ACB Injury Report 2001-02

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Cover photo: Steve Waugh strains his left calf whilst batting in the Ashes series

Summary

This report presents a summary and analysis of injuries occurring in Australian cricket at the state and national level over 7 seasons (1995-96 to 2001-02). The first three seasons were surveyed retrospectively, whilst the final four were surveyed prospectively. The survey definition of an injury was detailed and generally required the player to miss playing time in a major match. Average injury match incidence over the last 4 seasons varied from a low of 22.0 injuries per 10000 player hours in first class domestic matches to a high of 38.4 injuries per 10000 player hours in One Day Internationals. The average seasonal incidence was 19.3 injuries per squad (of 25 players) per season (of 20 matches). Injury prevalence (the percentage of players missing through injury at any given time) was 14.5% for pace bowlers, 3.7% for spin bowlers, 4.6% for batsmen and 1.5% for wicketkeepers. Compared to previous seasons, in season 2001-2002 there was a lower prevalence of injury than usual at international level (8.7% compared to 9.2%), but there was a higher prevalence than usual at domestic level (11.0% compared to 8.6%). Hamstring strains (10%), side strains (9%), groin injuries (7%), wrist and hand injuries (11%), lumbar soft-tissue injuries (7%) and medical illness (8%) were the most frequent injuries. Lumbar spine injuries (both stress fractures and other soft-tissue injuries) collectively accounted for the most missed player games. The greatest risk factors for bowling injuries that are immediately apparent are bowling speed and workload. Those bowlers rated as 'Fast' have the highest risk of bowling injury, 12 times higher than spin bowlers with the lowest risk. Bowlers who have bowled more than 20 first class or One Day match overs in the week leading up to a fixture have approximately twice the injury risk of those who have bowled less than 20 overs in the preceding week. Bowling workload particularly appears to be a risk for hamstring strains, side strains and shoulder injuries. A further risk for bowling injury is bowling second (i.e. batting first) rather than bowling first in a match, which may be due to either fatigue or lack of warm-up. In first class matches, bowlers in teams which bowled second had a 1.6 times greater risk of injury. In One Day matches, there was no disadvantage in bowling second in a day game, but a significant increase in risk in bowling second (i.e. at night) in a day-night game. An intervention recommended 2 seasons ago that was acted upon - replacing the boundary fence with a rope at all venues - has been successful to date at eliminating serious injuries from collisions with fences. A further recommendation (which has been followed in a less formal sense rather than legislated against) to reduce football cross-training drills has resulted in a reduction in these injuries last season. The focus on injury prevention in the medium term will be on bowling injuries in fast bowlers, including ongoing injury surveillance, an ongoing workload study and regular screening of all first class fast bowlers in Australia.

Introduction

Sports injury research and prevention has been recommended to follow a model of 4 stages [1].

Table 1 – Van Mechelen's recommendations for injury prevention

Stages of injury prevention
1. Identify frequency of common and serious injuries
2. Identify risk factors (both intrinsic and extrinsic) for the most common and serious injuries
3. Institute preventative programs based on modification of reversible risk factors
4. Monitor success of intervention with ongoing surveillance

This model is very similar to the approach used in general medicine for prevention of disease or illness (e.g. cardiovascular disease), and for prevention of motor vehicle accidents [2]. The model is costly but the paradigm has been successful in preventing illness in general medicine and road accidents, where the stakes are obviously high. Because of the costs involved, the 'Van Mechelen' sports injury prevention model is most easily applied at a professional level. Most professional sports have, in recent years, published epidemiological data in the scientific literature. Examples include reports from the AFL [3 4], the NFL [5], the Football Association (UK) [6], Major League Baseball [7], the NBA [8] and professional rugby league [9] and union [10 11] competitions.

To date the science of injury prevention in cricket is in its infancy, with very few proven risk factors and demonstrations of injury reduction [12]. There have only been few publications in the sports medicine literature regarding the epidemiology of cricket injuries, including the only publications in the medical literature of injuries to elite cricketers, from South Africa [13 14]. A summary of injury surveillance in Australian cricket taken from an earlier version of this report has recently been published in the *British Journal of Sports Medicine*, and is included as an appendix.

Cricket, however, is not the only sport that is in the early stages of injury prevention. A study analysing Major League Baseball insurance payments, published in 2001, stated that the amount of missed playing time through injury had steadily increased throughout the 1990s [7]. However, because there is no published injury data in the medical literature about the specific injuries and injury risks in Major League Baseball, the authors could give very little explanation as to the cause of the rise in injuries or suggestions to reverse it.

The major problem with not following the 'Van Mechelen' model is that any preventive work that is undertaken remains speculative. For example, Australian sports scientists have published world-leading research in the past on the likely relationship between a 'mixed' bowling action and lumbar spine injuries in fast bowlers [15-17]. Although most clinicians recognise that advising against a 'mixed' action is probably an important preventive measure, the actual contribution of this advice to prevention of injuries is hard to determine due to the paucity of past injury surveillance.

The ACB injury surveillance project

Injury surveillance in professional cricket in Australia has been prospectively undertaken continuously since the start of the 1998-99 season [18]. A previous study was attempted during the 1995-96 season at the ACB and state level. Data for seasons 1995-96 to 1997-98 has been retrospectively surveyed over the past 3 seasons using a number of different methods.

Methods

Definition of matches

This report covers injuries from the following cricket seasons:

Year	Season	Dates	Data collection
7	2001-02	October 2001 – June 2002	Prospective
6	2001	May 2001 – August 2001 (Ashes tour)	Prospective
6	2000-01	August 2000 – April 2001	Prospective
5	1999-00	August 1999 – April 2000	Prospective
4	1999	May 1999 – June 1999 (World Cup)	Prospective
4	1998-99	September 1998 – April 1999	Prospective
3	1997-98	September 1997 – April 1998	Retrospective
2	1997	May 1997 – August 1997 (Ashes tour)	Retrospective
2	1996-97	August 1996 – April 1997	Retrospective
1	1995-96	September 1995 – April 1996	Some prospective and some retrospective

Table 2 - Summary of seasons involved in survey

The Australian cricket team plays matches in each summer season, and occasionally plays matches in winter seasons on tours to England. Tours to countries other than England occur as part of the summer season, usually at either the start (August – October) or finish (February – April) of the season. State domestic cricket is not played in winter and follows a consistent timetable over summer from October to March each year.

The matches under consideration for this report are:

1. Test Matches (Australian team)
2. One Day Internationals (Australian team)
3. Pura Milk Cup (Sheffield Shield) matches (state teams)
4. ING/Mercantile Mutual One Day matches (state teams)

Although matches between touring international teams and regional teams are often first class fixtures, from the perspective of injury surveillance they are difficult to compare to other first class fixtures, as there is a much greater threshold for teams to 'rest' players with minor injuries. For this reason they are not included as major matches in this survey.

The length of matches (exposure time) was considered to be 6 hours for every day of actual play in first class matches and 6 hours 40 minutes for all One Day matches (unless abandoned without a ball being bowled). Therefore a 5-day Test match was considered to have been played over 30 hours, whereas a Test match lasting only 3 days was considered to have been played over 18 hours. This formula takes into account some of the variation in length of matches, but not all time lost through shortened play. It also does not take into account the fact that players who are on the batting team, but not currently batting, are not exposed to an injury risk during that time. Calculating exact exposure time for injury risk in cricket would be overwhelmingly complex.

Definition of teams

This survey covers the following teams:
(1) Australian team
(2) New South Wales state team
(3) Queensland state team
(4) South Australia state team
(5) Tasmania state team
(6) Victoria state team
(7) Western Australia state team

There are slight selection differences between first class and one day teams at national and state level. However, because no distinction is made between likely team selection when contracts are issued, the Australian team and state teams are considered to be single squads, rather than being split up into two sets of overlapping squads for one day and first class cricket.

The definition of a squad member is as follows:

For seasons 1998-99 onwards, a squad member is:
1. Any player under contract to the team in question.
2. Any uncontracted player who is selected to play in the team (including 12th man), from the time of his first game until the end of that season.
3. Any player chosen in an Australian touring squad, if uncontracted, is added to the Australian squad at the start of the tour

The definition of "until the end of that season" includes the Northern hemisphere season as being part of the previous Australian season (e.g. 1999 World Cup was considered part of the 1998-99 season). This is because player contracts are reviewed in the Australian winter.

For seasons 1995-96 to 1997-98, a squad member was:
1. Any player who was selected to play a match for that team over the entire season.
2. Any player who played for that team during the previous season, but was missing for the entire season due to a long-term injury or illness.

The definition is different prior to 1998 as this part of the injury survey was conducted retrospectively and there was a less formal system of player contracts, particularly at state level.

Definition of injuries

A reportable injury is any injury or illness which does *any* of the following:

1. **Affects the availability for selection of a team or squad member in a major match**
2. **Requires surgery at any stage of the year**
3. **Causes a team member to be limited in performance during a major match, including:**
    a. **to retire hurt from batting or bat with a runner**
    b. **to be absent from the field for greater than one hour**
    c. **to finish bowling due to injury before the end of a normal over**
    d. **preventing a bowler from being available to bowl for a least a session (in a first class match) or as many overs as required by the captain (in a one day match)**
    e. **preventing a regular wicketkeeper from playing in this position**

With respect to "affecting the availability for selection", this represents a 'Category 1' injury, according to the ACB guidelines for insurance claims. Australian players who miss state fixtures according to Category 2 (not injured, but not playing due to risk of developing injury through overuse) or Category 3 (player physically or mentally tired for which rest is beneficial) are not considered injured.

A player who makes himself available for selection, but not in his usual position, can be considered missing through injury if he is not selected. For example, an all-rounder who sustains a shoulder injury making him physically unable to bowl, but who is available to be selected as a batsman only, and who is not selected, is considered 'injured' rather than 'not selected'.

A player who was returning from injury in a lower grade was only considered 'unavailable' through injury for the higher grade if he was medically restricted in duties or length of playing time. As a general rule, a return from injury in the domestic first class competition meant that a player was also 'available' for a Test match, whereas a return in a two-day local match may not have. The team medical staff made the decision for a particular player as to whether his non-selection was due to 'injury' or simply due to not being picked.

The definition of an **injury recurrence** is:

A recurrent injury is one that had previously caused a player to miss game(s), then after recovering enough to allow his selection in a team then recurred forcing further game(s) to be missed. This is considered a second injury with respect to incidence. Any other injury (e.g. chronic condition) which has multiple exacerbations, but which does not cause missed games in the sequence described above, is defined as a single injury for statistical purposes.

Definition of injury rates

There are two major measures of injuries in a sport setting – **injury incidence** and **injury prevalence**.

Injury incidence analyses the number of new injuries occurring over a given time period, and was measured in two ways in this survey.

Injury match incidence considered only the number of injuries occurring during major matches, using 12 players (per team) and length of matches (in hours) in the denominator. The unit of measurement was *injuries per 10,000 player hours*.

Injury seasonal incidence considered the number of defined injuries occurring per squad per season. This took into account gradual onset injuries and training injuries as well as match injuries. A 'squad' was defined as 25 players and a 'season' defined as 20 matches (of either first class or one day variety) for the purposes of this calculation. Smaller or larger squads and longer or shorter seasons had the incidence adjusted so that rates between different squads and years could be compared. The unit of measurement was *injuries per squad per season*.

Injury prevalence considered the average number of *squad members* not available for selection through injury for each match divided by the total number of *squad members*. Injury prevalence was expressed as a *percentage*, representing the percentage of players missing through injury on average for that team for the season in question. It is calculated using the numerator of 'missed player games' as described above.

For the purposes of comparing bowlers to batsmen, a bowler was defined each season as a player who averaged more than 5 overs bowled in major matches during that season, or the season before. The inclusion of the "season before" in the definition of a bowler was to include players who had bowled in the previous season but were bowling less the following season due to injury. As a result of this definition, most "part-time" bowlers were defined as "bowlers".

Non-bowlers were subdivided into "wicketkeepers" and "batsmen", based on whether they kept wicket in at least 50% of games played during each season.

Bowlers were previously rated as "Fast", "Fast-medium", "Medium" or "Slow/spin" according to the player profiles in Allan's Cricket Annuals[19-21], although the profiles on the ACB website are now used.

Injury diagnosis was coded in a cricket-specific modification of the OSICS system, with similar diagnoses grouped together in 'injury categories'. Incidence and prevalence rates were reported for injuries overall and also for specific injury categories.

The ACB injury database and methods to ensure compliance

A database program written in Microsoft Access was developed by John Orchard with assistance from Barry Shimmin-Clarke (programming) and suggestions from various users. A paper sheet for data entry was initially circulated. All states and the Australian team now enter injury details into a database and record player status for each game in an Excel spreadsheet.

The primary recorder of injuries was the main team doctor at two states and the main team physiotherapist for four states and for the Australian team. Recorders were encouraged to enter all injuries that presented to medical staff for entry into the database. The survey injury definition (to separate 'significant' injuries from 'trivial' injuries) was made for the purposes of statistical comparison in this report.

The injury survey coordinator kept records of all matches played by squad members and ensured that each state provided an explanation to the survey whenever one of their players was not selected, in order to keep the spreadsheet results accurate. Codes were used to explain the common reasons for missing games: I (or a abbreviated diagnosis) – injured; A – unavailable due to Australian team commitments (for state squads); T – selected as twelfth man; N – not selected (including when rested); O – not available for other reasons (e.g. suspended or personal reasons).

Insurance forms completed by medical officers were cross-checked to ensure data was also entered as part of the survey. Media and web site reports were regularly checked by the injury survey coordinator as a way of prompting injury recorders to provide a diagnosis.

Method for retrospective injury surveillance

A variety of methods were used to retrospectively record injuries from the 1995-96, 1996-97 and 1997-98 seasons.

1. Team medical officials were asked to provide any historical records that they had available.
2. Records of matches played were obtained from ACB statistician Ross Dundas.
3. Injuries reported by the media in those seasons were generally recorded in Allan Miller's seasonal cricket annuals [19-21]. These reports were used to prompt team medical officials for recall.
4. Original data entry forms from Errol Alcott's surveillance in season 1995-96 were transferred to the new database.
5. Insurance records on file at the ACB were checked for payments made to players for missing matches through injury.
6. When the researched historical information was drafted, a printout of each player's injury history was checked by team medical officials.

After the procedure of retrospective reporting, it is considered that dataset of injuries from these years is highly accurate in the following circumstances:

1. For Australian team players, as injury history is better recalled and can be verified from a number of different sources.
2. For injuries that caused matches to be missed in state level players, the records were usually easily accessible.
3. For the 1995-96 season there was assistance with some prospective recording, which was added to using the methods described above.

With respect to minor injuries in state players in seasons 1996-97 and 1997-98 (those satisfying the injury definition but not causing missed games), the retrospective dataset may slightly under-estimate injuries. Cricket teams in Australia have been fortunate to have had good continuity of care, with the South Australian state team the only team which has not had continuous service from at least one member of the medical team over the six year period.

Results

Injury exposure from 1995-96 to 2001-02

Table 3 lists the number of matches per team per season, whilst Table 4 lists the number of players in each team squad per season and Table 5 the total number of player matches.

Table 3 - Team matches from 1995-96 to 2001-02

Team	Competition	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02
Australia	One Day Int.	17	27	25	33	27	26	18
	Test Match	6	15	9	12	13	13	9
New South Wales	ING Cup	6	6	8	8	7	11	11
	Pura Milk Cup	10	10	10	10	10	10	10
Queensland	ING Cup	7	7	8	7	8	10	11
	Pura Milk Cup	10	11	10	11	11	11	11
South Australia	ING Cup	6	5	7	7	7	10	10
	Pura Milk Cup	11	10	10	10	10	10	10
Tasmania	ING Cup	5	5	6	6	6	10	10
	Pura Milk Cup	10	10	11	10	10	10	11
Victoria	ING Cup	5	6	6	8	6	10	10
	Pura Milk Cup	10	10	10	10	11	11	10
Western Australia	ING Cup	7	7	7	6	8	11	10
	Pura Milk Cup	11	11	11	11	10	10	10

Table 4 – Squad numbers from 1995-96 to 2001-02

Squad	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02
Australia	18	29	30	31	30	32	30
New South Wales	26	29	26	30	32	30	35
Queensland	21	22	22	20	23	26	28
South Australia	18	22	27	31	23	23	27
Tasmania	17	18	18	21	20	27	28
Victoria	27	27	26	26	23	27	31
Western Australia	19	22	23	23	26	30	30

Table 5 – Player matches available from 1995-96 to 2001-02

Squad	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02
Australia	414	1218	1020	1327	1108	1153	748
New South Wales	416	464	468	510	504	566	664
Queensland	357	396	396	350	399	494	566
South Australia	306	330	459	465	387	413	530
Tasmania	255	270	306	303	308	475	566
Victoria	405	432	416	455	363	523	556
Western Australia	342	396	414	367	449	570	587

A technical point is that an uncontracted player who was added to a squad mid-season upon playing his first match was not considered to be at risk of missing this first game through injury (because he was only added to the squad on playing the game). These figures in Table 5 are used as the denominator in calculating injury prevalence, where injury prevalence is the number of player matches missed through injury divided by the number of player matches that players may have possibly played.

Injury incidence

Injury incidence results are detailed in Tables 6-8.

Injury match incidence in the units of injuries per 10000 player hours is higher in One Day matches than first class matches at both international and domestic levels. However, because first class matches are played over a much longer duration than One Day matches, they produce a higher number of injuries per match, even though the hourly rate is lower.

The matches with the highest incidence of injuries are One Day Internationals. The three seasons 1998-99 to 2000-01 yielded a particularly high rate of injury in One Day Internationals that were played in Australia in the Carlton and United tri-series during January and February. This coincided with a change in programming so that the One Day matches were played in a continuous block over a five week period after the Test matches had finished, whereas previously the One Day matches were mixed with the Test matches. However, this structure was maintained in 2001-02 and there was a low incidence of injury in this series.

It should be noted that Tables 6 and 7 reveal lower injury rates generally in the earliest 3 seasons. Some of this difference may be related to the lighter load of matches over this three year period (see Table 3). There is probably a significant methodological influence in that the injury surveillance for the earlier three seasons was retrospective. Whilst ever effort was made to gain an accurate historical picture, there were probably some 'minor' injuries that would have satisfied the survey definition that have been missed due to the retrospective nature of this surveillance.

The injury incidence of domestic first class matches and *away* Test matches is very similar, as is the injury incidence of domestic One Day matches and *away* One Day Internationals. The incidence of *home* Test Matches and One Day Internationals is higher than other matches. Whether this can be attributed to a more crowded schedule, harder grounds, or other factors, is not clear at this stage.

Table 8 lists the frequency of specific injury types and their onsets. Bowling injuries are far more common than batting or fielding injuries. The trunk/lumbar spine and groin/thigh regions are the most frequently injured body areas in bowlers in particular.

Injury prevalence

Injury prevalence rates (Tables 9-11) follow a similar pattern to injury incidence. The average injury prevalence was between 8% and 9% for all of the domestic matches and Test matches. One Day Internationals had an average injury prevalence of 9.7%, which was slightly higher in Australia (11.6%) than overseas (8.2%).

As expected, pace bowlers (14.5%) had a higher injury prevalence than spin bowlers (3.7%), batsmen (4.6%) and wicket-keepers (1.5%).

Table 6 - Injury match incidence 1995-6 to 2000-01 seasons (injuries/10000 player hours)

		1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	Last 4 years
Domestic One Day		18.9	11.4	19.5	32.5	23.9	30.8	15.4	25.1
First Class Domestic		17.3	11.7	18.1	23.2	18.9	17.6	28.6	22.0
State matches	Total	17.6	11.7	18.4	24.8	19.7	20.6	25.5	22.7
One Day International	Home	13.6	34.1	49.6	79.5	54.5	41.9	24.8	50.4
	Away	38.9	43.0	38.9	32.5	24.1	22.7	38.9	28.7
	Total	24.1	40.4	43.6	49.6	35.3	32.7	30.3	38.4
Test Match	Home	22.4	22.7	10.8	30.3	52.4	15.2	10.8	27.4
	Away		10.8	46.6	9.2	22.4	22.3	12.6	17.2
	Total	22.4	14.7	22.2	17.2	37.2	19.6	11.4	22.0
International matches	Total	23.1	23.1	30.8	30.4	36.5	24.1	17.7	27.9
All matches	Total	18.4	14.4	20.8	26.2	23.6	21.4	24.2	23.8

Table 7 - Injury seasonal incidence 1995-6 to 2000-01 seasons (injuries/team/season)

Squad name	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	Last 4 seasons
Australia	20.5	14.0	18.1	16.6	22.2	18.3	19.4	19.0
New South Wales	19.2	15.1	17.1	21.7	17.0	19.6	15.8	18.4
Queensland	11.2	16.4	21.5	17.3	25.2	16.3	17.7	18.9
South Australia	11.4	22.7	13.1	35.8	20.7	26.9	14.2	24.1
Tasmania	11.8	9.3	18.0	21.7	16.4	20.3	13.3	17.4
Victoria	18.5	11.6	18.0	17.6	30.6	19.2	21.6	21.7
Western Australia	2.9	15.2	14.5	19.2	20.1	10.6	17.0	16.3
All states	13.0	15.1	16.9	22.6	21.5	18.4	16.6	19.4
All teams	14.2	14.7	17.2	20.5	21.7	18.4	17.1	19.3

Table 8 – Injury incidence (frequency and percentage) by category and onset (1995-6 to 2001-02) overleaf

		Injuries in international and interstate matches							Other injuries	Total	
Body area	**Injury category**	**Batting**	**%**	**Bowling**	**%**	**Fielding**	**%**	**Keeping**		**All**	**%**
Head & neck	Fractured facial bones	3	4%			1	1%		3	7	1%
	Lacerations and other head injuries	7	10%			5	7%		4	16	2%
	Neck injuries	2	3%			1	1%		2	5	1%
Upper limb	Shoulder tendon injuries			11	7%	7	9%		17	35	5%
	Shoulder instability					1	1%		3	4	1%
	Upper arm fractures					1	1%			1	0%
	Elbow injuries					1	1%		2	3	0%
	Forearm fractures	2	3%			1	1%		2	5	1%
	Arm lacerations & haematomas	4	6%						1	5	1%
	Wrist and hand injuries	11	16%	3	2%	20	27%	3	33	70	11%
	Upper limb stress fractures			1	1%				1	2	0%
	Other upper limb injuries					1	1%		1	2	0%
Trunk & back	Side and abdominal strains			28	19%	4	5%		27	59	9%
	Rib fractures			3	2%				2	5	1%
	Other trunk injuries								1	1	0%
	Lumbar stress fractures			5	3%				14	19	3%
	Lumbar injuries (other than stress fractures)	1	1%	14	10%	2	3%	1	30	48	7%
Lower limb	Groin injuries	6	9%	12	8%	3	4%		26	47	7%
	Hamstring strain injuries	14	20%	17	12%	9	12%		24	64	10%
	Quadriceps strain injuries	3	4%	13	9%				11	27	4%
	Knee ligament injuries	1	1%	2	1%	4	5%		8	15	2%
	Knee cartilage injuries	2	3%	8	5%			1	29	40	6%
	Knee tendon injuries	1	1%	2	1%			1	13	17	3%
	Calf muscle strain injuries	2	3%	4	3%	3	4%		8	17	3%
	Leg stress fractures			4	3%				4	8	1%
	Lower limb fractures (not stress fractures)	2	3%			1	1%		4	7	1%
	Lower limb haematomas & lacerations	7	10%	2	1%	4	5%		6	19	3%
	Shin splints/compartment syndrome			1	1%					1	0%
	Ankle and foot sprains	1	1%	5	3%	5	7%		21	32	5%
	Heel and achilles injuries			7	5%	2	3%		11	20	3%
	Foot stress fractures			2	1%				5	7	1%
	Other lower limb injuries			1	1%				2	3	0%
Medical	Medical illness	3	4%	2	1%				46	51	8%
ALL		69	100%	147	100%	75	100%	6	358	655	100%

Body area	Injury category	Batsman		Keeper		PaceBowler		Spinner	
Head & neck	Fractured facial bones	3	0.0%			8		6	0.2%
	Lacerations and other head injuries	2				3	0.0%	1	0.0%
	Neck injuries					6	0.1%		
Upper limb	Shoulder tendon injuries	29	0.3%			137	1.4%	35	0.9%
	Shoulder instability					3	0.0%		
	Upper arm fractures					9	0.1%		
	Elbow injuries					28	0.3%		
	Forearm fractures	8	0.1%			5	0.0%	2	0.1%
	Arm lacerations & haematomas	1	0.0%						
	Wrist and hand injuries	66	0.7%	2	0.1%	57	0.6%	28	0.7%
	Upper limb stress fractures					8	0.1%		
	Other upper limb injuries					2	0.0%		
	Side and abdominal strains	14	0.1%			151	1.5%	6	0.2%
Trunk & back	Rib fractures					18	0.2%		
	Other trunk injuries					1	0.0%		
	Lumbar stress fractures	28	0.3%			157	1.6%		
	Lumbar injuries (other than stress fractures)	41	0.4%	2	0.1%	133	1.3%	1	0.0%
	Groin injuries	34	0.4%			119	1.2%		
Lower limb	Hamstring strain injuries	22	0.2%	9	0.5%	100	1.0%	9	0.2%
	Quadriceps strain injuries	16	0.2%	1	0.1%	51	0.5%		
	Knee ligament injuries	29	0.3%	3	0.2%	17	0.2%	30	0.8%
	Knee cartilage injuries	44	0.5%	8	0.4%	116	1.2%	1	0.0%
	Knee tendon injuries	6	0.1%	1	0.1%	33	0.3%		
	Calf muscle strain injuries	4	0.0%			15	0.1%	6	0.2%
	Leg stress fractures					53	0.5%		
	Lower limb fractures (not stress fractures)					47	0.5%	4	0.1%
	Lower limb haematomas & lacerations	2	0.0%			8	0.1%		
	Shin splints/compartment syndrome					1	0.0%		
	Ankle and foot sprains	36	0.4%	1		39	0.4%	6	0.2%
	Heel and achilles injuries	23	0.2%			45	0.4%	3	
	Foot stress fractures					38	0.4%		
	Other lower limb injuries	4	0.0%			4	0.0%		
Medical	Medical illness	20	0.2%	2	0.1%	47	0.5%	6	0.2%
TOTAL	*Missed games and percentage missing*	432	4.6%	29	1.5%	1459	14.5%	144	3.7%

Table 9 – Injury prevalence (missed games and percentage of players unavailable) by position (1995-96 to 2001-02) on previous page

Table 10 - Injury prevalence (percentage of players unavailable through injury) 1995-96 to 2001-02

Competition		1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	Last 4 seasons
Domestic one day		5.8%	8.1%	7.4%	7.1%	6.9%	8.0%	11.3%	8.7%
First class domestic		4.9%	8.0%	7.0%	6.6%	7.0%	9.2%	10.6%	8.5%
State	TOTAL	5.2%	8.0%	7.2%	6.8%	7.0%	8.6%	11.0%	8.6%
One day international	Home	6.7%	11.6%	8.2%	15.6%	12.3%	9.3%	9.2%	11.6%
	Away	4.8%	7.1%	16.0%	8.1%	6.9%	8.9%	10.0%	8.2%
	Total	5.9%	8.4%	12.5%	10.8%	8.9%	9.1%	9.5%	9.7%
Test cricket	Home	3.7%	6.9%	6.7%	8.5%	9.8%	14.4%	8.0%	10.1%
	Away		5.5%	13.3%	4.9%	9.4%	6.0%	4.8%	6.5%
	Total	3.7%	6.0%	8.9%	6.4%	9.6%	9.0%	6.8%	8.1%
International	TOTAL	5.3%	7.6%	11.6%	9.7%	9.1%	9.0%	8.7%	9.2%
All matches		5.2%	7.8%	8.5%	7.8%	7.7%	8.7%	10.6%	8.8%

Table 11 – Comparison of injury prevalence between states

Team	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	Last 4 seasons
Australia	5.3%	7.6%	11.6%	9.7%	9.1%	9.0%	8.7%	9.2%
New South Wales	8.7%	5.2%	9.2%	4.5%	5.0%	5.3%	6.5%	5.4%
Queensland	5.9%	18.4%	6.1%	4.0%	5.3%	9.0%	17.3%	9.8%
South Australia	6.2%	7.3%	7.6%	9.3%	9.6%	9.5%	14.7%	11.0%
Tasmania	2.4%	2.6%	8.5%	7.4%	6.2%	7.5%	9.2%	7.8%
Victoria	4.2%	7.6%	6.5%	7.9%	6.4%	13.8%	12.6%	10.6%
Western Australia	2.6%	5.6%	5.1%	7.4%	9.4%	7.1%	6.8%	7.6%
Average	5.2%	7.8%	8.5%	7.8%	7.7%	8.7%	10.6%	8.8%

Injuries that were more prevalent in bowlers included foot & ankle injuries, knee tendon injuries, lumbar soft-tissue injuries and stress fractures, shoulder tendon injuries and side strains.

There were no striking differences in injury prevalence between states over the six year period. Certain states had individual years in which injury prevalence was very high, usually due to a few players suffering long-term injuries that stopped them playing for the majority of the season.

Compared to previous seasons, in season 2001-2002 there was a lower prevalence of injury than usual at international level (8.7% compared to 9.2%) but a higher prevalence than usual at domestic level (11.0% compared to 8.6%).

Risk factors for bowling injury

As bowling was the activity most related to injury, various factors were further analysed to determine whether they were associated with risk of bowling injury at the end of season 2000-01. As many of the risk factors from this analysis were recently published in an article in the *British Journal of Sports Medicine*, this report shall use the same analysis. Further analyses of these risk factors shall be performed in future seasons, when more injury data and risk factors are available.

High workload

A comparison was made between the number of match overs bowled over various periods in the lead up to specific bowling injuries and the average number of overs bowled by uninjured players. The values for workload were obtained from a statistical database supplied by Ross Dundas. These figures do not take into account number of overs bowled during the match in which injury occurred. They only take into account players assessed as 'regular' bowlers (i.e. those that average more than 5 overs per match played).

Table 12 - Bowling match workload and risk of bowling injury

	Average match overs bowled in previous:			
Bowlers who suffered:	**Week**	**2 weeks**	**Month**	**3 months**
No injury	8	17	34	92
Hamstring injury	17	31	53	137
Quadriceps injury	10	21	39	87
Groin injury	7	16	44	137
Shoulder injury	17	31	58	185
Lumbar soft-tissue injury	10	25	42	124
Side strain	14	24	41	104
Other bowling injury	13	26	48	112

It can be seen that injured players had generally bowled more than non-injured players. Hamstring and shoulder injuries had the greatest correlation between high workload and likelihood of injury. The relationship between workload and specific

injury types is further explored below. In addition, a far more detailed workload study is in progress under the supervision of Rebecca Dennis, which assesses training workloads. This has a greater potential to prevent injury, as match workload is difficult to limit, but training workloads can be more easily manipulated.

Bowler speed

Table 9 shows that many bowling injuries are far more prevalent in pace bowlers (those of 'Fast', 'Fast-medium' or 'Medium' ranking) than spin bowlers. These include side strains, lumbar injuries (stress fracture and soft-tissue), lower limb muscle strains, knee cartilage injuries and foot and ankle injuries. Upper limb injuries, such as shoulder tendon injuries and wrist and hand sprains, are actually slightly more prevalent in spin bowlers. For the majority of trunk and lower limb injuries in bowlers, speed should be assessed as a potential risk factor. Generally, this is not a risk factor that a bowler would wish to reverse, as pace is one of the greatest weapons against batsmen. The rankings of speed are used at this stage as a general guide – in the future, more specific assessment of player speed should be made, in particular the components of the bowling motion that contribute to speed, and which of these also contribute to injury.

Location of match

Table 6 suggested that injuries were less likely on overseas tours than for matches in Australia. It is possible that Australian pitches are harder than most countries overseas, and that this may be a risk factor for injury. On the other hand, the fixtures are generally more crowded in the Australian summer than when players are on tour, and there is more pressure for Australian players to play and exert themselves in domestic matches than tour matches. It is very difficult to create an injury definition that allows an exact comparison between injury risk on tour compared to injury risk in Australia. Injury statistics from the AFL show that there is a higher risk for certain injuries in the Northern states of Australia [22]. The variation in ground conditions between states is much greater in the Australian winter than in summer.

Table 13 shows that potentially, some injuries such as quadriceps strains or lumbar soft tissue injuries may be related to ground hardness. These injuries are slightly more likely in the Northern States (Queensland, Western Australia, South Australia and New South Wales) than the Southern States (Victoria and Tasmania), and even less likely when playing out of Australia. The numbers of specific injuries are not great enough to date to be statistically significant. In future years of the injury survey, analysis between weather conditions and injuries will be undertaken to search for any correlation.

Table 13 - Match location and risk of bowling injury

Location:	Overseas	Australia	
Likelihood of:	All	South	North
No injury	98.0%	97.7%	97.3%
Hamstring injury	0.3%	0.4%	0.3%
Quadriceps injury	0.0%	0.1%	0.3%
Groin injury	0.0%	0.4%	0.2%
Shoulder injury	0.1%	0.0%	0.2%
Lumbar soft-tissue injury	0.1%	0.3%	0.2%
Side strain	0.1%	0.4%	0.6%
Other bowling injury	1.3%	0.7%	1.0%

Level of match

Table 14 reveals that the risk of bowling injury is not much different for games played at international level than domestic (state) level. This suggests that the differences in injury incidence and prevalence for the state and national teams may be primarily due to other factors, such as differences in workload. Shoulder tendon injuries showed a trend towards being more likely at international level.

Table 14 - Level of match and risk of bowling injury

	Level of play:	
Likelihood of:	National	State
No injury	97.4%	97.5%
Hamstring injury	0.3%	0.3%
Quadriceps injury	0.1%	0.2%
Groin injury	0.2%	0.2%
Shoulder injury	0.4%	0.1%
Lumbar soft-tissue injury	0.1%	0.2%
Side strain	0.4%	0.5%
Other bowling injury	1.1%	0.9%

Bowling first or second in a match and time of match

There is an apparent increase in risk for bowling injury for the team that bowls second (i.e. bats first) in a match. The figures from Table 15 correspond to a relative risk of 1.60 (95% confidence interval 1.04-2.46) for teams bowling second in a first class match. In One Day matches, there were more injuries on the teams bowling second in day-night matches only (RR 3.48, 95% CI 1.12-10.74). There were slightly more injuries in teams bowling first in daytime One Day matches but this was not statistically significant. These observations may be related to fatigue or lack of warm-up. At the start of a match, bowlers in the opening innings have plenty of opportunity to warm-up in the nets. When bowling in a subsequent innings, the bowlers potentially may have to bat immediately before they start bowling, without a warm-up. Perhaps bowlers are more likely to warm-up before the second innings of a One Day match if the match is played in the day rather than at night.

Table 15 - Bowling first or second and risk of bowling injury

Risk of bowling injury:	Bowl first	Bowl second
Day-night limited overs	0.8%	2.9%
Day limited overs	1.8%	0.9%
First class matches	2.8%	4.4%

Player age

Table 16 reveals that, somewhat surprisingly, there is no strong relationship between player age and injury risk. There is a well-known association between age and certain muscle strain injuries in football [4]. Perhaps speed is a confounding factor in cricket, as speed may be a risk factor for certain injuries, but bowlers may slow down slightly as they age in cricket.

Table 16 - Player age and risk of bowling injury

Bowlers who suffered:	Average age
No injury	27.4
Hamstring injury	27.5
Quadriceps injury	26.0
Groin injury	27.4
Shoulder injury	30.4
Lumbar soft-tissue injury	27.9
Side strain	26.0
Other bowling injury	27.2

Past history of injury

There is an apparent association between many cricket injuries and a past history of that injury, including muscle strains, knee injuries, shoulder tendon injuries and groin injuries. Some of these relationships will be explored further below.

With respect to side strains, there is neither a positive or negative relationship between past history of side strain injury and future injury. This is unusual, as most injuries have an increased likelihood if there is a past history of that injury. It is possible that there are two or more different varieties of side strain, and that certain side injuries have a likelihood of recurrence, but that other types of side strain have a negative correlation with future injury (i.e. once you have suffered that type of injury you are somewhat immune from recurrences in the future)

Side of body

Shoulder injuries, groin injuries and knee cartilage injuries are more likely on the bowling side of the body. Side strains, lumbar stress fractures and hamstring injuries are more likely on the non-bowling side of the body.

Table 17 - Side of injury occurrence for bowlers

Type of injury	Occurred on bowling side	Occurred on non-bowling side
Foot and leg stress fractures	3	5
Groin injuries	8	4
Hamstring strain injuries	6	12
Knee cartilage injuries	9	4
Knee tendon injuries	6	4
Lumbar soft-tissue injuries	4	8
Lumbar stress fractures	0	7
Neck injuries	2	0
Quadriceps strains	5	5
Shoulder injuries	17	3
Side and abdominal strains	7	34

Bowler biomechanics

It is highly likely that there are associations between bowler mechanics and risk of certain injuries. An assessment of these is beyond the scope of the injury surveillance project in its current form. It is highly recommended that further screening of elite pace bowlers is performed in the future and that biomechanical risk factors are correlated with injury outcomes to assess these risks.

Multivariate analysis for bowling injury during a match

Table 18 shows that when the above listed risk factors are considered together for all bowling injuries, the major risk factors for injury are bowler speed, high match overs in the previous week, number of days of play and bowling second (batting first) in a match. Bowler speeds were divided into ‘Fast’, ‘Fast-medium’, ‘Medium’ and ‘Spin’ depending on how players were rated in Allan’s Cricket Annuals. The risk of injury increases steadily over each of these categories. Bowlers who had bowled a high number of match overs in the week before a match (greater than 20) also had a significantly greater risk of injury. The increased risk of first class matches (according to number of days play) compared to One Day matches is essential due to increased exposure.

Table 18 - Logistic regression equations for risk of bowling injury

Match type	Variable		B	SE	Risk ratio	95% CI
ALL	High match overs previous week (>20)		0.65	0.20	1.91	1.28-2.85
	Bowling speed	Spin			1.0	
		Medium	1.15	0.51	3.16	1.17-8.55
		Fast-med	2.16	0.40	8.69	4.00-18.90
		Fast	2.50	0.42	12.19	5.36-27.70
	Days play	1			1.0	
		2	-0.03	1.03	0.97	0.13-7.20
		3	0.97	3.03	2.63	1.45-4.77
		4	0.80	0.21	2.23	1.49-3.34
		5	0.97	0.38	2.64	1.25-5.58
FIRST CLASS	High match overs previous week		0.60	0.245	1.81	1.12-2.93
	Bowling speed	Spin			1.0	
		Medium	1.13	0.61	3.1	0.94-10.23
		Fast-med	2.11	0.47	8.2	3.27-20.63
		Fast	2.58	0.49	13.2	5.02-34.73
	Bowling second		0.48	0.22	1.62	1.04-2.50
ONE DAY	High match overs previous week		0.84	0.36	2.30	1.13-4.70
	Bowling speed	Spin			1.0	
		Medium	1.18	0.92	3.27	0.54-19.70
		Fast-med	2.26	0.73	9.60	2.28-40.47
		Fast	2.28	0.72	9.77	2.06-46.26

Risk factors for specific bowling injuries

Multivariate (logistic regression) risk factors analysis was performed for the six most likely specific bowling match injuries (hamstring, quadriceps, shoulder tendon and side strains, along with groin injuries and lumbar soft-tissue (non-stress fracture) injuries. Groin and lumbar injuries did not have a high enough frequency to reveal any significant risk factors at this stage, however the other four injuries all revealed some significant risk factors according to logistic regression.

Hamstring injury

Hamstring injuries were related to high number of overs in the previous week and past history of hamstring injury.

Table 19 - Logistic regression equation for risk of hamstring injury while bowling

Injury type	Variable	B	SE	Risk ratio	95% CI
Hamstring strain	High match overs previous week (>20)	1.26	0.53	3.54	1.25-9.98
	Past history of hamstring injury	1.15	0.52	3.15	1.14-8.72

Quadriceps strain injury

Quadriceps strains were more likely in first class matches in the early (spring) months of the cricket season, and in players with a past history of quadriceps strain.

Table 20 - Logistic regression equation for risk of quadriceps injury while bowling

Injury type	Variable	B	SE	Risk ratio	95% CI
Quadriceps strain	Past history of quadriceps injury	1.75	0.70	5.78	1.46-22.88
	Early (spring) months of season (August-November)	1.43	0.65	4.19	1.17-15.02
	First class match (compared to One Day)	4.19	0.80	4.47	0.93-21.45

Shoulder injury

Shoulder injuries were more likely in players who had bowled a high number of overs in the previous three months (greater than 180 match overs), and those with a past history of shoulder injury.

Table 21 - Logistic regression equation for risk of shoulder injury while bowling

Injury type	Variable	B	SE	Risk ratio	95% CI
Shoulder injury	High match overs previous 3 months (>180)	2.40	0.83	10.97	2.15-56.00
	Past history of shoulder injury	1.96	0.83	7.12	1.40-36.36

Side strain injury

Side strains were more likely in players who had bowled more than 20 overs in the previous week, and were strongly related to bowling speed. Although a common injury in fast bowlers, the pathology in side strains is not well understood. There may be more than one type of side strain, with various sub-types having different risk factors.

Table 22 - Logistic regression equation for risk of side strain while bowling

Injury type	Variable		B	SE	Risk ratio	95% CI
Side strain	High overs previous week (>20)		0.97	0.43	2.65	1.15-6.10
	Bowling speed	Spin				
		Medium	1.63	1.22	5.12	0.47-56.28
		Fast-med	2.40	1.03	11.07	1.48-82.96
		Fast	2.77	1.07	16.00	1.98-129.20
	First class match (compared to One Day)		0.96	0.45	2.61	1.09-6.29

Risk factors for non-bowling injuries

It was reported 2 seasons ago that there were two injury mechanisms that 'stood out' as being potentially immediately preventable, in that risk factor studies were not needed because they are obvious. There were a number of injuries that occurred between 1995-96 and 1999-00 from sliding into the boundary fence, and it was felt that these could be prevented by instituting a boundary rope at all grounds. In baseball and softball, the use of slide-away bases has been shown to lower the rate of serious ankle injury [23]. The boundary rope policy was instituted at all grounds in the early stages of season 2000-01. There were no significant injuries from fence or rope collision in 2000-01 or 2001-02, indicating that this policy has been successful to date.

A number of injuries have occurred from football cross-training drills and these could be prevented by substituting other less dangerous drills as cross-training activities. At the 2000 conference in Melbourne, vigorous debate was entered into regarding the feasibility of eliminating football drills from the cross-training regime of elite cricket players. Some fitness personnel felt that it was very difficult to avoid monotony in cricket training and that the benefit of occasionally including touch football or

soccer games in the training regime outweighed the negative of injury risk. It was left to the individual discretion of fitness advisers as to whether to continue these drills. There were further incidents of football-related injuries in season 2000-01, including one season-ending injury, although there was only one significant football injury in 2001-02. This policy should be further reviewed for the upcoming season.

Discussion

Comparison with other reported injury rates

The reported injury incidence is low compared to other professional sports, reflecting that cricket is a relatively safe game, and is played over a long duration. For example, the injury prevalence in cricket at slightly less than 9% overall is a lower figure than has been previously reported in the football codes in Australia (15% AFL, 16% first grade rugby league, 13% state rugby union) [24]. There is also a factor that there was a strict injury definition for this survey. The frequency of players receiving physiotherapy treatment for 'minor' injuries that do not affect their ability to participate would be substantially higher than the rates reported in this survey. However, it would be harder to monitor changes in injury rates because of the difficulty in setting standards of reporting for 'niggling' injuries.

Injury prevalence did not vary much between the seasons surveyed prospectively and retrospectively, suggesting that the retrospective methodology was accurately able to ascertain games missed through injury. Injury incidence (particularly seasonal incidence) was lower in the years surveyed retrospectively, which is probably best explained by an under-reporting of minor injuries in those years. The potential deficiencies in retrospective methods may not be acceptable if these years included in a paper submitted to a scientific journal. Despite the methodological concerns, the largest increase in risk after season 1998-99 was seen in home One Day Internationals, suggesting that there has been an increase in risk since the summer timetable has changed to separate the Test and One Day series. This is probably not an irreversible increase, as it is likely to be related to the high workload that players undergo playing in back-to-back Test matches and then immediately progressing to the One Day series. If coaches, players and fitness advisers are made more aware of this as a potentially high-risk period, then caution can be exercised and hopefully the injury incidence and prevalence kept under control.

The approximately 4% overall injury prevalence in batsmen and spin bowlers is an acceptable figure and, in general, all that is required is further monitoring of this rate to see that it does not increase over time.

It is not surprising that wicketkeepers (<2%) had the lowest overall injury prevalence. This may be explained by the lack of sprinting and long throwing in the field, the total lack any bowling whatsoever and the reluctance of wicketkeepers to miss games when carrying minor injuries for fear of 'losing' their position in the side.

The 14.5% injury prevalence in pace bowlers requires further study of risk factors for injuries, in the hope that some injuries may be prevented in the future. Injuries that particularly need further study are side strains, hamstring and groin injuries, shoulder

tendon injuries and stress fractures. The planned screening and workload studies of pace bowlers are to be encouraged.

An injury surveillance system has recently been implemented at the provincial and international level in South Africa, according to recent presentations [25] and published papers [13 14]. It is pleasing to report that the detail of this Australian report compares favourably to the South African publications, although the injury profile is very similar. The account of injuries in elite South African cricketers[13 25] listed the following profile of injuries: of 163 injuries, the most common areas injured were hamstring (20), fingers (18), lumbar spine (17), knee (8), ankle (8), heel (8) and ribs (6). Previous injury surveillance reported from South Africa has reported a 'seasonal injury incidence' rate of 72/100 players per season at provincial level [26]. This is the equivalent of 18 injuries per team per season in this study (as a squad was defined as being 25 players). The rate for the six seasons studied in Australia was 17.5 per team per season, which is very similar to this South African study, even though the methodology is not directly comparable. A previous report of the injury rate in first class Australian cricket was an incidence of 333/10000 player hours [27], which is higher than the injury match incidence of this report, although the injury definition was different. The South Africans reported that bowling injuries (40.5%) were more common than fielding (25.6%) and batting (21.5%) injuries, similar proportions to our study. It is hoped that further countries will conduct and publish results of future injury surveillance for comparison, and that similar methodology is used to allow comparison to be made.

In Australia at the amateur level, cricket is a common source of presentation with injury to an emergency department. Cricket accounts for 7.3% and 3.7% of adult and child sporting presentations to emergency departments in Australia, making it the fifth and eighth most frequent sport presenting [28]. The high number of presentations reflects more cricket's popularity as a participant sport rather than any inherent danger of the activity. Previous comparisons in South African cricket has found that schoolboys and club cricketers have lower injury incidences than elite cricketers [26 29].

Lumbar spine injuries in bowlers

It has been previously reported that fast bowlers undergo accelerated degeneration of the lumbar spine over the course of their career [17].

This report confirms that in terms of missed playing time, lumbar spine injuries extract the greatest toll on bowlers. Stress fractures, particularly of the pars interarticularis of L4 and L5 on the non-bowling side, are the largest culprits in terms of specific diagnosis. There are many other lumbar injuries that are caused by multiple pathologies. Disc degeneration and prolapses represent another large category, although the diagnosis is often unclear even with MRI scanning. Disc pathology in fast bowlers would be almost ubiquitous in an elite fast bowler, making it hard to use judge the relevance of various lesions on an MRI scan at the time of acute pain.

As part of planned future screening in Australia, it is planned that all elite fast bowlers will have a yearly MRI scan of the lumbar spine to track changes over time.

Studies have previously associated a 'mixed' action with the development of lumbar spine injuries [15-17]. There is still no published data to show that coaching intervention can prospectively lower the lumbar stress fracture risk for a player. The most difficult confounder to take into account is bowler speed. Speed is probably a risk factor for injury, although counter-rotation of the shoulders does not appear to be an important contributor to development of speed in studies published to date [30].

Side strain injuries in bowlers

Side strains appear to be a unique type of muscle strain. Firstly they are unique to fast bowlers in cricket and javelin throwers, who use a somewhat similar technique. Secondly, they appear to affect a very high percentage of fast bowlers at least once at some stage of their career. Thirdly, they do not appear to have a high recurrence rate over the course of a bowler's career, as most other muscle strains exhibit.

They occur on the non-bowling side of the body and the majority are strains of abdominal muscle insertions on to the lower ribs. Bony stress lesions can occur. There is a school of thought that a side strain is almost a 'rite of passage' for an elite fast bowler that is almost certain to occur once in his playing career and is thereafter unlikely to return. Although recurrences over a bowler's career are not excessively common, they can and do occur. It is quite likely that there are different varieties of side strain within the overall category, and that some of these varieties are highly recurrent and/or related to overuse, whereas others are related to speed and/or are a one-off injury.

It has been a difficult process to try to establish a radiological register of side strains, because most imaging is still done only on hard copy with single films. Efforts must be made to try to collect and publish a large case series of side strains with imaging using MRI and/or CT scan and/or bone scans.

Shoulder injuries in bowlers

Shoulder injuries are another common problem in bowlers, almost always involving the shoulder of the bowling arm. Tendon pathology, particularly of the rotator cuff tendons, is the most common diagnosis. Shoulder tendon injuries are one of the few injuries that are more common in spin bowlers than pace bowlers. High workload over a number of months appears to be a risk factor for shoulder tendon injuries. Shoulder instability may be a contributing factor in some cases, but is notable as being rare as a diagnosis in isolation. Shoulder instability affects throwing as much as bowling, although with respect to shoulder injuries in bowling, it is often difficult to determine the relative contribution of instability and overuse tendinopathy. The bowling action, as opposed to throwing, does not put the shoulder into the apprehension position for anterior instability. Although comparative figures are not available, the relative incidence of shoulder injuries in elite baseball pitchers would be expected to be higher than in bowlers.

Upper body contact injuries

Hand injuries are common in cricketers at all levels [31]. Belliappa reported that most injuries in amateur players occur during fielding, but that batting injuries increase in proportion as the level of play increases. This is probably due to superior fielding skills of elite players, plus the increased speed of balls that must be faced when batting. Although hand injuries are common and the odd forearm fracture occurs, the rates are not high enough to suggest that poor protective equipment is being worn by batsmen at the elite level, or that fielders should wear more protective equipment.

Muscle strain injuries

Hamstring, quadriceps, calf and adductor strains all affect cricketers, including bowlers, fielders and batsmen, whilst running between the wickets. All muscle strains appear to affect both sides of the body without absolute discrimination.

Adductor strains and other groin injuries may be related to preferred "turning side" when running between the wickets and this area could be studied further.

Previous studies have suggested that hamstring injuries may be related to relative weakness [32-36]. Although this research is not conclusive, the high rate of hamstring strain in cricketers (batsmen, bowlers and fielders) would make study of hamstring strength a relevant risk factor.

Hamstring injuries appear to be related to high workload in the short-term, whereas quadriceps strains are more common early in the season and may be related to harder and drier grounds, as has been noted in the AFL [4].

Knee injuries

Knee injuries do occur in cricketers, but fortunately not to the extent of dominating the injury lists as they do in many other sports. Knee cartilage problems are one of the few serious injuries that tend to affect wicketkeepers, perhaps due to the stress of prolonged squatting.

Knee ligament injuries are uncommon, although a few may occur during football cross-training drills. This has in fact happened on over ten occasions in the last six seasons. Although this is not a common injury mechanism, these were often serious injuries, often resulting in surgery (particularly to the knee). Injuries during touch football, soccer or Australian Rules games are preventable injuries for cricketers and perhaps these drills should be foregone and replaced by alternate sports with low injury risk, such as volleyball and water polo.

It is interesting to note that the South African injury surveillance reported that three players suffered injuries playing football (soccer) as part of cross-training [25].

Injuries from contact with boundary fences

An uncommon but potentially preventable injury mechanism has been ankle and shin injuries caused whilst sliding into the fence whilst trying to prevent a boundary when fielding. There were two significant long-term injuries caused by this mechanism over the five years 1995-96 to 1999-00. Over that time period there were five other injuries caused by collision with the boundary fence, although two occurred overseas and two in grade cricket, and none of these had serious consequences. A recommendation to replace all boundary fences with ropes was made prior to the 2000-01 season and acted upon. Over the next two seasons there were no significant injuries arising from collisions with fences or ropes, indicating initial success of this policy.

Conclusions

1. Injury prevalence (the percentage of players missing through injury at any given time) is 14.5% for pace bowlers, 3.7% for spin bowlers, 4.6% for batsmen and 1.5% for wicketkeepers. Lumbar spine injuries (both stress fractures and other soft-tissue injuries) collectively accounted for the most missed player games in pace bowlers. The greatest risk factors for bowling injuries that are immediately apparent are bowling speed and workload. Those bowlers rated as 'Fast' have the highest risk of bowling injury, 12 times higher than spin bowlers with the lowest risk. Bowlers who have bowled more than 20 first class or One Day match overs in the week leading up to a fixture have approximately twice the injury risk of those who have bowled less than 20 overs in the preceding week. Monitoring of bowling workloads at all states has commenced and should be continued as a high priority.
2. A further risk for bowling injury is bowling second (i.e. batting first) rather than bowling first in a match, which may be due to either fatigue or lack of warm-up. In first class matches, bowlers in teams which bowled second had a 1.6 times greater risk of injury. In One Day matches, there was no disadvantage in bowling second in a day game, but a significant increase in risk in bowling second (i.e. at night) in a day-night game.
3. The focus on injury prevention in the medium term should be on bowling injuries in fast bowlers, including ongoing injury surveillance, an ongoing workload study and regular screening of all first class fast bowlers in Australia. This includes all pace bowlers having their exact workload monitored and an annual biomechanical assessment, lumbar spine MRI and other risk factors screening at the Australian Institute of Sport in Canberra.
4. At the ACB Forum immediately preceding the 2000-01 season, it was recommended that all major grounds in Australia have a boundary rope rather than use the fence as a boundary. Prior to this, there had been two major ankle injuries (and five other minor injuries) over five seasons caused by collisions with the fence whilst fielding. Although this was a small number, it was foreseen that this could be reduced almost to zero by institution of ropes at all playing grounds in Australia. This action was implemented with great success over the short-term.
5. The small but serious incidence of knee injuries occurring in football cross-training drills was enough to recommend at the 2000 Forum that these drills only be undertaken with great caution. Some delegates felt that a total ban was appropriate, whereas others felt that the benefits of touch football as a cross-training tool outweighed the risks. Despite the discussion, injuries to cricketers playing football (including one serious injury) continued to occur in season 2000-01, although there were only minor injuries from playing football in 2001-02. Cricketers do need variety in their training, but alternatives to football, with a lower injury risk, such as volleyball, could be used instead.

Attached in the appendix are two papers recently published in the *British Journal of Sports Medicine* arising from this injury surveillance project. With publication in a major international scientific journal, the ACB research team has now set a standard for injury surveillance in cricket worldwide.

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ORIGINAL ARTICLE

Injuries in Australian cricket at first class level 1995/1996 to 2000/2001

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Objective: To describe and analyse injuries and illness occurring in Australian cricket at first class level.

Methods: Injuries occurring to the state and national teams were surveyed prospectively between the seasons 1998/1999 and 2000/2001, and the three preceding seasons were surveyed retrospectively. The definition of an injury was detailed and generally required the player to miss playing time in a major match.

Results: Average injury match incidence in the seasons studied prospectively varied from a low of 19.0 injuries per 10 000 player hours in first class domestic matches to a high of 38.5 injuries per 10 000 player hours in one day internationals. The average seasonal incidence was 19.2 injuries per squad (25 players) per season (20 matches). Injury prevalence (the percentage of players missing through injury at any given time) was 14% for pace bowlers, 4% for spin bowlers, 4% for batsmen, and 2% for wicket keepers. The most common injuries were hamstring strains, side strains, groin injuries, wrist and hand injuries, and lumbar soft tissue injuries. Bowlers who had bowled more than 20 match overs in the week leading up to a match had an increased risk of sustaining a bowling injury (risk ratio 1.91, 95% confidence interval (CI) 1.28 to 2.85). A further risk for bowling injury is bowling second in a match—that is, batting first (risk ratio 1.62, 95% CI 1.04 to 2.50). A risk factor for injury in fielding is colliding with the boundary fence.

Conclusions: Further study is required to determine ways to minimise the risk of injury in fast bowlers. Cricket grounds should mark a boundary line on the playing field to prevent players colliding with fences in the field.

For one of the world's most popular team sports, there have been relatively few publications in the medical literature on cricket injuries.[1] Many of the previously published epidemiological data on cricket injuries, particularly at the elite level, have come from South Africa.[2–7]

In Australia at the amateur level, cricket injuries are common, probably reflecting the popularity of the sport rather than the relative danger. Cricket accounts for 7.3% and 3.7% of adult and child sporting presentations to emergency departments in Australia, making it respectively the fifth and eighth most common sport presenting.[8]

Lumbar stress fractures of the pars interarticularis are known to have a particularly poor prognosis in fast bowlers in cricket, and these injuries have previously been researched in detail.[9–13] Other specific body areas affected by cricket injuries that have been reviewed are the shoulder[14] and the hand.[15]

The aims of this study are to present a profile of injuries in Australian cricket at the elite level between the seasons 1995/1996 and 2000/2001, and to present a preliminary analysis of some of the risk factors for injury.

METHODS

The Australian cricket team plays matches in each summer season (October–March) and occasionally in winter seasons on tours to England. Tours to countries other than England occur as part of the summer season, usually at either the start (August–October) or finish (February–April) of the Australian season. First class cricket is not played in Australia in winter.

The matches under consideration over the study period were all Test matches and one day international matches involving the Australian team, and all Pura Milk Cup (Sheffield Shield) and ING-Mercantile Mutual Cup (one day) matches involving the six Australian state teams.

The length of matches (exposure time) was considered to be six hours for every day of actual play in first class matches and six hours 40 minutes for all one day matches (unless abandoned without a ball being bowled). Therefore a five day Test match was considered to have been played over 30 hours, whereas a Test match lasting only three days was considered to have been played over 18 hours. This formula takes into account some of the variation in length of matches, but not all time lost through shortened play. It also does not take into account the fact that players who are on the batting team, but not currently batting, are not exposed to an injury risk during that time. Calculating exact exposure time for individual players in cricket would be overwhelmingly complex.

The prospective component of this study started in the 1998/1999 season, at the same time that the Australian Cricket Board (ACB) and state teams instituted a standard system for contracting first class players on an annual basis. The cohort under surveillance from seasons 1998/1999 onwards was:

- any player under contract to one of the teams;
- any uncontracted player who was selected to play in one of the teams (including 12th man), from the time of his first game until the end of that season;
- any uncontracted player chosen for an overseas touring squad.

For seasons 1995/1996 to 1997/1998, the cohort for each season was retrospectively defined as:

- any player who was selected to play a match for that team over the entire season;
- any player who had played for that team during the previous season, but was missing the entire current season because of a long term injury or illness.

A survey injury was defined as any injury or illness to which any of the following applied:

(1) it affected the availability for selection of a player in a major match;

(2) it required surgery at any stage of the year;

(3) during a major match:

(a) it caused a batsman to retire hurt or bat with a runner;

(b) it caused a fieldsman to be absent from the field for more than one hour;

(c) it caused a bowler to finish bowling because of injury before the end of a normal over;

(d) it prevented a bowler from being available to bowl for at least a session (in a first class match) or as many overs as required by the captain (in a one day match);

(e) it prevented a regular wicket keeper from fielding in this position.

The reason for using the broader statement "affecting the availability for selection" rather than simply "missing a match because of injury" is the nature of the various roles in cricket. Occasionally, a bowler or all-rounder is unable to bowl but makes himself available for selection (or plays at a lower level) as a batsman only. In these situations the player may have still played in a match on a given date, but was suffering from an injury that had ruled him out of contention for playing at a higher level.

The definition of an injury recurrence was one that had previously caused a player to miss game(s), then, after it had recovered enough to allow the player's selection in a team, it recurred requiring further game(s) to be missed. This was considered a second injury with respect to incidence. Any other injury—for example, a chronic condition—that had multiple exacerbations but did not cause games to be missed in the sequence described above was defined as a single injury for statistical purposes.

Injury incidence analyses the number of new injuries occurring over a given time period, and was measured in two ways.

Injury match incidence considered only the number of injuries occurring during major matches, using 12 players (per team) and length of matches (in hours) in the denominator. The unit of measurement was injuries per 10 000 player hours.

Injury seasonal incidence considered the number of defined injuries occurring per squad per season. This took into account gradual onset injuries and training injuries as well as match injuries. A squad was defined as 25 players, and a season as 20 matches (of either first class or one day variety) for the purposes of this calculation. The incidence was adjusted for smaller or larger squads and longer or shorter seasons so that rates between different squads and years could be compared. The unit of measurement was injuries per squad per season.

Injury prevalence considered the average number of squad members not available for selection through injury for each match divided by the total number of squad members. Injury prevalence was expressed as a percentage, representing the percentage of players missing through injury on average for that team for the season in question. It is calculated using the numerator "missed player games" as described above.

For the purposes of comparing bowlers with batsmen, a bowler was defined each season as a player who averaged more than five overs in major matches during that season or the season before. The inclusion of the "season before" in the definition of a bowler was to include players who had bowled in the previous season but were bowling less the following season because of injury. As a result of this definition, most "part time" bowlers were defined as "bowlers".

Non-bowlers were subdivided into "wicket keepers" and "batsmen", based on whether they kept wicket in at least 50% of games played during each season.

Bowlers were rated as "fast", "fast-medium", "medium", or "slow/spin" according to the player profiles in Allan's Cricket Annuals.[16–20]

Injury diagnosis was coded in a cricket specific modification of the OSICS system,[21 22] with similar diagnoses grouped together in injury categories. Incidence and prevalence rates were reported for injuries overall and also for specific injury categories.

A database program written in Microsoft Access was developed for entry of injuries as part of this survey and distributed to all states. The primary recorder of injuries was the main team doctor at two states and the main team physiotherapist for four states and for the Australian team. The injury survey coordinator kept records of all matches played by squad members and ensured that each state provided an explanation to the survey whenever one of their players was not selected.

A variety of methods was used to retrospectively record injuries from the 1995/1996, 1996/1997, and 1997/1998 seasons.

(1) Team medical officials were asked to provide any historical records that they had available.

(2) Records of matches played were obtained from the Australian Cricket Board (ACB).

(3) Injuries reported by the media in those seasons were generally recorded in Allan Miller's seasonal cricket annuals.[17–19] These reports were used to prompt team medical officials for recall.

(4) Data from a previous attempt at starting injury surveillance during the 1995/1996 season were used.

(5) Insurance records on file at the ACB were checked for payments made to players for missing matches through injury.

(6) When the researched historical information was drafted, a printout of each player's injury history was checked by team medical officials, who in all but one state had remained constant since the 1995/1996 season.

Injuries that occurred during bowling were analysed further with respect to risk factors. Multivariate analysis of bowling injury risk was undertaken with a forward stepwise logistic regression procedure using the SPSS program (SPSS Inc, Chicago, Illinois, USA).

RESULTS

Tables 1 and 2 detail injury incidence. Table 1 includes a separate column to show only those seasons surveyed with a prospective methodology. Table 2 lists the frequency of specific injury types and their onsets. Bowling injuries are far more common than batting or fielding injuries. The trunk/lumbar spine and groin/thigh regions are the most commonly injured body areas in bowlers in particular.

Injury seasonal incidence was 17.5 injuries per squad per season over the six seasons, and 19.2 injuries per squad per season for the three seasons surveyed prospectively. There was a very similar seasonal injury rate for both the Australian and state squads, with the Australian team seasonal incidence being 17.5 (18.2 for the prospective seasons) and the average state incidence being 17.6 (19.2 for the prospective seasons).

Injury prevalence rates (table 3) follow a similar pattern to injury incidence, with the major exception of lumbar stress fractures, an uncommon injury but which accounts for a large proportion of missed playing time in bowlers because of its severity. The average injury prevalence (in units of percentage of players missing through injury) was 7% for the domestic matches. One day internationals had an average injury prevalence of 10%. Injury prevalence was higher in pace bowlers (14%) than spin bowlers (4%), batsmen (4%), and wicket keepers (2%).

The injury prevalence rates for the seasons surveyed prospectively and retrospectively were similar, with an average

Table 1 Injury match incidence in the seasons 1995/1996 to 2000/2001 (injuries/10 000 player hours)

	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01	All years	Last 3 years
Domestic one day	18.9	11.4	19.5	32.5	23.9	30.8	23.8	29.3
Domestic four day	17.3	11.7	18.1	22.5	17.6	17.0	17.3	19.0
Domestic (state) matches								
Total	17.6	11.7	18.4	24.2	18.6	20.1	18.4	21.0
One day international								
Home	13.6	34.1	49.6	68.1	54.5	41.9	44.7	54.5
Away	38.9	43.0	38.9	32.5	24.1	22.7	33.3	27.3
Total	24.1	40.4	43.6	45.4	35.3	32.7	38.1	38.5
Test match (five day international match)								
Home	22.4	22.7	10.8	30.3	52.4	15.2	25.8	34.4
Away		10.8	46.6	9.2	22.4	17.8	17.3	16.1
Total	22.4	14.7	22.2	17.2	37.2	16.8	21.4	23.7
International matches								
Total	23.1	23.1	30.8	28.7	36.5	22.2	27.6	29.2
All matches								
Total	18.4	14.4	20.8	25.4	22.8	20.6	20.4	22.9

Table 2 Injury incidence (frequency and percentage) by category and onset (1995/1996 to 2000/2001)

		Injuries in international and interstate matches					
Body area	Injury category	Batting	Bowling	Fielding	Keeping	Other injuries	Total injuries
Head & neck	Fractured facial bones	1 (2)		1 (2)		3	5 (1)
	Lacerations and other head injuries	4 (7)		2 (3)		2	8 (2)
	Neck injuries	2 (4)		1 (2)		2	5 (1)
Upper limb	Shoulder tendon injuries		8 (6)	5 (8)		16	29 (6)
	Shoulder dislocations and subluxations			1 (2)		3	4 (1)
	Elbow injuries			1 (2)		2	3 (1)
	Forearm fractures	2 (4)		1 (2)		2	5 (1)
	Arm lacerations & haematomas	3 (5)				1	4 (1)
	Wrist and hand injuries	8 (14)	3 (2)	17 (28)	1	27	56 (11)
	Upper limb stress fractures		1 (1)			1	2 (0)
	Other upper limb injuries					1	1 (0)
Trunk & back	Side and abdominal strains		26 (21)	3 (5)		16	45 (9)
	Rib fractures (traumatic and stress)		2 (2)			1	3 (1)
	Lumbar stress fractures		4 (3)			10	14 (3)
	Lumbar injuries (other than stress fractures)	1 (2)	10 (8)	2 (3)	1	27	41 (8)
Lower limb	Groin injuries	5 (9)	10 (8)	2 (3)		21	38 (7)
	Hamstring strain injuries	12 (21)	15 (12)	9 (15)		20	56 (11)
	Quadriceps strain injuries	2 (4)	11 (9)			5	18 (3)
	Knee ligament injuries		1 (1)	3 (5)		8	12 (2)
	Knee cartilage injuries	2 (4)	7 (6)		1	21	31 (6)
	Knee tendon injuries	1 (2)	2 (2)		1	11	15 (3)
	Calf muscle strain injuries	2 (4)	3 (2)	2 (3)		7	14 (3)
	Leg stress fractures		4 (3)			4	8 (2)
	Lower limb fractures (not stress fractures)	1 (2)		1 (2)		3	5 (1)
	Lower limb haematomas & lacerations	7 (13)	1 (1)	4 (7)		4	16 (3)
	Shin soft tissue overuse injuries		1 (1)				1 (0)
	Ankle and foot sprains		5 (4)	4 (7)		13	22 (4)
	Heel and achilles injuries		7 (6)	1 (2)		9	17 (3)
	Foot stress fractures		2 (2)			2	4 (1)
	Other lower limb injuries		1 (1)			1	2 (0)
Medical	Medical illness	3 (5)	2 (2)			38	43 (8)
All		56 (100)	126 (100)	60 (100)	4	281	527 (100)

Values in parentheses are percentages.

injury prevalence for all players of 7.8% for the entire study and 8.1% for the seasons surveyed prospectively.

Table 4 shows that the major risk factors for injury are bowler speed, high number of match overs in the previous week, number of days of play, and bowling second (batting first) in a match. Bowlers who had bowled a high number of match overs in the week before a match (more than 20) also had a significantly greater risk of injury. The increased risk in first class matches (according to number of days played) compared with one day matches in the initial analysis is essentially due to increased exposure.

There were two unusual injury mechanisms which appear to be preventable without further risk factor or intervention studies being required. Seven injuries occurred between 1995/1996 and 1999/2000 from players colliding with the fence when sliding to field the ball, and it was felt that these could be prevented by using a boundary rope. In baseball and softball, the use of slide away bases has been shown to lower the

Table 3 Injury prevalence (missed games and percentage of players unavailable) by position (1995/1996 to 2000/2001)

Body area	Injury category	Batsman		Wicket keeper		Pace bowler		Spinner	
Head & neck	Fractured facial bones	3	0.0%					6	0.2%
	Lacerations and other head injuries					1	0.0%		
	Neck injuries					6	0.1%		
Upper limb	Shoulder tendon injuries	25	0.3%			73	0.9%	35	1.1%
	Shoulder dislocations and subluxations					3	0.0%		
	Elbow injuries					28	0.3%		
	Forearm fractures	8	0.1%			5	0.1%	2	0.1%
	Arm lacerations & haematomas	1	0.0%						
	Wrist and hand injuries	34	0.4%			46	0.5%	26	0.8%
	Upper limb stress fractures					8	0.1%		
	Side and abdominal strains	3	0.0%			124	1.5%	6	0.2%
Trunk & back	Rib fractures (traumatic and stress)					13	0.2%		
	Lumbar stress fractures	9	0.1%			126	1.5%		
	Lumbar injuries (other than stress fractures)	39	0.5%	2	0.1%	121	1.4%	1	0.0%
	Groin injuries	30	0.4%			87	1.0%		
Lower limb	Hamstring strain injuries	18	0.2%	9	0.6%	85	1.0%	5	0.2%
	Quadriceps strain injuries	5	0.1%			50	0.6%		
	Knee ligament injuries	29	0.4%	3	0.2%	16	0.2%	29	0.9%
	Knee cartilage injuries	36	0.5%	8	0.5%	70	0.8%	1	0.0%
	Knee tendon injuries	6	0.1%	1	0.1%	29	0.3%		
	Calf muscle strain injuries	4	0.1%			14	0.2%	6	0.2%
	Leg stress fractures					53	0.6%		
	Lower limb fractures (not stress fractures)					40	0.5%	4	0.1%
	Lower limb haematomas & lacerations	2	0.0%			5	0.1%		
	Shin soft tissue overuse injuries					1	0.0%		
	Ankle and foot sprains	14	0.2%			34	0.4%	5	0.2%
	Heel and achilles injuries	20	0.3%			42	0.5%		
	Foot stress fractures					34	0.4%		
	Other lower limb injuries					4	0.0%		
Medical	Medical illness	16	0.2%	2	0.1%	42	0.5%	5	0.2%
Total		302	4.0%	25	1.6%	1160	13.7%	131	4.0%

incidence of serious ankle injury.[23] We noted this mechanism before the start of the 2000/2001 season, and, as a result, the ACB instituted a policy to use a boundary rope (well inside the fence) to mark the playing field limits at all grounds. There were no significant injuries from fence or rope collision in 2000/2001, indicating that this policy has been successful at preventing injuries in the preliminary stages.

Eleven injuries occurred during football activities undertaken as part of cross training drills (usually supervised by team staff); some were serious knee injuries.

Table 4 Logistic regression analysis of risk of bowling injury

Match type	Variable		B	SE	Risk ratio	95% CI
All	High match overs previous week (>20)		0.65	0.20	1.91	1.28 to 2.85
	Bowling speed	Spin			1.0	
		Medium	1.15	0.51	3.16	1.17 to 8.55
		Fast medium	2.16	0.40	8.69	4.00 to 18.90
		Fast	2.50	0.42	12.19	5.36 to 27.70
	Days played	1			1.0	
		2	−0.03	1.03	0.97	0.13 to 7.20
		3	0.97	3.03	2.63	1.45 to 4.77
		4	0.80	0.21	2.23	1.49 to 3.34
		5	0.97	0.38	2.64	1.25 to 5.58
First class	High match overs previous week		0.60	0.245	1.81	1.12 to 2.93
	Bowling speed	Spin			1.0	
		Medium	1.13	0.61	3.1	0.94 to 10.23
		Fast medium	2.11	0.47	8.2	3.27 to 20.63
		Fast	2.58	0.49	13.2	5.02 to 34.73
	Bowling second		0.48	0.22	1.62	1.04 to 2.50
One day	High match overs previous week		0.84	0.36	2.30	1.13 to 4.70
	Bowling speed	Spin			1.0	
		Medium	1.18	0.92	3.27	0.54 to 19.70
		Fast medium	2.26	0.73	9.60	2.28 to 40.47
		Fast	2.28	0.72	9.77	2.06 to 46.26

DISCUSSION

The reported injury incidence and prevalence are low compared with other professional sports, reflecting that cricket is a relatively safe game and is played over a long duration. For example, the injury prevalence in cricket at 8% overall is lower than previously reported for elite football competitions in Australia (15% Australian football, 16% first grade rugby league, 13% state rugby union).[24]

Injury prevalence did not vary much between the seasons surveyed prospectively and retrospectively, suggesting that the retrospective methodology used accurately ascertained games missed through injury. Injury incidence (particularly seasonal incidence) was slightly lower in the years surveyed retrospectively, which suggests an inability to retrospectively uncover all details of minor injuries in those years.

The injury definition, like many others in the sports medicine literature, is somewhat cumbersome. A recent argument has been made to simplify the definition of an injury in team sports, for example to define an injury simply as "a condition that causes a player to miss a match".[25] Our definition incorporates this component, but also adds extra possible criteria for an injury, which were considered necessary because of the length of a cricket match and the multiple roles that players may have during a game. A further definition that may be contested is the use of the value of 12 players in the denominator for injury exposure, as each team contains 12 players. However, only 11 fieldsmen and 2 batsman (13 players out of 24) are exposed to injury at any given time. It is hoped that, at future cricket conferences and scientific meetings, a standard international injury definition and methods for calculating incidence can be agreed upon and published.

The 4% overall injury prevalence in batsmen and spin bowlers is an acceptable figure, and, in general, all that is required is further monitoring of this rate to see that it does not increase over time. Wicket keepers (2%) had the lowest overall injury prevalence. This may be explained by the lack of sprinting and long throwing in the field, the total lack of any bowling whatsoever, and the reluctance of wicket keepers to miss games when carrying minor injuries for fear of "losing" their position in the side.

The 14% injury prevalence in pace bowlers requires further study of risk factors, in the hope that some injuries may be prevented in the future. The most important potentially reversible risk factor is bowler workload. The sporting activity most similar to bowling is pitching in baseball, for which workload is monitored much more closely than bowling.

More study is required to determine why bowlers are more likely to be injured when their team is bowling second in a match. Before the start of the first innings, bowlers will warm up in the nets, whereas in subsequent innings they may start bowling immediately after batting. If further analysis showed that there was an increase in injury shortly after the start of the second innings, then a case could be made to allow bowlers a short warm up period between innings.

Injuries to bowlers that particularly need further study are side strains, hamstring and groin injuries, shoulder tendon injuries, and stress fractures. Side strains appear to be unique to bowlers. They occur on the non-bowling side of the body and most are strains of abdominal muscle insertions on to the lower ribs. Sometimes the diagnosis is believed to be a rib stress fracture rather than a muscle strain.

Knee ligament injuries are uncommon in cricket and in fact in this study were most likely to occur in cricketers playing football as part of cross training drills. An injury surveillance study of cricket in South Africa reported that three players suffered injury by a similar mechanism.[26] If cricketers were not allowed to include football in their training, these injuries may be prevented, but this suggestion has not been welcomed as it is a fairly ingrained tradition, particularly on long international tours.

Take home message

Fast bowlers have the highest risk of injury in cricket. Bowlers are more likely to be injured when undertaking high workloads and when bowling second (after batting). Cricket grounds should use a boundary rope or line inside the fence to mark the playing field.

Ankle and shin injuries caused by sliding into the fence while trying to prevent a boundary when fielding can be prevented by using a rope or marked line rather than a solid fence to signify the edge of the field.

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COMMENTARY

The authors of this injury survey should be congratulated on producing such a comprehensive retrospective and prospective analysis of injury in cricket. Cricket is generally looked upon as a safe sport, but clearly, from this study, it can be seen that this is not the case for fast bowlers, who are more at risk of injury than state rugby union players even.[1] As the authors state, further investigation into the causative factors is required; such studies are currently being undertaken in Australia, South Africa, and England.

Injury surveillance is a crucial part of making sport safer. Van Mechelen *et al*[2] recommended a four stage approach to injury prevention:

(1) identify the incidence of common and serious injuries;

(2) identify risk factors (both intrinsic and extrinsic) for the most common and serious injuries;

(3) institute preventive programmes based on modification of reversible risk factors;

(4) monitor success of intervention with ongoing surveillance.

This study highlights this approach with the identification of boundary fences as a risk factor and the simple measure of replacing them with a rope reducing the injury risk to zero.

The authors cite the playing of football (soccer) in cross training as a particular concern in the cause of preventable injuries; this concern is duplicated in England where seven injuries resulted in 64 days missed cricket in the 2001 season (personal communication, Joint Physiotherapists in County Cricket and England & Wales Cricket Board Joint Study). Clearly alternative safe and enjoyable forms of cross training need to be found that are acceptable to both players and coaching staff.

Continuous surveillance is necessary in all countries playing first class cricket, and information collected should be shared. This study hopefully will be the catalyst for this to occur.

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SPORTING MISCELLANY

The windsurfing mentality

Numerous different types of injury are described as a consequence of windsurfing. The most recent survey of injury patterns in professional World Cup windsurfers found the second most common form of injury to be a head injury.[1] The cause was usually one handed loops or "table-tops", both spectacular forms of jump. Despite these findings, only 10% of windsurfers surveyed used a helmet. Less serious injuries such as abrasions are more common in amateur windsurfers. A similar mentality is seen however. While windsurfing in the warm, salty waters of the Red Sea recently I was intrigued by quite how much discomfort I and fellow windsurfers were prepared to put up with from the effects of the activity on our hands (fig 1). About 10% wore gloves.

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1 Gosheger G, Jagersberg K, Linnenbecker S, *et al*. Injury patterns and prevention in World Cup windsurfing. *Sportverletz Sportschaden* 2001;25:50–4.

Figure 1 Hands unaccustomed to windsurfing in warm, salty water: superficial abrasions from prolonged boom contact.

Figure 1 can be viewed in colour on www.bjsportmed.com

CASE REPORT

Exact moment of a gastrocnemius muscle strain captured on video

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A left gastrocnemius strain was sustained by an elite cricket batsman while he was taking off to run. The exact moment of injury, captured by a camera in the middle stump, appears to correspond to the sudden appearance of a deficit in the gastrocnemius muscle, seen through the player's trousers. The strain occurred when the entire body weight was on the left foot with the centre of mass well in front of the leg. The injury probably occurred close to the time when the gastrocnemius complex was moving from an eccentric to an isometric phase.

Lower limb muscle strains are common injuries in many sports, although the exact mechanisms have not been clearly established.[1 2] It is commonly believed that they occur during eccentric contractions.[3] Calf muscle strains are thought to usually occur during acceleration (take off) movements,[2] particularly when the knee is extending.[4] Some authors believe that hamstring muscle strains occur during the early stance phase of ground contact, when the hamstring muscle complex is actually shortening.[5] Others think that they may occur in sprinting during either the late swing phase (eccentrically) or early stance phase (concentrically).[1 6] However, there is virtually no scientific evidence indicating the timing of injury during the gait cycle.[1 7] Hamstring strains can also occur during water skiing and are due to stretching beyond maximal length; this mechanism is thought to be quite different from the usual injury mechanism during sprinting.[8] Quadriceps strains commonly occur during kicking, although it has not been established whether the rectus femoris is strained during a ground contact phase or when shortening at the time of ball contact.[2]

CASE HISTORY

The injury occurred to the last author (SRW), a 36 year old right handed batsman and captain of the Australian cricket team. He had a past history of multiple left hamstring strains, bilateral shin anterior compartment syndrome (treated surgically), and left L5 pars stress fracture. He was playing in the third Test of the 2001 Ashes series at Trent Bridge, Nottingham. A week before the Test match, he had played an exhibition squash match, which resulted in some minor tightness of the calf muscles; this was only considered significant after retrospective analysis of the injury. He had batted on the first day of the Test without incident, and then fielded for most of the second day. He started the third day playing in the field during England's second innings; after their innings had finished, he waited in the dressing room to bat at number five in the order. His wait to bat was punctuated by the lunch break and rain interruptions. He came in to bat with the score on 3/88 and was injured on the first ball he faced. He struck the delivery to the leg side with his weight on the back (right) foot and then set off to take a run. The injured leg was his front (left) leg, which had been brought back to take his weight as the right foot had pushed off (see video 1 on www.bjsportmed.com). He was unable to continue after the injury and retired hurt.

The injury was caught on film by cameras from the right side (showing a sagittal view), front (coronal view), and obliquely from the front and right side, all at 25 frames per second, and by a "stump cam" immediately behind the batsman at 12.5 frames per second. The exact moment of injury appears to correspond to the sudden appearance of a deficit in the medial fibres of the lateral gastrocnemius muscle (at 37.40 seconds on the video during stump cam view). After viewing the video, the player (SRW) felt "100% certain" that this was indeed the moment of injury, and the treating physiotherapist (EA) believes that the location of the deficit on the video corresponded to the clinical location of the strain. It appears therefore that the strain occurred between 37.32 and 37.40 seconds on the stump cam view, which correlates with 28.44 and 28.52 seconds on the right sagittal view. The muscle strain occurred when the entire body weight was on the left foot (the right foot has clearly just left the ground) with the centre of mass well in front and to the right of the left leg. On the sagittal view, in the frames just before 28.44 seconds, the left leg is partially obscured, but its appearance is approximately as follows: the left foot is at an angle of 0–5° to the ground in equinus (weight on the toes), the left ankle is between 10° and 15° of dorsiflexion, and the left knee is between 0° and 5° of flexion. Although it is impossible to make fully accurate statements, at the time of injury, the knee joint appears to be very slowly flexing or having no angular velocity and the ankle joint appears to be very slowly dorsiflexing, suggesting that the overall muscle-tendon length of the gastrocnemius is almost constant, or perhaps minimally lengthening. The player's weight is probably on the front of his left foot, and, as he is wearing spiked cricket boots, his front spikes have probably penetrated the surface at the time of injury. One to two frames after the injury, the knee appears to extend minimally (perhaps as a recoil from the torn fibres), while the ankle joint angle stays constant. The left heel leaves the ground about 0.5 seconds after the injury, by which stage the ankle is plantar flexing.

A magnetic resonance imaging scan showed a tear to both the lateral and medial gastrocnemius muscles at the musculotendinous junction. The player recovered quickly from the injury and was able to play in the fifth Test 19 days later.

DISCUSSION

We believe that this is the first video documentation of a muscle strain at the exact moment of occurrence, through the use of a unique form of technology in cricket, the stump cam. The gastrocnemius strain occurred when the entire body weight was on the left foot with the centre of mass well in front of the leg. The gastrocnemius muscle-tendon complex was at close to maximum length, and muscle-tendon length was almost constant at the time of injury. Therefore the injury probably occurred just as the muscle-tendon complex was moving from an eccentric to an isometric phase.

Take home message

A gastrocnemius muscle strain can occur during the push off phase of running when the gastrocnemius muscle-tendon complex is at almost constant muscle length.

Recent ultrasound images of gastrocnemius muscle-tendon units during jumping have shown that the length of the muscular and tendon components can be changing even when the overall muscle-tendon complex length is not.[9] This study showed that muscle fascicle shortening preceded tendon shortening.[9] It is perhaps between these two phases (muscle-tendon complex length relatively constant, muscle fascicles contracting and shortening, tendon structures lengthening and generating passive elastic recoil) that the strain at the musculotendinous junction is maximal. A study that measured the Achilles tendon force using an implanted optic fibre transducer during jumping found that the force could continue to increase after the muscle-tendon complex had changed from an eccentric to concentric phase.[10] This case shows that high velocity (change of length) of the muscle-tendon complex is not necessary for a muscle strain to occur.

A further discussion point to arise from this case is the difficulty that batsmen face because of lack of warm up. A batsman waiting to bat cannot know whether he will be called in the next minute or in many hours, so cannot warm up effectively. Although lack of warm up has not been proved to be a risk factor for muscle strain, it has often been proposed from anecdotal clinical evidence.[7]

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The video of this incident can be viewed on www.bjsportmed.com