of gumshields.	Players wearing a mouthguard sustained fewer injuries to mouth, lips, teeth, concussion and loss of consciousness compared to non-wearers.
Morton	Moderate (9.5/14)	To examine custom-fit mouthguards acceptability & effectiveness among 1 st & 2 nd rugby fifteens.	A significant difference existed between number of fractures occurring in mouthguard wearers & non-wearers.
Upton	Moderate (7/14)	Evaluate the efficacy of two types of mouthguards (lab made or "mouth-fitted") among rugby players.	Both types of mouthguards had a preventive effect against damage to teeth.

Table 18: Soccer Study Overview

First Author	Quality Score	Study Aim	Conclusion
Ekstand	Poor (2/5)	Test a prophylactic training program.	After a six-month follow-up, there were 75% fewer injuries in the intervention teams. There were also lower levels of the following outcomes among the intervention teams: ankle injuries, knee sprains and strains, operations, and absences from practices and games.
Caraffa	Moderate (10/14)	Assess the ability of a proprioceptive training program to reduce the incidence of ACL injury in soccer players.	The frequency of ACL injuries in the proprioception trained group showed a sevenfold reduction over the control group.
Elias	Moderate (8/14)	Assess the effects of emergency preventive measures to prevent heat exhaustion during a youth soccer tournament.	Rate of heat exhaustion per 1,000 player hours decreased following implementation of emergency measures.
Lehnhard	Moderate (7/14)	Determine whether strength training had an effect on the incidence of injuries in a college soccer team.	Team injury rates reduced Year 1: 12.1; Year 2: 15.9; Year 3: 11.1; Year 4: 8.6.

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