Cite this article as: BMJ, doi:10.1136/bmj.39185.605914.AE (published 18 May 2007)

BMJ

RESEARCH

Effect of nationwide injury prevention programme on serious spinal injuries in New Zealand rugby union: ecological study

Kenneth L Quarrie, manager,[1] Simon M Gianotti, team leader,[2] Will G Hopkins, chair,[3] Patria A Hume director[4]

[1]Research & Injury Prevention, New Zealand Rugby Union, PO Box 2172, Wellington, New Zealand

[2]Sport & Road, Accident Compensation Corporation, Wellington

[3]Exercise Science, Institute of Sport & Recreation Research New Zealand, Faculty of Health and Environmental Science, AUT University, Auckland 1020, New Zealand

[4]Institute of Sport & Recreation Research New Zealand

Correspondence to: K Quarrie
ken.quarrie@nzrugby.co.nz

doi: 10.1136/bmj.39185.605914.AE

ABSTRACT

Objective To investigate the effect of RugbySmart, a nationwide educational injury prevention programme, on the frequency of spinal cord injuries.

Design Ecological study.

Setting New Zealand rugby union.

Participants Population at risk of injury comprised all New Zealand rugby union players.

Intervention From 2001, all New Zealand rugby coaches and referees have been required to complete RugbySmart, which focuses on educating rugby participants about physical conditioning, injury management, and safe techniques in the contact phases of rugby.

Main outcome measures Numbers of all spinal injuries due to participation in rugby union resulting in permanent disablement in 1976-2005, grouped into five year periods; observed compared with predicted number of spinal injuries in 2001-5.

Results Eight spinal injuries occurred in 2001-5, whereas the predicted number was 18.9 (relative rate=0.46, 95% confidence interval 0.19 to 1.14). Only one spinal injury resulted from scrums over the period; the predicted number was 9.0 (relative rate=0.11, 0.02 to 0.74). Corresponding observed and predicted rates for spinal injuries resulting from other phases of play (tackle, ruck, and maul) were 7 and 9.0 (relative rate=0.83, 0.29 to 2.36).

Conclusions The introduction of the RugbySmart programme coincided with a reduction in the rate of disabling spinal injuries arising from scrums in rugby union. This study exemplifies the benefit of educational initiatives in injury prevention and the need for comprehensive injury surveillance systems for evaluating injury prevention initiatives in sport.

INTRODUCTION

Rugby union is a type of full contact football most commonly played between two teams of 15 players. The sport has an international following—the International Rugby Board, which is the sport's governing body, lists 95 countries in its online world rankings, although rugby is a major sport in fewer than 20. Box 1 gives a glossary of rugby related terms.

Spinal cord injuries, although rare on the basis of exposure per player, are a major cause of serious morbidity and mortality in rugby.[1] During the 1970s and 1980s an increase in the reported frequency of catastrophic spinal injuries associated with rugby was documented in medical journals from several countries in which rugby is a popular sport. The attention generated by letters to journals,[2 3] case reports,[4-6] and case series studies[7-10] prompted rugby administrators to act during the 1980s and 1990s to decrease the risks of spinal cord injuries, especially those related to the scrum. Measures to prevent injury have included changes to laws on scrum procedures, stricter application of existing laws, and educational initiatives.[11 12] Further case series studies have appeared recently.[11 13-19] Legal actions by injured players against referees, other players, and administrators have also contributed to raising the awareness of the importance of minimising the risks of rugby players sustaining permanently disabling injuries.[20 21]

A review of papers published up to 2001 reported that 40% of spinal injuries occurring in rugby were the result of the scrum, 36% were from the tackle, 18% from the ruck/maul, and the remainder were from either other or unknown causes. The definition of injury used in the studies reviewed, however, varied from admissions to spinal units (of which a proportion of players made full recoveries) through to tetraplegia.[1]

Ascertaining the numbers of spinal injuries occurring in rugby and the risks faced by players both in the scrum and in other facets of the game has been hampered by the relative rarity of the events and a lack of standardised procedures for collecting data.[1-12 22] In some countries, registers of spinal cord injuries exist on a national basis; in others, only regional data are available. A further impediment to evaluating the risks of spinal injuries in rugby has been a lack of reliable "denominator" data—the number and exposure of participants from which the cases result over a specified period.[22]

A recent call by a consultant general surgeon in the United Kingdom to ban the rugby scrum, which was based on his personal experiences as a rugby medical officer,[23] generated a flurry of correspondence in the electronic pages of the *BMJ*. The article cited evidence from an Australian survey that reported the elimination of scrum related spinal cord injuries in rugby league after the adoption of non-contested scrums in 1996.[14] Correspondents expressed widely divergent

opinions as to the merits or otherwise of such an action being taken in rugby union.

Our study had two aims. The first was to document the number of permanently disabling spinal injuries in New Zealand rugby union from 1976 to 2005. The second was to investigate whether the incidence of spinal injuries in New Zealand rugby union changed after the introduction in 2001 of RugbySmart, a nationwide injury prevention programme.

METHODS

Number of spinal injuries

To examine trends in the incidence of rugby related spinal injury in New Zealand, we collated and analysed data from 1976 to 2005 on the frequency and circumstances of rugby related spinal injuries. We extracted incidence data from the Accident Compensation Corporation database for serious rugby related spinal injury claims. The Accident Compensation Corporation is a no fault insurance system funded from taxes, which provides personal injury cover for all New Zealand citizens, residents, and temporary visitors. In return, people do not have the right to sue for personal injury, other than for exemplary damages. People make a claim at the time of seeking treatment. Across the population of New Zealand (4 million) approximately 1.6 million claims are made annually from all causes. Any serious injury that requires medical assistance automatically generates an Accident Compensation Corporation claim. The Accident Compensation Corporation uses the American Spinal Injury Association scales A to D to classify serious spinal injury claims that involve permanent functional impairment resulting from damage to the spinal cord.[24]

In addition to Accident Compensation Corporation data, we cross checked files from the New Zealand Rugby Foundation (using name, date of birth, and date of injury) to provide additional information about the phase of play in which the injury occurred. The New Zealand Rugby Foundation is part funded by the New Zealand Rugby Union and provides assistance beyond that delivered by the Accident Compensation Corporation to permanently disabled rugby players in New Zealand. For the purposes of modelling injury rates, we categorised the phase of play as scrum and other (tackle, ruck, and maul).

Box 1 | Glossary of rugby terms

Rugby union—A type of full contact football, usually played between two teams of 15 players. Players may carry the ball and pass or kick it. Points are scored by placing the ball over the opposition goal line or by kicking goals. Ten and seven a side versions of the sport are also played. The rules of the game are termed laws and are available at www.irb.com/EN/Laws+and+Regulations/

Rugby league—A variant of rugby played between two teams of 13 players and governed by a separate administrative body from rugby union. Rugby union and rugby league developed from the same parent game; although they have many similarities, some important differences exist. After a tackle in rugby league, the tackled player is allowed to stand up and restart play by placing the ball on the ground and hooking it back to a team member standing behind him. There are no rucks or mauls of the type that occur in rugby union. Scrums in rugby league involve minimal pushing, whereas pushing is a major feature of rugby union scrums

International Rugby Board—The governing body of the sport of rugby union internationally

New Zealand Rugby Union—The governing body of the sport of rugby union in New Zealand

New Zealand Rugby Foundation—A charitable body that provides financial and other assistance to permanently disabled rugby players in New Zealand

Forwards—Player numbers 1 to 8. The main role of forwards in rugby union is to win and retain possession of the ball

Backs—Player numbers 9 to 15. The main role of the backs in rugby union is to attempt to gain field position and score points

Scrum—A means of restarting play after minor infringements. The forwards from each team form together in three rows and close up with their opponents so that the heads of the front row players interlock. This creates a tunnel into which the ball is thrown. The front row players contest possession of the ball by hooking the ball back with their feet

Tackle—When a ball carrier is held by one or more opponents and is brought to the ground. Following a tackle in rugby union, play continues

Ruck—In rugby union, a ruck is a phase of play (often after a tackle) that occurs when the ball is on the ground. One or more players from each team, who are on their feet and are in physical contact, close around the ball and contest possession

Maul—Similar to a ruck except that the ball is off the ground and is held by a player who is simultaneously held by one or more opponents and a team mate

Bledisloe Cup—A rugby union trophy contested between the international teams of Australia and New Zealand

Spinal injury rates

We used records of numbers of players, available from the New Zealand Rugby Union from 1998 onwards, to estimate the average incidence of spinal injury per 100 000 players per year for the periods 1996-2000 and 2001-5 (table). We estimated the player numbers in 1998-2000 by using a combination of player registrations and evaluation of competition draws. From 2001, the New Zealand Rugby Union put in place a new registration system and the player numbers represent registered players only. To calculate the rate in 1996-2000, we used the average number of players from 1998-2000 as the denominator for the entire period, assuming that the numbers in 1996 and 1997 did not differ substantially from those in the following three years.

RugbySmart programme

Since January 2001, RugbySmart (www.rugbysmart.co.nz) has been the vehicle for delivering information on injury prevention to rugby coaches, referees, and players in New Zealand. The RugbySmart programme derives its approach from van Mechelen's sequence of prevention model.[25] The four steps of the model involve establishing the size of the injury problem (generally through surveillance), identifying the risk factors and causes of the injuries sustained in the activity, implementing preventive measures, and continuing injury surveillance or monitoring programmes.[25] Such ongoing injury surveillance programmes are designed to investigate whether the changes implemented have had a beneficial role in reducing the injury burden.

Establishing the size of the injury problem and identifying risk factors/causes

In New Zealand, information on the size of the injury problem in rugby has been derived primarily from the number and costs of claims to the Accident

Compensation Corporation. Risk factors for and causes of rugby injuries have been derived from both case reports[4-6] (primarily describing injury mechanisms) and prospective cohort studies designed for this purpose, both in New Zealand[26-28] and from other countries.[29 30]

Implementing preventive measures

The RugbySmart programme builds on work to prevent rugby injuries that has taken place in New Zealand since the early 1990s. A summary of the strategies used has been presented elsewhere.[31] RugbySmart represented an increase in the level of partnership between the Accident Compensation Corporation and the New Zealand Rugby Union and a substantial increase in financial resourcing of injury prevention in rugby. A full time position (manager of research and injury prevention) was created within the New Zealand Rugby Union to act as a driver for the development and delivery of RugbySmart.

RugbySmart is a multifaceted injury prevention programme and has developed over time as new information about risks has emerged. Research into the epidemiology of sports injury generally, and rugby injury especially, is monitored and evaluated in terms of relevance for inclusion in the updated RugbySmart materials in an attempt to provide evidence based best practice information on injury prevention to rugby participants.

Both players and coaches in New Zealand have identified rugby coaches as having a key role in communicating information on injury prevention and attitudes to players' safety.[31] In recognition of this, the board of directors of the New Zealand Rugby Union mandated that all coaches must complete RugbySmart on an annual basis. Coaches who did not comply with this directive were threatened with having their team withdrawn from competition. Players also saw referees as having an important role in maintaining safety.[31] Referees who did not complete RugbySmart were not assigned matches. Trained personnel deliver the programme at a local level. Most of the people who deliver the seminars are rugby development officers and referee education officers employed by provincial unions or clubs. More than 8000 coaches and 1500 referees have attended RugbySmart annually since it was introduced. Because completing RugbySmart is compulsory, the reach of the programme to coaches and referees is close to 100%.

Information and resources have been made available through compulsory seminars, the production of DVDs, a dedicated website, and provision of injury prevention "tools," such as a sideline concussion check card, to coaches and referees. Opinion pieces on various aspects of injury prevention have been a regular feature of the New Zealand Rugby Union coaching magazine (distributed free of charge to all New Zealand coaches three times a year). The principles espoused in RugbySmart with respect to safety in contact have been integrated throughout New Zealand Rugby Union coaching courses. Key messages on injury prevention, such as the relation between injury prevention and performance, techniques to minimise injury risk in the contact situations of rugby (box 2), the importance of progressive physical conditioning (especially with respect to building up to contact during the preseason period), and management of acute injuries, have been heavily marketed so that they will be acceptable to participants. This has been done in part by using high profile coaches, medical staff, and physical conditioning experts to feature in the DVDs. These people have widespread credibility with the audience to which the programme is primarily directed.

Monitoring and surveillance

Ongoing research into risks and monitoring of the incidence of rugby injury has occurred at various levels over the period of the programme. Beyond the nationwide injury data captured by the Accident Compensation Corporation, the Injury Prevention Research Unit from the University of Otago had injury surveillance projects in 2003-5 to examine self reported injury rates and injury prevention behaviours and attitudes among nationwide samples of players. A video based system for capturing injury data has been used to identify risks and circumstances of match injuries in professional rugby competitions in which New Zealand teams competed in 2002-5.

Player numbers and injury rate per year

Year	No of players (thousands)	Change from previous year (%)	Scrum injuries	Other injuries	Injury rate (per 100 000 players per year)
1996	NA	NA	3	1	NA
1997	NA	NA	0	1	NA
1998	122	NA	0	2	1.6
1999	130	6	4	1	3.9
2000	129	−1	2	3	3.9
2001	120	−7	0	2	1.7
2002	122	1	0	1	0.8
2003	121	−1	0	2	1.7
2004	129	6	1	1	1.6
2005	138	6	0	1	0.7

NA=not available.

Statistical analysis

To examine the effect of the RugbySmart programme, we used the generalised linear modelling procedure (Proc Genmod) in SAS version 9.1 to calculate changes in numbers of scrum related and other spinal injuries before and after the introduction of RugbySmart. The aim of the modelling was to estimate the linear effect of time period on the number of injuries per five year period. The model was of the form injury number= RugbySmart period, where RugbySmart was coded as 1 for the period 2001-5 and 0 otherwise, and period was the five year period presented in the figure. We did not build participation level (number of players) into the model, because accurate estimates of numbers of players were not available before 1998. The model

implicitly assumes constant player numbers over the entire period.

Owing to the nature of the dependent variable (count of injuries per five year period), we chose the Poisson response probability distribution. We made magnitude based inferences about true (population) values of effects by expressing the uncertainty in the effects as 95% confidence intervals.[32] We deemed an effect to be unclear if its confidence interval overlapped the thresholds for substantiveness (that is, if the likelihood of the injury rate ratio being substantially greater than 1.2 and less than 0.83 were both 2.5%).[33] To estimate the minimum clinically important difference, we calculated the typical number of spinal injuries occurring from scrums per five year period. A factor decrease of 1.2 equated to one person not being permanently disabled through a scrum related spinal injury per five year period, which we believed was a worthwhile clinical outcome. We aggregated counts into five year periods to avoid problems of zero cell counts[34] and to give a single prediction for the last five years for comparison with the observed incidence.

RESULTS

Seventy seven permanently disabling injuries were recorded in 1976-2005. In 1976-2000 the scrum accounted for 48% (33/69) of spinal injuries; in 2001-5 the percentage was 12.5 (1/8). Tackles accounted for 36% (25/69) of spinal injuries in 1976-2000 and 87.5% (7/8) in 2001-5. The remaining 11 injuries resulted from the ruck or maul. The figure shows the frequency of permanently disabling spinal cord injuries in New Zealand rugby grouped by five year period from 1976.

In 2001-5 eight spinal injuries occurred in New Zealand rugby, whereas the predicted number based on the rate from the previous periods was 18.9 (relative rate=0.46, 95% confidence interval 0.19 to 1.14). Only one scrum related spinal injury occurred in 2001-5, which was clearly less than the predicted number of 9.0 (relative rate=0.11, 0.02 to 0.74). Seven spinal injuries occurred as a result of tackles, rucks, and mauls in 2001-5; the predicted number was 9.0. The difference in the number of observed spinal injuries resulting from tackles, rucks, and mauls relative to the predicted number was rated unclear (relative rate=0.83, 0.29 to 2.36).

The average annual number of players registered was 126 800 in 1996-2000 and 125 900 in 2001-5. The rates of spinal injuries from scrums and from other phases of play per 100 000 players per year were therefore 1.4 and 1.3 in 1996-2000 and 0.2 and 1.1 in 2001-5.

DISCUSSION

RugbySmart and spinal injury numbers

A major goal of the New Zealand Rugby Union and the Accident Compensation Corporation in establishing RugbySmart was "to eliminate spinal injuries within the context of a contact sport." The results are consistent with a decrease in spinal cord injuries in New Zealand rugby since 2000, primarily owing to a reduction in injuries occurring in scrums. This decrease coincides with the introduction of the RugbySmart programme. The ability of the governing body of New Zealand rugby to require completion of RugbySmart as a prerequisite to being able to coach or referee has led to the programme having extensive reach among people identified as important for communicating messages on injury prevention to improve players' safety.

If the true rate of scrum related spinal injury was the observed average rate of 6-7 per five years, the chance of observing one or zero scrum related spinal injuries in 2001-5 if the underlying rate of injury to players had not changed and the total exposure of players to rugby had remained constant was only 1%. Thus a small chance exists that the decrease observed in this study reflects expected statistical variation, but a real decrease in the rate of spinal injuries from scrums occurred in New Zealand over the period 2001-5 is much more probable.

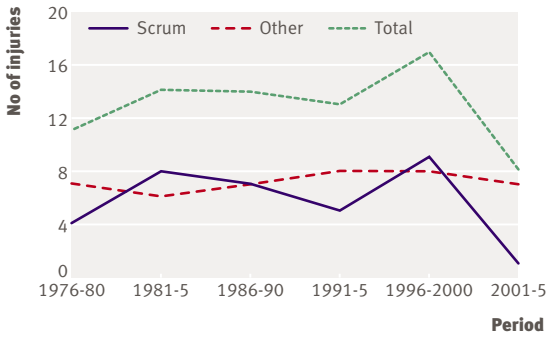
Although the number of sports injury prevention programmes running worldwide has greatly increased over the past two decades, few have completed all four steps inherent in the "sequence of prevention" model.[25 35] RugbySmart is one of the first examples of a nationwide programme to have evaluated the effects of the injury prevention initiatives introduced through ongoing nationwide surveillance. The RugbySmart programme was designed to be an injury prevention system that provides participants with up to date information about risks of rugby injury and preventive techniques. Evaluation of the programme, which will be discussed in depth in a paper in preparation, consists of targeted injury surveillance projects; examination of participants' knowledge, attitudes, and behaviours; and monitoring of Accident Compensation Corporation claims.

One of the weaknesses of this study is the lack of a control group. Because the New Zealand Rugby Union wanted to implement a nationwide injury prevention programme from the beginning, we were unable to create a control group to which RugbySmart was not delivered. Although the finding that numbers of spinal injuries in New Zealand rugby have decreased is positive regardless of the reasons for the drop, examining factors besides the RugbySmart programme that may have contributed to the decline can help us to assess how much weight we should place on the apparent impact of RugbySmart.

Box 2 | Common principles for safe technique in contact in rugby union promoted in RugbySmart

- Eyes focused on target area
- Chin up, eyes open
- Low body position
- Keep back flat
- Shoulders above hips
- Use legs to drive powerfully into contact

Changes in law are a means of altering behaviour that have the potential to decrease the risk of injury. In 1992, the International Rugby Board introduced a change that altered the sequence of events in scrum engagement. Little evidence suggests that any decrease in scrum related spinal injuries in New Zealand that followed this change was sustained through the subsequent five year period (see figure). No substantive changes occurred to the law relating to the scrum, ruck, maul, or tackle through the period of the RugbySmart intervention (2001-5) that would have been expected to affect players' risk of sustaining a spinal injury.



Permanently disabling spinal injuries (American Spinal Injuries Association scale A to D) in New Zealand rugby union, 1976 to 2005

Players' exposure to scrums, tackles, and rucks

A decrease in exposure to scrums could have contributed to the decrease in the number of scrum related spinal injuries seen in 2001-5 compared with previous periods. Such a decrease in exposure to scrums could have resulted from fewer players participating in rugby, fewer matches a year for those who did participate, fewer scrums per match, or some combination of the three. The amount of confidence we can have in discounting these varies. For example, although an overall decrease in scrum related spinal injuries between 1996-2000 and 2001-5 similar to that seen could have resulted with no change in risk per player had the number of players decreased enough, the actual number of players needed before the intervention to allow a large enough decrease is unfeasibly high. This would have required a playing population in 1996 and 1997 of 2.6 million, or around 20 times higher than the number of players recorded in the following years. Over the longer term, we have little evidence on which to base any conjecture of the possible impact of numbers of players on numbers of injury.

Decreases in the typical exposure per player (assuming that the number of players remained constant), commensurate with fewer matches being played in a season, could also result in a lower number of spinal injuries being seen. Across all levels, the number of competitions and the number of matches played per competition have not, to our knowledge, changed substantially in New Zealand over the past decade. The New Zealand Rugby Union has no information to suggest that this has been the case, although the relative balance between numbers of competitions in rural and urban areas has shifted, mirroring population trends in New Zealand.

Neither of the above scenarios—a large decrease in player numbers or in typical exposure per player—would account for the differential decrease in numbers of scrum related spinal injury compared with those from other phases of play. However, at least part of the decrease in scrum related spinal injury numbers is probably due to a decrease in the number of scrums per match. Evidence from international matches indicates a long term decrease in the number of scrums per match. A comparative analysis by the International Rugby Board of international matches played in the early 1980s and the early years of the 21st century found that the average number of scrums per match had dropped from 31 to 19. In Bledisloe Cup matches, the number of scrums showed a decrease of 17% per decade from 1972 to 2004, with an additional 8% decrease coincident with professionalism in 1995.[36]

We do not have figures for typical numbers of scrums per match throughout all grades of rugby in New Zealand. In our experience, junior grades tend to follow the patterns of play at higher levels. We would be surprised if the number of activities per match at lower levels was following markedly different trends over time than at the higher levels, but we have no historical measurement of these. At international level, the number of scrums per match in under 19 and under 21 competitions does not differ noticeably from that at senior level. International Rugby Board statistics indicate that the numbers of scrums per 80 minutes of match play at international level in 2003 for seniors and in 2004 for under 21 and under 19 grades were 21, 22, and 22.[37] Given the above, we can attribute approximately 8-10% of the decrease in scrum related spinal injuries to a decrease in exposure as a result of fewer scrums per match in the 2001-5 period than occurred in 1996-2000.

Although the effect is not clear, the RugbySmart programme seems to have been unsuccessful in reducing the number of spinal injuries unrelated to the scrum. Compared with the relatively controlled environment of the scrum, the direction and size of forces applied to players' bodies in the tackle, ruck, and maul are much less predictable. The scrum may thus be more amenable to education based injury prevention initiatives than the tackle, ruck, or maul.

Whether the underlying risk to players (as opposed to the number of injuries observed) has changed in the tackle, ruck, and maul is difficult to determine. For example, the injury data do not take into account possible changes in the frequency of tackles and rucks in rugby. Substantial increases in both of these phases of play have been noted in professional rugby.[36] In Bledisloe Cup matches between New Zealand and Australia, the mean number of tackles per match increased from 150 (SD 32) in 1995 to 270 (25) in 2004. The average number of rucks per match increased from

WHAT IS ALREADY KNOWN ON THIS TOPIC

Spinal cord injuries, although rare on the basis of exposure per player, are a major cause of serious morbidity and mortality in rugby

WHAT THIS STUDY ADDS

The number of permanently disabling spinal injuries in New Zealand rugby has markedly decreased following the introduction in 2001 of RugbySmart, a nationwide injury prevention programme

This study exemplifies the benefit of educational initiatives in injury prevention and the need for comprehensive injury surveillance systems for evaluating such initiatives in sport

72 (18) to 178 (27) over the same period.[36] We do not know whether or to what extent such increases have been reflected in lower grades. However, if we presume that the style of play at the community level of the sport has moved in the same direction as that at the international level, the risk per event for these phases of play may have decreased. Further research into the risks and circumstances of injuries in tackles (both spinal and other injuries) is warranted.

Spinal injury rates in New Zealand and Australia

The rate of spinal injuries in New Zealand rugby in 1996-2000 was 2.7 per 100 000 players per year (including both scrum related and other injuries). The rate in 2001-5 decreased to 1.3 per 100 000 players per year. Studies from Australia have also reported annual incidences of spinal injury.[11 14 15] The rate of spinal injuries in New South Wales rugby in 1996-2000 was 5.1 per 100 000 players per year (calculated from information provided by Berry and colleagues[11]). Over the following three year period, the rate increased to 9.8 per 100 000 players per year. The Australia-wide rate in 1986-96 was 3.5 per 100 000 players per year (based on estimates of player numbers from 1985, 1990, and 1996). The rate in 1997-2002 was 3.2 per 100 000 players per year.[14 15]

The apparent differences between the rates in New South Wales and those for Australia as a whole can be partially accounted for by the fact that the denominator used for calculating the rates in New South Wales does not include school age players who play only at school and do not register with a club. The authors of these studies have pointed out that the data for player numbers on which the injury rates are based are less than optimal. In New Zealand, the denominator figure includes all school and club players. Given the limitations of the denominator data from Australia, concluding whether the risks of spinal injury involved in New Zealand rugby are lower than those in Australia is difficult.

Reported differences in rates resulting at least partly from different denominators raises an important question about which players should be included when calculating the incidence of serious spinal injuries within a region or country. In New Zealand, no case of a permanently disabling spinal injury to a player under the age of 14 has been reported in the past 30 years. Should players aged 13 and under be included in or excluded from the denominator? We have included such players in the figures presented in this paper because they are presumably at some risk of sustaining such injuries, even though none has occurred over the period studied. On the other hand, if young players have a much lower risk of spinal injury, then including the large number of these players in the count of those at risk may produce artificially low rates of spinal injuries. The variation in rates between Australian and New Zealand studies reported in this paper provides an example of the importance of agreeing definitions and procedures for the collection of such data between regions and countries.

Injury prevention in rugby

Several avenues for injury prevention are available to rugby administrators, including changes in law and educational programmes. Although changes in law can effect change quickly, we believe that research into their probable effects on patterns of match activity and the overall risk of injury to participants should be done before their introduction. Historical evidence shows that changes in law have resulted in changes in the relative frequency and nature of match activities, characteristics of players, and epidemiology of injuries that were not foreseen when the changes were introduced.[36 38]

The results presented here provide evidence that educational programmes are a viable option for decreasing the rate of serious spinal injuries in rugby union scrums. In the absence of evidence that other factors have had a major role, we believe that the RugbySmart programme has probably played a positive part in decreasing the risks to players in New Zealand of sustaining serious spinal injuries through participation in rugby.

Conclusion

Although serious spinal injuries in rugby are an emotive issue, we believe that decisions on prevention of injuries in this area should be based on evidence rather than opinion. The introduction of the RugbySmart injury prevention programme in New Zealand has coincided with a drop in the number of spinal injuries over the past five years. A decrease in injuries from scrums has been the major contributor to this reduction. Whether the programme has had an effect on injuries from other phases of play (tackles, rucks, and mauls) is unclear. Educational initiatives seem to represent a viable option for decreasing the rate of serious spinal injuries in rugby union scrums.

We acknowledge the assistance of staff from the Accident Compensation Corporation, the New Zealand Rugby Union, and the New Zealand Rugby Foundation in the preparation of this manuscript. We also gratefully recognise the work of provincial union rugby development officers and referee education officers in delivering the RugbySmart programme to coaches and players throughout New Zealand.

Contributors: KLQ reviewed the literature, led the writing of the paper, and contributed to the design and analysis. He was responsible for the development and delivery of RugbySmart on behalf of the New Zealand Rugby Union from the inception of the programme. SMG was responsible for extracting and

verifying injury data from Accident Compensation Corporation records and writing the section of the methods on the Accident Compensation Corporation system; he contributed to the writing of the remainder of the paper. He was responsible for the development and delivery of RugbySmart on behalf of Accident Compensation Corporation from 2002 onwards. WGH provided statistical advice and contributed to analyses. He provided editorial comment on a draft version of the paper. PAH led the development of the 10 point action for sports injury prevention that was used as a template for RugbySmart. She provided editorial comments on a final draft of the paper. KLQ is the guarantor.

Funding: None for the preparation of the manuscript. The RugbySmart programme is funded by the Accident Compensation Corporation and the New Zealand Rugby Union. The employment positions of SMG (Accident Compensation Corporation) and KLQ (New Zealand Rugby Union) are funded by the respective organisations.

Competing interests: KLQ and SMG are responsible for the production of the RugbySmart programme on behalf of the New Zealand Rugby Union and Accident Compensation Corporation respectively. WGH and PAH: none declared.

Ethical approval: AUT University ethics board.

1 Quarrie KL, Cantu RC, Chalmers DJ. Rugby union injuries to the cervical spine and spinal cord. *Sports Med* 2002;32:633-53.
2 Williams JP, McKibbin B. Cervical spine injuries in rugby union football. *BMJ* 1978;ii:1747.
3 Silver JR. Rugby injuries to the cervical cord [letter]. *BMJ* 1979;i:192-3.
4 Scher AT. 'Crashing' the rugby scrum—an avoidable cause of cervical spinal injury: case reports. *S Afr Med J* 1982;61:919-20.
5 Scher AT. The 'double tackle'—another cause of serious cervical spinal injury in rugby players: case reports. *S Afr Med J* 1983;64:595-6.
6 Scher AT. Rugby injuries to the cervical spinal cord sustained during rucks and mauls: case reports. *S Afr Med J* 1983;64:592-4.
7 Kew T, Noakes TD, Kettles AN, Goedeke RE, Newton DA, Scher AT. A retrospective study of spinal cord injuries in Cape Province rugby players, 1963-1989: incidence, mechanisms and prevention. *S Afr Med J* 1991;80:127-33.
8 Silver JR. Injuries of the spine sustained in rugby. *BMJ* 1984;288:37-43.
9 Scher AT. Rugby injuries to the cervical spine and spinal cord: a 10-year review. *Clin Sports Med* 1998;17:195-206.
10 Taylor TK, Coolican MR. Spinal-cord injuries in Australian footballers, 1960-1985. *Med J Aust* 1987;147:112-3, 116-8.
11 Berry JG, Harrison JE, Yeo JD, Cripps RA, Stephenson SC. Cervical spinal cord injury in rugby union and rugby league: are incidence rates declining in NSW? *Aust N Z J Public Health* 2006;30:268-74.
12 Haylen PT. Spinal injuries in rugby union, 1970-2003: lessons and responsibilities. *Med J Aust* 2004;181:48-50.
13 Shelly MJ, Butler JS, Timlin M, Walsh MG, Poynton AR, O'Byrne JM. Spinal injuries in Irish rugby: a ten-year review. *J Bone Joint Surg Br* 2006;88:771-5.
14 Carmody DJ, Taylor TK, Parker DA, Coolican MR, Cumming RG. Spinal cord injuries in Australian footballers 1997-2002. *Med J Aust* 2005;182:561-4.
15 Spinecare Foundation and the Australian Spinal Cord Injury Units. Spinal cord injuries in Australian footballers. *ANZ J Surg* 2003;73:493-9.
16 Secin FP, Poggi EJ, Luzuriaga F, Laffaye HA. Disabling injuries of the cervical spine in Argentine rugby over the last 20 years. *Br J Sports Med* 1999;33:33-6.
17 Wetzler MJ, Akpata T, Laughlin W, Levy AS. Occurrence of cervical spine injuries during the rugby scrum. *Am J Sports Med* 1998;26:177-80.
18 Rotem TR, Lawson JS, Wilson SF, Engel S, Rutkowski SB, Aisbett CW. Severe cervical spinal cord injuries related to rugby union and league football in New South Wales, 1984-1996. *Med J Aust* 1998;168:379-81.
19 Armour KS, Clatworthy BJ, Bean AR, Wells JE, Clarke AM. Spinal injuries in New Zealand rugby and rugby league—a twenty year survey. *N Z Med J* 1997;110:462-5.
20 Vowles v Evans & Others [2002] All ER 134.
21 Smolden v Whitworth & Nolan [1997] PIQR P133.
22 Garraway M, MaCleod D, Sharp J. Rugby injuries—the need for case registers (letter). *BMJ* 1991;303:1082-3.
23 Bourke JB. Rugby union should ban contested scrums. *BMJ* 2006;332:1281.
24 Maynard FM Jr, Bracken MB, Creasey G, Ditunno JF Jr, Donovan WH, Ducker TB, et al. International standards for neurological and functional classification of spinal cord injury. *Spinal Cord* 1997;35:266-74.
25 Van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries: a review of concepts. *Sports Med* 1992;14:82-99.
26 Bird YN, Waller AE, Marshall SW, Alsop JC, Chalmers DJ, Gerrard DF. The New Zealand rugby injury and performance project: V. Epidemiology of a season of rugby injury. *Br J Sports Med* 1998;32:319-25.
27 Durie RM, Munroe A. A prospective survey of injuries in a New Zealand schoolboy rugby population. *NZ J Sports Med* 2000;28:84-90.
28 Quarrie KL, Alsop JC, Waller AE, Bird YN, Marshall SW, Chalmers DJ. The New Zealand rugby injury and performance project: VI. A prospective cohort study of risk factors for injury in rugby union football. *Br J Sports Med* 2001;35:157-66.
29 Babic Z, Misigoj-Durakovic M, Matasic H, Jancic J. Croatian rugby project—part II: injuries. *J Sports Med Phys Fitness* 2001;41:392-8.
30 Bathgate A, Best JP, Craig G, Jamieson M. A prospective study of injuries to elite Australian rugby union players. *Br J Sports Med* 2002;36:265-9; discussion 269.
31 Chalmers DJ, Simpson JC, Depree R. Tackling rugby injury: lessons learned from the implementation of a five-year sports injury prevention program. *J Sci Med Sport* 2004;7:74-84.
32 Sterne JA, Davey Smith G. Sifting the evidence—what's wrong with significance tests? *BMJ* 2001;322:226-31.
33 Batterham AM, Hopkins WG. Making meaningful inferences about magnitudes. *Int J Sport Physiol Perf* 2006;1:50-57.
34 Agresti A. *Categorical data analysis*. Hoboken: John Wiley & Sons, 2002.
35 Chalmers DJ. Injury prevention in sport: not yet part of the game? *Inj Prev* 2002;8(suppl 4):22-5.
36 Quarrie KL, Hopkins WG. Changes in player characteristics and match activities in Bledisloe Cup rugby union from 1972 to 2004. *J Sports Sci* 2007;25:895-903.
37 International Rugby Board. *Rugby World Cup 2003, Under 21 World Championship, Under 19 World Championship—a statistical comparison*. Dublin: International Rugby Board, 2004.
38 Merton RK. The unintended consequences of purposive social action. *Am Sociol Rev* 1936;1:894-904.

Accepted: 5 April 2007