

Seasonal and geographical analysis of ACL injury risk in Australia

John Orchard, Ian Chivers, David Aldous

There are northern (warm-season) and early-season biases for ACL injuries in the AFL that have been revealed by a long-standing reliable injury surveillance system¹⁻³. Recent study has suggested that the underlying explanation for these trends is the relative predominance of high-traction grasses in the northern states and early in the football season³. Little is known about the relative risk of ACL injury at non-professional level in Australia or in the NRL competition.

Recently, many media commentators have claimed an increase in injuries on dry sporting fields, possibly caused by drought in Australia and subsequent water restrictions in major centres^{4, 5}. Unfortunately there is no national injury surveillance system in Australia to investigate these claims. A national sports injury insurance scheme, the Accident Compensation Corporation (ACC), exists in New Zealand⁶. Although New Zealand has a superior system of monitoring injuries that occur in sport, its methods are not perfect because of lack of exposure data (number of sports participants and matches played). There is also little climatic variation between the different regions of New Zealand to test any hypothesis based on geographical differences.

In the United States, ACL injuries in the NFL show a strong early-season bias for matches played outdoors on Astroturf, but not indoors⁷. There is a small early-season bias for matches played on natural grass. The Astroturf data is consistent with the observation that shoe-surface traction on Astroturf positively correlates with the ambient

temperature⁸, which is dropping over the course of the season in outdoor stadiums, but not in indoor stadiums.

ACL injuries are particularly common in the major football codes (Australian football, rugby league, rugby union, soccer) and in snow sports. They also occur at a slightly lower rate in basketball, netball, volleyball and martial arts. ACL injuries are thought to be very common in netball, although the likely reason why this is considered a higher risk sport in Australia (compared to basketball) is that it is played mainly by females, who have a much higher relative risk for ACL injuries than males^{9, 10}.

The first section of this study examines available data for operations performed on the cruciate ligaments across Australia to see whether there is evidence of any northern (warm-season) bias at the community level. Estimates of the number of ACL injuries in Australia can be made, as the Health Insurance Commission (HIC) provides details of the number of item numbers claimed for each procedure under Medicare in each of the states and territories of Australia each month, with data going back to July 1994. The second section of the study examines ACL incidence in the NRL competition to look at both the geographical and temporal spread of ACL injuries occurring in first grade matches.

One hypothesis to be tested is that there will be a northern (warm-season) state bias for number of reconstructions performed in males, due to the popularity and high risk of the football codes, and the expected risk that warm-season grasses in Australia may pose a greater risk

of ACL injury. As somewhat of a control, the figures for females will be examined, with the expectation that any northern (warm-season) state bias would be minimal, as the higher risk sports that are popular with females are generally not played on natural grass. The hypotheses to be tested with respect to the NRL data are that there will be warm-season and early-season biases in a similar fashion to the AFL competition.

Methods

HIC data for cruciate ligament primary reconstructive surgery from the decade July 1994 to June 2003 in each Australian state and territory was downloaded from the website

http://www.hic.gov.au/statistics/dyn_mbs/forms/mbs_tab4.shtml.

The item numbers which were assessed were 49536, 49539 and 49542, which cover all primary cruciate ligament reconstructions. Item 49551 was not included, which is used for revision surgery for 49536, 49539 and 49542, where either the first operation has failed or the ACL has been re-injured.

Participation figures for various states were taken from the report by the ABS of Participation in Sport and Physical Activities 1999-2000¹¹.

Population figures were taken from the Australian Census 2001.

The ACT and Northern Territory are territories rather than states, but will be referred to as states for the purposes of the data presentation and discussion.

Table 1 - Major sports at risk for ACL injury in young males, along with estimated grass profiles for various states of Australia

STATE	MAJOR FOOTBALL CODE(S)	PROXIMITY TO SNOWFIELDS	GRASS PROFILE	EXAMPLES OF COMMON GRASS TYPE(S) ON COMMUNITY FIELDS
New South Wales	Rugby league and union, soccer	Close	Mainly warm-season	Kikuyugrass
Queensland	Rugby league and union, soccer	Very distant	Warm-season	Bermudagrass and Queensland blue couch
South Australia	Australian football, soccer	Distant	Mainly cool-season	Ryegrass and annual bluegrass
Tasmania	Australian football, soccer	Distant	Cool-season	Ryegrass and annual bluegrass
Victoria	Australian football, soccer	Close	Mainly cool-season	Ryegrass and annual bluegrass
Western Australia	Australian football, soccer	Very distant	Warm-season	Kikuyugrass and Bermudagrass
ACT	Rugby league and union, Australian football, soccer	Very close	Cool-season	Ryegrass, annual bluegrass, Kentucky bluegrass, fescues.
Northern Territory	Australian football and rugby league	Very distant	Warm-season	Kikuyugrass and Bermudagrass

Comparisons of relative risks with 99% confidence intervals are performed using the Taylor series expansion method¹².

This study also examined ACL incidence data for natural grass surfaces in the NRL to see whether or not there is a northern (warm-season) bias, similar to that seen in the AFL.

A player status for all first grade players in the NRL was kept by the author over the time period 1999-2004 inclusive, based on media reports of injuries. Where players were missing through injuries and the diagnosis was available in the media, a record of injury was kept. Media reports are definitely not 100% accurate, yet for serious diagnoses like ACL tears in professional sport the accuracy probably approaches 100%¹³. ACL injuries are so important and serious (particularly the vast majority which require immediate surgical reconstruction) that, if a first grade player suffers one in a major game, it is almost certainly reported extensively in the media. Surface characteristics for each stadium were assessed by the primary author (who as club doctor for the Sydney Roosters visited each ground once per year on average) in conjunction with Michael Finch, the ground manager for Aussie Stadium (Table 2).

Table 2 - Grounds analysed in the NRL

STATE	GROUND	GRASS TYPE
NSW	Aussie Stadium, Sydney	Bermudagrass and ryegrass
	Telstra Stadium, Homebush	Bermudagrass and ryegrass
	Showgrounds, Homebush	Bermudagrass and ryegrass
	Campbelltown Stadium	Bermudagrass and ryegrass
	Leichhardt Stadium	Kikuyugrass
	OKI Jubilee Stadium, Kogarah	Kikuyugrass and ryegrass
	Brookvale Stadium	Kikuyugrass and ryegrass
	Penrith Stadium	Kikuyugrass and ryegrass
	Energy Australia Stadium, Newcastle	Bermudagrass, ryegrass and Kikuyugrass
	WIN Stadium, Wollongong	Bermudagrass and ryegrass
Queensland	Parramatta Stadium	Bermudagrass and ryegrass, 2003-04 some annual bluegrass ('poa')
	Express Advocate Stadium, Gosford	Bermudagrass and ryegrass
	Toyota Park, Cronulla	Bermudagrass and ryegrass
ACT	Suncorp Stadium	Bermudagrass and ryegrass
	ANZ Stadium	Bermudagrass and ryegrass
	Dairy Farmers Stadium	Bermudagrass
Melbourne	Canberra Stadium	Ryegrass
New Zealand	Olympic Park	Ryegrass
	Ericsson Stadium	Bermudagrass, ryegrass and annual bluegrass

Results

The states and territories of Australia are listed in Table 1, along with the most common football codes played, proximity to snowfields and expected major grass types on football fields.

The number of cruciate ligament reconstructions performed in the private system over the decade 1994-2003 are listed in Table 3. The majority of these were in people aged 15-44, with reconstructions more common in males than females. Population figures for Australia in 2001 from the Census data are listed in Table 4.

Table 5 and Table 6 show estimates, for males and females respectively, of participation in those sports considered to have a significant risk of ACL injury. For males, sports were grouped into high risk sports (outdoor contact football codes and snow sports) and medium risk (touch football, basketball, netball, volleyball and martial arts). For females, a single group of high risk sports was created (netball, soccer, Australian football, snow sports, touch football, basketball and martial arts). Participation numbers were taken directly (or estimated, for shaded figures) from the ABS report¹¹. Participation data for other popular sports such as cricket, tennis, hockey, swimming, cycling, running, golf and aerobics were not considered in this analysis as the risk of ACL injury in these sports was considered to be low.

Table 7 shows the ratio of male to female reconstructions (among age group 15-44) in each state. There were more reconstructions performed in males in every state, despite that the relative risk of ACL injury is known to be higher in females. The explanation is almost certainly a participation bias, with males far more likely to participate in higher risk sports (Table 5 and Table 6). The male:female ratio was higher in the warmer northern states of Queensland, Western Australia and New South Wales, and lower in the

cooler states of Tasmania, Victoria, South Australia and the ACT.

Table 8 shows the percentage of various populations estimated to have undergone cruciate reconstruction over the decade July 1994-June 2003. Although there are many assumptions and systematic errors within these estimations, the errors may be similar for each state. Table 9 shows the risk for each state compared with the Australian averages (including 99% confidence intervals for the rows involving male and female reconstruction rates per high risk sport participant). These figures show a significantly lower cruciate reconstruction rate in males in Tasmania (compared to the rest of Australia) with a similar trend in Tasmanian females that was not nearly as strong. In males there is also a significantly lower reconstruction rate in Victoria and, with respect to participation in high risk sports, a higher rate in Queensland and Western Australia, neither of which is seen in females.

For the section of the study involving ACLs occurring in the NRL, there were 51 reported ACL injuries occurring in first grade matches (including representative matches and finals) over the period 1999-2004 inclusive. There were eight in 1999, seven in 2000, eight in 2001, thirteen in 2002, nine in 2003 and six in 2004.

There was no obvious northern bias present for ACL injuries (Table 10), with the rate of injuries at northern venues (18.2/1000 games) being comparable to Sydney venues (21.8/1000 games) and southern venues (23.4/1000 games). The highest individual stadium rates were Ericsson Stadium in Auckland and Parramatta Stadium, both of which have generally had a mixed grass profile of annual bluegrass, ryegrass and bermudagrass, although the ACL injury rates at both of these venues was not substantially higher than other grounds.

There was no significant difference between grounds with a bermudagrass profile in the early

season (17.1/1000 games) and grounds with a kikuyugrass profile in the early season (26.9/1000 games), although kikuyugrass stadiums had higher absolute rates of ACL injury. The relative risk for kikuyugrass compared to bermudagrass was 1.58 (95% CI 0.80-3.11).

There was however a strong early-season bias, with 33 ACL injuries occurring in rounds 1-13 of the NRL season and only 16 occurring in rounds 14-26 or the finals (risk ratio 2.1, 95% CI 1.1-3.8).

Discussion

The first section of this study examines Medicare data for cruciate reconstruction in the various states of Australia. Medicare is responsible for all insurance claims in the private hospital setting, which is where the majority of ACL reconstruction surgeries take place. ACL reconstructions are performed in public hospitals on public patients, but a waiting list of 1-2 years makes this option a difficult one for active sportspeople. Therefore many young Australians who play the sports that are at risk of ACL injury will either have private health insurance to use if they suffer an ACL injury or will pay for the procedure privately using cash and/or the proceeds from alternate sports insurance. Table 11 shows that private health insurance rates are fairly similar in each state¹⁴ with in fact Tasmania having the highest rate of private health insurance and Queensland the lowest.

The HIC item number data also cover ACL injuries that do not occur playing sport (other than work-related or traffic accident injuries) and PCL reconstructions, although these would be small in number, as most ACL injuries are either sport- or work-related and most PCL injuries are not reconstructed.

It is presumed that the majority of sports-related ACL injuries occur in sports listed in the results. The majority of the high risk sports in which males participate are played

Table 3 – Primary cruciate ligament reconstructions performed in the private medical system in Australia over the decade July 1994 - June 2003

STATE	NSW	VIC	QLD	SA	WA	TAS	ACT	NT	AUST
Cruciate ligament reconstructions	18822	12165	8145	5056	5580	671	1423	584	52446
Males aged 15-44	11869	7241	5113	2989	3456	404	794	352	32218
Females aged 15-44	5360	4017	2386	1763	1733	232	493	194	16178

Table 4 - Population for states of Australia (by state and for males aged 15-44), 2001 Census

STATE	NSW	VIC	QLD	SA	WA	TAS	ACT	NT	AUST
Population (total)	6593840	4784260	3592503	1519607	1874670	483666	322089	197780	19368414
Males aged 15-44	1358610	1006297	763135	307897	405864	91853	72743	51678	4058077
Females aged 15-44	1367095	1026791	778122	304903	404386	95058	74477	47754	4098586

Table 5 - Participation rates in high risk sports for males, by state, Australia 1999-2000 (Australian Bureau of Statistics) 11

MALES	NSW	VIC	QLD	SA	WA	TAS	ACT	NT	AUST
Aussie Rules	12000	84400	10000	31600	25800	8000	2000	1500	184000
Rugby total	85000	1000	35000	500	3000	0	4000	2500	121600
Soccer	67500	26300	20900	14300	20200	4000	3400	1700	158200
TOTAL Outdoor football	164500	111700	65900	46400	49000	12000	9400	5700	463800
Snow Sports	48300	38700	3000	3800	2000	1000	4100	500	106200
TOTAL high risk sports	212800	150400	68900	50200	51000	13000	13500	6200	570000
Touch football	66700	2000	39300	1000	11200	2400	4600	2600	134700
Basketball	48700	98800	23800	21900	19800	3000	2400	1300	219700
Netball	9800	10900	22400	1400	8700	900	1900	600	56500
Volleyball	21200	34300	13700	3800	11300	1000	2700	1600	90500
Martial Arts	50700	39000	27800	6700	23000	1900	3500	1100	153600
TOTAL medium risk sports	197100	185000	127000	34800	74000	9200	15100	7200	655000
TOTAL high-medium risk sports	409900	335400	195900	85000	125000	22200	28600	13400	1225000

Table 6 - Participation rates in high risk sports for females, by state, Australia 1999-2000 (Australian Bureau of Statistics) 11

FEMALES	NSW	VIC	QLD	SA	WA	TAS	ACT	NT	AUST
Soccer	11200	7000	9600	1300	3600	800	500	200	34200
Snow Sports	34000	33700	2000	3000	1000	500	3400	0	77600
Touch football	29200	1000	19000	500	2800	600	3500	1300	57900
Aussie Rules	500	3300	500	400	300	100	200	200	5500
Basketball	31600	24000	10900	5000	16400	2000	1500	900	92300
Martial Arts	56000	30000	30100	12500	15900	2100	2600	1100	150300
Netball	91100	80100	40900	32400	57500	9500	5700	2400	319600
Volleyball	11500	12000	16900	4000	10800	500	1500	1900	59100
TOTAL high risk sports	265100	191100	129900	59100	108300	16100	18900	8000	796500

Table 7 - Ratio of cruciate reconstructions performed in males compared to females (ages 15-44) for the decade July 1994 - June 2003

ACL RECONSTRUCTION RATE FOR 15-44	NSW	VIC	QLD	SA	WA	TAS	ACT	NT
Male:Female	2.2	1.8	2.2	1.7	2.0	1.8	1.6	1.7

Table 8 - Rates of private cruciate reconstructions in various populations for the decade July 1994 - June 2003

	NSW	VIC	QLD	SA	WA	TAS	ACT	NT	AUST
Total population	0.29%	0.25%	0.23%	0.33%	0.30%	0.14%	0.44%	0.30%	0.27%
Males 15-44	0.87%	0.72%	0.67%	0.97%	0.85%	0.44%	1.09%	0.68%	0.79%
Females 15-44	0.39%	0.39%	0.31%	0.58%	0.43%	0.24%	0.66%	0.41%	0.39%

Table 9 - Rates of cruciate reconstruction per state compared to Australian averages

ACL RECONSTRUCTION COMPARISON WITH AUSTRALIAN AVERAGES	NSW	VIC	QLD	SA	WA	TAS	ACT	NT
Total population	1.05	0.94	0.84	1.23	1.10	0.51	1.63	1.09
Males 15-44	1.10	0.91	0.84	1.22	1.07	0.55	1.37	0.86
Females 15-44	0.99	0.99	0.78	1.46	1.09	0.62	1.68	1.03
Males 15-44 (playing contact football codes)	1.04	0.93	1.12	0.93	1.02	0.48	1.22	0.89
Males 15-44 (playing high-medium risk sports)	1.10	0.82	0.99	1.34	1.05	0.69	1.06	1.00
Males 15-44 (playing high risk sports)	0.99 [0.96-1.02]	0.85 [0.82-0.88]	1.31 [1.26-1.37]	1.05 [1.00-1.11]	1.20 [1.14-1.26]	0.55 [0.48-0.63]	1.04 [0.95-1.14]	1.00 [0.87-1.16]
Females 15-44 (playing high risk sports)	1.00 [0.96-1.02]	1.03 [0.99-1.08]	0.90 [0.85-0.96]	1.47 [1.38-1.57]	0.79 [0.74-0.84]	0.71 [0.60-0.84]	1.28 [1.14-1.45]	1.19 [1.09-1.44]

Table 10 - ACL injury rates by NRL ground

GROUND	PREDOMINANT GRASS TYPE(S)	MATCHES	ACL INJURIES	RATE (N/1000 TEAM GAMES)
Gosford	Bermuda/ryegrass	36	2	27.8
Aussie Stadium	Bermuda/ryegrass	159	5	15.7
Toyota Park	Bermuda/ryegrass	76	2	13.2
Telstra Stadium	Bermuda/ryegrass	75	1	6.7
Dairy Farmer's	Bermudagrass	74	2	13.5
Parramatta	Bermuda/rye/annual bluegrass	74	6	40.5
ANZ Stadium	Bermuda/ryegrass	58	2	17.2
Campbelltown	Bermuda/ryegrass	41	1	12.2
WIN Stadium	Bermuda/ryegrass	39	0	0.0
Showgrounds	Bermuda/ryegrass	32	1	15.6
Suncorp Stadium	Bermuda/ryegrass	29	2	34.5
Colonial (Telstra Dome)	Bermuda/ryegrass	13	1	38.5
Newcastle	Kikuyu/ryegrass	78	2	12.8
Penrith	Kikuyu/ryegrass	74	5	33.8
Brookvale	Kikuyu/ryegrass	54	4	37.0
Leichhardt	Kikuyugrass	39	2	25.6
OKI Jubilee	Kikuyu/ryegrass	15	1	33.3
Ericsson	Bermuda/rye/annual bluegrass	78	7	44.9
Canberra	Ryegrass	74	3	20.3
Olympic Park	Ryegrass	61	2	16.4

on natural grass. Netball is probably the most common sport associated with ACL injury in females in Australia and, although some games are played on natural grass, the vast majority are played on hard courts.

The major confounder in this analysis, in terms of trying to prove the hypothesis of a 'northern bias' for males in sports played on grass, would be ACL injuries that occur during skiing and other medium risk sports, such as basketball and martial arts.

Tasmania, which is the southernmost state of Australia, has a statistically significantly *lower* rate of private cruciate reconstruction for males 15-44 playing high risk sports than all other states and territories. It also has absolute lower rates of cruciate reconstruction. This is unlikely to be a bias due to Tasmania being a small state (in terms of either population or geography) as a low rate is not seen in the ACT or Northern Territory. Proximity to snowfields may possibly explain the higher rate of ACL injury seen in the ACT than in Tasmania. In the bottom two lines of Table 9, rates of participation in snow sports were taken into account, but it is unknown whether this adjustment (simply assuming that a snow sport participant has a similar annual ACL injury risk to that of a football player) was sufficient. With respect to the confounder of private health insurance rates, Tasmania has the highest rate of private health insurance for all Australian states (Table 11) which would be expected to lead to a higher percentage of surgery being performed in the private system, if anything. Being the coolest climate of all states in Australia with high rainfall, Tasmanian conditions are most suitable for ryegrass, which is probably the major grass used on the vast majority of football grounds in Tasmania.

Victoria, which is the second southernmost state, has a lower rate of ACL reconstruction in high-risk participation males (15-44) than South Australia and Western Australia which is also statistically significant. For the AFL-playing states, there is

Table 11 - Percentage of the population with private health insurance (2001), by state 14

STATE	CAPITAL CITY	REST OF STATE
NSW	50.4%	43.3%
Vic	49.6%	41.0%
Qld	45.4%	45.0%
SA	50.5%	41.7%
WA	53.9%	48.5%
Tas	56.7%	43.0%
National	50.2%	43.5%

a distinct trend for fewer cruciate reconstructions in males in states that are further south (reconstruction rate of WA>SA>Victoria>Tasmania).

The ACT has the highest overall risk of cruciate reconstruction per head of population, and this may be partially due to a higher proportion of the population who are active males from 15-44 and also a much higher proportion of the population who ski. There may be a slight correlation between the fact that the ACT is a dry climate and is the region where temperatures fall below freezing commonly in winter and cool-season grasses that are more tolerant of the cold (such as Kentucky bluegrass and fescues) may be more commonly used. Kentucky bluegrass may be a higher risk grass for ACL injury than ryegrass because of greater thatching potential^{7, 15-17}. There is no 'southern' bias seen for ACL injuries in the US National Football League and this may be because Kentucky bluegrass is the primary turfgrass used in the northern parts of the USA where it, in fact, has higher thatching rates¹⁸. In the USA, the predominant grass types used for NFL football tend to be heavy thatch forming grasses and turf managers are encouraged to use thatch as a method of providing extra cushioning for players¹⁹.

From Table 9 it can be seen that Queensland has lower absolute rates of ACL reconstruction than the Australian average but, because the proportion of males aged 15-44 playing high risk sports (football and snow sports) is lower than in other states, the risk per male high risk sport participant is actually significantly higher than in other states

(RR 1.31, 95% CI 1.26-1.37)

There are some variations in the figures by state for Australian females (Table 9), but in general these are less than the variations seen in males. The absolute rate of cruciate reconstruction in females is highest in South Australia and the ACT (Table 8), which may partially reflect the popularity of the sports of netball and skiing respectively in these regions, although their rates for females are still higher than other states when participation rates are adjusted for.

There is a general trend of a 'warm-season bias' for cruciate reconstruction for males in Australia in the states where Australian football is the predominant male sport (WA>SA>Vic>Tas). This trend is seemingly absent for females in these four states, supporting the hypothesis that in Australia, warm-season grasses are a risk for ACL injury in Australian football.

With respect to ACL injuries in the NRL competition, an early-season bias for ACL injuries is definitely present. Since most grounds use either bermudagrass and ryegrass or kikuyu and ryegrass, the cool-season species of ryegrass is likely to be predominant later in the season (late autumn and early winter). Either the presence of rye later in the season or the reduction in thatch through abrasion related to regular use, or both, is/are likely to be responsible for the early-season bias for ACL injuries in the NRL³. There is minimal difference between both grass type and location and injury rates and location in the NRL, hence it can be stated that there is no apparent northern (warm-season) bias in the NRL. Ryegrass

tends to produce less thatch than bermudagrass (Figure 1) which may explain why it is associated with a lower rate of ACL injury^{3, 15}.

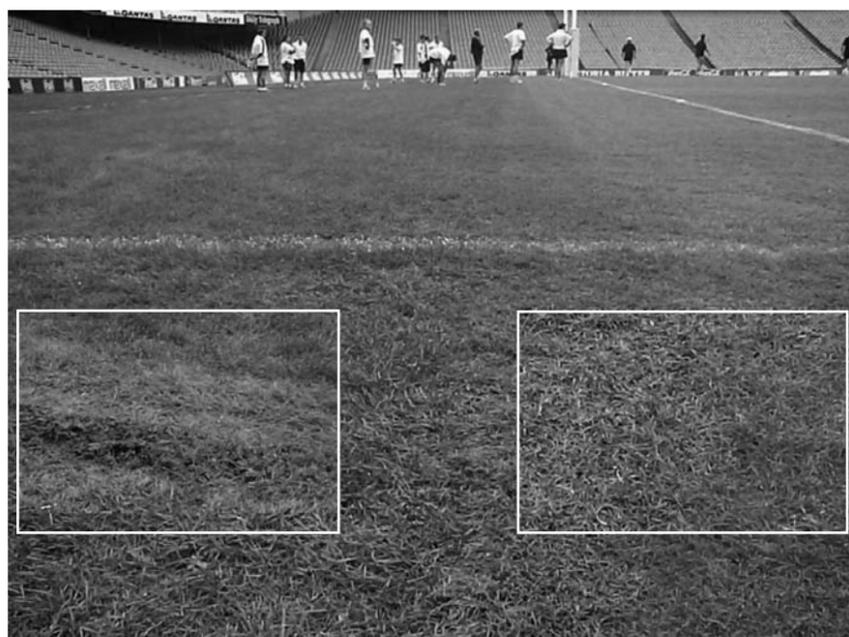
Although there are limitations in the quality and quantity of data in the NRL component of the study, they suggest that there is no evidence that either annual bluegrass or kikuyugrass compares favourably to bermudagrass with respect to ACL injury risk.

Previous research from Conway et al. (2003) using a similar data set to the one in this paper, suggested that North Queensland Cowboys, who are the most northern team in the NRL, had a similar rate of ACL injuries to the rest of the competition²⁰. They found their rate of ACL injury for North Queensland to be 2.73 injuries per 1000 player hours from 1998 to 2002, and found this to be not significantly different from other teams²⁰.

With respect to risk of rugby league injury in general (rather than for ACL injuries) at the various times of the season, most of this work in this area has been published by Gabbett, who in the climate of South-east Queensland in Australia has consistently found higher match injury incidence towards the end of the playing season in semi-professional and amateur rugby league²¹⁻²⁴. This is in contrast to the trends observed in other football codes played in winter²⁵. Gabbett has found that the intensity of matches increases towards the end of the playing season and he attributes this increase in intensity as the likely cause of the increased injury incidence towards the end of the season^{21, 22, 24}. The Gold Coast, where his studies have been conducted, being a subtropical climate with a generally wet autumn, may not exhibit the same changes in grass composition as traditional autumn-winter football season in a cooler climate²⁵.

Studies of rugby league injuries in the United Kingdom, where the professional competition changed from a winter to a summer season in 1996, have consistently showed a higher injury incidence in summer than winter rugby league²⁶⁻²⁸. When

Figure 1 - A comparison of ryegrass (left; shinier, darker, less thatch, some bare areas) and bermudagrass (right; lighter green, duller, thicker) on a NSW rugby league field



injuries were analysed by stage of the season and month of the year, it was found that summer months had a much greater correlation with risk of injury than stage of the season²⁶. That is, injuries were more common in the warmer months irrespective of whether these months were at the start or finish of the season. The 'dry-season' (summer) bias is proportionally greater in backs, who tend to suffer non-contact injuries, than in forwards, who tend to suffer contact-mechanism injuries²⁷. Authors who have noted an increased injury incidence in summer rugby league have attributed the dry-season (summer) injury bias to differences in the playing surface, particularly hardness²⁶⁻²⁸. Obviously historical confounders (other changes in the way that rugby league was played pre- and post- shift to a summer season) may have affected the results.

Notwithstanding that the NRL data presented in this study are unofficial and may contain some minor inaccuracies, they present further evidence that the rate of ACL injury on grounds which are ryegrass predominant (which includes most NRL venues in the second half of the season), is lower than for warm-

season grasses like kikuyugrass and bermudagrass. The confounding effect of the progressive reduction in thatch depth over the season is also likely to be contributing to a lower ACL injury rate in the second half of the season.

Although this study has many details which are unknown, including accurate details about grass types at venues throughout Australia, it is further secondary evidence that grass type may be responsible for fewer ACL injuries occurring in certain locations (ie, ryegrass in the more southern states in Australia leading to lower ACL injury rates). It is noted that there are many weaknesses and assumptions in this analysis. It would be far preferable for Australia to have a centralised sports injury surveillance system, as New Zealand does⁶, to monitor state by state trends in injuries.

The ACL injury rate and overall injury rates in the AFL have been lower over the past few seasons, possibly due to changes in preparation in grounds once the risk factors associated with various ground conditions have been published^{3, 29, 30}. It may be possible to reduce the rate of ACL injuries in Australia, particularly in the northern states, by changes to the

way that community football grounds are prepared. These may include promotion of ryegrass as a preferred species, watering of dry, hard grounds and scarification of grounds with an excessive layer of thatch^{3, 15, 25}. Because of the cost of ACL injuries to the community, it is strongly encouraged that a national ACL register is developed with measures taken in the longer term to reduce the rate of ACL injuries.

Conclusions

- There was a strong early-season bias for ACL injuries in the NRL competition over the period 1999-2004.
- No obvious geographical bias for ACL injuries was seen in the NRL competition over the same time period.
- In the 'AFL' states of Australia in the community, for males there is a 'northern' bias towards greater number of ACL reconstructions in the warmer states (WA and SA) compared to the southern states (Vic and Tas), in a similar fashion to the trend already seen in the AFL.
- In the 'rugby' states there is no evidence of a 'northern' bias.
- The NRL data are more similar to the data previously published for the US NFL, where there is also an early-season bias but no geographical bias.
- There is little evidence of a northern-bias for females for ACL reconstructions in the community.

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John Orchard, Ian Chivers and David Aldous are at the University of Melbourne