

**PITCHING INJURY PREVENTION
TO BASEBALLERS AND
SOFTBALLERS:
A REVIEW OF THE LITERATURE**



by

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Abstract:

Baseball and softball are popular non-contact, non-collision team sports in Australia. Although softball originated as an indoor version of baseball, the two games have evolved into separate sports with different sets of rules and playing conditions. Both sports involve four main activities or skills: throwing, including pitching and fielding; catching; batting; and base running. The major difference in how the games are played is the technique by which the ball is pitched to the batter. In baseball, the ball is pitched in an overarm or sidearm action, whereas in softball an underarm action is used. Over the past twelve years there have been few studies published describing the epidemiology of baseball/softball injuries, particularly outside the US. Baseball and softball are associated with the largest number of injuries leading to an emergency room visit than any other sport in the United States. In Australia, baseball/softball is ranked as the 13th most common sport and recreational activity leading to an emergency department injury presentation for children and the 16th amongst adults. There are four main mechanisms of injury in softball/baseball: sliding (into a base); jamming or collisions (including hits by a ball or bat and collisions with other players); falls; and overuse. The overall aim of this report is to critically review both the formal literature and informal sources that describe injury prevention measures for baseball and softball. Most of the identified literature is from US studies, given the popularity of the sport in that country. However, a brief overview of the epidemiology of baseball and softball injuries, particularly from an Australian perspective, is given to set the scene for the subsequent discussion of countermeasures. Countermeasures for preventing baseball/softball injuries include the use of break-away/quick release bases; protective equipment such as helmets and chest protectors, ball design; safe playing environments eg padded walls and back stops; stretching, conditioning and technique programs before commencing play; adequate rehabilitation; and prompt treatment of injuries. Recommendations for further countermeasure research, development and implementation include additional research into the biomechanics of playing techniques and the mechanisms of injury; epidemiological studies to identify risk factors; further controlled evaluations of the effectiveness of countermeasures, use of break-away bases; further development of protective equipment; improvements to ball design; and improved player education.

Key Words:

baseball, softball, injury prevention, countermeasures, evaluation

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EXECUTIVE SUMMARY

Baseball and softball are popular non-contact, non-collision team sports in Australia. Although softball originated as an indoor version of baseball, the two games have evolved into separate sports with different sets of rules and playing conditions. Both sports involve four main activities or skills: throwing, including pitching and fielding; catching; batting; and base running. The major difference in how the games are played is the technique by which the ball is pitched to the batter. In baseball, the ball is pitched in an overarm or sidearm action, whereas in softball an underarm action is used.

Over the past twelve years there have been few studies published describing the epidemiology of baseball/softball injuries, particularly outside the US. Baseball and softball are associated with the largest number of injuries leading to an emergency room visit than any other sport in the United States. In Australia, baseball/softball is ranked as the 13th most common sport and recreational activity leading to an emergency department injury presentation for children and the 16th amongst adults.

There are four main mechanisms of injury in softball/baseball: sliding (into a base); jamming or collisions (including hits by a ball or bat and collisions with other players); falls; and overuse. Because of the similarities between baseball and softball, the countermeasures for preventing these injuries are the same in the two sports.

The overall aim of this report is to critically review both the formal literature and informal sources that describe injury prevention measures for baseball and softball. Most of the identified literature is from US studies, given the popularity of the sport in that country. However, a brief overview of the epidemiology of baseball and softball injuries, particularly from an Australian perspective, is given to set the scene for the subsequent discussion of countermeasures.

Unlike other reports of baseball and softball injuries, this report does not focus specifically on the epidemiology of these injuries. Rather, it presents a detailed examination of the range of countermeasures promoted to prevent such injuries. Nevertheless, a brief overview of the epidemiology of baseball and softball injuries, particularly from an Australian perspective, is given to set the scene for the subsequent discussion of countermeasures.

Countermeasures for preventing baseball/softball injuries include the use of break-away/quick release bases; protective equipment such as helmets and chest protectors, ball design; safe playing environments eg padded walls and back stops; stretching, conditioning and technique programs before commencing play; adequate rehabilitation; and prompt treatment of injuries.

This report has discussed the full range of injury prevention activities for preventing baseball and softball injuries. Recommendations for further countermeasure research, development and implementation have been based on the review presented here as well as discussions with experts acknowledged in this report.

Many of the recommended countermeasures have yet to be proven to be effective and more attention to controlled studies “in the field” are needed. More effort directed to basic scientific studies to better understand the biomechanics of baseball and softball, the

mechanisms of injury and the role of various risk factors in causation are also required. Indeed, the evidence for the effectiveness of certain countermeasures such as warming-up, ball design, limiting the numbers of pitches and protective body padding remains equivocal.

RECOMMENDATIONS FOR FURTHER COUNTERMEASURE IMPLEMENTATION, RESEARCH AND DEVELOPMENT

Base Design

- Baseball and softball facilities in Australia should replace the standard stationary bases with breakaway or impact bases. As part of this program several studies are desirable.
- The injury prevention potential of the Australian safety base and the “easybase” should be formally evaluated.
- The effectiveness of break-away bases for preventing injury amongst young children needs to be determined.
- The injury prevention potential of Hollywood Impact bases and the breakaway bases should be compared in a controlled evaluation.
- The strongest evidence is for break-away bases but there is little evidence on the Australian version of these. An estimate of the number of injuries that would be eliminated by the adoption of the US design in Australia is needed before recommendations could be made in this regard.
- Injuries with the break-away bases appear to occur only when they fail to break away. This is more hazardous as the player slides into the base and expects it to give way. Failure rates on break-away bases, whether due to instalment, maintenance or manufacture should be determined.
- An audit of the types of bases used in Australia across the full range of participation levels should be undertaken, as part of a study to measure effectiveness of the program of replacement of conventional stationary bases.
- The role of other factors involved in sliding injuries, such as judgement errors and poor technique, need to be investigated further. Education and coaching programs aimed at addressing these factors should be developed and evaluated.

Ball Design

- The 16 inch ball should not be used in softball games.
- Baseball and softball games should be played with softer balls, meeting the standards, than harder core balls.
- Further research into the risk of death from chest impacts from balls of various hardness needs to be conducted (not necessarily in Australia).
- Further basic research into suitable models for testing the impact of balls should be undertaken (not necessarily in Australia).

- The evidence on soft versus hard baseballs is equivocal and better test procedures need to be developed (not necessarily in Australia).
- Baseball and softball associations should work with manufacturers to ensure that they comply with safety specifications for balls and bats.

Preventing overuse injuries

- Coaches should conduct pre-season stretching/strengthening programs.
- Coaches should evaluate and correct the pitching techniques of their players
- Coaches should limit the number of pitches per week for each player.
- Coaches should limit the number of pitches thrown by an individual player and enforce rest periods between pitching sessions, particularly for junior players.
- Information about warm-up, cool-down and stretching techniques specifically for baseball and softball should be developed and widely promoted to improve specific knowledge of techniques.
- Players should undertake pre-season stretching/strengthening programs to assist in the prevention of overuse injuries associated with pitching.
- Further basic scientific research into the mechanisms of overuse injuries should be undertaken.
- The effectiveness of stretching and strengthening programs to prevent overuse injuries to the shoulder and wrist needs to be evaluated.
- More research into the role of warm-up as an injury prevention measure for baseball and softball is needed.
- Research should be undertaken into the benefits of different types of warming-up, cooling-down and stretching practices.
- Research into the optimal duration and frequency of warm-up should be undertaken.

Protective Equipment

- Players should wear good quality, double eared helmets with face protectors.
- Players should wear energy absorbing chest padding when batting, pitching or catching to distribute any blows from a baseball impact over a broad area of the chest.
- Catchers should always wear shin protection, breast plate and a helmet with a mask and throat protection.
- Youth players, aged less than 19, should wear shin and knee protection.
- Male players should wear properly fitted genital protectors at all times in the field.
- Players should wear mouthguards to prevent dental injuries

- The evidence for other forms of protective equipment, rules and practices in the game seems to be largely anecdotal or based on convention. More developmental research into this is needed.
- Further detailed research into the mechanisms of ball-impact injuries, particularly to the chest, head and face, should be undertaken.
- The epidemiology of ball-impact injuries should be closely monitored in relation to the use of protective equipment
- Further development of protective headgear and chest protectors needs to be undertaken.
- Appropriate models for the testing of protective equipment, particularly chest padding, need to be developed.
- The efficacy of sliding pant' should be formally evaluated.

Modified Rules

- Children should be encouraged to play Tee ball as a means of developing baseball and softball skills.
- Older children should participate in modified softball as promoted by Aussie Sports and the Australian Softball Federation.
- Child and adolescents should be taught correct pitching techniques and playing procedures, including limiting the number of pitches and taking appropriate rest periods.

Sliding technique

- The relationship between different types of sliding techniques and injuries should be explored.
- Further studies into the biomechanics of sliding are needed to gain an understanding of different sliding techniques before introducing modifications.
- Players should be instructed to slide in the correct manner.

Education and coaching

- Coaches should undergo regular re-accreditation and yearly updates.
- Coach education schemes should be updated regularly to ensure they provide the most up to date information about injury prevention.
- Children should not play softball or baseball unless they are supervised. This is particularly important when several balls are moving around at once.
- Instruction clinics for the wider community should be developed and widely disseminated.
- Education resources for informal baseball and softball need to be developed and disseminated.
- The best means of disseminating this information should be determined.

Playing Environment

- Drinking water should be provided at all baseball and softball events.
- Baseballers and softballers should ensure they drink adequate water, before and during games.
- Baseballers and softballers should always use a broad spectrum sunscreen and wear a hat and/or sunglasses when appropriate.
- Baseball and softball events should not be planned for times when there is a likelihood of extremely hot, humid conditions. Whenever possible, such events should also be cancelled if such weather conditions eventuate.
- Baseball and softball fields should be regularly checked and maintained to eliminate hazards such as potholes, sprinkler pop-ups, loose debris, rubbish, etc.
- Baseball and softball fields should have protective padding around fences and posts, which a player may collide with during play
- Protective screening should be used to protect players in dugouts and on benches.

First aid and rehabilitation

- Softballers and baseballers should seek prompt attention for their injuries from a person with first aid qualifications.
- Organisers of events should ensure that there are qualified first aid personnel at all events.
- Injured baseball and softball players should ensure that they allow enough time for adequate rehabilitation before returning to their pre-injury level of activity.
- Research into the effects of rehabilitation programs for softballers and baseballers needs to be undertaken.

Other

- Improved data collection about the occurrence of baseball and softball injuries and their associated factors needs to be developed and maintained.
- Data collections should conform to guidelines for sports injury surveillance being developed and promoted nationally.
- Information about preventing baseball and softball injuries should be disseminated widely through baseball/softball broadcasts, baseball/softball equipment points of sale, baseball/softball magazines and more general magazines.
- A detailed epidemiological study of baseball and softball injuries in Australia should be undertaken to describe the injury profile amongst cases that do not present to emergency departments. This should also identify risk factors for injuries.

- Guidelines for minimum safety requirements for baseball/softball events (including the need for mobile phones, telephone contacts, first aid kits, etc) should be developed and widely disseminated.

1. INTRODUCTION

Baseball and softball are well-recognised non-contact, non-collision, team sports within Australia. Baseball is believed to be based on the sixteenth century English children's game of rounders (Hay, 1973). In Australia, baseball was introduced by United States gold miners, with records indicating that it was played in the goldfields in Ballarat in the 1850's (Australian Sports Commission, 1991). Australian enthusiasm for the game generally strengthened in 1888 when a United States sports equipment manufacturer, AG Spalding, decided to upstage cricket and to establish baseball as a major sport throughout Australia (Flower, 1996). Competitive baseball began in 1899 in NSW and today is well established throughout Australia (Flower, 1996).

An indoor version of baseball, called softball, was initially developed in the United States. The first set of rules and equipment for outdoor play were designed in 1895 and the outdoor game was officially named 'softball' in 1933 (Australian Sports Commission, 1991). Baseball and softball have since evolved into separate sports with different sets of rules. Both sports involve four main activities or skills (Hay, 1973):

- throwing, including pitching and fielding
- catching
- batting
- base running.

In softball, the ball is larger, the size of the diamond is smaller and the pitchers stand closer to the batter.

The major difference between the games is the technique by which the ball is pitched to the batter. In softball, the ball is pitched in an underarm action whereas in baseball an overarm or sidearm action is used. There are two types of softball pitching techniques used, depending on the style of softball involved. Fast-pitch softball tends to be the more formal version of the game, particularly in the United States. In fast pitch, the pitcher uses a windmill action to throw the ball thereby causing it to be released in a flat elevation. Slow-pitch softball, the more recreational form of the game and the more popular version in Australia, involves a slower pitching motion and the ball must arc approximately 6 to 12 feet when pitched.

In 1993, over 143,100 people were formally registered with the Australian Baseball Association. This included approximately 73,400 men and 69,710 juniors. The Australian Bureau of Statistics' Population Survey Monitor indicated that during the 1994/1995 high season (end of September - April), 32,000 Australians played formal baseball (Australian Bureau of Statistics, 1996). Another statistical report for 1991, found that one in ten Australians participated in some form of baseball (Brian Sweeney and Associates, 1991).

Although the number of formal players is less, more Australians play recreational softball than baseball. In 1993, Australia had over 60,000 people (approximately 8,490 men, 24,640 women, 25,250 juniors and 1710 veterans) formally registered with the Australian Softball Federation. Over 250,000 school students also participated in the game. In

addition, it is estimated that an additional 150,000 Australian participate in recreational softball annually. The Population Survey Monitor for 1994/1995 indicated that 61,000 Australians participated in organised softball (Australian Bureau of Statistics, 1996).

In Australia, softball is played predominantly by women. Men have been involved in fast-pitch softball since 1984 and their involvement in the sport continues to grow. Participation of men in social events may be a lot higher as these games tend to involve mixed competition. Participation rates in countries other than the United States have not been published. Of those from the United States, none specify the gender profile. It is difficult, therefore, to compare the Australian figures with those from other countries.

Over 40 million people play in organised baseball and softball leagues in the United States (Committee on Sports Medicine and Fitness (CSMF), 1994). Of these, approximately 4.8 million children aged 5-14 years participate in organised and recreational baseball and softball each year in the US (Committee on Sports Medicine and Fitness (CSMF), 1994).

It has been estimated that several million children and young adults in the United States also participate in baseball at a recreational level (e.g. little league and high school). Apart from the recreational level, there are individuals who participate at college and professional levels (inc. minor and major league) (Janda et al., 1993).

In the United States, softball is the most popular participant sport and the cause of more recreational injuries than any other sport (Janda et al., undated). It has been estimated that baseball and softball are two of the leading causes of sports related injuries presenting at emergency departments in the US (Janda et al., 1993).

2. AIMS

The overall aim of this report is to critically review both the formal literature and informal sources that describe injury prevention measures, or countermeasures, for baseball and softball. In doing so, it will provide an evaluation of the extent to which these countermeasures have been demonstrated to be effective. Because of the similarities between baseball and softball, the countermeasures are the same. Most of the identified literature is from the United States, given the popularity of the sport in that country.

Unlike other reports of baseball and softball injuries, this report does not focus specifically on the epidemiology of these injuries. Rather, it presents a detailed examination of the range of countermeasures promoted to prevent such injuries. Nevertheless, a brief overview of the epidemiology of baseball and softball injuries, particularly from an Australian perspective, is given to set the scene for the subsequent discussion of countermeasures.

Given the popularity of baseball and softball as both a formal sport and a recreation pursuit, the prevention of injuries is paramount. It is also hoped this review will stimulate evaluations of the currently advocated ways of preventing baseball and softball injuries.

3. METHOD

The sources of information used to compile this report were:

- Medline CD-ROM for published medical literature (over the past 15 years)
- Sport discus CD-ROM search for published sports literature (over the past 10 years)
- injury conference proceedings scans
- discussions with key Australian researchers and sporting organisations
- correspondence with relevant state sporting organisations
- correspondence with relevant international researchers
- a posting to the Injury List on the Internet
- Standards Australia
- world-wide standards index on CD-ROM 1995/96 issue (US Database: key words of helmet, sport, recreation)
- NEXUS database (key word of baseball and softball)
- other Internet and World Wide Web sites

The literature gathered for this review was critically assessed to determine the extent to which the various countermeasures had been evaluated and demonstrated to be effective in preventing injuries. A scale for rating the strength of the evidence presented in the identified literature was developed. This is shown in Figure 1.

Figure 1: Scale for assessing the extent to which countermeasures have been evaluated

STRENGTH OF THE SCIENTIFIC EVIDENCE	TYPE OF SCIENTIFIC EVIDENCE
least ↑	anecdotal or informed/expert opinion
	laboratory-based/equipment testing
	data-based evidence (uncontrolled)
↓ most	controlled evaluations

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

At the lowest level of proof (ie. the "least" evidence end of the scale) are anecdotal reports of injuries and their prevention and comments based on informed or expert opinion. This category would include, for example, statements like "I treated 5 cases of severe head injury during last year's baseball season and all would have been prevented if they were wearing a helmet at the time" or "none of the pitchers I treated last year had done adequate warm-up before playing".

Laboratory-based evidence is a very important source of information about sports injury countermeasures. This category includes studies that have investigated equipment design and testing, development of standard testing procedures and biomechanical research, including that performed on animals, cadavers and simulated body tissue such as crash-test dummies. Such information provides detail about the extent to which countermeasures such as softer baseballs and chest protectors perform under certain stress and/or impact conditions. This research is generally performed under laboratory conditions which are often controlled. However, such conditions may not be a good representation of actual field or playing conditions.

Data-based evidence can take a number of forms. Case-series studies or routine surveillance systems document the incidence of new injury cases over periods of time. Patterns in this data can be examined over time to draw conclusions about the impact that countermeasures may have had on injury rates. Cross-sectional epidemiological studies provide some information about injury prevalence at a given point of time but are unable to assess the influence of countermeasures on injury rates. Quasi-experimental studies are not controlled evaluations but do enable a comparison of pre-intervention with post-intervention data to examine the effects of some countermeasures.

Controlled evaluations provide the most definitive evidence for the impact of countermeasures. Case-control studies and longitudinal (cohort) studies are common forms of controlled studies. Neither study type allows random assignment of people (or injuries) to test and control groups, though they are examples of natural experiments. A randomised controlled trial is considered to provide the best evidence. In such studies, the units of interest (ie pitcher, base, protective padding, etc) are randomly assigned to test and control groups.

Another important aspect of countermeasure implementation is the extent to which they are accepted or adopted by the users for whom they were intended. Countermeasures must be acceptable to those they were designed to protect. Community consultation and awareness programs must therefore be considered in any implementation process. It is also important to assess barriers towards the use of injury countermeasures. An examination of attitudes, knowledge and behaviours is crucial to this. Studies looking at these factors are generally conducted after implementation of a countermeasure and can

highlight the need for behavioural or educational change at either the individual or organisational level. Because of the importance of this sort of research, the literature describing these studies is also included in this review.

Another measure of the success of countermeasures is a demonstration of their cost/benefit ratios. This information is often needed by regulatory bodies and those involved in policy or rule making, to inform their decisions about countermeasures. Unfortunately, there have been few studies of the economic benefits of baseball and softball injury countermeasures. Those identified have been included in this review.

In the following sections the relevant literature for the effectiveness of each countermeasure is critically reviewed. Based on the studies reviewed, and discussions with the experts acknowledged in this report, recommendations for future countermeasure research, development and implementation are also given.

4. THE EPIDEMIOLOGY OF BASEBALL AND SOFTBALL INJURIES

4.1 General Overview

Since 1985, there have been very few published studies describing the epidemiology of baseball and softball injuries, particularly outside the United States. The studies that have been published have generally used data collected by the US Consumer Product Safety Commission (CPSC) which represents a sample of emergency departments in the United States.

Baseball and softball are associated with the largest number of sporting injuries leading to an emergency department visit in the United States (Janda et al., 1992b). In a study by Kyle et al. (1996), baseball injuries to children were ranked the third highest in terms of overall consumer product related emergency department presentations. It is important to note that baseball in this study also included softball and tee ball, as the coding system employed for the database used one code to identify all three sports.

The published studies from the US have identified the following table of mechanisms of traumatic injury during softball/baseball (Wheeler, 1984; Nadeau et al., 1990; Janda et al., 1992b). These are summarised in Table 1.

Table 1. Common mechanisms of traumatic baseball/softball injury

sliding	42-71%
jamming or collisions	25-28%
falls	8.7-17%

These injury mechanisms are closely related to the four main activities or skills of the game (Hay, 1973). The majority of sliding injuries are to the ankles and knees and a large number of these are fractures (Wheeler, 1984; Nadeau et al., 1990). Studies in the United States have found that a high proportion of injuries (ie between 42%-71% of cases) result from sliding into a base (Wheeler, 1984; Janda et al., 1986; Centres for Disease Control (CDC), 1988; Nadeau et al., 1990; Janda et al., 1992b). Jamming or collision injuries usually involve a player being hit by a ball and generally involve the fingers (Wheeler, 1984; Nadeau et al., 1990). Falls often resulted in injuries to the upper extremities, particularly the elbow and wrist (Wheeler, 1984; Nadeau et al., 1990). Table 1 summarises the three major mechanisms of traumatic injury in baseball and softball, and those that would most often present to an emergency department. There are also, however, a significant number of overuse injuries associated with baseball and softball, particularly to the shoulder.

In a review of the literature on baseball and softball injury, Walk et al. (1996) found that abrasions were reported to be the most common injury in children and youth. Other common injuries were, fractures, sprains and lacerations. The injury patterns showed that the injuries to children were associated with them being unable to coordinate their

movements during sliding and not being able to avoid collisions with other players or bases. For players at the interscholastic level, injuries included fractures, lacerations and sprains. Players at the intercollegiate level and professional levels suffered mainly from bruising, strains and abrasions. The results of this study are summarised in Table 2.

Table 2. The nature of baseball and softball injuries in the United States

	Abrasions	Concussion	Dislocation	Fractures	Inflammation	Laceration	Non-specific	Sprain	Strain
BASEBALL									
youth	43-52	2-3		19		10		13-18	
high school				33		33		33	
college				3-10				34-37	26-28
amateur	25						12	12	37
pro	1			1	12	3	42	5	18
SOFTBALL									
high school				33			33		33
college				11-27				32-40	12-25
recreational adult	3.6		1-5	6-15	10	7-8	15	26-42	26-28

Source: Walk et al. (1996)

Walk et al. (1996) also found that injuries to the head and upper extremities were more frequent in children, as were hits by a pitched ball. On the other hand, injuries to the upper and lower extremities, mainly the knee, ankle and shoulder, were more frequent in the college, amateur and professional levels of play (Walk et al., 1996).

Table 3. Comparison of the body regions injured in baseball and softball in the United States

	head	spine/trunk	upper extremities	lower extremities
BASEBALL				
youth	33.0-40.4%	3.0-7.0%	32-100%	19-24.7%
college	2.0-67%	1.0-7.9%	20-49.5%	39.8-60.3%
amateur	3.0-25%	3.0%	12.5-60.1%	15.2-62.5%
pro	4.9%	6.8%	42.9%	42.2%
SOFTBALL				
youth	4.0-32.7%		55.0%	12.2-100%
college	5.6%	6.9%-15.1%	27.3-100%	41.9-60.5%
amateur			30.0%	40.0%
recreational adult	5.0%		13.1-27%	70.6%-73%

Source: Walk et al. (1996)

A recent review of baseball related injuries to children aged 5 to 14 years was conducted by the Consumer Product Safety Commission in the US (Kyle et al., 1996). This review reported that hospital emergency rooms treated about 162,100 children aged 5 to 14 years for baseball-related injuries in 1995. This review also established that over half (55%) of the injuries were due to children being hit by a ball. Specifically, 20% of cases were hit by a pitched ball, 18% by a batted ball, 14% from a thrown ball and 3% were hit while trying to catch a fly ball (Kyle et al., 1996). Collision type injuries, (ie. with another person or being hit by a bat), each accounted for 12% of cases; 9% of cases resulted from tripping and 8% of cases resulted from sliding. It was also reported that over one third of the injuries were to the face and that a majority of these resulted from being hit by a ball. Three quarters of these injuries occurred to older children aged 10 to 14, representing about half of the total number of children playing baseball. Of the total number of injuries to children, the CPSC considered about 33% to be severe, including fractures, concussion, internal injuries and dental injuries. The less severe injuries included contusions, abrasions, lacerations, strains and sprains. More than 50% of the injured children under the age of 11 sustained injuries to the head and neck area. In contrast, a larger percentage of older children sustained injuries to their arms and legs.

Australian data from emergency department presentations for baseball/softball injuries in children shows that, being hit by a ball and falls accounts for the majority of injuries (44% and 26% respectively). In contrast, balls and sliding are the major causes of injury in adults (38% and 22% respectively) (Victorian Injury Surveillance System, unpublished). These differences from the United States picture can be partially explained by the fact that sliding is not allowed in slow-pitch softball, the most popular version of the game in Australia. Furthermore, when children first begin to play the sport they may have problems with coordination and find it difficult to catch the ball or judge where it will fall.

One Australian study found that baseball/softball ranked in the top twenty sport and recreational activities leading to emergency department presentation for both children and adults (Finch et al., 1995). For children, aged under 15 years, baseball/softball injuries were ranked 13th (1.6% of child sports and recreation presentations) and for adults they ranked 16th (1.8% of all adult sports and recreation presentations). A limitation of this study was that baseball and softball could not be separated since they were assigned the same code in the injury database.

The Victorian Baseball Association (VBA) reported that during the 1995/96 season (summer (Sept-April) and winter (May-August)), fifty six separate injuries were compensated by their insurer for a total of \$25,396.75 (Flower, 1996). These compensated injuries involved injuries to 6 teeth, 2 broken arms, 9 knees. The majority of the other injuries were strains, broken fingers, etc. The VBA further reported that approximately 11,000 participants played 22 games each during the season. (Flower, 1996).

Injury prevention is important because baseball/softball injuries are associated with significant formal and informal costs. The cost to the player of sporting injuries can be quite high when the medical care, time lost from work and time lost from the game are taken into account. The injury can also affect the injured players' employer if time is taken off work to recover (Janda et al., 1993).

Ankle and knee sprains are common amongst injured baseballers and softballers. It has been estimated that the average cost of ankle and knee sprains in the United States, is between \$200US - \$400US per injury. This could exceed \$5000 if the injury is a fracture requiring hospitalisation (Janda et al., 1986). Additional costs of ongoing treatment and rehabilitation of an ankle or knee sprains would also be quite high. In Australia, the estimated average cost of ankle injuries in 1987-88 was \$160AUS per injury and for knee injuries it was an average of \$700AUS per injury (Egger, 1990). Since ankle and knee injuries are so costly to the injured baseballer/softballer, it is important to consider measures designed to prevent these injuries.

4.2 Catastrophic Injuries

Baseball strikes to the head and chest have caused deaths in children in the US. The United States CPSC reported 88 deaths to children aged from 5 to 14 years, from 1973 to 1995, of which 36 were to children younger than 10 years old (Kyle et al., 1996). This report also found that of the 88 deaths, 68 (70%) were due to hits from a ball and 13 (15%) to hits by a bat. Of the 68 ball impact deaths, 38 (56%) resulted from blows to the chest. A further 21 (31%) deaths were caused by a ball hitting a player's head, whilst 9 (13%) of the cases involved impacts to other areas. This is discussed further in Section 6.3.

In a review of the literature, Walk et al. (1996) stated that there were numerous references in the literature to catastrophic injuries, however only 10 of these were case reports. All of the reports involved children between the ages of 4 and 14 years, and 9 of the 10 involved children between 8 and 14 years (Walk et al., 1996). Seven of the ten cases involved a pitched ball, and the remaining involved a batted ball (Walk et al., 1996). Likewise 7 of the cases resulted from impacts to the chest and 3 from impacts to the head. Of these ten cases, seven were fatal.

To date, no person in Australia has died as a result of a baseball injury (Flower, 1996).

4.3 Victorian Emergency Department Presentations

In Australia, there have been no published studies specifically describing the frequency and causes of baseball/softball injuries. Data from a Victorian emergency department presentation database are presented here for the first time to describe these injuries.

The Victorian Injury Surveillance System (VISS) collects detailed information from 7 campuses of 5 Victorian public hospitals: Royal Children's Hospital, Western Hospital - Footscray and Sunshine campuses, Preston and Northcote Community Hospital, Royal Melbourne Hospital and Latrobe Regional Hospital - Traralgon and Moe campuses.

The child data is based on 5 years of data collection, 1989 to 1993, at 3 hospitals: Royal Children's Hospital, Western Hospital and Preston and Northcote Community Hospital, and 4 years of data collection, July 1991 to June 1995, at Latrobe Regional Hospital - Traralgon and Moe campuses.

The VISS adult injury collection is based on 9 hospital years of data. The collection periods for each participating hospital were: Western Hospital (11.12.90 to 31.12.92 - 2 years), Preston and Northcote Community Hospital (1.3.92 to 28.2.93 - 1 year), Royal Melbourne Hospital (1.3.92 to 28.2.94 - 2 years) and Latrobe Regional Hospital - Traralgon and Moe campuses (1.7.91 to 30.6.95 - 4 years).

Based on the above periods of collection, self reported information on 155,000 cases of all-cause injuries has been collected. Of these, 8053 cases were sports injuries to children, representing 10% of total child injury, and 7216 were sports injuries to adults, representing 11% of all adult injury.

Due to differing hospitals and periods of collection, the child and adult data are usually considered separately. This convention will be followed for the purposes of this report.

A limitation of the VISS database for baseball and softball injuries is that there is only one code to cover both sports. However, information about injuries incurred during each of the two sports separately has been able to be extracted on the basis of text searches for the words "baseball" and "softball" in the narrative description of the injury event. Sections 4.3.1 and 4.3.2 provide a detailed description of the cases for baseball and softball, respectively.

4.3.1 Baseball Injuries

4.3.1.1 Child cases

There were 60 recorded cases of baseball injuries to children aged less than 15 years on the VISS database, representing 0.7% of all sports injuries to children. In over three-quarters of these cases, the players were aged 10-14 years and 90% were male. Injuries occurred most often early in the season during October and November (40%).

Thirty-seven per cent of injuries occurred at school, 35% at areas for organised sport, 10% at a residential location, 10% at parks or playgrounds and 1% in a public car parking area. Seven per cent occurred at an unspecified location.

Forty-seven per cent of players were participating in organised competition or practice at the time of injury, 17% were participating in informal baseball and 29% did not specify the nature of the baseball being played. A further 7% of injured children were playing generally in the area where a match was taking place. An examination of the case narratives identified that 18% of players were on the fielding side and 10% were on the batting side. The remainder did not provide enough detail to specify on which side they were playing when the injury occurred.

One third of injuries occurred as a result of being hit by a baseball, half of which were to the face, (e.g. *"Playing baseball, missed catch, ball hit player on the nose"*). Two of these players were hit by pitched balls. A further 27% of injuries were due to hits by a baseball bat; one quarter of these occurred because the player got too close to the batter, (e.g. *"Playing baseball and was standing too close to the bat, hit by bat"*). Of the remainder, 12% were the result of a fall, slip or trip; 7% were associated with sliding to

bases; 7% were collisions with another player; and 7% were finger injuries resulting from misjudged catches.

The use of safety or protective devices was noted in only 13% of cases. These devices included helmets (7% of total), gloves (5%), jaw guards or masks (2%) and catcher's equipment (2%). There is, however, likely to be an underestimation of the wearing rates of protective equipment associated with the cases recorded by VISS. Some of the equipment is considered such a normal part of the uniform (e.g. gloves), that players may not consider it to be a safety device and as such neglect to report its use on the VISS form.

Twenty-three per cent of child cases sustained injuries serious enough to warrant hospital admission. More than half of those requiring admission had been hit in the face by either the ball or the baseball bat. Twenty-nine per cent of the cases requiring admission were limb fractures. A further 35% per cent of cases required significant treatments (ie, review or referral), mostly to a general practitioner or back to the emergency department. Another quarter required only minor treatment and 17% required no treatment.

More than half (56%) of the total number of injuries sustained were to the head and face. These were particularly bruising of the face and scalp (11% of total injuries sustained), lacerations of the face and scalp (6%) and concussion (6%). Another 13% of injuries were to the fingers, particularly sprains/strains (6%).

4.3.1.2 Adult Injuries

Over the data collection period described above, VISS recorded 41 cases of baseball injuries to participants aged 15 years or over, representing 0.6% of adult sporting injuries. Two-thirds of injuries occurred in the 15-24 year age group. As with the children, males were the most commonly injured participants, accounting for 95% of the adult total.

In Victoria, the regular baseball season generally runs between the months of September and April. The Provincial season is from mid April until mid September. More than half of the cases of injury to adults recorded by VISS, however, occurred in the provincial season, particularly in the months of May (22% of total) and July (15%). All but one of these provincial injury cases related to organised competition or practice.

Ninety per cent of adult injury cases occurred at areas of organised sport, 5% at schools and 2% at a residential location. Another 3% occurred at an unspecified location. Eighty-eight per cent of participants were playing in formal competition, 5% were practising or warming up for a game and 1% of cases were coaching. Five per cent of participants did not specify the nature of the baseball they were playing. Twenty-seven per cent of participants specified that they were on the batting side and 15% on the fielding side. The remainder did not supply enough detailed information to determine on which side they were playing.

The most common injury scenarios were as follows: 27% of injuries occurred when the participant was hit by the ball (e.g. "*Playing baseball, hit by thrown ball*"); 22% while sliding to base, (e.g. "*Playing baseball, sliding to 2nd base, other player had foot on*

base, base didn't give"); 15% were associated with over-exertion during the course of the game, (e.g. *"Playing baseball, twisted ankle while running, bad foo* 15% collided with another participant; 10% fell, slipped or tripped; and 5% were hit by the baseball bat.

The use of safety or protective devices was noted in only 20% of cases. These devices included helmets (12% of total cases), gloves (10%) and knee pads (2%). As for the children, there is likely to be an underestimation of the wearing rates of protective equipment associated with the cases recorded by VISS.

Twelve per cent of cases required hospital admission. A further 59% of cases required review or referral, with, 27% of total cases being referred to a general practitioner for follow up, 15% being required to return to the emergency department for a review and 15% to an outpatients clinic for the same purpose. Another twenty-two per cent required only minor treatments and 7% required no treatment.

More than half of the total number of injuries sustained were to the lower limbs, particularly strains or sprains of the ankle (18% of total injuries) and knee (7%). Fractures accounted for a further 22% of injuries sustained, particularly to the nose (5%) and tibia/fibula (5%). There were no recorded cases of injury to the shoulders.

4.3.1.3 Comparison of child and adult cases

A comparison of the most common mechanisms for child and adult baseball injuries presenting to emergency departments in Victoria is given in Table 1. Because the available literature generally recognises 3 main mechanisms of injury (sliding, jamming/collisions and falls), these categories are used in this table. The narrative descriptions of the injury events recorded by VISS allow for further breakdown of the jamming/collision category into those injuries sustained when misjudging a catch and those cases where the player is hit by the ball or bat in the course of the game.

Table 4: Mechanism of baseball injury amongst cases presenting to Victorian emergency departments

	Child injury cases (N = 60) %	Adult injury cases (N = 41) %
Sliding	7	22
Fall, slip or trip	12	10
Collision/jamming		
- misjudging catch	7	2
- hit by ball	33	27
- hit by bat	27	5
- collision with other player	7	15
- collision with fixed object	0	2
Over-exertion		
- running	0	10
- other	3	5
Other	4	2
TOTAL	7%	17%

Table 4 shows that sliding and over-exertion type injuries are more prevalent amongst adults than children. Children appear to be more commonly hit by a ball or bat, suggesting that they do not know how to avoid oncoming balls or appreciate the need to be well away from a swinging bat.

4.3.2 Softball Injuries

4.3.2.1 Child Injuries

There were 90 recorded cases of softball injury to children aged less than 15 years on the VISS database, representing 1% of all sports injuries to children. Over 90% of those injured were aged 10-14 years and 67% were female. Injuries most often occurred early in the season October/November (41%).

Almost 56% of injuries were sustained at school and a further 30% at areas for organised sport. Of the remainder, 3% occurred at a residential location, 2% at a park and 9% occurred at an unspecified location.

Forty-three per cent of players were participating in organised competition, a further 34% did not specify the nature of the softball being played, 17% were participating in informal softball and 6% were involved in training. An examination of the case narratives identified that 20% of the injured players were on the fielding side and 11% were on the batting side. The remainder did not provide enough detail to specify on which side they were playing when the injury occurred.

More than a quarter of injuries (27%), occurred when the player fell, slipped or tripped. Poor ground conditions, particularly holes, featured in 20% of falls-related cases, e.g. *“Training for softball when fell into a hole whilst running and twisted ankle”*. Another 8% of fall cases involved the bases, none of which involved sliding.

Twenty-two per cent of players were injured when they were hit by the ball, almost two-thirds of these were hits to the face and head, e.g. *“Standing on a softball base, missed the catch, hit in eye and nose area”*. A further 14% of players received finger injuries when misjudging or incorrectly catching a ball, e.g. *“Playing softball, tried to catch ball, ball hit finger bending it back”*; 12% were hit by the softball bat, e.g. *“Playing in softball game, hit by swinging bat by the batter”*; 9% over-exerted, e.g. *“Playing softball, injured shoulder when swinging bat too hard”*; 5% of injuries related to direct contact with another player and 3% of players were injured whilst sliding to the base.

The use of safety or protective devices was noted in only 11% of cases. These devices included gloves (4% of the total of injured players recorded use), chest plates (3%), face guards or masks (2%) and a helmet (1%).

Only 6% of players sustained injuries serious enough to warrant hospital admission. Forty-three per cent of cases required review or referral, almost half of these cases (the equivalent of 24% of the total) were referred to an outpatient clinic. Another 34% of players required only minor treatments and 17% required no treatment.

Over half of the total number of injuries sustained were to the upper limbs. Finger injuries, alone, accounted for almost a quarter of the total number of injuries. Most common injuries to the upper limbs were finger fractures (9% of total injuries), finger strains/sprains (8%) and radius/ulna fractures (7%). Other common injuries included ankle strain/sprain (6%) and bruising to the eyes (4%).

4.3.2.2 Adult Injuries

Over the period of data collection, VISS recorded 36 cases of softball injuries to players aged 15 years or over, representing 0.5% of adult sporting injuries. Injuries were most common in the 15-19 years old age group (39% of total). As with children, females were the most commonly injured group, accounting for 69% of the adult total.

Unlike injuries to children which were more common at the start of the season (October and November), injuries to adults were more common at the end of the softball season with 47% occurring in the months of February and March.

Three quarters of adult injury cases occurred at areas for organised sport, another 8% occurred at schools and 3% in parks. Fourteen per cent occurred at an unspecified location. Eighty-one per cent of players were participating in formal competition, 17% of players did not specify the nature of the softball they were playing and one injured person was teaching the game to students. Thirty-six per cent of players specified they were on the batting side and 22% on the fielding side. The remainder did not provide enough detail to specify on which side they were playing when the injury occurred.

One third of players were injured while progressing between bases, over half of these occurred when the player was sliding into a base, e.g. *“Playing softball, slid for base and landed onto outstretched arm”* or *“Whilst playing softball skid along ground and struck foot on base plate”*. Other common injury scenarios include over-exertion (28%) (e.g. *“Pitching at softball, experienced pain in shoulder”*); finger injuries when misjudging or incorrectly catching a ball (22%) (e.g. *“Playing indoor softball, trying to catch the ball, ball bent players thumb back”*); or being hit by the ball (11%).

The use of safety or protective devices was noted in only 19% of cases. These devices included gloves (8% of total players recorded use), helmets (8%) face guards or masks (3%) and a box (3%).

Only 6% of players sustained injuries serious enough to warrant hospital admission (if 23% for baseball). Fifty-six per cent of cases required review or referral. One third of total cases were referred to a general practitioner for follow up and 17% to an outpatients clinic. Another quarter required only minor treatments and 14% required no treatment.

Forty-two per cent of the total number of injuries sustained were strains or sprains, particularly to the ankle (17% of total injuries), knee (11%) and finger (11%). Finger injuries were common accounting for one quarter of all injuries with sprains, dislocations and fractures being the most common finger injuries. Injuries to the shoulder accounted for another 5% of total injuries sustained. VISS can record up to 3 separate injuries per case.

4.3.2.3 Comparison of child and adult cases

A comparison of the most common mechanisms for child and adult softball injuries is shown in Table 5. The available literature generally recognises 3 main mechanisms of injury in softball - sliding, jamming/collisions and falls. Examination of the narratives recorded by VISS allow for further breakdown of the jamming/collision category into those injuries sustained when misjudging a catch and those cases where the player was hit by the ball in the course of the game.

Table 5: Mechanism of softball injury amongst cases presenting to Victorian emergency departments

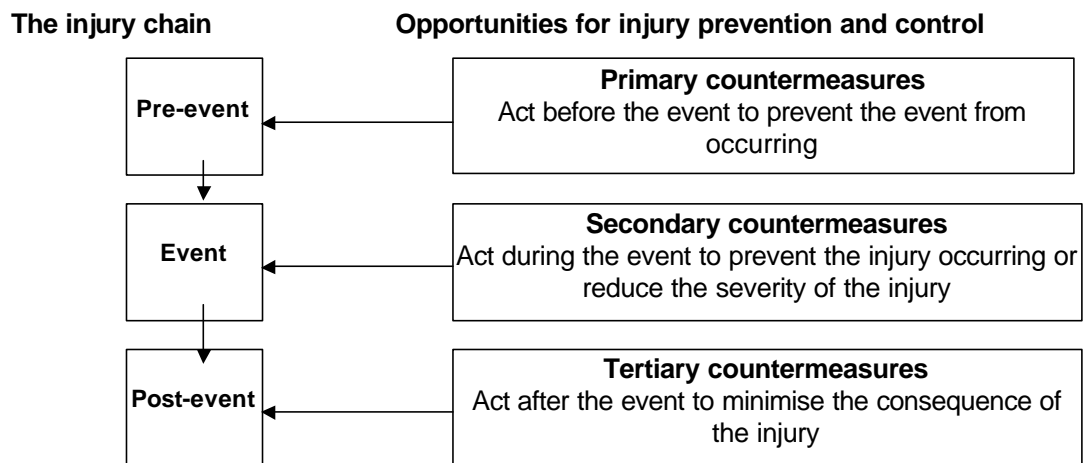
	Child injury cases (N = 90) %	Adult injury cases (N = 36) %
Sliding	3	19
Fall, slip or trip	27	8
Collision/jamming		
- misjudging catch	14	22
- hit by ball	22	11
- hit by bat	12	3
- collision with another player	4	3
Over-exertion		
- pitching	0	3
- running	2	11
- other	7	14
Other	9	6
TOTAL	18	34

According to the emergency department data presented above, sliding does not seem to be involved in a large proportion of softball injuries in Australia. This may be due to the fact that slow pitch softball is the more popular version of the game and sliding is not allowed (Duyvestyn, 1996). Sliding injuries do occur in fast pitch baseball and softball, however. Comparison of Tables 4 and 5 suggest that falls, slips and trips are more common in softball than baseball, particularly for children. Similarly, misjudging catches appears to be more of a problem for softballers. On the other hand, hits by the ball or bat are more common in baseball.

5. PRINCIPLES OF PREVENTION

Injuries are considered to result from a culmination of a set of circumstances and pre-existing conditions that may best be understood as a chain of events: pre-event, event and post-event (Robertson, 1983). Injury countermeasures are measures that can 'counter', prevent or reduce the risk of injury. A number of researchers have described how countermeasures can be targeted at the different links in the chain of events leading to injury (Haddon, 1972; Ozanne-Smith and Vulcan, 1990; Watt and Finch, 1996). Such injury countermeasures can be equated with primary (pre-event), secondary (event) and tertiary (post-event) prevention (Figure 2). Primary countermeasures act before an event or incident that could potentially lead to injury, to prevent the event from occurring in the first place. Secondary countermeasures act during the event, to prevent the injury occurring or to reduce severity of the injury. The third level of countermeasures acts after the chain of events/incidents leading to injury and help to minimise the consequences of injury.

Figure 2. Countermeasure opportunities in the injury chain



Source: Watt & Finch (1996)

There is a multitude of factors that contribute to the risk of injury in baseball and softball. Generally, more than one factor is involved in each injury. Consequently there are numerous countermeasures aimed at the primary, secondary or tertiary level of injury prevention. These are summarised in Table 6.

Table 6: Baseball and softball injury countermeasures

Primary	Secondary	Tertiary
adequate water intake attention to biomechanics coach education warm-up modified rules training UV protection playing environment base design pre-season conditioning technique	environment bases protective equipment -helmets -padding -gloves -chest protectors -visors surface	availability of first aid equipment prompt first aid rehabilitation rest, ice, compression, elevation, referral

Baseball and softball injury countermeasures can also be classified as either passive or active. Passive measures are independent of human behaviour and include such things as the wearing of safety helmets or the use of breakaway bases. Active countermeasures, on the other hand, involve some human involvement or behaviour modification for their success. Generally, passive countermeasures are more successful than active ones because they do not rely on human behaviour. Countermeasures aimed at the primary, secondary or tertiary levels of prevention can be either active or passive. Many of the widely used countermeasures for preventing baseball and softball injuries are passive. Table 7 reclassifies the countermeasures in Table 6 as active or passive.

Both baseball and softball are considered to be non-contact, non-collision team sports. It has been suggested that since softball is mainly a recreational sport, many of its participants may be “out of shape” and therefore at greater risk of injury (Janda et al., 1986). Though collisions sometimes occur, they are usually player collisions with a bat, ball, another player or a fixed object. The cause of most of these injuries is generally errors in technique (e.g. missed catches) (Nadeau et al., 1990). There has been no specific pattern identified for injuries caused by falls. Baseball and softball injury prevention methods include making the environment safer for recreational players by maintaining fields and facilities, providing padded walls and back stops, undertaking a good stretching programme before commencing play, good conditioning and technique programme, reducing alcohol consumption and use of break-away/quick release bases (Janda et al., 1992b; Janda, 1994).

Table 7. Passive and active countermeasures

Active factors	Passive factors
attention to biomechanics	playing environment
nutrition	modified rules
rehabilitation	surface
first aid	base design
pre-season conditioning	availability of protective equipment
technique	provision of first aid equipment
training	
warm-up	
adequate water intake	
coach education	
UV protection	

Sports injury risk factors can also be described as intrinsic or extrinsic factors (Kannus, 1993). Intrinsic, or internal, factors are related to levels of the physical and mental health of the athlete. Extrinsic, or external, factors refer to factors that impinge externally on the athlete’s performance. Different countermeasures are used to address the intrinsic and extrinsic risk factors. Overuse injuries are commonly associated with intrinsic factors. Table 8 re-categorises the countermeasures given in Table 6 into intrinsic and extrinsic factors. Typically, the intrinsic factors are addressed by primary prevention activities. Attention to extrinsic factors involves primary, secondary and tertiary levels.

Table 8: Intrinsic and extrinsic factors associated with baseball and softball injury countermeasures

Intrinsic factors	Extrinsic factors
attention to biomechanics	adequate water intake
nutrition	coach education
first aid	base design
pre-participation screening	footwear
pre-season conditioning	UV protection
rehabilitation	modified rules
technique	playing environment
warm-up	protective equipment
training	

In the next section, the literature assessing the effectiveness of the various countermeasures for the prevention of baseball and softball injuries is reviewed. For each countermeasure, the rationale for its use as a safety measure, together with a critical review of the extent to which it has been fully evaluated, is presented.

6. DETAILED REVIEW OF BASEBALL AND SOFTBALL INJURY COUNTERMEASURES

6.1 Playing Equipment

6.1.1 Base Design

Base running and sliding probably account for the majority of significant traumatic injuries to softball players in the United States (Janda et al., 1986). Indeed, sliding has been identified as being the major cause of traumatic injuries in baseball and softball. Janda et al. (1996) have suggested that sliding is associated with up to 71% of all softball injuries. On the other hand, the CPSC review estimated that 13,000 sliding injuries occurred in 1995 to children 5-14 years, constituting 8% of the total emergency room treated baseball injuries (Kyle et al., 1996). About 70% of these injuries occurred in softball, 28% in baseball, and 2% in tee-ball (Kyle et al., 1996). It has also been stated that, baseball and softball are similar sports and both players use sliding techniques to reach bases quicker or to avoid being tagged. Once having slid and made contact with the base the runner must maintain contact until 'time' has been called or the ball is thrown elsewhere (Allingham, 1996). If a runner could run through the base and need only to tag it (as he/she does at first and home bases), the need to slide would be negated (Allingham, 1996). However, this would require a major change to the rules of the game.

The sliding technique involves a player either sliding into a base "foot-first" or "hand-first". "Foot-first" sliding involves the player's foot making contact with the base, whilst their buttocks, lower back and thighs making impact with the ground. Although the majority of sliding injuries are associated with "foot-first" sliding, "hand-first" sliding injuries do occur. In "hand-first" (or head-first) sliding, the hand makes contact with the ground or base and deceleration is achieved by the chest and thighs making contact with ground. This "hand-first" sliding action provides a larger surface area with which to absorb the impact (Corzatt et al., 1984). In this style of sliding, the fingers and small joints of the hand are at greatest risk of injury because they are not able to cope with the force required to decelerate the whole body (Nadeau et al., 1990).

The typical stationary base used in organised softball games is up to 5 inches in height. The base is foam filled and bolted to a metal post that is sunk into the ground and concreted into place (Janda, 1994). This type of base is immovable and the impact generated by a player sliding into it can cause serious injuries to the foot and hand. This is because the standard stationary base is not designed to absorb the force from players sliding into it (Sendre et al., 1994). There would be benefit, therefore, from using modified bases designed to reduce the force on impact. It has been suggested that the use of modified bases could have a dramatic effect on the health and fitness of softball athletes with a consequent reduction in health care costs (Janda et al., 1986). Modifying the design of bases, as a means of injury prevention, has been investigated in a number of studies of baseball and softball injuries. In the following sections, studies of the various types of bases and their injury prevention potential will be discussed.

The usual cause of sliding injuries is the runner's attempt to prevent overrunning the base by using it to rapidly decelerate (Wheeler, 1984). However, sliding injuries can also

occur in a number of other ways. For example, the force of the infield surface against the skin as the player slides can cause burns to the skin, especially to the chest and buttocks. Rapid deceleration of the player from sliding into a stationary base can lead to bruising, fractures and sprains. Furthermore, twisting of the flexed knee whilst sliding can lead to significant knee injuries (Janda et al., 1986).

Base sliding injuries in baseball are mostly due to judgement errors, poor sliding techniques and poor physical condition (Janda et al., 1993). The introduction of modified bases to playing fields is a passive countermeasure that can be used to reduce the significance of these factors. Although modifying bases will reduce the frequency of many sliding injuries, other injuries could still occur from runners' errors in judgement, improper sliding technique, poor timing, inadequate physical conditioning, and alcohol consumption (CDC, 1988; Janda et al., 1988). The CPSC review found that 87% of base contact injuries studied involved standard bases, about 9% involved modified 'safety' bases and 4% occurred where the type of base was unknown (Kyle et al., 1996).

6.1.1.1 Recessed and low profile bases

Recessed or low-profile bases are similar in design to the home plate and are level with the infield surface (Janda et al., 1986). Wheeler (1984) found that no sliding injuries occurred at the home plate and this led to the suggestion that recessed bases could be a good option. It is believed that injuries rarely occur at the home plate because the player slides over, and not into, the base. It was therefore concluded by Wheeler (1984), that recessing the second and third bases, like the home plate, would reduce injuries.

An alternate suggestion to improving base design is the use of low profile rubber bases which have been found to be more economical than standard cloth bases (Janda et al., 1986). Recessed bases were explored as a preventive method in another study, but the umpires objected to them as they found it difficult to determine "safe versus out" callings because visualisation was poor (Janda et al., 1990; Janda, 1994). Another report suggested that the use of a high-contrast colour, instead of the standard white colour, in the base would enable the umpire to call a game quite easily, as the base would be more visible (Janda et al., 1986).

Although recessed or low profile bases may be a viable option for injury prevention purposes, there has been no published data to date on the effectiveness of these types of bases for preventing injuries. Recently, attention has been directed more towards the design of quick-release or break-away bases.

6.1.1.2 Quick-release/break-away bases

A quick-release or break-away base is one for which the top portion of the base breaks away on impact. Early designs of break-away bases were based on magnetised surfaces or velcro joins. However, these designs often failed because dirt lodged between the two surfaces and impaired their joining ability. In improved designs, the break-away base is anchored to a rubber mat that is flush with the infield surface. This is then anchored to the ground with a metal post similar to that used for stationary bases (Janda et al., 1988; Janda et al., 1990). The breakaway portion has sockets on the undersurface that attach

to rubber grommets on the top of the rubber mat. The purpose of the quick-release feature is to reduce the impact load generated when a player impacts with the base (Janda, 1994).

A biomechanical study of the kinematics of sliding identified that there were four phases to sliding: the sprint, attainment of the sliding position, the airborne phase and the landing phase (Corzatt et al., 1984). This study found that most of the injuries occurred in the landing phase when a small amount of the body, either the foot or hand, is used to absorb the shock of impact. This provides some rationale for the use of break-away bases to reduce the impact forces.

The impact force required to dislodge a break-away base is significantly less than that needed for a stationary base. Breakaway bases are available in four models: youth, teen, adult, professional; the difference between these models is the amount of force needed to break the base, e.g. the youth model breaks away easier than the other models (Janda, 1984). As stated by Janda, the adult-model break-away base requires 700 foot pounds of force to release. In contrast, it would take 3,500 foot-pounds of force to dislodge a stationary base; this is 5 times the force required for break-away bases (Janda, 1994).

A phased study of the effectiveness of breakaway bases for preventing sliding injuries has been conducted by Janda and colleagues (1994) in predominantly recreational softball leagues in the United States. The first phase was a retrospective study of community and hospital records to identify the causes and types of injuries that occur while playing softball (Janda et al., 1986). The data established that the most frequent cause of softball injuries was sliding, accounting for 71% of injuries. These sliding injuries occurred mostly during rapid deceleration against stationary bases.

Phase II was a controlled trial that compared injuries from stationary base fields with those that occurred on break-away base fields (Janda et al., 1988; Janda et al., 1990). The study was conducted over two seasons and involved 633 games played with break-away bases and 627 games with stationary bases (Janda et al., 1988; Janda et al., 1990). During the study period, 45 sliding injuries occurred on fields with stationary bases compared with only 2 injuries on fields with break-away bases. These two cases of injury occurred when the base did not break away. Injuries were calculated as occurring in 7.2% of games using stationary bases and 0.3% of games using break-away bases. This represented a 96% reduction in the risk of injury when using break-away bases (Janda et al., 1988; Janda et al., 1990).

Acceptance of break-away bases by players and games officials was also assessed in the Phase II study. Field supervisors reported that the break-away bases did not significantly delay games and umpires did not have problems calling "safe versus out" when bases were released (Janda et al., 1988). They also found that relocating the break-away part of the bases onto the rubber mat was quick and easy and that they were durable.

Phase III was a follow-up study of 1035 games played on fields all of which had break-away bases. There were only 2 ankle sprains recorded, of which only 1 occurred when

the player was sliding into the base (Janda et al., 1990). This corresponds to an injury occurring in 0.19% of games.

Phases I, II and III of this study showed that sliding injuries were the most frequent type of injury. Taken together, they have also demonstrated that the use of break-away bases can reduce these injuries. A limitation of the studies, however, is that the results were only for recreational softball games. Janda conducted a follow-up study (Phase IV) to look at sliding injuries in high performance baseballers (ie. college and professional players) and compared standard and break-away bases. The study was run over a 2 year period (2 seasons) and 19 college and professional minor league baseball teams participated. Seven teams participated in the first year and 12 in the second. The teams played on break-away bases during home games and with stationary bases at away games. Base sliding injuries were recorded by team physicians, athletic trainers, managers and administrative staff. The definition of an injury for this study was: "an event which led to a player being removed from competition" (Janda et al., 1993). This study used the same break-away bases that were used in the Phase I and Phase II.

The Phase IV study confirmed that more sliding related injuries occurred on fields using stationary bases than on those with the break-away bases. Two sliding injuries occurred on the fields with break-away bases and 10 on those with stationary bases (Janda et al., 1993). This represented 1 injury for every 243 games on the break-away base fields compared with 1 injury for every 50 games on the stationary base fields. When expressed as a rate, these figures translate to 0.41 injuries/100 break-away base field games and 2.01 injuries/100 stationary base field games. This translates to a rate ratio of 1 break-away base injury to 5 stationary base injuries. The results from this study therefore showed an 80% reduction in the risk of sliding related injuries. Although this figure is not as high as the one found in the softball studies, it still represents a significant reduction.

Surveys of the team players, managers and administration staff were also conducted. All were found to be positive about the bases and planned to use them. The Phase IV study reported similar findings to Phase II with umpires not having a problem making judgement calls and not finding that the use of the bases altered the game (Janda et al., 1993).

A study by the United States CPSC examined the ability of protective equipment to reduce baseball injuries and deaths. This review concluded that safety bases which release upon impact and leave no holes in the ground when the base is released are most likely to be effective (Kyle et al., 1996). The break-away bases studied by Janda et al. (1990) met this criterion. The CPSC also stated that models based on age, gender and skill levels could provide the most effective level of protection (Kyle et al., 1996).

Breakaway bases are more expensive than stationary bases (\$400US versus \$180US per set, respectively). However, stationary bases are usually replaced every year whereas breakaway bases last four times as long (Ramotar, 1993). Based on study data and participation figures from the United States Amateur Softball Association (ASA), the Centres for Disease Control have estimated that the exclusive use of breakaway bases in softball league would prevent approximately 1.7 million sliding injuries each year and save about \$(US)1.9 billion in medical costs (Duda, 1988). This means that the potential

savings in medical costs would outweigh the extra cost required to purchase breakaway bases if injuries from sliding could be prevented (Janda et al., 1988; Janda et al., 1990).

The American Softball Association (ASA) and the National Federation of State High School Associations in the United States, have both approved the use of breakaway bases but they are not yet mandatory (Porter, 1996). Breakaway bases have been used in ASA world and national championships and umpires have found no problems with making judgment calls (either safe or out) (Duda, 1988). In the United States, federal recommendations require breakaway bases to be used on all recreational baseball and softball playing fields in federally operated facilities (Centres for Disease Control, Atlanta, 1993; Fling, 1991). Break-away bases were used during all games during the Atlanta Olympic Games (Janda, 1996).

As most base sliding injuries result from runner judgement errors, poor sliding technique and inadequate physical conditioning, break-away bases could be used as a passive intervention to reduce the effects of these factors since the nature of the game would not need to be changed (Janda et al., 1993).

To date there have been no studies looking at the effectiveness of the break-away bases in children's baseball games outside the United States. The Victorian Baseball Association has stated that break-away bases will be investigated and trialed at the Victorian State Centre (Fowler, 1996)

6.1.1.3 Impact bases

Hollywood Impact Bases were introduced in 1989. They were designed, developed and produced to help reduce the frequency and severity of sliding and base-running injuries (Sendre et al., 1994). The Hollywood Impact Base is designed with a honeycomb underside that compresses inward and downward to absorb the shock from a foot or hand impacting with the base. The compression downwards also prevents feet or hands from getting under the base and hitting the centre post. The cost of a Hollywood Impact Base is slightly more expensive than a stationary base being \$200US versus \$170US.

Sendre et al. (1994) conducted a study to compare Hollywood Impact Bases with stationary bases to determine the effectiveness of these bases in reducing sliding related injuries. The study involved male and female baseball and softball teams and leagues of different skill levels. Bases of both designs were on fields being used by the teams and the teams were rotated so that they played with both types of bases. The study looked at the number of injuries per player-game. Injuries were documented on a card and only collected for sliding or base-running related injuries. Stationary bases were only used in the second year of the study.

During the 2 year follow up, athlete-exposure was approximately 12.9 players per team or practice game. Fields using the Hollywood Impact Bases recorded no injuries in the first year and only one in the second year. On the other hand, a total of 4 injuries was recorded on stationary base fields. The mean injury rate for Hollywood Impact Base fields was 0.03 per 1000 athlete-exposures compared to 1 per 1000 for stationary base fields (Sendre et al., 1994). Hollywood Impact Bases were associated with 1 injury in every 1285 games, whereas stationary bases resulted in 1 injury every 38.8 games played.

The authors concluded that there are significantly fewer sliding injuries when impact bases are used (Sendre et al., 1994).

6.1.1.4 Other base designs

Although the standard stationary bases are the major type of base used in Australia, other types of bases are sometimes recommended and used, especially for younger players. For example, the "Easy Base" is a base that has velcro straps attached (Ausport, 1996). The velcro straps are pegged into the ground and then attached across the bottom of the base, thereby allowing the base to break away at high impact. The velcro needs to be fitted correctly or the base will not dislodge.

An Australian safety base has been designed for use at first base (Ausport, 1996). The base consists of two bases joined together as one. One side of the base is white indicating where the first base player should stand and the other side is orange for the base runner to use. The base was designed to eliminate collisions between players when the base runner over-runs first base. Similar bases are used elsewhere.

The safety base is recommended by the Australian Softball Federation for all games and anecdotal evidence suggests that the safety base eliminates many facial injuries (Duyvestyn, 1996). No systematic research has been conducted to specifically examine the effectiveness of these bases.

The Amateur Softball Association of America (ASA) has recently been approached to adopt safety standards for bases. Many studies, particularly those done by the University of Michigan, suggest a need to develop a more compatible base (Porter, 1996).

6.1.1.5 Recommendations for further implementation, research and development

- Baseball and softball facilities in Australia should replace the standard stationary bases with breakaway or impact bases. As part of this program several studies are desirable.
- The injury prevention potential of the Australian safety base and the "easybase" should be formally evaluated.
- The effectiveness of break-away bases for preventing injury amongst young children needs to be determined.
- The injury prevention potential of Hollywood Impact bases and the breakaway bases should be compared in a controlled evaluation.
- The strongest evidence is for break-away bases but there is little evidence on the Australian version of these. An estimate of the number of injuries that would be eliminated by the adoption of the US design in Australia is needed before recommendations could be made in this regard.
- Injuries with the break-away bases appear to occur only when they fail to break away. This is more hazardous as the player slides into the base and expects it to give way.

Failure rates on break-away bases, whether due to instalment, maintenance or manufacture should be determined.

- An audit of the types of bases used in Australia across the full range of participation levels should be undertaken, as part of a study to measure effectiveness of the program of replacement of conventional stationary bases.
- The role of other factors involved in sliding injuries, such as judgement errors and poor technique, need to be investigated further. Education and coaching programs aimed at addressing these factors should be developed and evaluated.

6.1.2 Ball Design

6.1.2.1 Background

Impacts from the ball to the head are the cause of the most severe and frequent baseball injuries in children 5 to 14 years old in the United States (Kyle et al., 1996). In a review by the United States CPSC, 77% of all baseball related deaths over a 12 year period were due to a player being hit by a ball. Of the 77% of deaths due to ball impact, 56% were to the chest, 36% to the head and 13% to other regions (Kyle et al., 1996). This study also found that, over half of all emergency department presentations for baseball related injuries during 1995 were due to being hit by a ball (Kyle, et al., 1996). Likewise, data collected by the Victorian Injury Surveillance System show that the most common baseball injury for children and adults was being hit by the ball (33% and 27%, respectively).

Given the incidence of ball impact injuries, it has been suggested that use of softer balls may avoid serious head, face or chest injuries (Kennedy and Fitzgerald, 1989). In the United States, the National Operating Committee on Standards for Athletic Equipment (NOCSAE) approved a voluntary safety standard in 1989, limiting the hardness of softballs (Duda and Roos, 1989). The Standard is aimed at encouraging the use of softer, safer balls in the children's and recreational leagues. The Standard is based on the impact that occurs when a ball travelling 60 mph strikes a headform model protected by a batter's helmet. This impact should not produce more than a 35% chance of a serious head injury in an average person (Duda and Roos, 1989). The Committee on Sports Medicine and Fitness in the United States (1994), also encourages the use of softer balls in children younger than 10 years as they are less skilled and coordinated.

In Australia there are no such standards. However, manufacturers do supply soft-centred balls. At the junior level (children under 13 years) a modified ball is used which is 11 inches in circumference and has a soft poly core centre. The softer softballs are recommended for use in junior level games around Australia and in Victoria the softer core ball is compulsory. The Victorian Baseball Association states in its junior league playing conditions that the under 12's must use a rubber ball in all games. Such balls have a lower bounce than the softer core baseballs (Flower, 1996).

Official major and youth league standard baseballs have a core of cork or rubber, which is wound with natural or synthetic fibres, such as wool or cotton, and covered with two pieces of leather sewn together with 108 stitches. Softer baseballs have a much larger core made of soft, spongy natural or synthetic substances, such as soft polyurethane,

rubber, or kapok, with no winding, and a cover. Softer than standard softballs have a spongier core than standard softballs (Kyle et al., 1996). The assessment of the injury reduction potential of softer than standard balls has two major components: head impacts and chest impacts. Both of these are discussed in the following sections.

6.1.2.2 Softer balls

Janda et al. (1992a) developed a laboratory model to test chest impacts to children from balls. The test involved using pigs, a 6 year old child dummy and a fifth percentile hybrid III female dummy. The impact tests involved using a standard hardball and various softer core baseballs on protected and unprotected chests. The study concluded that different types of softer core baseballs had no demonstrated protective effect on the various models. In some cases, it was considered that they could exacerbate the impact forces of a baseball to the chest.

Viano et al. (1993) conducted an independent study to evaluate and check the requirements of the NOCSAE standard safety test. The study used a 5th percentile Hybrid III female dummy to test the effectiveness of various softer baseballs, as it is similar in size to a 10-12 year old child. The ball was projected via a pneumatic baseball gun which was positioned 30 cm away from the head. Measurements of head impacts were made and a Head Injury Criterion (HIC) was determined. The HIC measures the likely level of injury after a blow to the head in terms of head accelerations and the time period over which they were applied. Both front and side impacts to the head were video recorded. The results were then compared with those using the NOCSAE protocol, which specifies a head-neck-trolley model for direct head impacts mainly designed for helmet safety. Under this protocol the dummy is loosely supported so that the whole body reacts to the impact.

The study found that softer baseballs reduced the amplitude of the acceleration of the head and increased the impact duration from approximately 1 to > 2 ms in forehead impacts. The "Reduced Injury Factor (RIFF) 1" ball had a HIC reduction of 42 - 86.3%. The test showed that direct side temple impacts produced a greater risk of injury. Based on the HIC, the risk of injury ranged from 11% (softer balls) to 20% (hard ball) for serious head injury. The study found that the risk of head injury was higher for softer baseballs and lower for hard balls when compared using the NOCSAE tests. Examination of the videotaped impacts also showed that softer baseballs had a larger contact area than the hard ball therefore reducing the risk of skull fractures (Viano et al., 1993).

Viano and his colleagues concluded that the NOCSAE standard may be effective for assessing head protection provided by helmets. However, the head-neck-trolley model may not be the correct model to use for direct head impacts. The head-neck-trolley system has a neck that is rigidly connected to the trolley and the skull in the head remains stiff when impacted by a hard ball. This method was initially developed to evaluate the effectiveness of helmet protection in baseball.

The CPSC review of baseball injuries found that the type of ball involved in ball impacts was specified in the majority of cases. Softer-than-standard baseballs were involved in fewer and less severe injuries than the standard balls (Kyle et al., 1996). While softer baseballs represented 10% or more of the baseball market, they were involved in just 3%

of the injuries (Kyle et al., 1996). Injuries associated with softer baseballs were limited to contusions, abrasions, and lacerations, none of the more serious injuries, such as fractures or concussion, were seen with softer baseballs (Kyle et al., 1996). The CPSC also completed a review of the literature about softer baseballs, including the suggestion that softer balls could increase the risk of chest impact deaths. This independent review concluded that the models (ie. swine, child dummy and 5th percentile hybrid III dummy) being used in these tests did not provide an accurate representation of child players and found no evidence that softer balls would increase the risk of death from chest impact (Kyle et al., 1996). The CPSC review concluded that softer than standard baseballs and softballs, which have a softer, spongier core than standard baseballs and softballs, meeting the standards, could reduce ball impact injuries to the head.

The Department of Civil Engineering at Monash University is currently undertaking a computer simulation study of head impacts from a baseball to explore these issues further (Grzebieta, 1996). This study is being conducted with the Madymo program utilising a fifth percentile hybrid III dummy model.

6.1.2.3 Size of balls

The size of the ball is an important factor in the ability to catch a ball, without damage to the players' hand. A study looking at softball related hand injuries presenting at a particular clinic found that all the injuries were caused by a 16 inch circumference ball (Degroot and Mass, 1988). Most of the hand injuries occurred because of the way the ball was caught. A 16 inch ball is too big to be caught with a single glove. This means that either hand is just as likely to be injured, since the 16 inch ball needs to be caught with both hands. The authors recommend that to prevent hand injuries a smaller 12 or 10 inch ball should be used. In addition it was recommended that gloves be worn by players.

The size of the softballs used in Australia is 12 inches in circumference, except for the soft centred ball which is 11 inches. This is a reduction from the initial size used in slow pitch games of 16 inch. The 12 inch ball is also used by the majority of programs in the ASA (Porter, 1996)

6.1.2.4 Other

The Amateur Softball Association of America (ASA) is currently involved in a program of ball testing to ensure that manufacturers comply with safety specifications (Porter, 1996). The ASA is also progressing towards establishing new standards for the specification of bat manufacturing (Porter, 1996). The ASA works closely with the Sporting Goods Manufacturers Association to establish safety and injury prevention standards.

6.1.2.5 Recommendations for further implementation, research and development

- The 16 inch ball should not be used in softball games.
- Baseball and softball games should be played with softer balls, meeting the standards, than harder core balls.

- Further research into the risk of death from chest impacts from balls of various hardness needs to be conducted (not necessarily in Australia).
- Further basic research into suitable models for testing the impact of balls should be undertaken (not necessarily in Australia).
- The evidence on soft versus hard baseballs is equivocal and better test procedures need to be developed (not necessarily in Australia).
- Baseball and softball associations should work with manufacturers to ensure that they comply with safety specifications for balls and bats.

6.2 Preventing overuse injuries

Baseballers and softballers, like any athletes today, are expected to train harder and longer, and to commence at an earlier age, if they are to succeed at the elite level. It is, therefore, not surprising that physicians are diagnosing an increasing number of overuse injuries, as the hours of repetitious practice produce a gradual deterioration in the functional capacity of the body. An overuse injury results from an accumulation of stresses to the involved tissue - bone, ligaments or tendons. The tissue and anatomic sites of an overuse injury may vary but, according to Herring and Nilson (1987), the cause is still the same: repetitive episodes of trauma overwhelming the body's ability to repair itself. Once an overuse injury develops, the condition remains until physiological equilibrium is re-established between the stress load and the body's healing ability (Ting, 1991).

Training, technique, footwear, surface, warm-up and conditioning are all factors contributing to overuse injuries with numerous primary and secondary factors playing a role in prevention. Rehabilitation techniques are also important.

In baseball and softball, overuse injuries are particularly related to pitching and throwing. Repetitive throwing and pitching can cause tissue breakdown. Causes have been attributed to excessive throwing, lack of flexibility, muscle imbalance, improper mechanics and throwing pitches that involve a sidearm motion (Walk et al., 1996). Repetitive pitching and throwing may cause elbow overuse injuries in young children. These, in turn, may lead to abnormalities in later life. Overuse injuries are also associated with the running involved in the games.

Comprehensive training and conditioning programs related to all levels of play are good preventive methods for overuse injuries related to pitching and throwing (Janda, 1994). Limiting the number of pitches per week for each player, making rest periods between pitching mandatory and teaching proper pitching techniques can help to prevent overuse throwing injuries.

Catchers can also suffer overuse problems. They can suffer hand problems such as circulatory, finger and nerve injuries to the glove hand. Also, catchers crouch may cause back and knee injuries due to the amount of time spent in the crouch position (Walk, 1996).

6.2.1 Pitching Techniques

Pitching in baseball requires coordination of the nerves and muscles in the upper extremities, rotation of the pelvis and trunk, and both strength and endurance in the lower extremities (Braybon, 1989; Pappas et al., 1985). If the nerves or muscles weaken, stress to the shoulder or elbow could result causing a decrease in the players pitching performance.

The motion of pitching a ball is a continuous one. To simplify the analysis of this motion, studies have tended to break it down into three phases (Pappas et al. 1985):

- cocking, which is a preparatory phase
- acceleration
- follow-through, which involves deceleration of the throwing arm.

These three phases have been broken down further by other authors. Jobe et al. (1988) describe the motion of pitching as having five phases: a wind-up phase, early cocking, late cocking, acceleration and follow through. Wells and Bell (1995) combined the two cocking phases to make up four phases. Fleisig et al. (1995) and Dillman et al. (1993), discuss six phases of an overhand throw: wind-up, stride (or early cocking), arm cocking, arm acceleration, arm deceleration and follow-through. Though the various authors have assigned names or separated the motion differently, their explanation of the throwing motion is consistent.

It has been identified that forces involved in each of the above phases may cause specific injuries, especially in the cocking and acceleration stages (Pappas et al., 1995; Jobe et al., 1988).

Dillman et al. (1993) conducted a quantitative study looking at the arm motion about the shoulder during pitching. Twenty-nine pitchers were chosen for the study after meeting the criteria of being a healthy successful adult pitcher. They were known as the “elite” pitchers. During the study, an automated high-speed video digitising system was used to record three dimensional throwing patterns. Retro-reflective markers were attached to the players at major joints. This allowed an evaluation of arm motions about the shoulder plus a total body analysis. The primary arm motions studied were: shoulder abduction (i.e. movement of the shoulder away from the mid line of the body), horizontal abduction (i.e. drawing away) and external/internal rotation (i.e. turning). A qualitative analysis of pitching a baseball during the six phases of throwing was also conducted. It was concluded that the major motion about the shoulder is external and internal rotation. Throwing a baseball at maximum velocity is a highly dynamic skill. Since the shoulder joint is very mobile, it should be physically prepared before, and during, throwing events where maximum velocity is required (Dillman et al., 1993).

Fleisig et al. (1995) examined the kinetics of the shoulder and elbow joint amongst 26 highly skilled, healthy adult baseball pitchers. High-speed motion analysis was used to perform the calculations. Reflective markers were attached to various points on the players upper and lower body, and four high speed cameras were used to record the locations of the markers. Kinetic values (i.e. joint force and torque) of the elbow and shoulder joints were calculated using kinematic (i.e. motions) variables.

This study found that the highest levels of kinetics occur during the arm cocking, arm acceleration and arm deceleration phases of the pitching motion. The patterns of the joint kinetics were similar to those found in previous studies. Two critical points identified for the shoulder were the instant of maximum internal rotation torque during arm cocking (ie. coming down on shoulder, about to release) and the instant of maximum compressive force during arm deceleration (ie. the follow through). Kinetic data from this study supports the idea that most overuse injuries occur at these instants within the pitching motion (Fleisig et al., 1995).

Another study identified the motions of the wrist and related these to those of the shoulder together with total body motion (Pappas et al., 1995). The authors believed that, once these motions were identified, proper pitching techniques could be developed. Furthermore, this information might help to evaluate, prevent and rehabilitate after injury (Pappas et al., 1995). A computerised hand and wrist motion analysis system was modified to evaluate and identify the wrist kinematics during the pitching cycle. A wrist goniometer with software was developed to record both flexion/extension (ie. movement of the palm towards inside of wrist and outside the wrist) and radial/ulnar deviation arcs (ie. movement towards the thumb and little finger). The system consisted of a glove that attached to a processing module. Data was collected via the glove and converted into data points which represented the wrist position relative to time. Preliminary data was collected on 5 right-handed professional pitchers during 1992. Graphs of the wrist position versus time were produced for each pitch. The motion versus time changes were consistent for most pitches. Four phases of motion of the wrist were identified: cocking, acceleration, deceleration and recovery. The wrist motions were also found to correlate with those of the shoulder.

During pitching, the shoulder must be flexible and stable. There is a delicate balance between functional mobility and stability of the shoulder, therefore making it prone to injury when stressed by high demands, and/or poor technique (Jobe et al., 1988). Over-demand and overloading of pitching can lead to injury and inflammation of many muscles in the shoulder. Shoulder pain is a common complaint among pitchers in baseball and softball. Pitchers incurring repeated minimal injuries can suffer chronic shoulder pain, commonly referred to as overuse injuries. Overuse injuries are thought to be caused by large forces and torques (ie. rotary forces) that occur at the shoulder and elbow joints during pitching (Fleisig et al., 1995). Overuse shoulder injuries in baseball and softball pitchers can result in a reduction in the performance of their pitching. A loss of playing time or hindrance to their career can also result if they require significant rest, rehabilitation or surgery (Johansen et al., 1995; Pappas et al., 1985). Conditions such as inflammation and tendinitis, if left untreated, can lead to major problems such as injuries of the muscles involved in rotating the shoulder (ie the rotator cuff). A shoulder that is pushed to its limits without proper warm-up, conditioning or throwing mechanics will eventually breakdown from overuse (Jobe et al., 1988).

6.2.2 Stretching and Strengthening Programs

It has been commonly assumed that fast-pitch softball pitchers do not suffer from pitching injuries because they pitch underarm. A study of 24 elite fast-pitch softball pitchers, however, found that they suffered from many injuries, mainly to the arm and mostly whilst pitching (Loosli et al., 1992). The main cause was due to pitchers routinely pitching for

numerous innings in games and practices. At the time, no investigation had been conducted into preventive strategies for pitching injuries. Changes in the nature and amount of pitching undertaken by players, achieved by specific strength and endurance training programs, were suggested. Similar factors were also considered by Braybon (1989) in her study on throwing pain in the shoulders of female softball players.

Injuries to the shoulder muscles and joints are also common in young baseball players. Jobe et al. (1988) stated that the best preventative or early treatment available is repair of the musculoskeletal damage. This consists of a specific strengthening programme geared towards the muscles involved in rotating the shoulder.

Pappas et al. (1985) discussed a rehabilitation and conditioning program that looked at the flexibility and dynamic muscular balance around the shoulder. The authors recommended that after a rehabilitation program, players should partake in a conditioning/strengthening program. They also recommended that uninjured players should use a conditioning/strengthening program in the off-season to prevent shoulder pain.

Though many strength, stretching and rehabilitation methods have been described, Johansen et al. (1995) found that overuse injuries were still occurring. The pitching process tends to increase the external rotation and limit the internal rotation of the shoulder joint. Johansen et al. (1995) consequently devised a new stretching technique for the internal rotation of the shoulder which modified the traditional stretching methods. These authors claim that their modification to traditional programs should be an integral part of training and rehabilitation programs of any athlete requiring near maximal performance of the shoulder.

As indicated previously, pitching not only affects the shoulders; it can also affect the total body e.g. back, hip, knee, ankle (Pappas et al., 1985). This suggests that the whole body, and not just the shoulder, should be conditioned before play. Elbow injuries, especially in the child and adolescent baseball player, have been reported as the most frequent area to be injured (Wells and Bell, 1995). Overuse injuries related to the elbow are commonly referred to as "Little League elbow" and result from repetitive twisting on the elbow during overhead throwing (Wells and Bell, 1995). Young players who have just begun to pitch are inexperienced in proper pitching techniques. They are also still physically developing and are therefore at increased risk of "Little League elbow". Furthermore, severe injuries to young players could have long term effects as they are still physically developing (Wells and Bell, 1995).

Prevention of "Little League elbow" should involve pre-season stretching/strengthening programs, evaluation and correction of pitching techniques, limitation of the number of pitches made, along with education of coaches, parents and athletes on the condition (Wells and Bell, 1995).

The importance of stretching and strengthening programs in the prevention of pitching injuries to the shoulder and elbow has been stressed in many articles (Braybon, 1989; Walk et al., 1996). However, no studies that have formally evaluated the effectiveness of these programs were identified.

The Australian Baseball Association has also produced a series of posters title 'Better -up and stretching activities are displayed in detail (Australian Baseball Association, undated).

6.2.3 Rule changes

Changing the rules of the game can modify injury patterns. Some rule changes that have been suggested are abolishing sliding and restricting pitching time. Since sliding is an important element of the excitement of the game, rules abolishing sliding are unlikely to be acceptable.

It has been suggested that prohibiting base sliding would be an effective way of reducing sliding injuries. Some have indicated that this would cause resistance from fans and participants and players would find it unacceptable (Janda et al., 1990). There have also been some concerns voiced that abolishing sliding may cause an increase in collisions and associated injuries, as base runners would be forced to run through bases (Sendre et al., 1994).

Restricting pitching time in junior competition players is likely to reduce the risk of overuse injuries that may cause problems in later years (Kennedy & Fitzgerald, 1989). These restrictions are enforced in games in Australia. Baseball Australia has a policy for under age teams restricting the type of pitch and number of pitches to be thrown by youth players. This is an attempt to reduce adolescent overuse injuries due to pitching (Allingham, 1996). Recently introduced measures include rigid counts on under age players (U12 - 60 pitches, U14 - 80 pitches, U16 - 90 pitches and U18 - 100 pitches) in any one assignment (Flower, 1996). If a junior throws more than 20 pitches in a junior game he/she is not permitted to throw in Senior competition in the same day (Flower, 1996). Pitching time restrictions are also practised in the United States (Janda, 1990). Further research into the effects of rule changes is clearly required, to eliminate fears of changing the game without significant benefits, along with meeting the requirements of the players, supporters and umpires.

6.2.4 Warm-ups and Conditioning Programs

Good stretching programs before and after play, together with comprehensive conditioning and technique programmes before and during the season, are considered to be very important for conditioning a player's body to help prevent injury (Sports Medicine Australia, undated).

Laboratory studies have demonstrated that the mechanical properties of connective tissues can be altered in response to loading and that temperature variations can bring about changes in joint range of motion (Woo et al., 1990). In reviewing the literature, Best and Garrett (1993) claimed that warm-up prior to exercise, particularly before exhaustive exercise, will help to reduce the incidence and severity of musculoskeletal injuries.

Conditioning programs should involve exercises that develop flexibility, endurance and strength. Flexibility (stretching) will help players to avoid painful pulls to muscles and tendons. Endurance will help players to last through games without becoming exhausted and straining out-of-shape muscles. Strengthening in the off and regular seasons will

help players' bodies cope with playing in all games during the season (Croce, 1987). Particular reference must be made to the pitcher, who, as already stated has a strong chance of suffering from shoulder injuries.

A person who has undertaken little or no conditioning, or preparation, is more likely to be injured than one who has regularly exercised off the field and during the off season (Croce, 1987). Players should condition themselves so that they can become less susceptible to injuries. Stretching becomes more important as people get older as they tend to be less flexible than children.

The Victorian Baseball Association has produced comprehensive play books for Clubs which provide warming up and stretching techniques (Flower, 1996). There have been no published evaluations of the role of warm-up and conditioning programs specifically for preventing baseball or softball injuries.

6.2.5 Recommendations for Further Implementation, Research and Development

- Coaches should conduct pre-season stretching/strengthening programs.
- Coaches should evaluate and correct the pitching techniques of their players
- Coaches should limit the number of pitches per week for each player.
- Coaches should limit the number of pitches thrown by an individual player and enforce rest periods between pitching sessions, particularly for junior players.
- Information about warm-up, cool-down and stretching techniques specifically for baseball and softball should be developed and widely promoted to improve specific knowledge of techniques.
- Players should undertake pre-season stretching/strengthening programs to assist in the prevention of overuse injuries associated with pitching.
- Further basic scientific research into the mechanisms of overuse injuries should be undertaken.
- The effectiveness of stretching and strengthening programs to prevent overuse injuries to the shoulder and wrist needs to be evaluated.
- More research into the role of warm-up as an injury prevention measure for baseball and softball is needed.
- Research should be undertaken into the benefits of different types of warming-up, cooling-down and stretching practices.
- Research into the optimal duration and frequency of warm-up should be undertaken.

6.3 Protective Equipment

Direct contact by the ball is the most frequent cause of death and serious injury in baseball especially to children 5 to 14 years old (Kyle et al., 1996). Some preventive

measures that could be adopted to protect young players from direct ball contact are: batting helmets and face protectors; use of a catcher's helmet, mask, chest and neck protectors; protective screening of dugouts and benches; using softer balls; and wearing eye protectors on helmets or goggles for fielders to reduce risk of eye injury from balls (Committee of Sports Medicine and Fitness, 1994).

It has been suggested that, when batting, young children should wear gloves because being hit by a ball in the fingers could damage soft tissues and bones (Kennedy and Fitzgerald, 1989). Kennedy and Fitzgerald (1989) also recommended groin protectors for boys and breast protection for girls to prevent serious bruising when batting.

6.3.1 Chest Protectors

Some of the most severe and frequent baseball injuries are the result of ball impacts to the chest. The CPSC has identified that 56% of all deaths to children aged 5-14 years during 1973-1995, resulted from a ball impact to the chest (Kyle et al., 1996). Upper trunk impacts accounted for 3% of the 88,700 estimated emergency room-treated ball impacts in 1995 (Kyle et al., 1996). To reduce the severity of the ball impacts, and hence reduce the incidence of chest related fatalities and injuries, chest protectors have been recommended (Kyle et al., 1996). Chest protectors are produced in two styles: a small 6 by 6 inch polyethylene square intended to protect the heart from ball impacts, and a high density plastic foam vest intended to protect the heart, as well as the rib cage and other vital organs.

In regard to the efficacy of chest protectors, there has been a series of three articles, which is particularly relevant (Viano et al., 1992a, 1992b; Janda et al., 1992).

Firstly, Viano et al. (1992a) conducted a review of the baseball deaths in children to identify the mechanisms of injury. This review found that baseball impacts occurred most often to batters, pitchers and catchers in organised play. In most cases, the impact was to the anterior chest wall, though some occurred to the back and throat. The authors concluded that it would be difficult to prevent many chest injuries in recreational games as the players were unlikely to wear protective gear. However, in organised games, coaching advice about protective gear could be provided to players. It was also concluded that there is an underestimation of the frequency of chest-impact injuries, as only children presenting at emergency departments are reported to the CPSC.

Viano et al. (1992a) also considered that the velocity of impact loading to the chest needs to be reduced to prevent fatal chest injuries. The authors reported that wearing energy-absorbing chest padding could reduce the energy transfer to the chest if it did not also increase the energy absorbed by soft tissue. The padding could therefore distribute the impact force over a broader area of the chest, thereby dissipating it (Viano et al., 1992a).

Viano et al. (1992b) tested these contentions by further exploring the mechanism of death from baseball chest impacts in children. They used an animal model. While the literature identified many possible mechanisms for fatality due to blunt impact to the chest, these authors, wanted to create a model of paediatric chest injury. The authors justified their choice of the pig model by claiming that its thoracic geometry and internal organ size are similar to that of a child. The swine was restrained and fitted into a nylon sling so that it

could be rotated into a vertical position exposing its chest. Various medical devices were used to monitor and collect information (e.g. blood samples). A pneumatically powered tube was used to throw a standard baseball towards the chest at a speed of 95 mph. The study found that baseball impacts at 95 mph caused repeatable arrhythmias (ie. heartbeat irregularities) and traumatic apnea (ie. interruption of breathing patterns). In most cases, the swine died except when given ventilatory support throughout the test.

In a similar study, Janda et al. (1992a) evaluated protective sporting equipment claimed to prevent child chest impact fatalities by means of a non-living laboratory model of chest impact scenario. In this study, pigs, a 6 year old child dummy and a Hybrid III female dummy were used in the impact tests. The impact tests involved using a standard baseball used as a control and various softer core baseballs on both protected and unprotected chests. Protected chests were covered by various vests and foams. The impact test on the animal model caused death when a standard hard ball and generic closed-cell foam chest protector were used. With the softer core baseball, death also occurred when no chest protector was used. Reduced chest deformation was observed with the child crash dummy when chest protectors were used. However, similar or increased values for force and momentum transfer were found when three different chest protectors and a softer core baseball were used. Impact studies comparing the softer core baseballs and regular baseballs showed little protective benefit associated with the softer core balls. The authors also found that commercially available chest protectors showed little protective effect. They concluded that closed cell foam protection may contribute to impact injury (Janda et al., 1992a).

These above three studies were the only published papers that the CPSC review identified which concluded that the protective equipment tested was ineffective and might increase the risk of injury (Kyle et al., 1996). Because such a finding could have profound implications for the design and promotion of protective equipment, and because some of the information presented by the articles was in a specialised technical area, the CPSC commissioned a review of the articles by six experts (Kyle et al., 1996).

The reviewers considered that the 95 mph ball speed used was probably too high, because it was greater than that possibly received by a child on the field, despite there being no evidence of actual child pitching speeds (Kyle et al., 1996). This speed is also reported to be well above the speed estimated in most of the baseball related concussion of the heart deaths.

The reviewers also felt that concussion of the heart may be simply related to the timing at which the baseball hits the chest in relation to the cardiac cycle, and that the force of the impact may not be as important (Kyle et al., 1996). In relation to the use of swines as models, the reviewers felt that they were placed in unnatural positions, which may have influenced variables such as heart rate and blood pressure and the animal's impact tolerance. Another problem identified was the fact that the study also used repeated blows to the chest of the animals, allowing cumulative damage, which is not representative of a single blow from a baseball. Furthermore, the authors replaced the stiff chest structure of the child dummy with a crushable styrofoam padding claiming it was representative of the resistance of the body (Janda et al., 1992a). However they provided no justification for this alteration. In relation to the third model, (ie. a hybrid III, fifth percentile female dummy), the reviewers believed that the observed increase in

viscous criterion with one of the softer baseballs tested may have been statistically significant. However, the authors had presented no statistical analyses of their data and provided insufficient information in their reports for the reviewers to determine this. Furthermore, the reviewers had considerable doubt about the reliability of the viscous criterion as a measure of risk of heart concussion in youth baseball (Kyle et al., 1996).

Overall, the reviewers concluded that the biological and biomechanical models used to mimic chest impact deaths in children were not accurate representations of the way deaths occurs to children on the baseball field (Kyle et al., 1996). The CPSC's review panel was also unable to determine if chest protectors were effective in preventing deaths from chest impacts as it was unknown how baseball impacts to the chest actually cause death. They therefore concluded that the effect of any equipment on the risk of chest impact death remains impossible to determine at this time.

In response, Janda et al (1996) indicated that the velocity of 95mph was chosen because it produced a fatal arrhythmia with the greatest consistency. Also the speed of the ball may not necessarily be the result of pitching, but rather the speed of a hit ball. Janda et al (1996) also considered their models were appropriate replicas of a child, as no specific child replica exists at this time. Furthermore, given that different models were used, the similarity of results added credence to their conclusions.

6.3.2 Helmets and Face Guards

Ball impact injuries to the head/neck accounted for 54% of ball impact injuries and approximately 47,900 emergency room treated injuries in 1995 in the United States (Kyle et al., 1996). Ball impacts to the head also account for 21 deaths during 1973-1995 (Kyle et al., 1996). Ball impacts to the face are estimated to make up 37% of the total baseball related injuries for 1995. Of these 74% resulted from being hit by a ball, 19% from being hit by a bat, and 7% from collisions with another player or object (Kyle et al., 1996). On the basis of these sorts of figures it is recommended that players wear helmets with face guards.

Face guards on batters' helmets are intended to protect the batters face from being hit by the ball (Kyle et al., 1996). The CPSC review identified no published scientific studies reporting that batters wearing a helmet with a face guard did not suffer facial injuries (Kyle et al., 1996). They also reported that face guards which met the voluntary standard would be effective in preventing facial injuries (Kyle et al., 1996). The standard requires that the face guard must be able to prevent a ball travelling at 67 mph from touching the face of a test dummy wearing a helmet with face guard.

In Victoria, double eared batting helmets are required to be worn by all players and bat-boys in the Baseball Junior league (Flower, 1996). Others are required to wear single ear helmets. Children participating in the under 12 and under 14 leagues are required to wear a batting helmet with chin straps. It is also compulsory for catchers to wear helmets with masks during the game and also during warm-up pitches.

6.3.3 Protective Eye Wear

Data from the CPSC, as shown that baseball ranks with basketball, hockey, football and racquet sports as one of the leading causes of sports-related eye injuries in the United States (Walk et al., 1996). Approximately one-third of baseball eye injuries are from being struck by a pitched ball (Committee of Sports Medicine and Fitness, 1994). A 15 year Japanese study of eye injuries occurring in sport, found that flying balls were the cause of 86% of sporting related eye injuries (Tokuyama et al., 1992). This study also found that baseball, soccer, softball and tennis together, accounted for 90% of these injuries.

To protect players' eyes, the Sports Eye Safety Committee of the National Society to Prevent Blindness in the US recommends the use of batting helmets with polycarbonate faceguards, constructed to the United States standard F910, be used. These face guards cover the lower part of the face from the tip of the nose to below the chin. They also protect the teeth and facial bones (Committee of Sports Medicine and Fitness, 1994). The United States Academy of Paediatrics Committee on Sports Medicine and Fitness, also published recommendations in 1994 for preventing baseball and softball injuries in children aged 5 to 14 years. One of those recommendations was to encourage players to wear polycarbonate eye protectors on their batting helmets (Stenger, 1994). They further recommended that eye protectors should be especially required for anyone suffering an eye injury.

6.3.4 Other

To prevent abrasions and other injuries during sliding, some players may wear 'sliding pants'. These are shiny pants with a padded hip area. It is believed that they reduce the impact forces when the hip hits the ground (Allingham, 1996). The shiny surface ensures the shearing force is firstly dissipated between the outer pants and the skin (Allingham, 1996). The efficacy of these garments has not been objectively investigated. Other protective devices which have not been evaluated in the literature, but are considered to be important, include genital protection for males and mouthguards for dental protection.

6.3.5 Recommendations for Further Implementation, Research and Development

- Players should wear good quality, double eared helmets with face protectors.
- Players should wear energy absorbing chest padding when batting, pitching or catching to distribute any blows from a baseball impact over a broad area of the chest.
- Catchers should always wear shin protection, breast plate and a helmet with a mask and throat protection.
- Youth players, aged less than 19, should wear shin and knee protection.
- Male players should wear properly fitted genital protectors at all times in the field.
- Players should wear mouthguards to prevent dental injuries

- The evidence for other forms of protective equipment, rules and practices in the game seems to be largely anecdotal or based on convention. More developmental research into this is needed.
- Further detailed research into the mechanisms of ball-impact injuries, particularly to the chest, head and face should be undertaken.
- The epidemiology of ball-impact injuries should be closely monitored in relation to the use of protective equipment
- Further development of protective headgear and chest protectors needs to be undertaken.
- Appropriate models for the testing of protective equipment, particularly chest padding, need to be developed.
- The efficacy of 'sliding pants' should be formally evaluated.

6.4 Other Countermeasures

6.4.1 Modified Rules

When it comes to sports performance, children must not be thought of as little adults (Stanitski, 1988). Significant differences exist between child and adult athletes, and those interested in injury prevention must understand the difference (Meyers, 1993). Growth and maturation rates even amongst children, demonstrate marked variability along with concomitant gains in coordination and strength, flexibility, and endurance (Stanitski, 1988).

Tee ball, the modified version of baseball, has been developed for primary aged children. Its aim is to give children an introduction to the game and a chance to develop skills before progressing to more competitive levels. The game was introduced in Australia in the 70's and over 83% of Australian primary schools now include Tee ball as part of their physical education program (Aussie Sport, 1991).

Tee ball is played in almost the same way as baseball except that the pitcher is replaced with a rubber tee (Aussie Sport, 1991). The tee is placed in front of the batter and the batter hits the ball sitting on top of the tee. Additional modifications of the adult form of baseball include a smaller diamond, use of a rubber or synthetic ball, the batting tee is used and shoes with spikes are discouraged. Helmets are mandatory for batters and base runners and fielders should wear caps for sun protection.

Modified softball is also played in over 85% of primary schools in Australia (Aussie Sport, 1991). Modified softball resembles softball more closely than does the game of Tee ball because batters are required to hit a pitched ball. Again the field dimension, ball and bat are smaller than the adult game and helmets for batters and base runners must be worn at all times. The catcher must also wear a helmet, face mask with throat protector and a chest protector.

By gradually introducing and developing more formal skills, children's entry skills are far greater when they start to play with a harder ball at a more competitive level. This means

that they are more likely to catch the ball properly, avoid the ball more effectively when batting, and pitch the ball better, all of which help to avoid injury.

As already shown, overuse injuries to the shoulders can occur easily. It is important therefore that children and adolescents are taught the correct pitching technique as well as giving themselves appropriate rest periods.

6.4.1.1 *Recommendations for further implementation, research and development*

- Children should be encouraged to play Tee ball as a means of developing baseball and softball skills.
- Older children should participate in modified softball as promoted by Aussie Sports and the Australian Softball Federation.
- Child and adolescents should be taught correct pitching techniques and playing procedures, including limiting the number of pitches and taking appropriate rest periods.

6.4.2 Sliding Technique

Baseball players use sliding so that they can get to a base faster. Corzatt et al. (1984) defined it as the ability to sprint along a base path and suddenly convert a vertical body to a nearly horizontal one (Corzatt et al., 1984). There are two styles of sliding, head-first and feet-first (Corzatt et al., 1984). Feet-first seems to be the most common type of sliding used by players.

An indepth investigation of the mechanics of head-first and feet-first sliding identified four phases of sliding: 1) sprint to base, 2) attainment of sliding position, 3) airborne phase and 4) landing phase (Corzatt et al., 1984). The study involved filming professional baseball players during a game and four players were filmed while trying to steal second base; 2 head-first and 2 feet-first. This allowed the authors to study the kinematics of each slide and the potential for injury.

Corzatt's (1984) study found that in the airborne phase of sliding, feet-sliders travelled further vertically than head-first sliders. As a result, the greater vertical displacement causes the slider to impact the ground with greater force. In the landing phase the feet-first sliders showed that the heel was making contact with the ground rather than the buttocks, thigh and lower back. This latter scenario increases the risk of serious injury due to the severe plantar flexion at the ankle. Examination of the head-first slides showed that players were actually making contact with their hands, rather than with their thighs and chest. Both sliding techniques showed a potential for injuries especially when the hands and feet are absorbing the force of the impact (Corzatt et al., 1984).

Coaches have been known to suggest to their players that when they forward slide they should put their hands in a fist or grab some dirt so that their hands are clenched instead of open when they impact with the base (Flower, 1996).

6.4.2.1 *Recommendations for further implementation, research and development*

- The relationship between different types of sliding techniques and injuries should be explored.
- Further studies into the biomechanics of sliding are needed to gain an understanding of different sliding techniques before introducing modifications.
- Players should be instructed to slide in the correct manner.

6.4.3 Education and Coaching

In Australia, it is not mandatory for all baseball and softball coaches to be accredited (Flower, 1996; Duyvestyn, 1996). As knowledge about injury prevention for baseball and softball develops, coaches need to be made aware of this. Coach education is vital to provide this information.

Coaches of baseball and softball are recommended to complete coaching courses which range from level 0 to level 3 organised by the National Coaching Scheme and also by the Aussie Sport Coaching Program. Coaching accreditation courses and yearly updates for those holding accreditation highlight protection measures (Flower, 1996).

Many impacts with a bat or ball, particularly in children, may be due to situations in practice where several balls are moving around the diamond during practice drills, and when play is unsupervised on the sidelines (Allingham, 1996). Children and inexperienced players cannot attend to multiple drill situations where as many as three or four balls may be moving around the diamond (Allingham, 1996). Insufficient coaching expertise or numbers of coaches may be a contributing factor.

The Amateur Softball Association of America (ASA) Junior Olympic coach development program teaches coaches various aspects of safety and injury prevention ie. proper stretching, proper intake of fluids, certain biomechanical teaching of softball fundamentals, etc (Porter, 1996).

6.4.3.1 *Recommendations for further implementation, research and development*

- Coaches should undergo regular re-accreditation and yearly updates.
- Coach education schemes should be updated regularly to ensure they provide the most up to date information about injury prevention.
- Children should not play softball or baseball unless they are supervised. This is particularly important when several balls are moving around at once.
- Instruction clinics for the wider community should be developed and widely disseminated.

- Education resources for informal baseball and softball need to be developed and disseminated.
- The best means of disseminating this information should be determined.

6.4.4 Playing Environment

Baseball and softball are played on an oval field of flat grass. The field is often used for more than one sporting activity and has little cover from the elements. Given this playing environment, it is not surprising that factors such as playing surface and weather can contribute to the risk of injury.

Baseball and softball are also often played in the summer months during which there is an increased risk of sunburn, skin cancer, dehydration, heat exhaustion and heat stroke.

No specific evidence of preventive measures in regard to climate-related baseball and softball injuries was identified by this review. Suggestions for injury prevention have been based on general thermoregulation recommendations, such as wearing appropriate clothing, using sunscreens, maintaining hydration and by undergoing a process of acclimatisation. Given the playing environment it is not possible to promote adequate shade (ie. trees or shade structures).

Also important in regard to the playing field is the need to eliminate the possibility of injury occurring due to potholes, sprinkler pop-ups and even the occurrence of rubbish on the field. This is particularly the case in situations where the field is used for more than one sporting activity and can often be used as a social arena.

There is a need to create and maintain a safe environment for players to reduce the risk of injuries. This includes keeping fields and facilities well maintained and padding walls and back stops (Janda, 1994). Fences, posts, etc should be padded in case players run into them while trying to catch the ball (Kennedy and Fitzgerald, 1989).

Recommendations have been made by a committee in the United States that protective fencing of dugouts and benches should be used to prevent players being hit by a ball (Stenger, 1994).

6.4.4.1 *Recommendations for further implementation, research and development*

- Drinking water should be provided at all baseball and softball events.
- Baseballers and softballers should ensure they drink adequate water, before and during games.
- Baseballers and softballers should always use a broad spectrum sunscreen and wear a hat and/or sunglasses when appropriate (eg. when in dugouts and on benches).

- Baseball and softball events should not be planned for times when there is a likelihood of extremely hot, humid conditions. Whenever possible, such events should also be cancelled if such weather conditions eventuate.
- Baseball and softball fields should be regularly checked and maintained to eliminate hazards such as potholes, sprinkler pop-ups, loose debris, rubbish, etc.
- Baseball and softball fields should have protective padding around fences and posts, which a player may collide with during play
- Protective screening should be used to protect players in dugouts and on benches.

6.4.5 First Aid and Rehabilitation

Injuries need to be properly managed to restrict the possibility of further damage. Overall, the treatment goals are pain relief, promotion of healing, decreased inflammation, and a return to functional and sports activities as soon as possible.

The Victorian Baseball Association now includes physiotherapists as an integral part of their official staff in all elite programs (Flower, 1996). Clubs are encouraged to have qualified sports trainers.

In the majority of collision type injuries, and some overuse injuries, this will mean rest, ice, compression, elevation and referral (RICER). RICER should be implemented for any ligament sprains, muscle strains and muscle haematomas (Sports Medicine Australia, undated).

Returning to play too early after injury can make the player susceptible to further injury. The coach should ensure that the risk of further injury is reduced. Concentration on muscle stretching exercise routines before play will assist in preventing injury (Sports Medicine Australia, undated). According to Powell et al. (1986), a previous injury may be more likely to re-occur because the original tissue, or the injury may not have healed completely. This leads to the conclusion that complete and controlled rehabilitation of an injury needs to be achieved, and sensible preventive precautions taken, before the person begins to play baseball or softball again. A rehabilitation programme cannot be regarded as having been completed until the athlete is free from pain. Muscle strength must have returned to about the pre-injury level and movement of the joints has recovered to pre-injury level.

6.4.5.1 *Recommendations for further implementation, research and development*

- Softballers and baseballers should seek prompt attention for their injuries from a person with first aid qualifications.
- Organisers of events should ensure that there are qualified first aid personnel at all events.

- Injured baseball and softball players should ensure that they allow enough time for adequate rehabilitation before returning to their pre-injury level of activity.
- Research into the effects of rehabilitation programs for softballers and baseballers needs to be undertaken.

7. CONCLUSION

This report has discussed the full range of injury prevention activities for preventing baseball and softball injuries. Recommendations for further countermeasure research, development and implementation have been based on the review presented here as well as discussions with experts acknowledged in this report.

Some of the recommended countermeasures have yet to be proven to be effective and more attention to controlled studies “in the field” are needed. More effort directed to basic scientific studies to better understand the biomechanics of baseball and softball, the mechanisms of injury and the role of various risk factors in causation are also required. Indeed, the evidence for the effectiveness of certain countermeasures such as warming-up, ball design, limiting the numbers of pitches and protective body padding remains equivocal.

In addition to the specific recommendations in this report, the following set of more general recommendations can be made:

- Improved data collection about the occurrence of baseball and softball injuries and their associated factors needs to be developed and maintained.
- Data collections should conform to guidelines for sports injury surveillance being developed and promoted nationally.
- Information about preventing baseball and softball injuries should be disseminated widely through baseball/softball broadcasts, baseball/softball equipment points of sale, baseball/softball magazines and more general magazines.
- A detailed epidemiological study of baseball and softball injuries in Australia should be undertaken to describe the injury profile amongst cases that do not present to emergency departments. This should also identify risk factors for injuries.
- Guidelines for minimum safety requirements for baseball/softball events (including the need for mobile phones, telephone contacts, first aid kits, etc) should be developed and widely disseminated.

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