

The FREED framework for community sports injury prevention implementation in New Zealand

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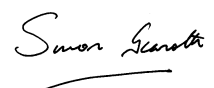
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ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (unless acknowledged in the contributions to co-authored papers), nor material which to a substantial extent has been accepted for the award of any other degree or diploma of a university or other institution of higher learning (except for collaborative work in Chapters 4 and 8 which was submitted by Ken Quarrie for his PhD and is acknowledged in the contributions to co-authored papers).

Chapters 2-9 of this thesis have been published. My contribution and the contributions by the various co-authors to each of these papers are also outlined at the beginning of each chapter. All co-authors have approved the inclusion of the joint work in this doctoral thesis.

A handwritten signature in cursive script, reading "Simon Gianotti", with a horizontal line underneath.

Simon Gianotti
17th August 2009

CANDIDATE CONTRIBUTIONS TO CO-AUTHORED PAPERS

Chapter publication reference	Author %
<p>Chapter 2. Gianotti, S.M., Hume, P.A. A cost-outcome approach to pre and post-implementation of national sports injury prevention programmes. <i>Journal of Science and Medicine in Sport</i>, 2007. 10(6): 436-46.</p> <p>Contributors: SG reviewed the literature, developed the design, extracted and verified injury data from Accident Compensation Corporation records, completed the analysis and led the writing of the paper. PH provided editorial review on drafts of the paper.</p>	SG: 95%, PH: 5%
<p>Chapter 3. Gianotti, S.M., Marshall, S.W., Hume P.A., Bunt, L. Incidence of anterior cruciate ligament injury and other knee ligament injuries: A national population-based study. <i>Journal of Science and Medicine in Sport</i>, 2009. 12(6): 622-627.</p> <p>Contributors: SG reviewed the literature, developed the design, extracted and verified injury data from Accident Compensation Corporation records, completed the analysis and led the writing of the paper. SM provided advice on the approach to take in the methodology. PH provided editorial review on drafts of the paper. LB provided data extraction and analysis.</p>	SG: 80%, SM: 10%, PH: 5%, LB: 5%
<p>Chapter 4. Quarrie, K.L., Gianotti, S.M., Hopkins, W., Hume, P.A. Effect of a nationwide injury prevention programme on serious spinal injuries in New Zealand rugby union: ecological study. <i>British Medical Journal</i>, 2007. 334 (7604): 1150-1153.</p> <p>Contributors: KQ 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. SG 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. WH provided statistical advice and contributed to analyses. He provided editorial comment on a draft version of the paper. PH led the development of the 10 point action for sports injury prevention that was used as a template for RugbySmart. PH provided editorial review on drafts of the paper.</p>	KQ: 50%, SG: 40%, WH: 5%, PH: 5%
<p>Chapter 5. Gianotti, S.M., Hume, P.A. Concussion sideline management intervention for rugby union leads to reduced concussion claims. <i>Neurorehabilitation</i>, 2007. 22(3): 181-189.</p> <p>Contributors: SG reviewed the literature, developed the design, extracted and verified injury data from Accident Compensation Corporation records, completed the analysis and led the writing of the paper. PH provided editorial</p>	SG: 95%, PH: 5%

review on drafts of the paper.	
<p>Chapter 6. Gianotti, S.M., Hopkins, W.G., Hume, P.A., Harawira, J., Truman, R. An interim evaluation of the effect of a new scrum law on neck and back injuries in rugby union. <i>British Journal of Sports Medicine</i>, 2008. 42(6): 427-430.</p> <p>Contributors: SG reviewed the literature, developed the design, extracted and verified injury data from Accident Compensation Corporation records, completed the analysis and led the writing of the paper. WH provided advice on statistical analysis. PH provided advice on the design, analysis and editorial review on drafts of the paper. JH and RT provided assistance with data extraction.</p>	SG: 70%, WH: 10%, PH: 10%, JH: 5%, RT: 5%
<p>Chapter 7. Gianotti, S.M., Quarrie, K.L., Hume, P.A. Evaluation of RugbySmart: A rugby union community injury prevention programme. <i>Journal of Science and Medicine in Sport</i>. 2009. 12: 371-375.</p> <p>Contributors: SG reviewed the literature, developed the design, extracted and verified injury data from Accident Compensation Corporation records, completed the analysis and led the writing of the paper. KQ provided advice and development of the methodology. PH provided editorial review on drafts of the paper.</p>	SG: 50%, KQ: 40%, PH: 10%
<p>Chapter 8. Gianotti, S.M., P.A. Hume, Tunstall, H. Efficacy of injury prevention related coach education within netball and soccer. <i>Journal of Science and Medicine in Sport</i>, 2010. 13: 32-35.</p> <p>Contributors: SG reviewed the literature, developed the design, extracted and verified injury data from Accident Compensation Corporation records, completed the analysis and led the writing of the paper. PH provided editorial review on drafts of the paper. HT provided editorial comments on drafts of the paper.</p>	SG: 90%, PH: 5%, HT: 5%
<p>Chapter 9. Gianotti, S.M., Hume, P.A. 2009. The FREED framework for community sport injury prevention implementation in New Zealand. <i>British Journal of Sports Medicine</i>. Under review.</p> <p>Contributors: SG was responsible for design, quality assessment, literature search, and writing of the manuscript. PH was also responsible for design, quality assessment, and editing the drafts of the paper.</p>	SG: 95%, PH: 5%

In undertaking this thesis, opportunities have presented themselves for which I am grateful for. I have been fortunate to have my research and publications recognised internationally and I have been asked to speak in different countries on the PhD work.

ETHICAL APPROVAL FOR THE THESIS WORK

As an employee of ACC, AUTECH ethics was not needed for the projects that made up the data collection and analysis phases of the thesis. This was because ACC ethics procedures were in place when the data that I analysed in the course of the research were collected. ACC has a 'Code of Claimant Rights' and there is the Privacy Act 1993 which I have to comply with.

ABSTRACT

The primary objective of the research underpinning this thesis has been to develop a framework that supports the implementation of community sports injury prevention programmes. Despite the wide acceptance of van Mechelen's [1] widely accepted four-stage framework, known as the sequence of prevention, most research still focuses on his first two stages which address the incidence and causes/mechanics of injuries rather than the important third stage of implementing preventive measures. This thesis focuses on the implementation stage and proposes a new FREED framework for community sports injury prevention (Funding, Resources, Environment, Evaluation and Delivery). The FREED framework is the outcome of extensive analysis of the results of programmes implemented in New Zealand that have shown a decrease in the number and costs of injuries in a number of sports that have a strong community base.

A series of sport injury prevention programmes were developed, implemented, and assessed in cost-benefit terms for their effectiveness in changing behaviour and reducing injury counts and costs. The publications documenting the various programmes and methods of analyses are presented as chapters in this thesis. From lessons learnt during the research for each of the publications, themes were extracted and used to create the FREED framework. The FREED framework identifies key factors that have contributed to the success or failure of community sport injury prevention in New Zealand. In the final chapter, a case study of the application of the FREED framework to the New Zealand Rugby League injury prevention programme demonstrates the strengths and weakness of the approach in the real world of community sports.

Development of a comprehensive framework for community sports injury prevention necessitated consideration of three thematic areas: 1) Specific sports (rugby union, football, netball); 2) Different participants (players, coaches, administrators), and 3) Injuries of different kinds from minor ones, such as dental, through to catastrophic ones such as spinal injury or concussion. The first New Zealand example of an effective injury prevention programme that took account of all of these was the 88% reduction in catastrophic spinal injuries from the scrum in rugby union. This followed the implementation of the scrum injury prevention programme in 2001.

A more general sports concussion injury prevention programme resulted in a decrease in concussion claims for sports that the programme targeted (snow, horse and rugby) and a 66% decrease in the time players were waiting before seeking concussion treatment. The return on investment (ROI) in the rugby concussion programme alone was a minimum of \$12.60 per dollar invested. This return on investment is reflective of the benefits, in fiscal terms of the reduction of injuries.

Analysis of the effectiveness of injury prevention programmes in changing behaviour and reducing injury counts and costs in a range of community sports environments showed positive ROI ranging from \$2.41 to \$15.14 per dollar invested. A soccer programme, which did not interfere with how the game was played, resulted in a 2.5% decrease in the targeted knee and ankle injuries, and produced a ROI of \$2.41. Rule changes to scrum engagements resulted in a 31% decrease in moderate to serious scrum neck and back injuries, producing a higher ROI.

From the analysis of injury prevention in specific sports and for different participants, which comprises the substance of chapters 2-8 of the thesis, the FREED framework was developed to document key factors that contributed to the success or failure of community sports injury prevention in New Zealand. As previously outlined the FREED acronym takes the first letter of the five main factors: funding, resources, environments, evaluation and delivery. These are discussed in detail in chapter 9 where a case study of the application of the FREED framework to the New Zealand Rugby League injury prevention programme reveals its strengths and weakness in a real world community sports context. The five factors are highly interdependent but it is clear from the analyses in chapters 2-8 that adequate funding is crucial for there to be any effective significant return on investment in community sports injury prevention.

At the community level there are limited opportunities, due to perception and control, to have people engaged with an injury prevention programme. It is the quality of the resources (financial, human - e.g. coaches, and services such as ACC), that allows for the prevention programme to continue past the testing and initial engagement stages. The importance of resources is emphasized throughout the discussions in chapters 2-8, most notably those dealing with concussion (chapters 5-7) and in chapter 8 on soccer and netball. These all show that resources supporting injury prevention were being used the following season.

The FREED framework can be applied in communities across the country; it is not a framework that has been developed in a particular community or in a controlled experimental environment. The FREED framework is based on examples of the implementation of community sports injury prevention programmes in different parts of New Zealand. Community injury prevention is important if the field of sports injury prevention is to evolve. Most injuries occur in an environment of community sports. While the FREED framework was being developed, the field of community sports injury prevention was largely based on theory or limited case studies. Partly because of its comprehensive accident compensation insurance, New Zealand has been in an excellent position to trial various intervention approaches based on targeting specific injuries, specific sports, and specific groups. Drawing on these targeted practical examples, the FREED framework that focuses on implementation of injury prevention was developed. The Accident Compensation Commission, where the author works, was a critically important source of reliable data for many of the analyses that are reported in chapters 2-9 and the various conference presentations and posters.

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I would like to acknowledge the sports of Rugby Union, Soccer/Football, Netball, Rugby League, Snow, (Skiing and snowboarding) Touch Rugby and Mountain Biking, particularly the volunteers, administrators, coaches, referees/umpires, players/participants who essentially became my lab where I could develop, implement and determine the effectiveness of sport injury prevention initiatives for the FREED framework. Within these sports there were individuals who were key: Ken Quarrie from New Zealand Rugby Union; and Helen Tunstall for New Zealand Football.

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Enormous thanks go to my supervisors, Professor Patria Hume and Professor Will Hopkins. Patria, who in a McDonalds in Prague, Czech Republic (of all places), helped me outline my thesis on the back of a napkin; was always the voice of reason and was a rock. Patria, who had more PhD students than she should, looks after them like members of her own family and shares the passion of her student's topics. Patria who managed to put off kidney transplant for thirty years and finally did it so she didn't have to attend meetings and could focus on research. Will who is always insightful and challenging, not afraid of being challenged back by his students, and is an asset to the University. Hopefully he will put off retiring for many more years as we need this type of thinking influencing the next crop of minds. I look forward to continuing to publish work with both of my supervisors.

RESEARCH OUTPUTS DURING THE DOCTORAL THESIS

It was important during the course of the research for the thesis and the development of the FREED framework to gain feedback on the various studies that formed the basis of our practical work in sports injury prevention. The conference presentations and posters, drawing on the data reported in each chapter, enabled the conference system to be used to provide feedback on research findings. Therefore the list of papers/presentations/posters, by theme, indicates where feedback was gained.

Theme 1 – SportSmart and ACC data base

- Hume, P.A., Gianotti, S.M. and Brooks, D. (2005). The New Zealand SportSmart injury prevention programme. *British Journal of Sports Medicine* **39**(6): 391. (Abstract). Presented at 1st World Congress on Sports Injury Prevention, Oslo, Norway.
- Gianotti, S.M. and Hume, P.A. (2005). SportSmart, the New Zealand sports injury prevention education intervention programme. *Journal of Science and Medicine in Sport* **8**(4 Supplement): 243. (Abstract). Presented at Sports Medicine Australia conference, Melbourne, Australia.
- Dick, R.W., Goulet, C., and Gianotti, S.M. (2009). Implementing large scale injury prevention programmes, in *Sport Injury Prevention: Olympic Handbook of Sports Medicine*, R. Bahr and L. Engebretsen, Editors. 2009, Wiley-Blackwell West Sussex.
- Gianotti, S.M. (2008). Country-wide implementation of a prevention program - The New Zealand experience. 2nd World Congress on Sports Injury Prevention, Tromso, Norway. (Abstract).
- Gianotti, S.M. (2007). Power of ACC Data, University of Ballarat, Victoria, Australia.
- Gianotti, S.M. (2008). Influencing government policies that impact on sport injury prevention - the implementation of the New Zealand injury prevention strategy. 2nd World Congress on Sports Injury Prevention. Tromso, Norway. (Abstract).
- Holmes, K.A. and Gianotti, S.M. (2007). Injury Prevention in Sport and Recreation Programme Evaluation, University of Ballarat, Victoria, Australia.
- Gianotti, S.M. and Hume, P.A. (2007). A cost-outcome approach to pre and post-implementation of national sports injury prevention programmes. *Journal of Science and Medicine in Sport* **10**(6): 436-46.
- Gianotti, S.M. and Hume, P.A. (2005). Should we spend the money? - The method used to determine investment in a football community injury prevention programme. Sport Medicine and Science Conference, Queenstown, New Zealand (Abstract).
- Gianotti, S.M. and Hume, P.A. (2005). Should we spend the money? - The method used to determine investment in a football community injury prevention programme. *Journal of Science and Medicine in Sport* **8**(S4): 220. (Abstract). Presented at the Sports Medicine Australia Conference, Melbourne, Australia.
- Gianotti, S.M. (2005). Using the break even point and behaviour change rate to assist the decision to implement a national sports injury prevention programme. *British Journal of Sports Medicine* **39**(6): 386. (Abstract).

- Holmes, K.A. and Gianotti, S.M. (2007). Decision making regarding investment in injury prevention utilising a cost benefit approach. XVII International Society of Skiing Safety Congress, Congress Book of Abstracts, Aviemore, Scotland. (Abstract).
- Gianotti, S.M., Marshall, S.W., P.A., Hume. and Bunt, L. (2009). Incidence of anterior cruciate ligament injury and other knee ligament injuries: A national population-based study. *Journal of Science and Medicine in Sport* **12**(6):622-627.
- Quarrie, K.L., Gianotti, S.M., Hopkins, W. and Hume, P.A. (2007). The effect of a nationwide injury prevention programme on serious spinal injuries in New Zealand rugby. *British Medical Journal* **334**(7604): 1150-1153.
- Quarrie, K.L., Gianotti, S.M. and Hopkins, W. (2005). The prevention of serious injuries in New Zealand rugby union. *British Journal of Sports Medicine* **39**(6): 386. (Abstract). Presented at 1st World Congress on Sports Injury Prevention, Oslo, Norway.
- Gianotti, S.M., Quarrie, K.L., and Hopkins, W. (2006). RugbySmart – The prevention of serious injuries in New Zealand Rugby Union. Sport Medicine and Science Conference, Wellington. (Abstract).

Theme 2 – Injury prevention for specific injuries

- Gianotti, S.M. and Hume, P.A. (2007). Concussion sideline management intervention for rugby union leads to reduced concussion claims. *Neurorehabilitation* **22**(3): 181-189.
- Gianotti, S.M., Hume, P.A. and Quarrie, K.L. (2004). Concussion side line management intervention for rugby union in New Zealand. New Zealand Sports Medicine and Science Conference, Auckland, New Zealand. (Abstract).
- Gianotti, S.M., Pope, H. and Hume, P.A. (2005). The development, implementation and assessment of a concussion education management programme in community sport. Injury Prevention Network of Aotearoa New Zealand Conference. (Abstract).
- Gianotti, S.M., Hume, P.A. and Quarrie, K. (2004). Implementation of a community level sport concussion management system in New Zealand. *British Journal of Sports Medicine* **38**(5): 660-661.
- Gianotti, S.M., Hopkins, W.G., Hume, P.A., Harawira, J. and Truman, R. (2008). Interim evaluation of the effect of a new scrum law on neck and back injuries in rugby union. *British Journal of Sports Medicine* **42**(6): 427-430.
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- Quarrie, K.L., Gianotti, S.M., Chalmers, D.J. and Hopkins, W. (2005). An evaluation of mouthguard requirement and dental injuries in New Zealand rugby union. *British Journal of Sports Medicine* **39**: 650-651.
- Hume, P.A., Schipper, R., Cartwright, S., Durward, C., Inskip, C., Sheerin, K., McIntyre, J., Gianotti, S.M. and Allen, B. (2006). Letter to the editor. Boil-n-bite mouthguards. *Sport Health* **24**(3): 7-8.

- Hume, P., Schipper, R., McIntyre, J., Sheerin, K., Inskip, C., Gianotti, S.M. (2006). Impact testing of 18 adult mouthguards. *Proceedings of XXIV International Symposium on Biomechanics in Sports 2006*, Salzburg, Austria, University of Salzburg, p.679-682. Austria.
- Hume, P.A., Schipper, R., McIntyre, J., Sheerin, K., Inskip, C. and Gianotti, S.M. (2006). Impact testing of 18 adult mouthguards. Sport and Exercise Science New Zealand Conference, Wellington. (Abstract).
- Gianotti, S.M., Hume, P.A., Brooks, D. and Spackman, A. (2005). Training community coaches and managers in the immediate treatment of strains and sprains. Sport Medicine and Science Conference, Queenstown. (Abstract).
- Gianotti, S.M., Hume, P.A., Brooks, D. and Spackman, A. (2005). Training community coaches and managers in the immediate treatment of strains and sprains. *Journal of Science and Medicine in Sport* 8(4 Supplement): 94. (Abstract).

Theme 3 – Injury prevention for specific sports

- Gianotti, S.M., Quarrie, K.L. and Hume, P.A. (2009). Evaluation of RugbySmart: A rugby union community injury prevention programme. *Journal of Science and Medicine in Sport* 12: 371-375.
- Gianotti, S.M. (2008). RugbySmart (workshop). 2nd World Congress on Sports Injury Prevention, Tromsø, Norway. (Abstract).
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Theme 5 – The FREED framework for community sports injury prevention

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CHAPTER 1

INTRODUCTION

When I started out in sports injury prevention as a practitioner in 2002 there was little literature that focused on the implementation of prevention programmes. This thesis intends to remedy the gap by developing an implementation framework that can be applied in the context of sports injury prevention. The creation of such a framework is therefore the central objective of my thesis. To achieve this framework I needed to explore real examples of sports injury prevention. There were several ways I could have approached the development of the framework. The first was to focus on a particular sport or a particular type of injury as a case study and use the findings from this to specify the components of a framework. This approach was rejected as it would have been limited to a specific set of circumstances that would be sport or injury-type specific. This would only have helped practitioners of specific types of sports injury prevention.

Another approach was to articulate a hypothetical framework which could then have been tested using a variety of cases or prospective studies to demonstrate strengths and weaknesses. This would have been ideal if I had had the framework in mind at the outset. However, when I started my doctoral research there was little literature available on injury prevention implementation frameworks and models so this was not a suitable alternative, albeit an attractive one from an academic perspective.

What I decided to do was to merge the “real world” with the “academic world” and develop the framework from the application and implementation of sports injury prevention interventions. To borrow from an early American reality show, “the cases are real, the people are real”. The framework emerged from the findings presented in chapters 2-8. For this reason, the FREED (Funding, Resources, Environment, Evaluation and Delivery) framework for implementing community sports injury prevention interventions is not presented in any detail until chapter 9. The chronological order of the chapters describing specific programmes, and the associated papers reporting on aspects of those programmes, shows the learning along the way. I have been able to adopt this approach because the unique position provided by my employment by New Zealand’s Accident Compensation Commission (ACC) means I have access to funds for injury prevention and also to a national injury dataset that contains information that can be used to monitor progress in terms of reducing injury prevalence and cost. This privileged access to ACC data has enabled me to make an original contribution to the body of knowledge about injury prevention.

A national data collection system that uses consistent definitions for injuries and systematically records the incidence of different types of injuries year upon year is ideal for monitoring and assessing the effectiveness of injury prevention programmes. The ACC has such a data collection system which can be used to validate a framework for implementing sports injury prevention programmes [1]. The ACC invests over \$NZD1.8 million annually in sport and

recreation injury prevention programmes [source?]. These programmes are designed to limit an estimated total cost of around \$NZD400 million represented by the 460,000 sport and recreation injury claims in the 2008/09 financial year [source?]. In a population of 4.1 million people (2009) ACC received a total of around 1.6 million claims in 2008/09, with just over a quarter of these for sports and recreation injuries. Notwithstanding this significant investment in sports injury prevention, and the availability of consistent national data on the incidence of different kinds of sports injuries, there has been little work done by ACC to establish a framework for implementing sports injury prevention interventions and programmes,

It was clear that this thesis and the framework that it generated would have more validity if the results (of my research) on injury prevention were published. I needed to complete a series of studies of injury prevention in different sports that I could use as my empirical data when developing the framework. The various conference presentations, posters and papers I prepared with my supervisors and colleagues gave me a platform I could draw on for publications. This, in turn, gave me a range of quality-assured research outputs from which I could synthesize key findings to inform the implementation framework I was seeking to address injury prevention. During the research journey I gained insights from other models that relate to injury prevention, and these influenced my thinking about what was needed for successful implementation of sports injury prevention strategies and techniques.

There were some unsuccessful attempts at injury prevention by ACC during my journey. As noted by Finch [2], unsuccessful attempts are hard to publish in peer-reviewed journals which is unfortunate because practitioners and researchers can learn from both successful as well as unsuccessful outcomes. Valuable lessons were learnt from unsuccessful attempts at injury prevention, and fortunately more injuries were not created in the process. Chapter 9 contains a discussion of some of these failures, showing how the lessons learnt contributed to the development of the FREED framework.

Having outlined the rationale for the approach I have taken to present the results of my research for the thesis, the next section provides a review of some of the key literature in the field of injury prevention. This review highlights the lack of research relating to implementation. It needs to be noted that each of the published papers, which form the chapters in this thesis, also contains a review of literature addressing the topic covered in the chapter. After the introductory literature review I provide a brief comment on the ACC data base and its role in the development of the FREED framework followed by an overview of the structure of the thesis and key themes addressed in the eight substantive chapters.

A selective literature review

Practitioners look for existing models in the literature to help make sense of the real world. In the case of sports injury prevention, an emerging field, there was little to draw from relating to

implementation frameworks or interventions in community sport. In a review of 12,000 published manuscripts Klügl et al. [3] found only 492 publications dating from 1938 that actually assessed the implementation or the effectiveness of the sports injury prevention interventions. The majority of these articles, including some reproduced as chapters in this thesis, addressed training or protective equipment and mechanical devices.

While Klügl et al. [3] have provided a useful review of the existing literature, the main use of their findings has been to advocate for more rules changes as a means to reduce injuries [4]. Rules changes are important for prevention of injuries and there are two chapters in the thesis reviewing cases where new rules were used to reduce injuries. Other ways of reducing sports injuries are also highlighted in other chapters of the thesis. Bahr and Englebreetsen, in their *Sports Injury Prevention: Olympic Handbook of Sports Medicine* [5], made provision for a chapter on 'Implementing large-scale injury prevention programs' [6]. With few examples available in the published literature, the editors relied on the case studies in this thesis to inform their discussion with evidence based findings.

While preventing sport and recreation injuries requires an understanding of the factors that contribute to both the occurrence of injury and the uptake of, or compliance with, potential preventive strategies [7], methodologically sound studies of injury prevention programmes are rare in all types of sports [8]. Further, there are surprisingly few well-designed controlled studies investigating strategies to prevent injuries [9]. Even in the world's most popular sport, football (soccer) with approximately 200,000 professional and 240 million amateur players [10], only a few studies [11-20] have investigated the actual effectiveness of injury prevention interventions. This is largely due to the methodological problems associated with sports injury research that have been described in detail by Noyes et al. [21], Finch [22] and Junge & Dvorak [23]. In addition problems of consistency with respect to injury definition and data collection have been noted across a variety of sports and types of injuries [24]. The definition of injury varies between studies, making comparisons of findings from specific cases difficult. Uniform definitions are important and necessary in order to enhance comparability of research data [25]. The diagnosis and treatment of an injury type can also vary. For example Kapoor et al. [26] presented to orthopaedic surgeons identical symptoms (acute and chronic anterior cruciate ligament injuries) in a case study and found significant variations in the suggested management of this injury.

Two early approaches to frameworks for addressing injury prevention and control are Haddon's matrix [27] and the public health approach [28]. The public health approach is a methodology for addressing injury at four stages: surveillance, risk factor identification, intervention evaluation and programme implementation. Haddon's Matrix likens injury to disease and has two axes. The first axis focuses on the host, agent, social environment and physical environment [29]. The second axis includes three time intervals spanning pre-event, event and post-event periods [28].

As expected there have been attempts to modify or improve both Haddon's matrix and the public health approach. Runyan [29] introduced a third dimension transforming Haddon's Matrix into a cube. The purpose was to make the matrix more useful for the decision process by including value criteria. There have been efforts to combine Haddon's matrix and the public health approach. Lett et al. [28] argued that the public health approach lacked a systematic point of application and Haddon's matrix lacked a systematic action plan. Combining the two concepts into one framework provided rigour and coherent constructs for understanding injury and implementation of the control activities.

The motivation for the continual adaptation of the public health approach and Haddon's matrix is to help make sense and understand the real world. Both Runyan [29] and Lett et al. [28] have evolved the model to assist with the task of injury control. They have identified a gap that they believe needs filling and this thesis makes a substantive contribution to filling this gap.

Models of prevention and injury control in sport

As noted earlier, there is little literature on how to implement sports injury prevention interventions at a national level, or on effective injury prevention implementation frameworks. Two main models are cited in the published research. The most frequently cited is van Mechelen's [25] 'sequence of prevention' model that has been subjected to extensive international peer review. It is considered 'familiar' in the sports injury prevention literature [30], and arguably has been the most cited model of sports injury prevention over the past decade [2]. The model has four sequential components, as indicated in Figure 1, and has parallels to the public health approach mentioned earlier.

The third stage in van Mechelen's model is the critical one in the context of injury prevention. It is heavily dependent on the second stage where causes of injuries are identified. The model is straightforward, and can be applied in any health intervention context. Despite this, there is little literature dealing with how to implement preventive measures. Often authors citing van Mechelen's model have chosen to group steps two and three together. The van Mechelen model has now clearly been demonstrated to be of very limited use for sports injury prevention as well as for general injury prevention (see, for example, Sleet et al. [31], Lindqvist et al. [32], Finch [2] and Bugeja et al. [33]).

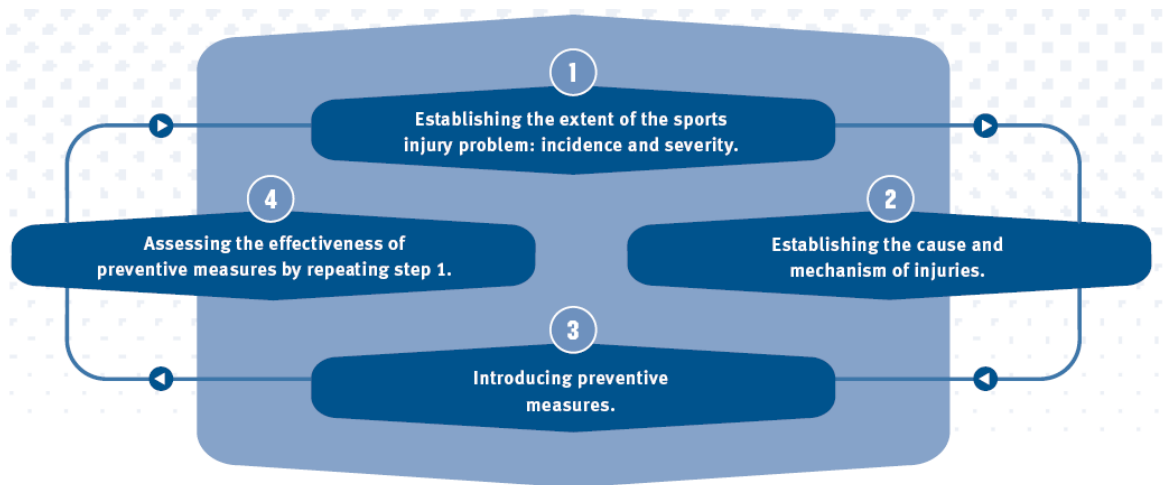


Figure 1: *The four stages in van Mechelen's 1992 'sequence of injury prevention' model [25].*

In 2006 the TRIPP framework, an adaptation of van Mechelen's "sequence of injury prevention", and an extension of the public health approach, appeared in the literature [2] (Figure 2). In proposing the TRIPP framework, Finch [2] argued the most serious limitation of the sequence of injury prevention model was that it did not consider the need for research into implementation issues, once prevention measures were proven effective. Finch claimed the TRIPP framework was "leading to real-world sports injury prevention". However, what was missing were real examples of 'how' to translate knowledge obtained from research into a framework that can be applied in the context of sports injury prevention. Clearly there was a gap in the literature regarding implementation that this thesis aimed to address.

Since commencing the research for this thesis there have been two attempts to develop an implementation framework. The first was by van Tiggelen et al. [34] who has adapted the sequence of injury prevention by adding a feedback loop and learning (Senge [36]). Van Tiggelen et al. [34] focussed on overuse injuries and developed their implementation framework in the relatively controlled settings of military training and professional sport. In these contexts, military leaders and coaches respectively can exert considerable control over the individuals under their command or whose careers rely upon selection. This level of control over behaviour and response results in a high level of compliance with prevention interventions. The feedback loop suits situations that provide for regular interaction between a group and the prevention measure.

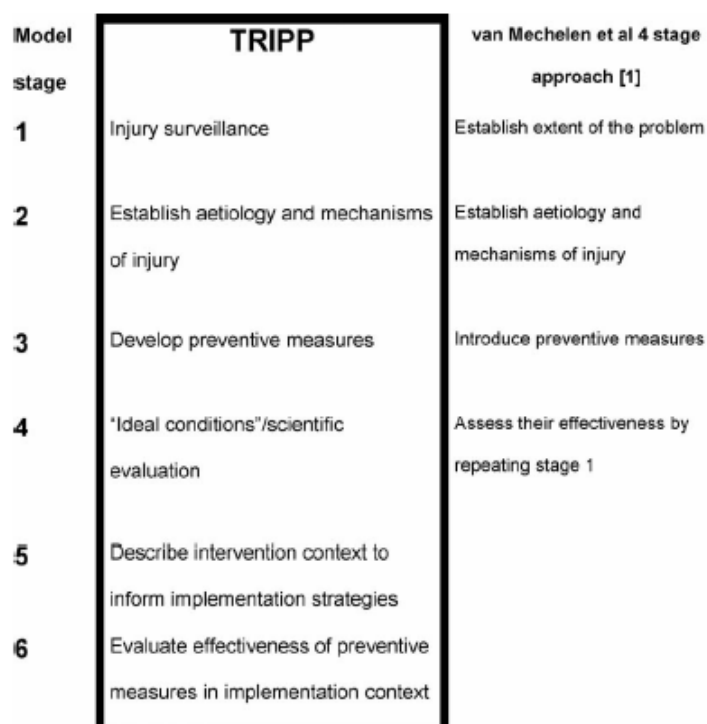


Figure 2. *The Translating Research into Injury Prevention Practice (TRIPP) framework for research leading to real-world sports injury prevention.*

Van Tiggelen's framework is suitable in situations where there is authority to manage compliance with injury prevention strategies. Its utility appears to be untested or unproven in the sorts of community settings where the sports and recreation studies in this thesis occurs. In New Zealand on the focus is on acute injuries [5, 35-45] due to the unique no-fault injury claim system administrated by the ACC. In community-based sports it is estimated that only 10% of injuries are the result of overuse of particular muscles or parts of the body. As Finch and Owen [46] have argued, there are different risk profiles and factors for professional/elite athletes and for community level sport/physical activity.

Another recent development has been Finch and Donaldson's [47] adaptation of Glasgow's [48] RE-AIM model, used to evaluate health promotion interventions, to include a sports setting matrix termed the RE-AIM SSM [47]. While RE-AIM can be used to design programs it is more commonly used to report results or compare interventions [49, 50]. Care is needed when directly applying the RE-AIM framework to interventions implemented in community sports settings because the definition of each dimension of the framework depended on the specific level of the sport being targeted [47]. The RE-AIM SSM is useful as it identifies some factors relevant for implementing injury prevention strategies but it has not been the approach taken by the ACC in New Zealand to reducing sports injury claims.

At one stage this thesis was going to take a similar approach to Finch and Donaldson [47] and adapt RE-AIM to sport. However as the research developed it was clear that a different approach was emerging with regard to implementation of sports injury prevention interventions. For example in the FREED framework there is a greater emphasis placed on aspects such as funding than is the case in Glasgow's RE-AIM model [48]. The application of cost is addressed via the RE-AIM website, rather than in published literature, where it is acknowledged that cost influences several RE-AIM dimensions in addition to adoption. Cost is usually related to intensiveness of intervention which is often related (positively) to efficacy and (negatively) to implementation [51]. Positioning cost or funding in this way gives greater weight to RE-AIM being more suited to evaluation rather than implementation. Further, "reach", as this is used in the RE-AIM model, is separated into two parts in the FREED framework - resources and delivery. The next section outlines briefly the main components of the FREED framework before reviewing the content of the remaining chapters.

The ACC database and the components of the FREED framework

As an Injury Prevention Programme Manager working at the ACC with responsibility for implementing sports injury prevention interventions, I was able to establish a number of implementation programmes which could be evaluated as part of the research for this thesis. The implementation framework which eventually emerged from the research is based on several case studies which draw heavily on the ACC's database. Our injury prevention work has drawn praise internationally and while Orchard [52] notes that New Zealand's system for addressing accidental injury via the ACC is not perfect, he does acknowledge that it is one of the world's best nationwide systems for compiling information on accidental injuries of all types, and exploring possible injury prevention interventions.

People who have a personal injury make a claim to ACC at the time of seeking medical treatment from one of the 30,000 registered medical professionals throughout New Zealand. When making a claim, information about the injury is collected using standard forms to ensure levels of consistency in the assessment of the claim and for subsequent data analysis. The injured person (unless seriously impaired) completes a narrative about the activity surrounding the injury (including details of location, activity prior, cause) along with providing their personal details (e.g., age, gender, contact details). The registered medical professional completes the form by providing information regarding initial diagnosis and other relevant medical information (e.g., surgical procedure). The claim is then filed with ACC and details are entered into a central database.

There is no disincentive for making a claim; people are not discriminated against, risk rated or penalised for the number of claims made. The guarantee of personal injury coverage is offset by the fact that one cannot sue for personal injury in NZ, except in the rare circumstances of exemplary damages (e.g., mental trauma or stress). There is a considerable incentive to make a claim, since the ACC will compensate for a wide range of injury-related costs, including medical

care and loss of earnings. To make people aware of coverage, ACC undertakes a number of public information campaigns. The type of information collected systematically and continuously across a country allows comparisons of injury type and occurrence to be made.

The number of cases covered in the ACC database makes it suitable for the application of the sorts of sequence of prevention frameworks that have been proposed in the literature [25]. In the 2008/09 financial year, for example the cost of 487,788 sports injury claims was \$446,476,287. By comparison, the 61,830 road accident claims for the same period cost ACC \$400,007,794. These sport injuries can be segmented into five of the six criteria used by van Mechelen et al. [25] to describe injury severity: nature of the sports injury [35, 37, 38, 43]; duration and nature of treatment [5, 35, 37, 38, 40, 43]; working time lost [5, 35, 39, 41, 45]; permanent damage [35, 39]; and cost [37-39, 43]. The remaining criterion, sporting time lost, [25] can only be classified by the ACC database into three categories: minor (medical treatment only), moderate to serious [39], and serious [53].

The ACC database is unique and allows for standard definitions and methods of data collection argued for by Chalmers [30]. The value of the ACC claims database has been recognised by others such as Orchard [52]. Noakes and Draper [1] argued that our paper on spinal injury prevention [36], for example, would not have been possible if there was not a national wide injury insurance that also covers sports injuries. Orchard [52] stated that New Zealand can currently apply the sequence of injury prevention and TRIPP frameworks to sports injuries as they have a national injury surveillance system in place.

To offset the cost of these sports injuries ACC invests in sports injury prevention. It is the largest and arguably the only organisation focused on sports injuries in New Zealand. While national sporting organisations do have injury prevention programmes, these are usually in partnership with ACC. Certainly in most sports there would not have been an injury prevention programme unless ACC was heavily involved in providing financial support, expertise or advice. The only exception was the Rugby Union that has had a prevention programme since 1996 but the main benefit of this, a decrease in serious spinal injuries, only came after ACC became involved in 2001 [36].

The focus of the ACC sports injury prevention programmes across the country is at the community level where almost all sports injuries occur. While professional sports injuries tend to receive the most media coverage these claims comprise less than 1% of ACC's injury cost burden. This makes the use of van Tiggelen et al's [34] model, with its clear focus on professional sports, of limited use in the New Zealand community sports context.

The FREED (Funding, Resources, Environment, Evaluation, Delivery) framework was developed to document main factors that contributed to the success or failure of community sports injury prevention in New Zealand. The key components of the framework, which

emerged from the case studies outlined in subsequent chapters, are summarized briefly below. Information contained in the ACC's database on injury claims is critical for operationalising the components of funding, evaluation and delivery – components that have not been easy to assess systematically outside the context of specific cases of injury prevention in earlier frameworks. The application of the FREED framework to the New Zealand Rugby League injury prevention programme, described in Chapter 9, illustrates the strengths and weakness of the FREED framework approach in a community sports context at a national scale.

Funding

Ensuring injury prevention funding is available is essential for a viable sports injury prevention framework. None of the injury prevention programmes that are discussed in the chapters that follow would have been implemented without funding, nor could they have continued without the support of on-going funding. The concussion programme, for example, discussed in chapter 5, demonstrated both savings and the return on investment. The cost-benefit model (chapter 2), that can be developed using ACC data, has been applied to a wide range of injury prevention programmes.

Resources

Interventions focused on specific groups of coaches in soccer and netball, highlighted the importance of this resource for effective delivery of injury prevention strategies. While delivery gets prevention programmes to the desired audience, resources ensure the quality of the initiative with the most appropriate messages for reducing injuries. At the community level there is limited opportunity to have people actively engaged with an injury prevention programme over any period of time. It is the quality of the resources that allows for the prevention programme to continue past initial engagement. The use of resources is highlighted in all of the case studies, especially those dealing with concussion (chapter 5), and in the discussions of soccer and netball which revealed showed that our resources were suitable because they were being used the following season.

Environments

All interventions to prevent sports injuries require a clear understanding of the environment within which a prevention programme can operate. While the Rugby Union interventions is the best example of this, Understanding the environment was critical in the case of the, catastrophic spinal, neck/back and concussion interventions that were being addressed by the Rugby Union. Understanding the environment and funding available will help determine resources and delivery.

Evaluation

The sports injury intervention programmes discussed in this thesis were only successful because they could be evaluated. Programmes focused on specific sports, such as rugby union further reinforced the importance of evaluation – specific sports programmes has a wider focus

than one injury type. The Rugby Union while successful with its interventions to address serious spinal, neck/back and concussion-related injuries would have benefitted from more evaluation being conducted before the implementation programme was in place.

Delivery

The programmes targeting specific injuries, such as catastrophic spinal, neck/back and concussion, demonstrated the effectiveness of having a delivery system for sports injury prevention. The case studies addressing neck/back injuries (chapter 6) and coaches (chapter 8) provide the best examples of this. Delivery needs to be supported by effective resources as concussion programme clearly showed.

Because the FREED framework can be used in a wide range of sports injury contexts, rather than being confined to a single set of circumstances, it can be used in the analysis of the implementation of community sports injury prevention programmes throughout New Zealand. It suggests an approach that could be used in other countries, although it is acknowledged that the ACC's unique database is critical for its operationalisation. The framework fills an important gap in the literature on sports injury prevention by addressing in a comprehensive way the implementation stage of models and frameworks that seek to translate research into injury prevention interventions into practice in real world injury contexts.

Structure of the thesis

In developing the FREED framework for implementing sports injury prevention interventions in New Zealand several themes needed to be addressed including: the ACC database, the SportSmart model, specific injuries, specific sports, specific groups, and the articulation and testing of the framework itself. Figure 3 outlines the way the thesis evolved. Each thematic section resulted in a number of publications that helped to define and develop the components of the community sports implementation framework (later termed FREED). The SportSmart model was the underpinning framework for the sports injury prevention programme and played an important role in the development of the thesis.

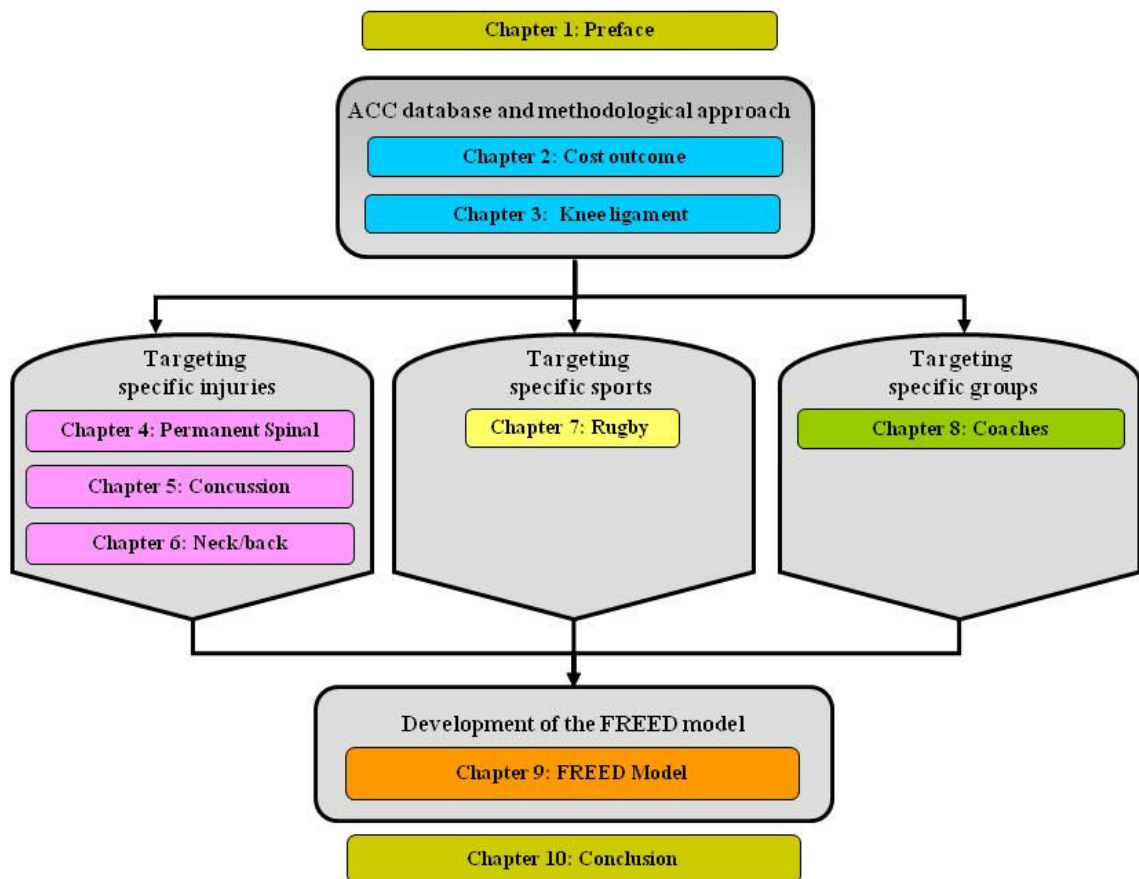


Figure 3: Outline of the thesis structure.

The first of the five substantive sections in the thesis explores the ACC claims database (Chapters 2 and 3). Chapter 2 outlines a cost-outcome approach for funders of sport injury prevention. The approach provides calculations of the return on investment in both pre-implementation and post implementation contexts. Chapter 3 contains an epidemiological analysis of knee ligament injury claims, with a specific focus on anterior cruciate ligament (ACL) surgery in sport. There has been intensive research into determining the cause of non-contact ACL injury over the past decade [54]. In view of this, it is surprising that few studies have reported data on the incidence of ACL and other knee ligament injury in the general population or in a sporting population. A comprehensive descriptive epidemiology, using population-based data, can identify high-risk subgroups within the general population, illuminate the settings and mechanisms of injury, and help target intervention programs aimed at reducing these injuries.

The next three substantive sections explore sports injury prevention implementation by targeting specific injuries, specific sports and specific groups. Section 2, with its focus on specific injuries, has three chapters. Chapter 4 presents the results of an analysis of an injury prevention programme designed to reduce serious spinal injuries in rugby union (rugby). Thirty years of data relating to permanent spinal injuries arising from playing rugby was analysed before and after implementation of the prevention programme. A forecast is used to determine the number of permanent spinal injuries there might have been if the injury prevention programme had been

available through the 30 year period and the results are then compared to the actual number that occurred.

Chapter 5 focuses on sports concussion and the implementation of a sideline concussion checklist (SSC) across a range of sports. Rather than focusing on the prevention of concussion, which is difficult given the biomechanics and forces involved, this intervention focuses on the management of suspected concussion at the community sports level. At this level the people expected to manage suspected concussion are likely to be coaches in the community who will have little or no medical training.

In Chapter 6 changes made to scrum engagement rules in rugby union by the International Rugby Board are examined. Data on neck and back injury claims from the scrum during the five years before the rules were changed are compared with expected and actual claims after the rules changes.

The third and fourth sections of the thesis comprise one Chapter each that focuses on prevention programmes targeting specific sports (Chapter 7) and specific groups involved in the delivery of sports injury prevention interventions (Chapter 8). Chapter 7 contains an examination of rugby union with reference to the entire programme rather than one or two specific injury sites such as those addressed in Chapter 6. The more holistic approach taken in Chapter 7 allows for more detailed behavioural analysis of how a comprehensive sports injury prevention programme works rather than focusing on specific types of sports injury claims. Chapter 8 focuses on coaches as a primary delivery mechanism for sports injury prevention interventions, particularly in soccer and netball. It examines the extent to which injury prevention messages and resources are used in successive seasons by coaches.

The final section of the thesis addresses the framework. Chapter 9 presents the FREED framework for implementing community sport injury prevention interventions using a nation-wide approach. The findings from earlier chapters are used to inform the development of the framework which is applied injury prevention in rugby league in this chapter. Figure 4 shows how each of the thesis chapters contributed to elaborating the components of the FREED framework implementing community sport injury prevention interventions in New Zealand.

Chapter 10 contains a general discussion of findings from the research projects described in chapters 2-9, provides some conclusions and outlines areas for future research.

A framework for community sport injury prevention implementation in New Zealand

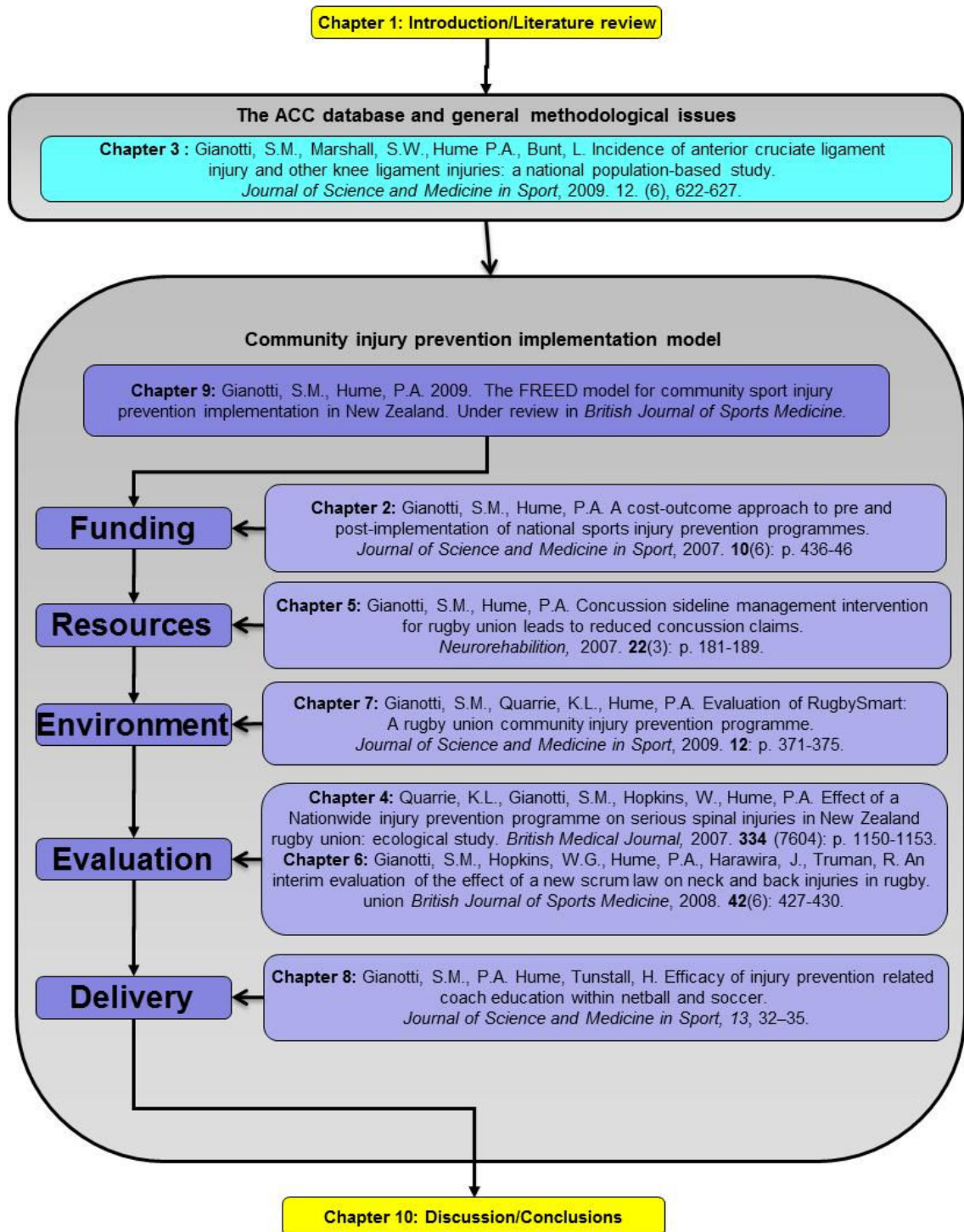


Figure 4: Contributions to the development of the components of the FREED framework for community sport injury prevention implementation in New Zealand.

CHAPTER 2

A COST-OUTCOME APPROACH TO PRE AND POST-IMPLEMENTATION OF NATIONAL SPORTS INJURY PREVENTION PROGRAMMES

This chapter comprises the following paper accepted by *Journal of Science and Medicine in Sport*:

Gianotti, S.M. and Hume, P.A. A cost-outcome approach to pre and post-implementation of national sports injury prevention programmes. *Journal of Science and Medicine in Sport*, 2007. **10**(6): p. 436-46. (Author contribution percentages: SG: 95%, PH: 5%)

Overview

In New Zealand (NZ), the Accident Compensation Corporation (ACC) has developed a pre and post-implementation cost-outcome formulae for sport injury prevention to provide information regarding the success of a prevention programme. The ACC provides for the cost of all personal injuries in NZ and invests in prevention programmes to offset 1.6 million annual claims that cost \$NZD 1.9 billion. The ACC invests in nine national community sport injury prevention programmes that represent 40% of sport claims and costs. Pre-implementation is used to determine the decision whether to invest in implementation and to determine the level of such investment for the injury prevention programme. Post-implementation is calculated two ways: unadjusted, assuming *ceteris paribus*; and adjusted assuming no prevention programme was in place. Post-implementation formulae provide a return on investment (ROI) for each dollar invested in the programme and cost-savings. The cost-outcome formulae approach allows ACC to manage expectations of the prevention programme as well as when it will provide a ROI, allowing it to take a long-term view for investment in sport injury prevention. Originally developed for its sport injury prevention programmes, the cost-outcome formulae have now been applied to the other prevention programmes ACC invests in such as home, road and workplace injury prevention.

Introduction

The need for cost analysis of injury prevention initiatives

The van Mechelen et al. 'sequence of injury prevention' model [25] has been documented in the literature [8, 10, 30] as a framework to describe the development, implementation and effectiveness of sport injury prevention. A key part to this model is stage three, 'Introducing prevention measures'. Despite the prevalence of the model and its wide acceptance there is little in the sport injury prevention literature discussing how the prevention measures are funded. Ensuring injury prevention funding is available is central to enable implementation. The level of injury prevention funding should be commensurable to the number and cost of injuries that the programme will be preventing. Gold et al. [55] acknowledged the challenge of predicting returns on investment in any field, but suggested there is a need for prevention to provide evidence to generate cost-savings prior to seeking funding or initiation of implementation. In a resource-

constrained world, decision makers want to know if a programme produces the desired result less expensively than alternative approaches [56]. Despite mounting evidence that prevention initiatives for injuries, heart diseases, stroke, diabetes, and cancer are effective, prevention is at a competitive disadvantage for time and money [55]. If funding for sports injury prevention is to continue long term, outside randomised control tests, or at a national level, cost-outcomes such as return on investment (ROI) and cost-savings are required.

Evidence to date for injury prevention cost-outcome initiatives

Cost-outcome studies of injury prevention programs are scarce in the published literature. A meta-analysis [56] of 84 injury prevention studies with cost-outcome measures in the United States of America, found only a few cost-outcome studies for a variety of injury prevention areas, with none identified for sport and recreation. Cost-outcomes studies have been conducted for the effectiveness of protective equipment such as cycle helmets [57] prophylactic ankle taping versus bracing [58], and proprioceptive balance board training [59]. In addition there have been studies that have reported the cost-outcomes of medical procedures such as magnetic resonance imaging [60]. Miller & Levy [56] argued that the major barrier to the number of studies having cost-outcomes appears to be a lack of information about the costs of injury and the costs of injury prevention countermeasures. This may account for the limited number of cost-outcome studies in sport injury prevention evident in the literature so far. Despite some literature that discusses cost-outcomes [56] there has been no definition provided. Drummond [61] identified four main forms of economic evaluation: Cost analysis, Cost-effectiveness analysis, Cost-utilisation analysis; and Cost-benefit analysis. Each form of economic analysis each deals with costs but differing in the way that the consequences of programmes are measured and valued. While the model chosen will depend on what is being measure, the approach taken in this paper is aligned to a cost-outcome description since it is unable to undertake a full comparison of alternative programmes.

The use of cost-outcome analysis for sport injury prevention by ACC

In New Zealand (NZ) the Accident Compensation Corporation (ACC) has applied cost-outcome formulae since 2003 for its national sports injury prevention programmes. Originally developed for sport, the same formulae have subsequently been applied for ACC's work, home, falls and road injury prevention programmes. ACC is a government taxpayer-funded monopoly, in existence since 1974 providing a 24-hour no-fault personal injury scheme, currently legislated by the Injury Prevention, Rehabilitation and Compensation Act 2001 (IPRC). ACC provides for the associated injury costs including medical treatment, income replacement, social rehabilitation and vocational rehabilitation, and ancillary services such as transport and accommodation. There is no disincentive for making a claim, people are not discriminated, risk rated or penalised for the number of claims made. From approximately four million people (estimated population of NZ), there were over 1.6 million personal injury claims registered with ACC costing \$NZD1.9 billion in the last financial year (1 July 2004 to 30 June 2005). The guarantee of personal injury coverage is offset by the restriction to sue for personal injury

except in the rare circumstances of exemplary damages e.g., mental trauma or stress. The national coverage and no-fault 24-hour system makes the ACC dataset useful for measuring injury prevention initiatives. ACC has developed its cost-outcome model to show a return on investment in its injury prevention programmes.

The ACC currently assesses moderate to serious claims (MSC) for its sport cost-outcome model. This is for four reasons. The first of these being cost. Of the 294,960 sport claims made in the last financial year, 8% were MSC, but represented 80% of the \$NZD222 million sport claims cost to ACC. Secondly, the IPRC gives provision for ACC to promote measures to reduce the incidence and severity of personal injury as a primary function. As result of section 263 (3) (a), the measures are targeted to result in a cost-effective, reduction in actual or projected rates. Thirdly, in practical terms better data are gathered for MSC than minor claims, particularly in relation to key sport information and 'how the injury occurred'. Currently ACC has initiated a process to capture into the system minor claim data. This process has been in place for two years and approximately 78.2% of the minor claims are now entered. Once all claims are entered then an adaptation of the model will be made to include minor claims. An adapted model has been developed but has not been sufficiently tested. Finally, combining low cost claims with high cost claims, creates clusters of costs and makes analysis using mean and standard deviations (SD) difficult. The annual mean \pm SD for sport MSC is \$5,262 \pm \$52.62 and for minor sport claims is \$164.15 \pm \$237.69. This makes combining the two claim types difficult and is a limit of using cost data that is not separated. The cost of MSC, the provision of the IPRC, the quality of MSC data compared with minor data in terms of cost and detail, and to avoid cost clusters, leads ACC's national sport injury prevention programmes to be designed to reduce the number and severity of MSC.

Although ACC had been investing in prevention programmes for a number of years, it wanted to select an appropriate level of investment based on activity suitable for the prevention programme. To provide a level of external validity to the process, the cost-outcome model was developed and reviewed by three internal ACC groups who work closely with the claims data, and an external consultancy firm and an academic. Recommendations were adopted to enhance the model, but the original working and logic remained intact. In addition ACC undertakes a number of quantitative and qualitative evaluations to assess the impact of the programmes.

Aim

To outline the ACC cost-outcome formulae for pre and post-implementation of its national sports injury prevention programmes.

Methods

The nine sport injury prevention programmes supported by ACC

During 2005 there were nine national sport injury prevention programmes ACC invested in. These nine sporting activities were high in participation and collectively represented 40% of the sport MSC to ACC in the last financial year. Van Mechelen [25] argued that any cost-analysis must identify the sports that are most expensive for the community, so that the first intervention can be focused there. This is also consistent with the direction of section 263 of the IPRC. ACC through the no-fault system has a census of claims made. As a result ACC is able to show the costs for different sports and different injury types. This allows ACC to measure the cost of injury against the cost of intervention.

The data base information used by ACC for the nine sports with injury prevention programmes

The definition of injury for coverage by ACC is currently legislated by the IPRC and must satisfy three criteria: it must be a personal injury; it must be the result of an accident; and there must a link between the two. People who have a personal injury make a claim at the time of seeking medical treatment from over 30,000 registered medical professionals throughout NZ. When making a claim all information about the injury is collected using a standard form, ACC45, to ensure levels of consistency for data analysis. The injured person (unless impaired) completes information about the activity surrounding the injury (scene, cause, mechanism, sport) along with their personal details. The registered medical professional completes the form by providing information regarding diagnosis and other relevant medical information. The claim is then filed with ACC and details entered into a central database, with a preference for MSC data being entered. Key data such as diagnosis and personal details for minor claims are entered, but key sport information is less likely to be entered. Table 1 shows the nine programmes and the areas targeted by that programme such as the activity prior to the injury, the scene of injury and demographic characteristics.

Pre-implementation cost-outcome formulae

The pre-implementation formula calculates the number of MSC the prevention programme must reduce to break even i.e., for each dollar invested in the injury prevention programme it must return one dollar of savings (\$1:\$1). The calculation provides an injury rate (IR) as a percentage of the number of participants the programme will be targeting (T). This is useful to determine if a programme is feasible or not. Pre-implementation is applied to the forthcoming ACC financial year (e.g., 1 July 2005 to June 2006 - 2005/06), reflecting the expectation in the next financial period. As the calculations conducted are either in the current period or just before the current period, discounting is not required. Typically discounting is a process of converting future dollars and outcomes into their present values [55].

Table 1: The specific search terms used in the ACC database for analysis of the nine sports targeted with injury prevention programmes.

Sport	Activity prior to injury	Scene of injury	Sport	Person's age on date of injury	Financial year programme implemented	Type of IP programme; example components	Key injury focus
Horse Riding (Horse)	sport and recreation		horse riding		2004/05	Rider education on handling horse, concussion, video clips on safety tips	Spinal cord damage, traumatic brain injury, neck/back/spine, falls.
Rugby League (League)	sport and recreation	sport and recreation	rugby league	between 15-44 years	1998/99	Currently being revamped to become LeagueSmart, will include concussion, tackle technique	Spinal cord damage, traumatic brain injury, neck/back/spine, shoulder, knee, ankle, concussion
Mountain biking (MTB)		off-road	cycling	aged 15 years or older	2005/06	Rider resources and MTB code of conduct	Shoulders, soft tissue, falls
Netball	sport and recreation	sport and recreation	netball		1999/00	Player and coach education, NetballSmart,	Soft tissue, knees ankles
Rugby Union (Rugby)	sport and recreation	sport and recreation	rugby union	between 15-44 years	1997/98	Education; RugbySmart Tackle video, Concussion cards. Enforcement; tackle rules, mouthguard use.	Spinal cord damage, traumatic brain injury, neck/back/spine, shoulder, knee, ankle, lower limbs, concussion
Skiing and Snowboarding (Snow)			snowboarding or snow skiing		2001/02	Snow code and player resources, Concussion, promoting of protective equipment e.g. wrist guards	Knees, wrists, concussion
Football/Soccer (Soccer)	sport and recreation	sport and recreation	soccer		1999/00	Player and coach education, SoccerSmart, shin guards, FIFA's "The 11" programme, concussion	Soft tissue, knees, ankles.
Touch Rugby (Touch)	sport and recreation	sport and recreation	touch rugby		1999/00	Player and coach education	Soft tissue, knees, knees ankle
Water-related activities (Water)			boating, fishing, kayaking, swimming (rivers, pools, lakes, or beaches), surfing, underwater diving, water-skiing or windsurfing		2000/01	Public education campaign, including resources and television to raise awareness	All

Pre-implementation utilises the following variables in the formulae:

PC = Programme Costs to implement at the national level for the year of analysis;

- **ALC** = Average Lifetime Cost. This represents the cost to ACC of a MSC in the area targeted for implementation, over the time length of the claim. This is important as treatment for some injuries can occur across more than one financial reporting year, particularly MSC. ACC has 30 years of injury data and is able to determine the length and cost of a particular injury type, and the last ten years is used as the best indicator. The size of the data set can estimate the number of treatments, visits, time off employment and other factors to provide what services from ACC the person may require. While the mid point is used, a 95% confidence level is generated. The ALC is the amount paid to either the injured person or to treatment providers. It does not include a portion of ACC operating costs. The ALC is presented at current costs and reviewed each year to reflect changes in costing that may occur, from year to year;
- **M** = maximum number of participants in the sport. This is the number of participants defined by a demographic (e.g., gender, age, ethnicity) and will determine the extraction criteria for the ALC;
- **H** = Historical number of MSC for the participants in the sport that a prevention programme is intending to be implemented. Similar to ALC, the last ten years provides the best historical data, but this is dependant on the injury e.g, a serious injury such as tetraplegia or paraplegia can be tracked back to 1974, when ACC came into existence; and
- **T** = Number of participants in the sport being targeted. This is matched to the type of intervention.

To determine the IR, the number of MSC to break even (BE) needs to be established using the following formulae:

$$BE = \frac{PC}{ALC}$$

The BE is then used to determine the IR as a percentage based on the estimated number of MSC in the targeted group:

$$IR\% = \frac{B}{\left(T \left(\frac{H}{M}\right)\right)}$$

While the IR is expressed as a percentage it is an indication, not a precise figure. The IR is then subject to a sensitivity analysis, determining upper and lower parameters. This can easily be achieved as the only variables that can be modified are programme costs (PC) and number of participants in the sport being targeted (T). All other formulae variables, (ALC, M, & H) are static and only change annually.

Once the IR is calculated and sensitivity analysis is conducted, a comparison against pilot studies, existing studies in the literature or similar prevention programmes is made to determine

if the IR is achievable or not. If no research or similar programmes exist, the IR is compared to sports or demographics with similar injuries. The IR is then subject to peer-review including the sensitivity analysis. The IR is used in the pre-implementation stage as it determines whether the programme is feasible or not. In determining the change in claims post-implementation cost-outcome formulae are used.

Once the final IR is determined it forms part of a business case to seek ACC funding for the prevention programme. The funding of the programme also relies on other business case supporting data such as literature, risk factors, current funding levels and whether the programme can actually be implemented as intended. Due to the ACC system having injury data for 54 sports, all sports have the potential to have a pre-implementation model developed. Which sports have a prevention programme depends on the strength of the business case and includes cost-outcome formulae.

Post-implementation cost-outcome formulae

Post-implementation is an annual exercise and calculates any change in the number of MSC to ACC in two ways. The first, unadjusted, is against the difference in MSC from baseline before implementation to the point in time being measured, typically a number of years and assumes the principle of *ceteris paribus*. The second, adjusted, is based against forecast as to the number of MSC that would have occurred if no prevention programme were implemented. Having a forecast allows factors outside the control of a prevention programme to be taken into account such as changes in ACC policy or population growth. Post-implementation is conducted annually rather than seasonally as ACC receives sport MSC throughout the year, but a higher concentration occurs in the months the sport is traditionally played. MSC can be matched to the programme by region, demographic, or injury type. The cost-outcome for both unadjusted and adjusted is expressed as a ratio for each dollar invested. Post-implementation is presented by the last full financial year (e.g., 1 July 2004 to 30 June 2005 - 2004/05), and is conducted at the end of each financial year.

Post-implementation uses the following variables in the formulae:

- **U** = unadjusted claims, the difference between the number of MSC before implementation and post-implementation at a particular point in time;
- **A** = adjusted claims. The claims are adjusted to show what would happen if no programme was in place. This is achieved by using a forecast made based on factors that would have impacted on the ACC claims database that need to be taken into account. Analysis by external consultants identified 28 factors [62, 63] and these are weighted based on the prevention programme i.e., aging population has less impact on sport MSC than a programme targeting falls in older adults. This analysis produces an adjusted number of MSC that is used to calculate a cost-outcome analysis. The identification of the 28 factors [62, 63] helps address the concern that it is not possible to rule out the effect of a change of variables over time other than the preventive

measure, which may also influence the outcome variable [25]. Factors were first identified from within ACC based on changes in the environment (e.g. policy changes) and these were then assessed to determine the effect;

- **TPC**, total programme costs since implementation. This includes only programme costs invested by ACC and excludes associated costs such as overheads and staff salaries; and
- **ALC**.

$$\text{Unadjusted cost-outcome} = \frac{U*ALC}{TPC}$$

$$\text{Adjusted cost-outcome} = \frac{A*ALC}{TPC}$$

Post-implementation formulae provide cost-savings and are presented over a ratio of \$NZD1 reflecting ROI.

Results

The results for the cost-outcome analysis for the nine prevention programmes are presented in Table 2 (pre-implementation) and Table 3 (post-implementation). The upper and lower bounds used in Table 2 and Table 3 represent that the ALC is calculated using a 95% confidence interval. It is present to provide a range for the ROI. The stage of injury prevention programme implementation and the variety in ALC to ACC, depicting the severity of injuries in each sport, is evident in the table data. A worked example with variables derived from Tables 2 and 3 is provided from the netball programme.

Pre-implementation cost-outcome application to netball

$$BE = \frac{PC}{ALC} = \frac{150,000}{5.035} = 29.79 \text{ claims to break even (BE)}$$

$$IR\% = \frac{BE}{\left(T \left(\frac{H}{M}\right)\right)} = \frac{29.79}{\left(50,000 \left(\frac{1310}{150,000}\right)\right)} = \frac{29.79}{\left(50,000 (0.0087333)\right)} = \frac{29.79}{436.665} = 6.82\% = IR$$

Post-implementation cost-outcome application to netball

$$\begin{aligned} \text{Unadjusted cost-outcome} &= \frac{U*ALC}{TPC} = \frac{47*5035}{377,300} = \frac{236,645}{377,300} = \text{return of 63 cents for every dollar invested} \\ \text{Adjusted cost-outcome} &= \frac{A*ALC}{TPC} = \frac{947*5,035}{377,300} = \frac{4,768,145}{377,300} = \text{return of 12.64 dollars for every dollar invested} \end{aligned}$$

Pre-implementation cost-outcome results

Most sport programmes are expected to provide a ROI and cost-savings to ACC. In 2005/06 the two exceptions will be mountain biking (MTB) and League. MTB is in its first year of implementation, whereas League had an injury prevention programme restructure and was re-focused to be consistent with other similar sport prevention programmes. This required additional funding (\$NZD100,000) justified by the previous ROI and cost-savings (see Table 3). As such both programmes are not expected to show a ROI till 2006/07. Typically, new or refocused prevention programmes take 12 to 18 months to show a return, especially at the national level. As large-scale national prevention programmes require a behaviour change and are outside the laboratory situation, a greater variation of uptake of prevention principles and change in behaviour will occur.

Post-implementation cost-outcome results

Post-implementation (Table 3) is measured against unadjusted MSC assuming a level of *ceteris paribus* applies, and adjusted MSC reflecting the forecast if no prevention programme was in place. The variation between the two clearly shows without adjustment only two programmes (Rugby and Snow) are providing a positive ROI, i.e., for every \$1 invested the programme returns at least \$1. Programmes such as Horse are in their first year of implementation and did not provide a ROI, or cost savings. The MTB prevention programme was not in existence in 2004/05 so does not provide any results, but is expected to provide results by the end of 2006/07. The Water prevention programme shows that even with adjusted MSC it is not providing a ROI or cost savings to offset programme costs.

In the netball example provided there are a number of factors that specifically impacted on this programme. This is reflected in the adjusted MSC. To provide an indication of the factor, some specific to ACC, some to NZ and some to netball, Table 4 presents these with an indication of the impact, high, medium, low.

Discussion

The ACC has the benefit of a system that has well-documented and carefully measured effectiveness that Miller & Levy [56] called for in determining cost-outcomes. The ACC has the ability to provide a level of cost-outcome analysis required under the IPRC. This has resulted in pre and post-implementation cost-outcomes. While the examples used in this analysis are focused on the entire national programme, the formulae can be, and are, applied to specific injuries (such as dental claims, concussion, spinal injuries, strains and sprains) and also to regions or particular demographics.

The ACC invested in injury prevention programmes before the development of the pre-implementation cost-outcome framework. The ACC decided to focus its prevention programmes on areas that were high in cost and numbers of MSC. This retrospectively has provided positive ROI and cost-savings (See Table 3). The development of a cost-outcome framework has allowed ACC to continue to invest and increase its investment e.g., Netball and Soccer had a \$NZD100,000 programme increase respectively from 2004 to 2005. The framework has also allowed ACC to extend the range of other programmes that it may not have considered implementing before (e.g., Horse and MTB), as well as indicating the level of investment suitable for a prevention programme (e.g., League). One of the benefits from this type of cost-outcome framework is that the IR assists decision makers by providing an objective analysis that helps determine the likelihood of the programme achieving a reduction in MSC to ACC, before investment. In the netball example provided, a IR of 6.82% is required. The focus shifts to whether the 6.82%, or IR, is achievable and the supporting evidence for this.

Pre-implementation formulae ensure smart targeting by calculating the IR from only the injuries from the target group (T) rather than all possible MSC for the sport. The emphasis moves to whether those people can be reached and the quality of the intervention. This is a crucial factor for implementing prevention programmes at the national level.

Central to the decision of implementation is the national sporting organisation (NSO). This is an essential part as it is only in partnership with the NSO that a prevention programme at the national level has any likelihood of success. Pre-implementation provides a useful framework for providing a starting point for dialogue before implementation, by highlighting the factors needed to reduce MSC as part of the prevention programme. If the IR is considered high and/or not supported by other evidence, this is then used to discuss more cost effective measures with the NSO. Typically cost (PC) and size of target (T) group is analysed to determine if either can be modified, subject to peer review, ensuring the variables used are correct at time of calculation. Other variables in the pre-implementation formulae (M, H and ALC) remain constant. This is then used to discuss more cost effective measures. The advantages are that it makes parties aware of the factors needed to make the programme a success. However, the formulae are reliant on a strong approximation of playing numbers (M). If this is incorrect then the IR will also be incorrect. In NZ there are few NSOs that have an accurate database of playing numbers. Participation studies can provide some insight, but these are usually not conducted annually. This is a limit of the formulae used.

Post-implementation results show a wide range occurs when comparing unadjusted and adjusted ROI and cost-savings (See Table 3). Having only one perspective would provide a limited view. Certainly having only unadjusted cost-outcomes is ignoring the real world and epidemiologic factors that affect injuries. For example Rugby has had an increase in playing numbers of 6.9% and 6.3% in 2004 and 2005 respectively [64], and volcanic activity has reduced the number of days available for skiing in a season. Adjusted cost-outcomes rely

heavily on the accuracy of the forecasts. An understanding of how post-implementation formulae are calculated is required otherwise the analyses generated are used in isolation and do not present a true and fair view. A positive post-implementation should be taken as just that, rather than an exact or precise figure. The longer the prevention programme returns a positive ROI and the larger the figure, the greater confidence surrounding it.

Table 2: Pre implementation cost-outcomes for the 2005/06 ACC financial year.

Pre implementation cost-outcomes for the 2005/06 ACC financial year using a mid point ALC												
Sport	Programme costs (P)	Average lifetime cost (ALC)	Break even point (BE)	Break Even point (BE) Rounded	Max number of participants in sport (M)	Historical number of MSC (H)	Number of participants in the sport being targeted (T)	Injury Rate (IR)	Projected IR	Projected number of claims reduced	Projected savings	Projected ROI per \$1 (lower; upper bounds)
Horse	\$ 30,000	\$ 17,478	1.72	2	76,000	457	16,000	1.78 %	5.0%	4.81	\$54,071.39	\$2.80 (2.53;3.08)
League	\$ 120,000	\$ 13,959	8.60	9	21,000	564	65,000	1.90 %	0.0%	0.00	\$120,000.00	\$0.00 (0.00;0.00)
MTB	\$ 50,000	\$ 8,782	5.69	6	177,200	785	30,000	4.28 %	3.0%	3.99	-\$14,958.10	\$0.70 (0.61;0.79)
Netball	\$ 150,000	\$ 5,035	29.79	30	150,000	1310	50,000	6.82 %	7.0%	30.57	\$3,926.98	\$1.03 (0.99;1.06)
Rugby	\$ 300,000	\$ 7,951	37.73	38	55,000	3164	52,500	1.25 %	4.0%	120.81	\$660,509.57	\$3.20 (3.07;3.33)
Snow	\$ 120,000	\$ 8,083	14.85	15	300,000	625	234,000	3.05 %	3.1%	15.11	\$2,132.32	\$1.02 (0.96;1.08)
Soccer	\$ 150,000	\$ 6,117	24.52	25	200,000	1,261	130,000	2.99 %	5.0%	40.98	\$100,691.87	\$1.67 (1.53;1.81)
Touch	\$ 25,000	\$ 5,523	4.53	5	200,000	590	32,500	4.72 %	5.0%	4.79	\$1,456.08	\$1.06 (1.01;1.11)
Water	\$ 668,000	\$ 32,449	20.59	21	1,872,000	725	1,179,360	4.51 %	5.5%	25.12	\$147,115.61	\$1.22 (1.09;1.35)

Table 3: Cost-outcome analysis post implementation to 2004/05 ACC financial year.

Cost-outcome analysis post implementation to 2004/05 ACC financial year using a mid point ALC								
Sport	Total programme costs (TPC)	Average lifetime cost (ALC)	No. of claims reduced unadjusted	No. of claims reduced adjusted	Programme savings unadjusted	Programme savings adjusted	ROI per \$1 unadjusted (lower and upper bounds)	ROI per \$1 adjusted (lower and upper bounds)
Horse	\$20,000	\$17,478	-92.00	0	-\$1,608,018.32	\$0.00	-\$80.40 (-72.55;-88.26)	\$0.00 (0.00;0.00)
League	\$152,130	\$13,959	-18.00	165	-\$251,256.42	\$2,303,183.85	-\$1.65 (-1.53;-1.78)	\$15.14 (13.98;16.30)
MTB	N/A	\$8,782	N/A	N/A	N/A	N/A	N/A	N/A
Netball	\$377,300	\$5,035	47.00	947	\$236,655.81	\$4,768,362.81	\$0.63 (0.61;0.65)	\$12.64 (12.25;13.03)
Rugby	\$1,425,234	\$7,951	588.00	1287	\$4,674,941.04	\$10,232,396.46	\$3.28 (3.15;3.41)	\$7.18 (6.89;7.47)
Snow	\$336,234	\$8,083	71.00	216	\$573,884.48	\$1,745,902.08	\$1.71 (1.61;1.81)	\$5.19 (4.88;5.50)
Soccer	\$250,800	\$6,117	-260.00	99	-\$1,590,529.20	\$605,624.58	-\$6.34 (-5.81;-6.88)	\$2.41 (2.21;2.62)
Touch	\$143,000	\$5,523	-56.00	63	-\$309,298.64	\$347,960.97	-\$2.16 (-2.06;-2.27)	\$2.43 (2.32;2.55)
Water	\$2,199,900	\$32,449	-167.00	16	-\$5,418,961.29	\$519,181.92	-\$2.46 (-2.20;2.72)	\$0.24 (0.21;0.26)

Table 4: Factors that impacted on MSC to ACC that relate to netball for the purposes of calculating the adjusted MSC.

Factors (no impact factors are excluded)	Impact value – High/Medium/Low
The growth in the population. There has also been a increase in the workforce population. These impacts on the number of people who makes claims, the type and nature of those claims.	Medium
Increased awareness of ACC entitlements and service. ACC actively encourages people to claim and runs public campaigns to ensure people access the services they are entitled to.	Low
Proactive contact with claimants by contact centres. When a person has been injured, particularly MSC they are managed to ensure they receive entitlements.	Low
Change in entitlements e.g. the re-introduction of lump sums payments. People may not have claimed if they received a weekly payment, but would as a lump sum.	Low
Extension of gatekeeper from doctors to include allied health providers. Previously to access additional medical service such as physiotherapy, a person had to be referred by a doctor. This meant that people no longer had to visit a doctor in order to access the most appropriate treatment provider for their injury, but could go directly to an allied health provider.	High
Elective surgery changes. ACC moved to have people who needed elective surgery receive it quicker by using private hospitals to provide such services. ACC commenced purchasing and fully funding elective surgery directly under contract. ACC previously funded elective surgery, at 60% of cost.	Low
Claim escalation rates (conversion from a claim receiving only acute primary health care benefits to one receiving compensation and other benefits)	Low
Awareness campaign to specific demographics that are underrepresented in claim statistic. ACC is targeting these groups to ensure they are aware of their entitlements under the scheme.	Medium
Relaxation of the requirement to identify an external force as part of the definition of accident. For an injury to be considered as caused by external force or resistance, it must be the direct result of a specific event or series of events. These must involve the application to the human body of an external force or resistance, or the sudden movement of the body to avoid an external force or resistance.	Low
Changes in funding. Direct payments of some health expenses by ACC rather than bulk funding)	Low
Changes in medical and vocational rehabilitation process and programmes	Medium
Health provider co-payments, Capitated Primary Health Organisations, and the incentive to claim	Medium
Current Injury Prevention programmes	High
Changes to allow health providers to electronically lodge claims making the process more efficient and decision made quicker.	High
Impact of winning the world championship on participation	Medium
Television and semi-profession growth of the sport that impacts on participation	Low

Both pre and post-implementation cost-outcomes for sport are centred on the reduction of MSC. While the rationale for this is logical (MSC are high in cost and severity) it does ignore the minor claims that make up 92% of sport claims to ACC. The prevention programme could be having an influence in these areas, certainly if MSC are reducing, but this is unknown as it is excluded in the analysis.

The calculations applied in this cost-outcome analysis only include treatment costs paid by ACC to either the injured person and/or the treatment provider. It does not include the value of pain, suffering, or loss of productivity to the country as a result of the personal sports injury. Other cost-outcome models usually incorporate a measure of the impact an injury has on the quality of life, costs to society, morbidity and mortality costs. These are typically the largest component of costs [65]. Placing a value on these can be subjective and difficult to measure from an injury perspective. As such ACC does not incorporate these into its model as it is primarily interested in the benefit to the organisation. Including quality of life and costs to society, if they were able to be quantified, into the formulae will only have a greater positive impact on the cost-outcome model.

The Water programme would benefit from the inclusion of cost-outcome formulae using aspects such as cost to society or quality of life. This is due to the programme's focus being the reduction of drowning, not injury. As such the post-implementation formulae are not suitable for the Water prevention programme as arguably it measures the wrong variables. The Water programme would be better suited to using another measure, such as a change in the number of drownings as an effective measure as opposed to MSC. Alternatively ACC could adjust the Water ALC to reflect quality of life or costs to society, morbidity or mortality costs and replace MSC with the number of drownings. There is a compensation component for next of kin for Water deaths from ACC, but this doesn't represent the cost to society. A future model for the Water programme will need to consider these costs.

Excluded from the formulae is the operating cost of ACC and legal implications. Toplin argued that these societal costs are relevant since they consume resources channelled into alternative uses [65]. While legal implications are incorporated into other cost-outcome models, the IPRC and the no-fault system means this is moot. Some operating costs would need to be incorporated into the cost-outcome formulae only if the programme was in place (e.g., injury prevention staff salaries). However, following Toplin's line of thinking [65] there would also have to be an amount allocated to the ALC as a reduction in MSC would require less resources and services from ACC to manage the injuries (e.g., 100 less MSC would require less operating costs). ACC is using a simple input-output model. Including a proportion of the operation cost will require additional assumptions and increase subjectivity into the cost-outcome formulae. Having a simple model that reduces elements of subjectivity provides the ACC cost-outcome model with greater credibility.

A clear limit of the ACC approach is the absence of discounting on the post-implementation formulae. This is currently subject to further analysis within ACC. While discounting is not relevant for pre-implementation, given that some prevention programmes have and will cover a number of years, discounting would benefit the model. Discounting is a standard accounting practice worldwide and has recognised and established tables for such calculations. Thus discounting is not open to the same level of subjectivity and interpretation as cost to society. While discounting will lower TPC, increasing the ROI and cost-savings, it should be undertaken to be consistent with literature and best-practice cost-outcome modelling.

The ACC has not incorporated all possible factors into its simple cost-outcome formulae. Some of these factors may be found in cost-outcome models. (e.g., cost to society, morbidity, mortality, discounting, or operating costs). There are examples of omitting outcomes and costs if they are not of interest to the decision maker [55] and this has been the case for ACC which has only focused on areas relating directly to their core business. This approach can reduce subjectivity, and can ensure expectations of the programme (i.e., reductions in MSC are achievable before investment has commenced).

The cost-outcome formulae show the value of injury prevention, albeit to ACC. As ACC meets the cost of the injury, it has a vested interest in funding successful injury prevention programmes. Having a cost-outcome framework allows ACC to select prevention programmes that fit with its goals, have a level of certainty before implementation, as well as focusing all stakeholders on the same variables to achieve success. The results of the ACC cost-outcome model do make a strong case for other countries contemplating sports injury prevention programmes or initiatives.

While initially developed for sport prevention programmes, the cost-outcome model had been integrated into other areas of ACC national prevention programmes e.g., workplace, home, road, falls. This is the distinct advantage of having a centralised injury database that collects injury information. An adequate injury registration system is essential to any assessment of the total cost associated with sports [65]. It also reduces an element of pre-selection regarding whether a person decides to seek treatment. Pre-selection may occur using hospitalisation data as less severe injuries or those with a delayed effect could likely be under reported [66, 67]. Given the population of New Zealand (four million) and the number of personal injury claims to ACC (1.6 million) in the last financial year, there seems to be little pre-selection occurring. This might not be the case in other countries intending to implement prevention programmes.

Conclusion

The ACC has developed its cost-outcome formulae to reflect its needs for continued investment in injury prevention programmes. It has, where possible, followed principles in the literature, but has opted for variables that reduce the element of subjectivity and speculation. This puts ACC

in a position to investment wisely in sports injury prevention ensuring correct funding levels and justification for that funding.

CHAPTER 3

INCIDENCE OF ANTERIOR CRUCIATE LIGAMENT INJURY AND OTHER KNEE LIGAMENT INJURIES: A NATIONAL POPULATION-BASED STUDY

This chapter comprises the following paper published by *Journal of Science and Medicine in Sport*:

Gianotti, S.M., Marshall, S.W., Hume P.A., Bunt, L. Incidence of anterior cruciate ligament injury and other knee ligament injuries: a national population-based study. *Journal of Science and Medicine in Sport*, 2009. Volume 12, Issue 6, November 2009, Pages 622-627 (Author contribution percentages: SG: 80%, SM: 10%, PH: 5%, LB: 5%).

Overview

There has been an intensive research effort directed at determining the cause of non-contact anterior cruciate ligament (ACL) injury over the past decade, but few studies have reported data on the incidence of ACL and other knee ligament injury in the general population. New Zealand's no-fault injury compensation data provides a national injury resource of data on claims for knee ligament injury. The goal of this paper was to provide a descriptive epidemiology of knee ligament injury in this country. Data were obtained for knee ligament injuries between 1 July 2000 and 30 June 2005. Injuries were categorised as non-surgical (NS), ACL surgeries (ACLS) and other knee ligament surgeries (OKLS). Incidence rates per 100,000 person-years were computed using population estimates. Costs and number of treatment/rehabilitation visits were obtained as an indication of severity. The incidence rate per 100,000 person-years was 1147.1 for NS, 36.9 for ACLS and 9.1 for OKLS. Males had a higher incidence rate than females for NS, ACLS, and OKLS. The mean (and median) number of treatment visits were NS: 6.6 (4), ACLS: 27.1 (24), and OKLS: 31.3 (24). The mean (median) treatment costs of these injuries were NS \$885 (\$129), ACLS \$11,157 (\$8574), and OKLS \$15,663 (\$8054). Analysis of injury descriptions for ACLS injuries indicated that 58% involved a non-contact mechanism of injury. These data underscore the high level of short-term disability associated with knee ligament injuries, especially ACL injuries that require surgery.

Introduction

There has been an intensive research effort directed at determining the cause of non-contact anterior cruciate ligaments (ACL) injury over the past decade [54]. In view of this, it is surprising that few studies have reported data on the incidence of ACL and other knee ligament injury in the general population or in a sporting population. A comprehensive descriptive epidemiology, using population-based data, can identify high-risk subgroups within the general population, illuminate the settings and mechanisms of injury, and help target intervention programs aimed at reducing these injuries.

It has been noted that although males account for the majority of injuries in the general population, when one accounts for physical activity (by examining specific sports), females are consistently observed to be at higher risk [68]. The fact that males account for more injuries than females in the general population is almost certainly due to their greater exposure to athletic tasks that predispose one to ACL injury, such as cutting and jumping, and to contact sports.

The paper provides a descriptive epidemiology of sport and general knee ligament injury of one country (New Zealand). New Zealand's (NZ) no-fault injury compensation system (administered by the Accident Compensation Corporation or ACC) means that NZ is uniquely positioned to provide a national detailed and national descriptive epidemiology including costs associated with treatment. Using this data, a comparison of the incidence and cost of ACL injury in relation to other knee injuries was conducted.

Methods

Data from ACC were used to provide a detailed descriptive epidemiology of knee ligament injury (including ACL injury). This national data system for tracking injury compensation includes data on costs and health care resource utilization. Knee ligament injuries were categorised as non-surgical (NS), anterior cruciate ligament surgeries (ACLS) and other knee ligament surgeries (OKLS). Incidence rates were computed using population estimates. Criteria for selection were injuries that involved knee ligaments: anterior and posterior cruciate; lateral and medial collateral ligament; lateral and medial meniscus; and other ligament injuries. Claim data were extracted for the period between 1 July 2000 and 30 June 2005. All injury costs incurred up to, and including, 19 May 2006 were included.

The ACC is a NZ government taxpayer-funded monopoly, in existence since 1974, providing a 24-hour no-fault personal injury scheme, currently legislated by the Injury Prevention, Rehabilitation and Compensation Act 2001. The ACC scheme provides universal no-fault coverage for most injury costs including medical treatment, income replacement, social rehabilitation and vocational rehabilitation, and ancillary services such as transport and accommodation.

People who have a personal injury make a claim to ACC at the time of seeking medical treatment from over 30,000 registered medical professionals throughout NZ. When making a claim, information about the injury is collected using standard forms to ensure levels of consistency for data analysis. The injured person (unless impaired) completes information about the activity surrounding the injury (e.g., location, activity prior, cause, narrative) along with their personal details (e.g., age, gender, contact details). The registered medical professional completes the form by providing information regarding initial diagnosis and other relevant medical information (e.g., surgical procedure). The claim is then filed with ACC and details are entered into a central database.

There is no disincentive for making a claim; people are not discriminated against, risk rated or penalised for the number of claims made. The guarantee of personal injury coverage is offset by the fact that one cannot sue for personal injury in NZ, except in the rare circumstances of exemplary damages (e.g., mental trauma or stress). There is a considerable incentive to make a claim, since the ACC will compensate for a wide range of injury-related costs, including medical care and loss of earnings. To make people aware of coverage, ACC undertakes a number of public information campaigns.

To ensure capture of high quality data and prevent fraud, ACC has in place a number of procedures. Given the volume of information, errors transposing information from paper to an electronic database will occur. The ACC is subject to extensive data quality procedures. An ACC data quality audit assessed gender at 100% and age at 98% correct respectively [69]. Other audit assessment figures are presented next to the relevant section in this paper.

Sports-related ACL surgeries were classified by “injury mechanism” (what the patient was doing when the injury occurred) based on a review of the short narrative injury descriptions included on the electronic claims record. People making claims can fill out a narrative box asking “What were you doing – what happened - how was the injury caused?” However, this is not a mandatory field and there is some variation in terms of the level of detail recorded in the narrative. The injuries were classified into one of four contact classifications: Direct contact (external force was directly applied to the injured knee, and was probably the proximate cause of the injury); Indirect contact (external force was applied to the athlete but not directly to the injured knee. External force was involved in the injury process but was probably not the proximate cause); Contact unknown (insufficient detail to distinguish); or Non-Contact (forces applied to the knee at the time of injury resulted from the athlete’s own movement and did not involve contact with another athlete or object) [70].

Population data for NZ were obtained from official government data [71] and provide estimates of resident populations between each 5-year census, the most recent being 2001. The population of NZ over the study period was approximately 4.1 million people [71].

Incidence rates (the number of injuries divided by the corresponding population times the number of study years, multiplied by 100,000) and corresponding 95% confidence intervals (95% CI) were calculated under standard large-sample Poisson assumptions. The mean, median and standard error of the number of visits and costs were also calculated.

Results

There were 238,488 knee ligament injury claims accepted by the ACC over this five-year period. Of these, 9,197 (3.9%) underwent surgery, with 7,375 (80%) identified as ACLS. The

population-based incidence rate per 100,000 person-years was 1,147.1 (95% CI 1,142.4; 1157.8) for NS, 36.9 (36; 37.8) for ACLS and 9.1 (8.7; 9.5) for OKLS.

Claim data summarising the location where the injury occurred are presented in Table 5. Only 59.5% of NS, 79.8% of ACLS and 81.5% of OKLS had location identified. An ACC data quality audit assessed the reliability of coding of location and activity to be 99% and 90% correct, respectively [69]. ACLS injury was more likely to be sports-related than the other two types of knee ligament injury. In 65% of ACLS injuries the location was a place of recreation or sport, compared to 32% of NS and 27% of OKLS.

Figure 5 presents the rate and 95%CI per 100,000 person-years for males and females by five year age groups for NS knee ligament (A), ACLS (B), and OKLS (C) injuries. Age/sex specific incidence rates for the subset of injuries that involved sport are also shown for NS (D), ACLS (E), and OKLS (F) injuries.

There were 27 cases (six were female and 21 male) where the person's age was not identified. All were non-surgical. Males had a higher rate than females in most of the age groups with males in some age groups having a rate over twice that of the females in that age group. When comparing the ACLS graph for the total population with sport ACLS graph, the shape is similar, whilst there is less similarity for the NS graphs, and little similarity for the OKLS graphs. For all types of knee injuries resulting from sports activities, the rates rose rapidly through adolescence and early adulthood and then gradually declined.

There were 3,997 sport-related (based on activity at time of injury) injuries that required ACL surgery. Of these, 81% contained enough narrative information the injury mechanism to be determined. Twelve sports accounted for 89% of sport ACLS and are presented for "injury mechanism" (what the patient was doing when the injury occurred) in Table 6. Nearly one-half (47%) of all ACLS injuries involved a non-contact mechanism. Excluding the ACLS injuries for which there was insufficient information to code mechanism from the denominator, the percentage of non-contact injuries was 58%.

The mean, median and standard error for the number of visits for treatment and the direct costs (NZD) of these injuries are reported in Table 7. The costs are to ACC and cover pre-operative exam surgery, hospital stay, post operative rehabilitation, disability, income replacement as a result of days away from employment etc, but do not include an estimate of the cost of the injury in terms of the quality of life or permanent disability. However, the cost to ACC and number of visits do provide a surrogate for severity. The high number of visits and direct costs associated with surgery is evident.

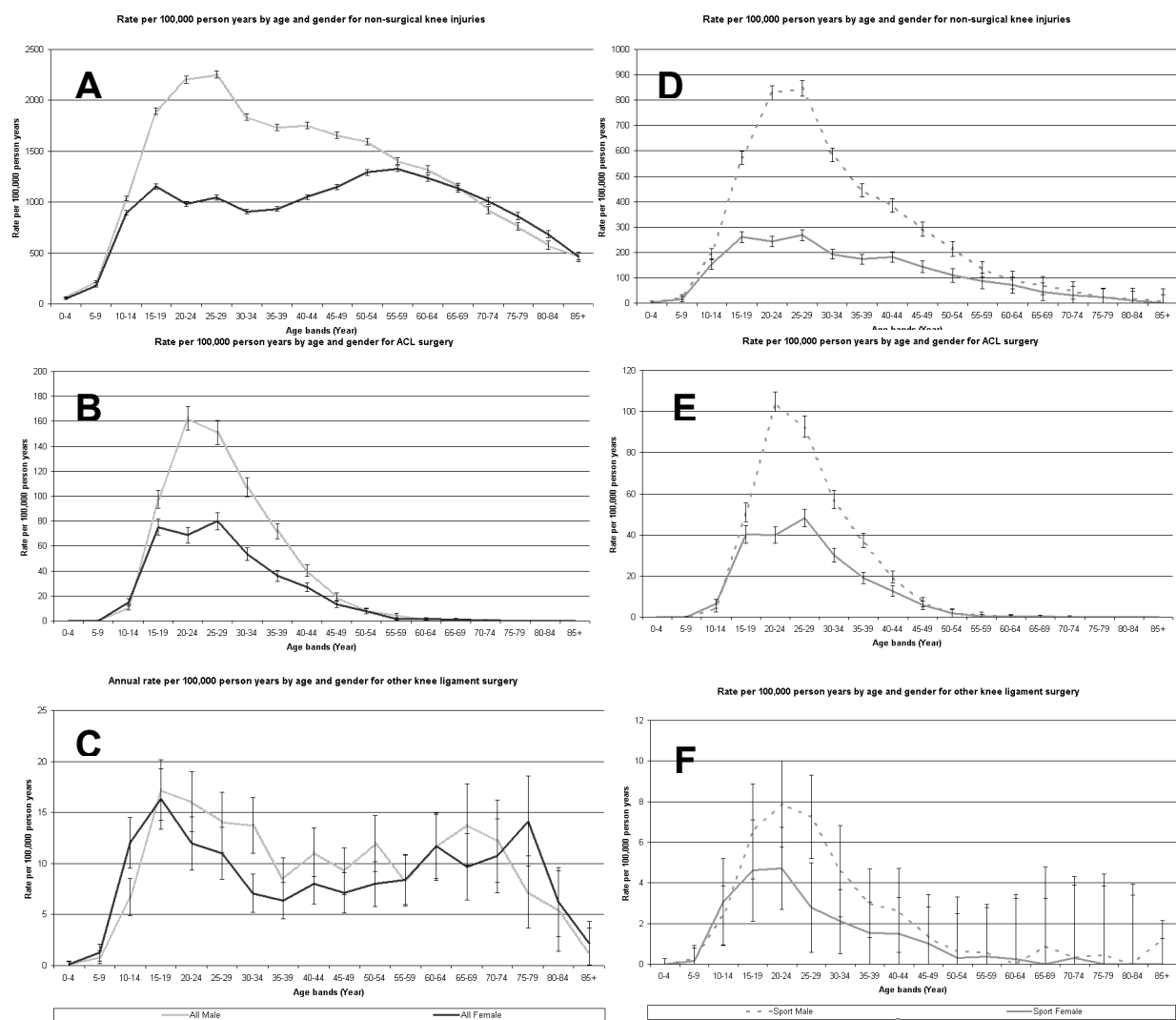


Figure 5: Annual rate per 100,000 person-years by age and gender for total NS, ACLS, and OKLS injuries (Figures A, B, and C) and for sport-related NS, ACLS, and OKLS injuries (Figures D, E, and F). Error bars indicate 95% confidence intervals. Note that the scale used for incidence (y-axis) varies between charts.

Table 5: Percentage by location where the injury occurred for non-surgical knee ligament injuries, ACLS, and other knee ligament surgery combined.

Location* where injury occurred	NS		ACLS		OKLS	
	Injury #	Percentage %	Incidence #	Percentage %	Incidence #	Percentage %
Commercial or service location	12,627	9.3	264	4.5	99	6.7
Farm	4,720	3.5	108	1.8	58	3.9
Home	35,639	26.1	655	11.1	441	29.7
Industrial Place	15,217	11.2	228	3.9	139	9.4
Other	12,283	9.0	489	8.3	175	11.8
Place of recreation or sports	44,323	32.5	3,833	65.1	397	26.8
Road or street	8,309	6.1	213	3.6	122	8.2
School	3,318	2.4	94	1.6	53	3.6
Total	136,436	100.0	5,884	100.0	1484	100.0

*Location was missing for 40% of NS claims, 20% of ACLS claims, and 18% of OKLS claims

Table 6: Type of contact in injury for sport related ACLS injuries that required surgery by sport.

Sport	Contact, could be Direct or Indirect #	Contact		Total Contact #	Non-contact		Insufficient information in narrative	Total
		Direct contact #	Indirect contact #		#	%	#	
Rugby union	349	74	57	480	276	36.5	196	952
Netball	76	24	33	133	483	78.4	130	746
Soccer	122	36	30	188	297	61.2	127	612
Touch rugby	38	7	17	62	217	77.8	74	353
Skiing	119	4	7	130	58	30.9	35	223
Basketball	11	8	10	29	113	79.6	30	172
Rugby league	64	7	6	77	41	34.7	34	152
Hockey	19	4	4	27	44	62.0	14	85
Motor sports/ Motor cycling	31	8	17	56	15	21.1	8	79
Squash	7	0	4	11	31	73.8	15	57
Martial arts	8	6	4	18	29	61.7	7	54
Snowboarding	14	4	7	25	24	49.0	5	54
Other sports	85	17	21	123	266	68.4	69	458
				1,359	1,89	58.2		
Total	943	199	217		4		744	3997

Table 7: Mean, median and standard error for the number of visits and cost of injury treatment to ACC for non-surgical knee ligament injuries, ACL surgery, and other knee ligament surgery.

		Number of visits for treatments			Cost of treatment to ACC		
		Mean	Median	Std Err	Mean	Median	Std Err
All	NS	6.64	4	0.02	\$ 885.31	\$ 129.31	\$ 6.81
	ACL	27.09	24	0.2	\$11,157.35	\$8,574.25	\$ 110.67
	OKLS	31.31	24	0.2	\$15,662.99	\$8,054.00	\$ 604.64
Pre Surgery - total	ACL	14.27	12	0.15			
	OKLS	15.32	10	0.41			
Post Surgery - total	ACL	12.46	11	0.1			
	OKLS	16.22	12	0.37			
Sport	NS	7.54	5	0.04	\$ 1,031.50	\$ 168.93	\$ 13.88
	ACL	27.81	25	0.24	\$10,939.99	\$8,913.57	\$ 116.25
	OKLS	26.9	22	1.01	\$ 9,346.16	\$6,214.16	\$ 524.54
Pre Surgery - sport	ACL	14.4	13	0.17			
	OKLS	12.6	9	0.64			
Post Surgery - Sport	ACL	12.5	11	0.1			
	OKLS	14.6	12	0.62			

Discussion

This descriptive epidemiology, using NZ's population-based data, has identified high-risk subgroups within the general population (sporting participants, males aged 20-39, and 55-59), has illuminated the settings (predominately places of sport and recreation for ACL injury requiring surgery) and mechanisms of injury (predominately non-contact causes in netball, soccer, basketball and squash). Rugby union, netball, soccer and touch rugby were the sports with the greatest number of injuries over the five year period analysed, accounting for 67% of the total of sport related knee ligament injuries. These sports are popular and are also the greatest number of sport ACC claims for all injury sites. We were surprised that males had a greater rate of injury in most age groups and as a whole. This tends to contrast what has appeared in the literature [54, 68, 70]. This could be due to the larger size of this study. We looked at the rate per year (rather than five years in this study) as a comparison and found the same trend and analysis. This study would have benefited from sport playing numbers to use as a denominator rather than population to further examine this trend.

It is notable that 80% of knee ligament surgery involved the ACL, and that 65% of ACL injuries resulting in surgery occurred from participating in a sports/recreational activity. The other 35% of injuries occurred outside of sport such as home, commercial/industrial workplaces or road (see Table 5). While sport and recreation injuries provide the largest proportion of ACLS, the forces applied to the knee can be replicated at home as a result of a fall; workplaces that have hazards such as heavy machinery, working at heights, manual labour; and road crashes. This study is one of the first to report statistics such as these for an entire nation. As such it can represent the rates as a comparison to sport and recreation ACLS. A limit in our study was being able to determine where the injury first originated. A person may have had a knee injury at home or work that is later aggravated during sporting activity. Alternatively the injury could have first occurred during a sporting activity that re-occurs in a home or workplace.

Any epidemiological analysis of injury data is dependent upon the quality of the data collection systems. For the ACC data base it is possible there are some missing or inaccurate data caused by: writing down the wrong code on the data collection sheet; underreporting of costs (not numbers) due to patients selecting private surgery whereby only a set amount is paid out by ACC (the patient may have to pay a portion themselves or have further private medical insurance); people who just don't go to a registered health provider; registered health providers not advising surgery (unlikely due to payment); patients who have not made a claim yet (data have been analysed to 19th May 2006, however, there is no time limit on when a patient can make an acute injury claim to ACC). It is also true that, despite the fact that ACL repair is an elective surgery with costs covered by the ACC, some providers may decide it is in the best interest of the patient not to perform ACL reconstruction, especially if the patient is elderly and/or not physically active. The net effect of these limitations would bias downwards our incidence estimates. A further limitation of our analyses for sports-related injuries is that the denominator of the number of participants in each sport in New Zealand is currently not routinely available, but is expected to become available in 2008.

Conclusions

The ACC data underscore the high level of short-term disability associated with knee ligament injuries, particularly those that result in surgery, in the general population. ACL injuries are particularly significant in this regard, since 80% of all knee ligament surgeries involved ACL surgery. Sports activities are the primary source of ACL injuries resulting in surgery (65%). This study emphasizes the need to develop interventions designed to reduce the risk of ACL and other knee ligament injury, particularly in sports.

CHAPTER 4

EFFECT OF NATIONWIDE INJURY PREVENTION PROGRAMME ON SERIOUS SPINAL INJURIES IN NEW ZEALAND RUGBY UNION: ECOLOGICAL STUDY

This chapter comprises the following paper published by *British Medical Journal*:

Quarrie, K.L., Gianotti, S.M., Hopkins, W., Hume, P.A. Effect of a nationwide injury prevention programme on serious spinal injuries in New Zealand rugby union: ecological study. *British Medical Journal*, 2007. **334** (7604): p. 1150-1153. (Author contribution percentages: KQ: 50%, SG: 40%, WH: 5%, PH: 5%).

Overview

The objective of this paper was to investigate the effect of RugbySmart, a nationwide educational injury prevention programme, on the frequency of spinal cord injuries. An ecological study design was used. The population at risk of injury comprised all New Zealand rugby union players. 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. The main outcome measures were the 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. 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). 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. Spinal cord injuries, although rare on the basis of exposure per player, are a major cause of serious morbidity and mortality in rugby [24]. 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. Since the 1980s and 1990s measures to prevent injury have included changes to laws on scrum procedures, stricter application of existing laws, and educational initiatives [72, 73].

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, and 18% from the ruck/maul (see

bmj.com for a glossary of terms). The definition of injury used in the studies reviewed, however, varied from admissions to spinal units through to tetraplegia [24].

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 [24, 73, 74]. 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 [74].

A recent call by a consultant general surgeon in the United Kingdom to ban the rugby scrum generated a flurry of correspondence in the BMJ [75]. 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 [76].

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

We collated and analysed data from 1976 to 2005 on the frequency and circumstances of rugby related spinal injuries in New Zealand. We extracted incidence data from the Accident Compensation Corporation database for serious rugby related spinal injury claims. This corporation is a no fault insurance system, which provides personal injury cover for all New Zealand citizens, residents, and temporary visitors. Any serious injury that requires medical assistance automatically generates an Accident Compensation Corporation claim.

In addition to Accident Compensation Corporation data, we cross checked files from the New Zealand

Rugby Foundation to provide information about the phase of play in which the injury occurred. For the purposes of modelling injury rates, we categorised the phase of play as scrum and other (tackle, ruck, and maul).

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. We estimated the player numbers in 1998-2000 by using a combination of player registrations and evaluation of competition draws. To calculate the rate in 1996-2000, we used the average number of players from 1998-2000 as the denominator for the entire period.

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].

RugbySmart is a multifaceted injury prevention programme and has developed over time as new information about risks has emerged. 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 [77]. All coaches must complete RugbySmart on an annual basis. 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. 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, 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.

Statistical analysis

To examine the effect of the RugbySmart programme, we calculated 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. We did not build participation level (number of players) into the model, because accurate estimates of numbers of players were not available before 1998.

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.

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. Figure 6 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).

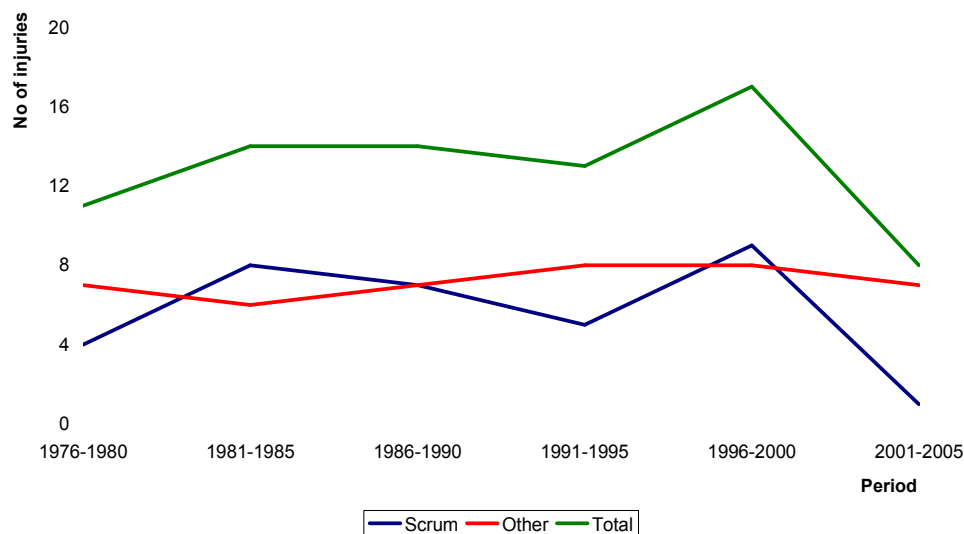


Figure 6: *Permanently disabling spinal injuries (American Spinal Injuries Association scale A to D) in New Zealand rugby union.*

The average annual number of players registered was 126 800 in 1996-2000 and 125 900 in 2001-5 (See Table 8). 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.

Table 8: Player numbers and injury rates 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

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.

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.

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.

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 6). 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.

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. Over the long term, we have little evidence on which to base any conjecture of the possible impact of numbers of players on numbers of injury. 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.

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 19.9. 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 [78]. 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. 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 [79]. We do not know whether or to what extent such increases have been reflected in lower grades.

Injury prevention in rugby

Several avenues for injury prevention are available to rugby administrators, including changes in law and educational programmes. We believe that research into the probable effects of changes in law 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 [79, 80].

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

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 is unclear. Educational initiatives seem to represent a viable option for decreasing the rate of serious spinal injuries in rugby union scrums.

CHAPTER 5

CONCUSSION SIDELINE MANAGEMENT INTERVENTION FOR RUGBY UNION LEADS TO REDUCED CONCUSSION CLAIMS

This chapter comprises the following paper published by *Neurorehabilitation*:

Gianotti, S.M. and Hume, P.A. *Concussion sideline management intervention for rugby union leads to reduced concussion claims*. *Neurorehabilitation*, 2007. **22**(3): p. 181-189.
(Author contribution percentages: SG: 95%, PH: 5%).

Overview

The effectiveness of a concussion management education programme (CMEP) in rugby in reducing the number and cost of concussion/brain injury (CBI) moderate to serious claims (MSC) was assessed. A RugbySmart™ educational video and a sideline concussion check (SCC) tool comprised the CMEP. Over 30,000 SCC, providing information on management of suspected concussion among community level rugby players prior to seeking medical treatment, were distributed from July 2003 to June 2005. Each year approximately 10,000 coaches and 2,000 referees participated in RugbySmart™. From 2003 to 2005 new rugby CBI MSC reduced by 10.7% (actual) and 58.2% (forecast). Rugby player numbers, new non-sport CBI MSC and new sport MSC all increased by 13.6%, 16.9% and 24.6% respectively in the same period. The median number of days between CBI injury and the player seeking medical treatment decreased from six days to four days. Cost savings after CEMP were \$USD690,690 (actual) to \$USD3,354,780 (forecast). The two-year cost of CEMP was \$USD54,810 returning \$USD12.60 (actual) and \$USD61.21 (forecast) for every \$USD1 invested (ROI). CMEP provided community coaches and managers with education on minimum best practice for managing suspected concussion, contributed towards ROI and savings for CBI MSC in rugby.

Introduction

The summary and agreement statement of the first International Conference on Concussion in Sport, Vienna 2001 [81], defined concussion as “a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces.” Common features defining the nature of a concussive head injury include: Caused by a direct blow to the head, face, neck, or elsewhere on the body with an “impulsive” force transmitted to the head; Typically results in the rapid onset of short lived impairment of neurological function that resolves spontaneously; May result in neuropathological changes but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury; Results in a graded set of clinical syndromes that may or may not involve loss of consciousness; Resolution of the clinical and cognitive symptoms typically follows a sequential course; and typically associated with grossly normal structural neuroimaging studies [81]. There were no changes to this definition at the Second International Symposium on Concussion in Sport, Prague 2004 [82].

There has been a lack of well-performed research on the incidence of concussion in rugby union (rugby). A review of rugby concussion studies highlights a variety in incidence from 0.1 per 100 player season [83] to 11.3 per 100 player season [84] making a comparative analysis difficult. When stringent inclusion criteria (such as medical care) are applied to concussion studies in the literature, the incidence rates appear lower [84]. In addition, lower rates of concussions were recorded in studies where teachers or coaches reported concussion rather than where athletic trainers or the players reported concussions. Only a study with a data set where trained medical doctors or neuropsychologists make the concussion diagnosis will provide any value for concussion analysis.

In professional rugby there are a number of medical experts who have a good understanding of concussion principles and use robust procedures in assessment and treatment [85]. At the community level, covering 99% of the 137,960 rugby players in New Zealand [86], there is little evidence of concussion management systems or processes. Anecdotally, at the community level, long-term memory questions such as “What’s your middle name?” or “Who is the Prime Minister?” have been employed [87]. As one former New Zealand international player reported “They let you stay on the field if you could count to three. Even at the senior level, the physiotherapist came on and asked you if you were okay. You carried on if you said ‘yes’ – simple as that” [88]. Further, being “knocked out” or losing consciousness was used as the definitive way of assessing if someone was concussed. It is now widely recognised that these types of questions and methods being used at the community level are of little diagnostic value in determining whether an athlete has sustained a concussion [81, 89].

In New Zealand there are a number of robust health systems in place to deal with concussion symptoms, with associated costs met by the Accident Compensation Corporation (ACC). The ACC is the Crown entity charged with the administration of New Zealand's 24-hour, no-fault accident compensation and rehabilitation scheme. The scheme provides personal injury coverage for all New Zealand citizens, residents and temporary visitors to New Zealand. In return, people do not have the right to sue for personal injury, other than for exemplary damages. People make acute personal injury claims to ACC resulting in medical information about the injury being collected. In the 2004/05 ACC financial year there were 1.6 million new claims from a population of approximately 4 million people; 296,000 were sport and recreation (sport) claims. As there is no disincentive for making a claim to ACC, the data set is useful for analysing the epidemiology of injuries and the effectiveness of injury prevention initiatives such as the concussion management education programme (CMEP).

Development of the sideline concussion check cards

To address the lack of suitable assessment and management of concussion in New Zealand community sport, ACC developed the sideline concussion check (SCC)¹ as part of a CMEP. At the community level ACC wanted to provide temporary interim management guidelines for a suspected concussion and to encourage players to seek medical treatment. The aim of introducing a standardised instrument was to remove the uncertainty [89] often encountered in assessing concussion on the sideline. Given the lack of concussion management that was occurring at the community level the Hippocratic aphorism '*Primum non nocere*' (first do no harm) [90] was applied.

The SCC was based on a similar card used by the University of Pittsburgh [91] that utilised 'Maddocks questions' [92], as well as a series of 'anterograde' and 'retrograde' questions shown as another predictive way of assessing concussion [93]. Changes were made to reflect New Zealand linguistics and situations. Subsequently several aspects of the SCC have been incorporated into the recently produced Sports Concussion Assessment Tool, developed for trained medical personnel [82]. The SCC is designed for community coaches who are unlikely to be medical personnel and only, at best, have minimal first-aid training.

The initial SCC was tested for suitability with two focus groups of community rugby coaches (n = 17) (held in April and May 2003). Focus group feedback supported the introduction of the SCC, as these groups considered that there was nothing else available for them. Focus groups were valuable for making further adjustments to improve the SCC, particularly identifying ways players would try and "beat the system" (i.e., remembering answers to standard questions to enable them to keep playing rather than being removed from play due to showing signs of concussion).

The SCC is 6½" x 3½" (16 x 9 cm) in size and folds in three sections down to 2" x 3½" (5 x 9 cm). It was designed to be small so it could be carried in the coaches, referees or match officials' pocket. The SCC was constructed of waterproof material so it could withstand handling in bags, pockets and in wet environments, as rugby is a winter outdoor sport.

Every SCC has a pouch containing five insert cards to provide the type of straight-forward advice for the first 48 hours including seeking medical treatment as recommended in the literature [94, 95]. The insert card ensures advice is consistent and reflects best practice. The insert card was given to the player/parents/player's support network to provide advice on how to manage any symptoms until the player sought medical advice. This was important, as typically there was a lack of medical staff available at the community level [84, 95]. The insert card acted as a safeguard if the symptoms manifested, if the player had yet to seek medical treatment after a suspected concussion. The insert card also provided useful advice ranging

¹ A 'Sideline Concussion Checklist-B' has been previously reported. However, this was a proposed checklist and no data or test using this instrument has been reported in the literature.

from return to play guidelines to the type of pain relief recommended. Extra insert cards could be ordered through the ACC website and/or free phone number and like the SCC, were free. To reflect New Zealand's multi-cultural society, insert cards were translated into Maori, Samoan and Tongan so they could be given to caregivers of children where English was not their first language.

The aim of this study was to assess the effectiveness of the concussion management education programme (CMEP) and SCC in rugby using concussion/brain injury (CBI) moderate to serious claims (MSC) made to ACC, and a return on investment analysis.

Methods

Sideline concussion check cards and education

The period between July 2003 and June 2005 was used for analysis of the CMEP. During this time 30,000 SCC were distributed to rugby coaches. In the first year (July 2003 to June 2004) 8,000 SCC were mailed directly to coaches with an additional 12,000 distributed in RugbySmart™ workshops. RugbySmart™ workshops are an annual compulsory requirement for coaches involved in all grades of rugby (children to adults). Teams that do not have at least one coach who is RugbySmart™ accredited are withdrawn from competition [96]. Approximately 10,000 rugby coaches and rugby referees attend RugbySmart™ workshops each year. The RugbySmart™ workshops have a 45-minute RugbySmart™ video including five minutes devoted to concussion management² and the SCC. In the second year (July 2004 to June 2005), 10,000 SCC were distributed in RugbySmart™ workshops; none were mailed directly to coaches.

The ACC concussion/brain injury database extraction

There are two types of acute personal injury claims that represent 99.6% of all claims to ACC, minor and MSC. Both are defined under the Injury Prevention, Rehabilitation, and Compensation Act (IPRC) 2001³ with ACC meeting most of the costs of the injuries. To qualify for ACC cover a person presents, with a personal acute injury as a result of an accident, to one of approximately 30,000 registered health professionals ACC has recognised throughout New Zealand.

A minor claim is when ACC only pays a registered health professional (e.g., doctor, physiotherapist) for the medical treatment of a patient who presents with an acute personal injury. Minor claims typically involve a few treatments with ACC meeting most of the cost of treatment. An MSC is a moderate to serious injury requiring entitlement beyond mere medical treatment only. A person with an MSC might have a mix of medical, income replacement and rehabilitation costs associated with an injury. Approximately 80% of the cost of a CBI is met by

² This segment can be view on www.rugbysmart.co.nz

³ For further information about ACC and claim data: www.acc.co.nz

ACC. To give an indication of severity, a person must be absent from employment for more than five working days to qualify for income replacement from ACC [97]. Of the 296,000 sport claims made to ACC in the 2004/05 financial year costing \$USD153 million⁴, only 8% were MSC, yet represented 80% (\$USD122 million) of the total cost. ACC measures the change in MSC pre and post implementation as an indicator of the effectiveness of injury prevention initiatives by comparing the actual number of claims as well as a forecast number of claims, based on the trends up to 30 years depending on the intervention. The forecast is used to estimate the number of new MSC that would have occurred had a prevention programme not been in place.

When a person presents for treatment, self-reported information about the injury is collected (such as date of injury, how the injury occurred, how the injury was caused, age, gender etc) and entered into the ACC database. Medical information such as injury diagnosis and injury site (head, knee, ankle etc) is completed by the registered health professional. A medical doctor makes the diagnosis for a CBI claim to ACC, which avoids potentially incorrect assessment of concussion as highlighted in the literature.

Data for this paper was extracted on 4th January 2006 from the ACC customised database allowing for any claims that occurred towards the end of the study period (June 2005) to be included.

To evaluate the effectiveness of the CMEP intervention, new rugby CBI MSC to ACC in 2004 and 2005 were compared with CBI MSC to ACC in 2003. Actual and forecast values were compared on the following criteria:

- Where the injury diagnosis and type were specified as CBI;
- Where the activity prior was 'Recreation or Sport Activity' and the scene of the injury was 'Place of Recreation or Sports';
- Where the sport involved was rugby; and
- From July 1999 to June 2005, presented in 12 month periods to match distribution.

A comparison was also made for two other groups of CBI MSC made to the ACC scheme from July 1999 to June 2005. The first comparison was non-sport CBI MSC and sport CBI MSC to assess whether there were any policies or CBI treatment changes. The second comparison was various sports that were specifically targeted for use of the SCC (Y) and those that were not targeted (N). To detect further environmental factors that could influence MSC, rugby playing numbers, new rugby MSC, and new sport MSC were also compared.

In addition the number of days from accident date to the date medical treatment was calculated to determine if the SCC directions encouraging players to seek medical treatment were being

⁴ An exchange rate of 69 United States of America cents for every NZ dollar was used.

followed resulting in a small number of days. This analysis was possible as accident date and first treatment date are collected when MSC data and information are entered into the ACC database.

Return on investment and potential savings analysis

The ACC is in the unique position of having 30 years of claims and costs data. This allows an estimate of the average lifetime cost of claims reflecting the length of time the claim requires ACC services (e.g. medical care, income replacement and rehabilitation costs). The average lifetime cost of a sport CBI MSC is approximately \$USD98,670 per new claim. The return on investment was calculated using the CBI MSC costs compared with the actual production and other programme costs of the CMEP (total cost of \$USD54,810 comprised of \$USD21,000 production costs and \$USD33,810 pro-rata RugbySmart™ overhead costs). Estimated potential savings/costs were then calculated by multiplying the number of MSC, both actual and forecast, *ceteris paribus*, by the average lifetime cost of a new sport CBI MSC. These savings were then divided by the total programme costs to provide a return on investment for every \$USD1 invested.

The equations [39] use the following variables:

- **A** = Actual claims, the difference between the number of MSC before implementation and post-implementation at a particular point in time;
- **F** = Forecasted claims. The claims are adjusted to show what would happen if no programme was in place. This is achieved by using a forecast made based on factors that would have impacted on the ACC claims database that need to be taken into account.
- **TPC**, Total Programme Costs since implementation. This includes only programme costs invested by ACC and excludes associated costs such as overheads and staff salaries; and
- **ALC**, Average Lifetime Cost. This represents the cost to ACC of a MSC in the area targeted for implementation, over the time length of the claim. This is important as treatment for some injuries can occur across more than one financial reporting year, particularly MSC. ACC has 30 years of injury data and is able to determine the length and cost of a particular injury type, and the last ten years is used as the best indicator. The size of the data set can estimate the number of treatments, visits, time off employment and other factors to provide what services from ACC the person may require. While the mid point is used, a 95% confidence level is generated. The ALC is the amount paid to either the injured person or to treatment providers. It does not include a portion of ACC operating costs. The ALC is presented at current costs and reviewed each year to reflect changes in costing that may occur, from year to year.

$$\text{Actual} = \frac{\text{A*ALC}}{\text{TPC}}$$

$$\text{Forecast} = \frac{F * ALC}{TPC}$$

Post-implementation formulae provide cost-savings and are presented over a ratio of \$1 reflecting ROI.

Results

The ACC's concussion/brain injury moderate to serious claims

Over the two-year period of implementation from July 2003 to June 2005, the following changes in MSC were observed (see Table 9):

- registered rugby playing numbers increased by 13.6%
- new rugby CBI MSC decreased by 10.7% actual and decreased by 58.2% against forecast
- new rugby MSC decreased by 0.4% actual and decreased 9.0% against forecast
- new sport CBI MSC decreased by 4.2% actual and decreased by 59.4% against forecast
- new sport MSC (for all injury types) increased by 24.6%
- non-sport CBI MSC increased by 16.9%

Results presented in Figure 7 show a comparison between non-sport and sport CBI MSC. This highlights the changes the environment had on MSC. Key factors identified included ACC return to workplace insurance market after a one-year absence (2000/01), and the development and funding of specialised concussion clinics (2001/02). There were no new major environmental changes identified after the CMEP was implemented.

Table 9: Key rugby and sport moderate to serious claims (MSC) data pre-implementation (2002/03) and post implementation (2003/04 & 2004/05) of the concussion management education programme (CMEP) including the sideline concussion check (SCC).

	2002/03		2003/04		2004/05	
	Number	Number	Annual % change	Number	Annual % change	Total %
Rugby players	120,903	129,253	6.9%	137,960	6.3%	13.6%
New rugby CBI MSC (actual)	51	39	-23.5%	44	12.8	-10.7%
New rugby CBI MSC (forecast)	51	56	9.8%	61	8.9%	18.7%
New rugby CBI MSC (forecast v actual)			-30.4%		-27.9%	-58.2%
New rugby MSC (actual)	3,329	3,428	3.0%	3,311	-3.4%	-0.4%
New rugby MSC (forecast)	3,301	3,480	5.4%	3,580	2.8%	8.3%
New rugby MSC (forecast v actual)			-1.5%		-7.5%	-9.0%

actual)						
New sport MSC	15,552	17,568	13.0%	19,618	11.7%	26.1%
Sport new CBI MSC (actual)	246	210	-14.6%	232	10.5%	-4.2%
Sport new CBI MSC (forecast)	246	290	17.9%	345	17.2%	35.1
Sport new CBI MSC (forecast v actual)			-27.6%		-31.8%	-59.4%
Non sport new CBI MSC	816	1019	24.9%	938	-7.9%	16.9%

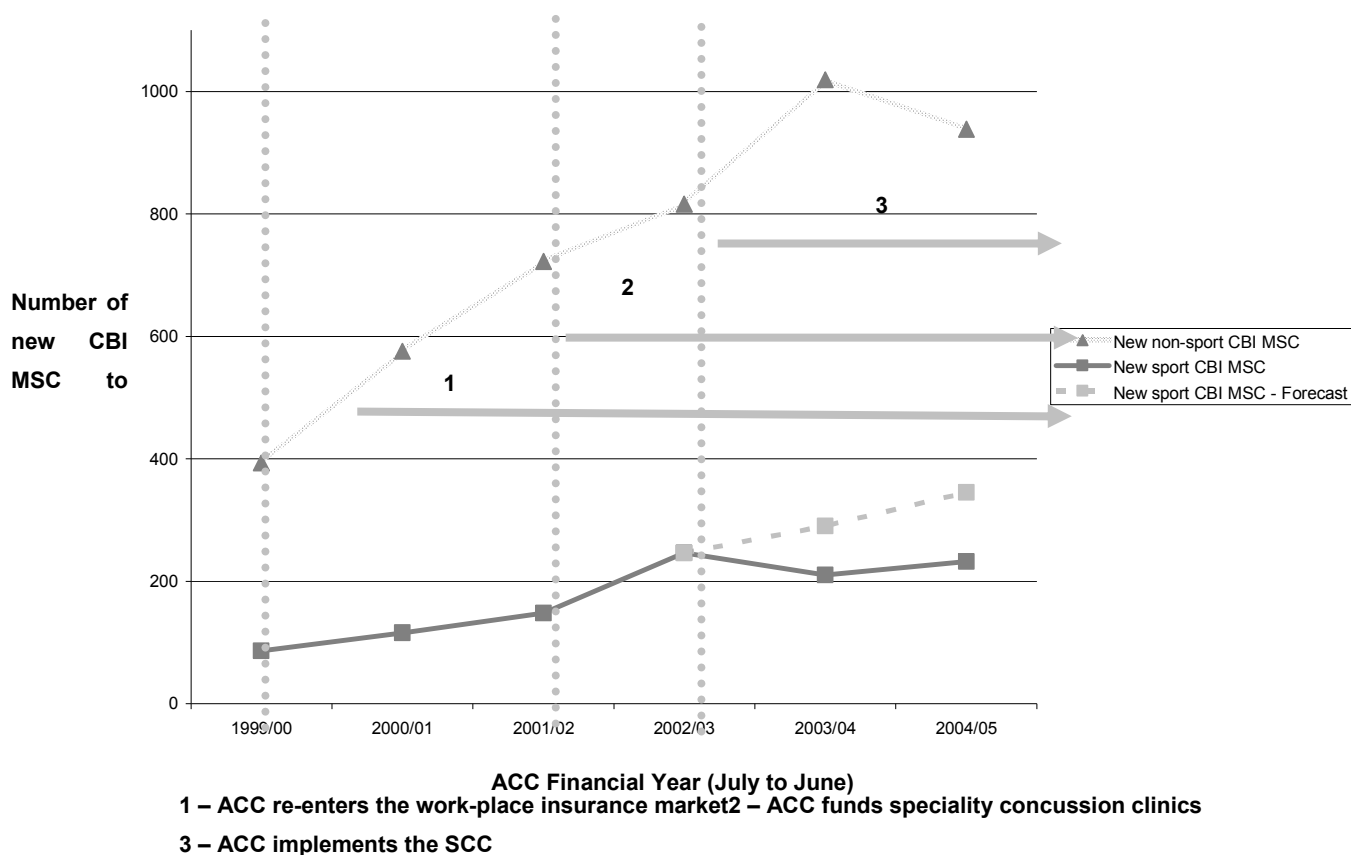


Figure 7: New concussion/brain injury (CBI) moderate to serious claims (MSC) made to Accident Compensation Corporation ACC from July 1999 to June 2005.

Examination of specific sports that were targeted from 2003/04 (T1) and from 2004/05 (T2) with the SCC indicated a decrease in CBI MSC compared with sports that were not targeted (N) (see Figure 8). For those sports that were not targeted, typically an increase in CBI MSC was observed. New rugby CBI MSC decreased by 24% (12 CBI MSC) in the first year, greater than the average of 15% decreased observed in all new sport CBI MSC. It is to be noted that the sports other than rugby had 100,000 SCC distributed (40,000 in 2003/04 and 60,000 in 2004/05). In the second year new rugby CBI MSC were greater than the first year, but there was still a decreased of 15% (7 MSC) compared with the baseline 2002/03 claims (See Figure 8). Against the forecast of the number of new rugby CBI MSC there were 17 fewer in year one and another 17 fewer in year two, (forecast of 56 and 61 respectively) providing a total of 34 less MSC after CEP was implemented (See Figure 8).

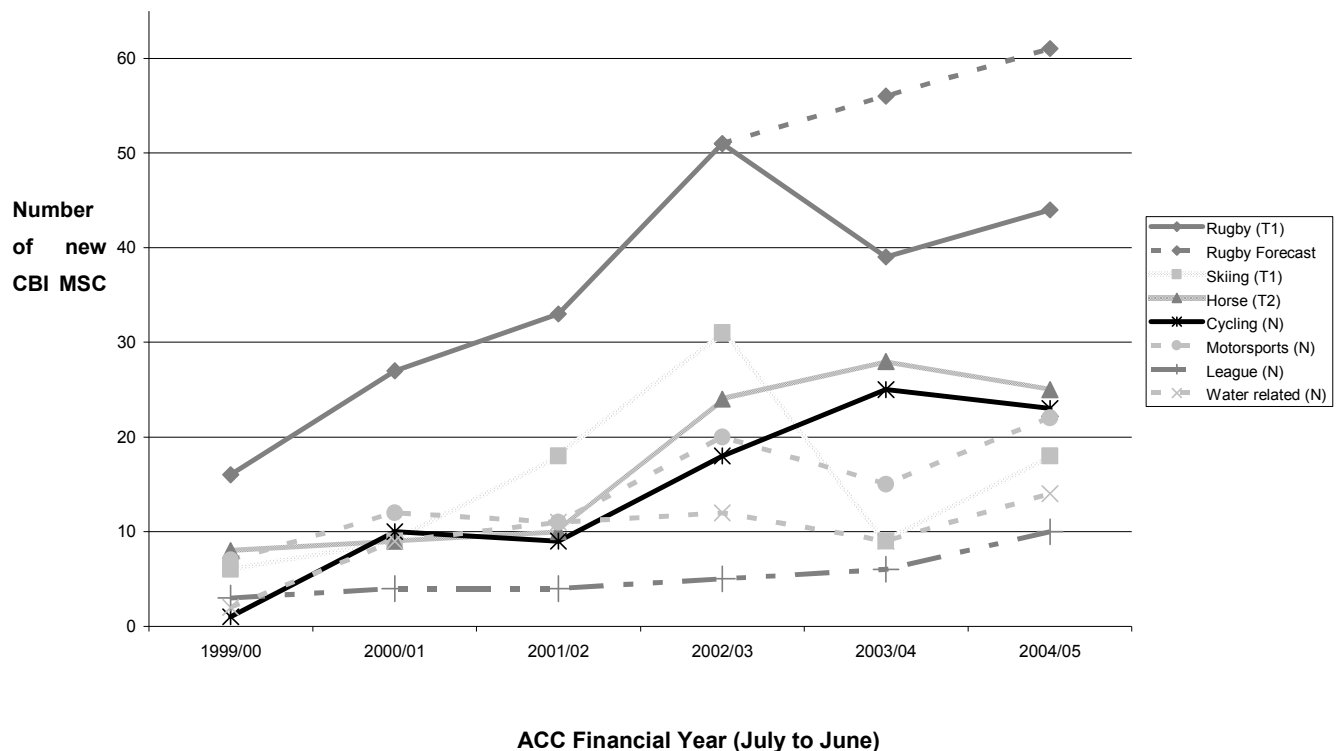


Figure 8: A comparison of new sport concussion/brain injury (CBI) moderate to serious claims (MSC) made to the Accident Compensation Corporation (ACC) from July 1999 to June 2005 for sports where the sideline concussion check (SCC) was specifically implemented compared with sports that were not specifically targeted.

An evaluation of the number of days between the injury and the player presenting for treatment were analysed using median days⁵. In addition, to provide a comparison, lower and upper quartiles were used, 25th and 75th percentiles respectively. The data were compared using rugby, sport (excluding rugby) and non-sport new CBI MSC. Analyses showed that the median of days from injury to first treatment had decreased from six days before implementation to four days after implementation. There were also decreases in the lower and upper quartiles. Non-sport and sport (excluding rugby) also showed decreases, but not to the same magnitude (See Table 10).

⁵ Mean days were excluded from analysis, as the SD indicated a lack of reliability using the mean for this purpose e.g., rugby mean (SD) pre-implementation was 9 (10) and post-implementation 8 (14).

Table 10: A comparative analysis of the number of days from injury to first treatment, pre-implementation (July 1999 to June 2003) and post-implementation (July 2003 to June 2005) of the concussion management education programme (CMEP) including the sideline concussion check (SCC).

	Number of days pre- implementation July 1999 to June 2003	Number of days post- implementation July 2003 to June 2005
Rugby		
Mean	9	8
Median	6	4
1st Quartile (25 th)	4	3
3rd Quartile (75 th)	10	6
Sport (excl rugby)		
Average	42.33	9.32
Median	6	4
1st Quartile (25 th)	4	3
3rd Quartile (75 th)	12	8
Non-sport		
Average	62.03	50.69
Median	7	5
1st Quartile (25 th)	4	3
3rd Quartile (75 th)	11	8

The ACC's return on investment and potential savings

The total cost to ACC of CMEP including 30,000 SCC for rugby was \$USD54,810. The seven fewer MSC (actual) and 17 fewer (forecast) since the implementation of the CMEP multiplied by the average lifetime cost of a new sport CBI claim of \$USD98,670 provides a potential saving of approximately \$USD690,690 (actual) to \$USD3,354,780 (forecast). This potential saving divided by the \$USD54,810 total CMEP programme cost, provided a return on investment range of \$USD12.60 (actual) to \$USD61.21 (forecast) for every \$USD1 invested.

Re-ordering of insert cards

An analysis of insert cards from implementation in 2003 to June 2005 showed 40,405 were re-ordered with a spread across the four different languages: English – 29,920; Maori - 4,895; Samoan - 2,885; and Tongan - 2,705. Due to ACC having other sports distributing the SCC (see Figure 8) it is not known how many were re-ordered for rugby. As 23% of the total 130,000 SCC distributed were to rugby, the same linear estimate can be conservatively made for the additional insert cards.

Discussion

The ACC's concussion/brain injury MSCs

The ACC claim data can be used to provide an assessment of the effectiveness of any injury prevention initiative. Diagnosis of claims is made by a medical doctor and is not subject to different criteria identified in comparing concussion incidence rates experienced in the literature. The ACC claims provide an analysis of an injury prevention initiative in terms of number and cost of injury. The limitation of using claim data to evaluate an injury prevention programme is that it is subject to external influences that need to be excluded. To provide a balanced assessment, other factors, such as population, must be identified that may have influenced claim numbers. This provides a forecast that is used to assess the preventive measures. The impact of some of these 'known' external influences can be seen in Figure 7 such as in 1999/2000 ACC did not participate in the work-related insurance market. This clearly affected MSC. The ACC returned to the work-related insurance market and MSC numbers initially increased to previous levels, continuing to rise. The impact of ACC's leaving and subsequent return to the work-related insurance market was observed in all ACC claims. With respect to concussion, in July 2001 onwards, ACC funded speciality concussion clinics over New Zealand which increased the number of recorded MSC as a result of concussion being correctly diagnosed and treated. While the factors identified arguably affected the overall trend of CBI MSC, there was no evidence of any changes made to the ACC CBI policy process for MSC approval from July 2002 onwards. The ACC's investigations found no other factors [39] that would significantly impact on claim numbers, but identified a number of factors that are considered 'extraneous random noise' [62, 63] such as the increased older workforce.

An analysis of any rugby specific factors that could have influenced the new rugby CBI MSC numbers was also undertaken. These factors were identified as rule changes (there was no evidence of changes to the rules of rugby, or evidence to indicate the rugby referees were interpreting the rules any different than before), rugby exposure numbers (there was a 13.6% increase in playing numbers; see Table 9), other injury prevention initiatives, and other CMEPs (none were identified). Given some sports (Motor Sport, Water related activities, Cycling) had an increased CBI MSC and others who implemented the SCC (Rugby, Snow, Horse riding) did not (see Figure 7), there is support for the argument that the ACC system did not change its policy or data collection. If a substantial change had occurred then there would be similar gradient curves observed in Figure 7 and between sports in Figure 86. Based on this analysis there were no identifiable rugby factors that would explain the decrease in new rugby CBI MSC. Arguably the number of new rugby CBI MSC should have increased given the increase in exposure (playing numbers).

The decrease observed from 2002/03 could have been from an unusual year with 'unknowns' occurring that were not present in 2003/04 and 2004/05. MSC could have decreased in 2003/04 despite the introduction of the SCC. Only a long-term analysis from future data will be able to conclusively assess the effect of the SCC. A long-term analysis would also indicate if any 'self-diagnosis' by players and coaches was occurring in determining their own return to play

decisions within the following week. If this were so, there would be an increase in MSC in future years if the 'self-diagnosis' were a 'mis-diagnosis'. However, ACC data shows 50% of injury MSC are made within 5 days of the injury, 95% are made within two weeks of injury, and about 1% occur over 250 days [62, 63]. Further a change in the number of days between injury and first treatment (see Table 10) did not indicate that 'self-diagnosis' or 'mis-diagnosis' was occurring.

Despite the limitations of the ACC data and the absence of a more suitable mechanism to assess the SCC, the results for the first two years are pleasing. This is especially so given non-sport CBI MSC increased in 2003/04, playing numbers (exposure) in rugby increased, new rugby MSC increased in 2003/04 but decreased in 2004/05. New rugby CBI MSC went against this trend in both years.

The intention to have a standardised system of community concussion management has been achieved. As a result concussion awareness has occurred. As one senior member of the rugby community commented *"This (SCC) is an extremely useful tool in helping community coaches with their understanding and management of concussion. I am yet to find one coach or person who weren't anything but positive about it. The design of the SCC, the ease of use and clarity has greatly assisted our coaches. It has heightened awareness and given coaches some tools to confidently manage concussion."* [98]. The re-ordered 40,405 insert cards are evidence that the SCC is being used and the change in the number of days between accident date and first treatment suggest advice is being followed.

The ACC return on investment and potential savings

A cost analysis is useful as an indicator of what the injury prevention programme is returning on investment. As ACC is a taxpayer funded system there is an expectation that injury prevention programmes return value for money. Forecast cost analysis is also important as it may identify environmental changes that may affect MSC. Only a long term trends analysis using accumulated MSC and costs will provide convincing evidence of whether the CMEP is returning value for money. Details on cost-benefit analysis are available in Gianotti and Hume [39].

Practical outcomes as a result of the CMEP analysis

After the initial evaluation of the use of the CMEP in the first year (2003/04) of implementation it was recommended that:

- The SCC should be extended to all sports and supported by other marketing mechanisms such as posters in community changing rooms. The SCC was implemented in horseback riding (Horse) in July 2004/05 with a decrease in new Horse CBI MSC (see Figure 7), and Soccer in March 2005. Concussion posters, specifically for rugby and soccer have now been available since June 2005.
- A reference to the ACC website that contains suggested return to play guidelines should be included on the SCC and insert card. This was undertaken in February 2005.

- A tear-off return to play strip with clinic/doctor stamp should be included so that there is an indication of medical clearance following a concussion before a player returns to play. This is to avoid players signing themselves.

CHAPTER 6

AN INTERIM EVALUATION OF THE EFFECT OF A NEW SCRUM LAW ON NECK AND BACK INJURIES IN RUGBY UNION

This chapter comprises the following paper published by *British Journal of Sports Medicine*:

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Overview

In January 2007 the International Rugby Board implemented a new law for scrum engagement aimed at improving player welfare by reducing impact force and scrum collapses. In New Zealand the new law was included in RugbySmart, an annual compulsory workshop for coaches and referees. The objective of this paper was to determine the effect of the new law on scrum-related moderate to serious neck and back injury claims in 2007. Claims filed with the Accident Compensation Corporation (the provider of no-fault injury compensation and rehabilitation in New Zealand) were combined with numbers of registered players to estimate moderate to serious scrum-related claims for players who take part in scrums (forwards). Poisson linear regression was used to compare the observed claims per 100 000 forwards for 2007 with the rate predicted from data for 2002–6. The observed and predicted claims per 100 000 forwards were 52 and 76, respectively (rate ratio 0.69; 90% CI 0.42 to 1.12). The likelihoods of substantial benefit (rate ratio ,0.90) and harm (rate ratio .1.1) attributable to the scrum law were 82% and 5%, respectively. The decline in scrum-related injury claims is consistent with a beneficial effect of the new scrum law in the first year of its implementation. Another year of monitoring should provide more evidence for the efficacy of the new law.

Introduction

Rugby union (rugby) scrummaging is considered to epitomise the physical nature of the game [99]. In the scrum, which is a means of restarting play after minor infringements [36], the front rows of each team's scrum pack (eight players in each pack in front, second and back row combination) engage through their heads and shoulders in a forceful driving motion [100-102]. As a result of the scrum a tunnel is created into which a scrum half player throws in the ball so that front row players can compete for possession by hooking the ball with their feet [103].

The scrum has received substantial attention over the years with regards to neck and back injury - especially the spinal cord [102, 104, 105]. With scrum engagement occurring through the head and shoulders, spinal cord damage upon engagement can result from hyperflexion with or without rotation [24] or high axial compressive neck forces combined with a bending moment and/or shear forces [102]. Scrum collapse as a result of improper engagement is another area that has been identified as a leading cause of scrum injury [24]. While spinal cord

damage is rare, there is a higher risk on scrum engagement compared with collapse [100, 102, 106].

Measures to prevent neck and back injury have included changes to laws on the scrum procedures, stricter application of the existing laws and educational initiatives [36, 72, 73, 100, 106]. On 1st January 2007 in all rugby-playing countries a new International Rugby Board (IRB) law governing the scrum came into effect. The scrum engagement law changed to a four stage “crouch, touch, pause, engage” sequence for the initial scrum engagement at all levels [107] based on the result of a review of the scrum by the IRB [108]. This new sequence was designed to standardize the distance the two sets of forwards were apart and reduce the collision forces at engagement [107, 108].

Although the IRB provided no injury epidemiology evidence for the potential benefits of the law change, there was some biomechanical evidence in the literature to support the new sequence, particularly addressing engagement and collapse. The forces on engagement have the potential to exceed axial neck load and bending movement tolerance limits [100]. Milburn [109, 110] identified forces during scrums against an instrumented scrum machine and found controlled engagement would reduce forces on the neck compared with usual scrum engagement technique. After initial engagement the sustained force decreased by about 20% [109, 110]. In another study measuring engagement force Du Toit [111] reported a 19% decrease in the force between a full scrum engagement and a staggered scrum engagement technique for schoolboy rugby union players under 19 years of age. However the Du Toit analysis was for sustained forces acting on the shoulder of the players rather than the neck, as Milburn determined. Both Milburn and Du Toit showed a reduced amount of force occurred by varying the technique (controlled or staggered) of scrum engagement.

In addition to controlling the forces at engagement, the new law was designed to reduce scrum collapse by standardising the distance the two sets of forwards are apart. Standardising the distance achieved by the front rows touching the opposition on the shoulder when the “touch” command in the four stage engagement sequence is given by the referee [108]. While having front rows too far apart will lead to scrum collapse at engagement, Milburn [110] reported that front rows who tend to stand too close to each other, and second row and back row forwards who apply the push before the front row is properly formed, contribute to the risk of scrum collapse at engagement.

Improving player welfare or reducing injuries through changing the laws is not new. Adherence to the laws of the game may reduce the rate of injuries [112]. Although rules are one of the most common methods used to prevent injury, there have been few interventions that have identified the benefits associated with specific rules [102]. Typically laws to prevent injuries centre around fair or foul play (including performance enhancing drugs) [113-116] Clark, 1995 #81]or protective equipment such as mouthguards [35, 117]. With respect to preventing head and neck

injuries, McIntosh and McCrory cited the usefulness of laws around pre-participation screening, rugby scrums, tackling (legal and illegal) as well as protective equipment [102].

We were interested in whether the new scrum law would reduce scrum neck and back injury rates for community rugby players in New Zealand. The unique nature of the NZ system for collecting nation-wide injury data, and the existence of an established system to communicate the new law via RugbySmart, made the interim evaluation of the effect of the new law possible.

Methods

Implementation of the new scrum law

To ensure consistency across NZ for the implementation of the new IRB scrum law, education on the law was incorporated into the RugbySmart DVD and was a focus for the RugbySmart workshops in 2007. RugbySmart is a joint injury prevention programme between Accident Compensation Corporation (ACC) and the NZ Rugby Union (NZRU) [36] designed to deliver injury prevention messages. Attendance at a RugbySmart workshop is an annual compulsory requirement and teams are withdrawn from competition for non-compliance by coaches, and referees are not assigned matches for non-compliance. Coaches are given a copy of the RugbySmart DVD at the completion of the one hour workshop and are encouraged to show it to their players. While the IRB had released footage of the new scrum law, ACC and NZRU re-videoed it to be consistent with its RugbySmart format. The new RugbySmart scrum law footage was approved by the IRB.

Moderate to serious neck and back ACC claims

To determine if the new scrum law had reduced injuries in NZ we used the ACC claims database [36]. In NZ, ACC provides a no-fault accident compensation and rehabilitation scheme covering costs of injury. People make claims against the scheme and as a result medical information such as the type and diagnosis of the injury is collected. The diagnosis of an injury is undertaken by a registered medical professional such as a doctor or physiotherapist, when the person seeks treatment for the injury. The registered medical professional (30,000 throughout NZ) submits the injury claim to ACC and a standardised set of injury codes are used to describe specific injury types. There is no-disincentive for making a claim, people are not discriminated or risk rated for the number claims made. People can elect to not claim by not seeking medical treatment. Minor injuries would fall into this category.

For this paper we assessed moderate to serious neck and back (including spine) claims to ACC that occurred in the scrum. These injuries were selected, because they occur predominantly in the scrum, particularly on engagement and collapse [100, 102, 106]. The RugbySmart programme has effectively eliminated serious spinal injuries arising from the scrum in NZ: the last was in 2002 [36]. A moderate to serious neck and back injury would include contusions, fractures, disc protrusions and prolapsed disc as a diagnosis. As an indication of severity or incapacity, an employed person, would be unable to work for a minimum of seven days.

We reviewed all rugby claims for moderate to serious neck and back injuries in rugby from 2002, determining the phase of play (e.g., scrum, tackle, ruck). When people making a claim to ACC were asked how the injury occurred (as a standard injury collection field), the information was used to determine the phase of play. If it was still unclear then contact was made with the person to clarify. Six claimants injured in 2002 were unable to be contacted. Analysis from 2003-2006 claims showed approximately 20% of neck and back claims were scrum-related. One additional claim was therefore added to the 2002 total. We assumed that all scrum injuries were from players in the forwards, as these are the only people who participate in the physical aspect of the scrum.

Final claims were extracted from the ACC database on 10th January 2008 and included all injuries up to and including 31st December 2007. The rugby season runs from February to August for community and amateur players. Representative rugby (a small number of games) occurred after the amateur season and took place in September and October in 2007. We considered sufficient time had passed from the end of the rugby season to final data extraction date on the basis of an assessment of scrum moderate to serious claims between 2003-2006 showing the number of days between the injury occurring and seeking ACC treatment was: mean 9 days; geometric mean 6 days; range 0-81 days. Analysis of the moderate to serious claims for this paper showed that between 2002 and 2006 only three injuries occurred past the amateur season and two injuries resulted from people taking more than two months to seek ACC treatment.

Player numbers

We used the number of players registered to NZRU to determine a rate per 100,000 forwards [36]. The age of players was collected by the NZRU. In NZ players older than 12 years of age are allowed to fully engage in scrums and push with force, therefore 12 years of age was the lower age limit for data analyses. We assumed that 8/15 of registered players were forwards.

The IRB has laws regarding scrum safety for different age groups. Players at the under 19 level (U19) have additional safety restrictions on the scrum (e.g., determines that a scrum can only be pushed 1.5 meters before the referee intervenes). In New Zealand almost all scrums are governed by the U19 safety restrictions [118]. Professional rugby, senior representative rugby (players aged over 19) and Senior 'A', competitions (the top grade in local/amateur competitions in a region), are the only game played under international scrum laws.

Statistical analyses

We analysed injury rate using the generalised linear modelling procedure (Proc Genmod) in the Statistical Analysis System (Version 9.1.3, SAS Institute, Cary NC) by assuming a simple linear trend in the logarithm of the injury rate [36]. The ratio of the observed to the predicted rate and its 90% confidence interval were estimated from the model by including an effect for the law change (with values of 0 for 2002-2006 and 1 for 2007). A simpler comparison of mean claim rate for 2002-2006 with the observed rate in 2007 was also performed. Likelihoods that the true

change in injury rate was beneficial and harmful were calculated using a spreadsheet [119], assuming least clinically important ratios for benefit and harm of 0.90 and 1/0.9.

Results

Table 11 shows the injury claims and numbers of forwards for the years 2002-2007, while Figure 9 shows the claims per 100,000 forwards. The observed and predicted claims per 100,000 forwards for 2007 were 52 and 76 respectively, giving a rate ratio 0.69 (90% confidence interval 0.42 to 1.12). The likelihoods of beneficial and harmful changes in the true rate of claims were 82% and 5% respectively. The mean rate of claims for 2002-2006 was 66 per 100,000 forwards; the observed rate relative to this mean rate was a ratio of 0.79 (90% confidence interval 0.53 to 1.18), and the likelihoods of beneficial and harmful changes were 70% and 8%.

Table 11: *Claims arising from scrum-related moderate to serious neck and back injuries sustained by forwards in New Zealand in 2002-2007.*

Year	Number of claims	Number of forwards
2002	24	39593
2003	29	39942
2004	22	40821
2005	25	41372
2006	33	39821
2007	20	38247

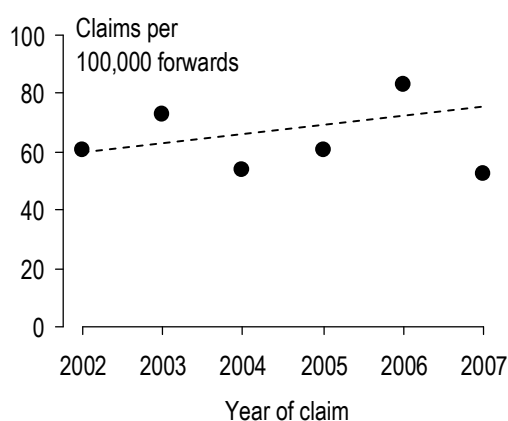


Figure 9: *Claims per 100,000 forwards for scrum-related moderate to serious neck and back injuries. Dashed line shows injury rates predicted from a linear model fitted to the 2002-2006 data.*

Most of the injuries from 2002-2007 occurred on a Saturday, which is the main game day. The numbers of injury claims on Saturday through Sunday were 111, 9, 3, 7, 6, 11 and 6 respectively.

Discussion

The new IRB scrum law came into effect with the aim of improving player welfare. At the end of the first year, our analysis showed that the new law change is likely to have reduced scrum-

related neck and back claims in NZ. The fact that most head and neck injuries occurred on the main game day underscores the importance of the law change for this type of injury.

There are several data analysis issues to consider when interpreting this interim evaluation. First, the moderate to serious claims we analysed were for acute injuries. Chronic injuries, such as spine degeneration, could not be analysed, because these injuries cannot be claimed through the ACC under current legislation. Secondly, the upward trend in claim rate apparent in Figure 9 is due partly to the fact that the highest claim rate occurred in 2006. The simpler comparison of claim rate for 2007 with the mean claim rate for 2002-2006 still showed the possibility of benefit from the new law, but the likelihood of harm was too high for the outcome to be considered clear. Thirdly, changes in the number of scrums in games could affect the rate of injury, but there are no available data to adjust for the number of scrums in games at the community level in NZ. We can think of no reason why the new law would result in fewer scrums per game or why the number of scrums would fall for any other reason. Fourthly, scrum safety has been part of the RugbySmart programme since 2001. In countries with no mandatory safety programme, the impact of the new law could be greater. Finally, the results are encouraging, but not conclusive. The ACC system can be used to track the effect of the law in 2008, as the only law changes will affect professional players, who represent approximately 0.2% of players in NZ.

Conclusion

At the end of the first year, our analysis shows that the new law change appears to have had the intended effect on scrum-related head and neck injuries. Another year of monitoring should provide more evidence for the efficacy of the new law. This study exemplifies how a nationwide injury database controlled by legislation can provide rapid follow-up for assessing efficacy of interventions.

CHAPTER 7.

EVALUATION OF RUGBYSMART: A RUGBY UNION COMMUNITY INJURY PREVENTION PROGRAMME

This chapter comprises the following paper published by *Journal of Science and Medicine in Sport*:

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Overview

RugbySmart, a rugby union injury prevention programme, was launched in New Zealand in 2001. It was compulsory for all coaches and referees to complete RugbySmart requirements annually in order to continue coaching or refereeing. After five years of implementation the programme partners, Accident Compensation Corporation and New Zealand Rugby Union, evaluated RugbySmart to determine its effectiveness in reducing injuries. The purpose was to evaluate the effect of RugbySmart on reducing injury rates per 100,000 players and resulting injury prevention behaviours. The RugbySmart programme was associated with a decrease in injury claims per 100,000 players in most areas the programme targeted; the programme had negligible impact on non-targeted injury sites. The decrease in injury claims numbers was supported by results from the player behaviour surveys pre and post RugbySmart. There was an increase in safe behaviour in the contact situations of tackle, scrum and ruck technique.

Introduction

The RugbySmart programme, a joint project between the Accident Compensation Corporation (ACC) and the New Zealand Rugby Union (NZRU), was implemented at the start of the 2001 rugby season (March 2001). Both ACC and NZRU contribute to the annual implementation of RugbySmart, investing in the development and delivery of the RugbySmart resources and workshops for coaches and referees. As ACC provides for the cost of rehabilitation and replacement of income it predominantly desires a reduction in the number of injuries while the NZRU wants to make the game a competitive, safe and popular sport.

RugbySmart was designed to systematically reduce the number and severity of injuries in community rugby by providing evidence-based information about injury risks and injury prevention strategies to coaches and referees. Although the strength of evidence available regarding specific risks and the efficacy of recommended practices varied widely, efforts have been made throughout the programme to update information as better evidence became available. Information was delivered to coaches and referees via video presentations combined with active participation in workshops; these were supported initially by printed materials, and subsequently by internet resources. The number of workshops for the approximately 10,000

coaches and 2,000 referees varied from region to region, reflecting differences in coach and referee numbers between more and less heavily populated areas.

Coaches were chosen to be the primary group to which RugbySmart was delivered, with the expectation that they would influence player behaviour [120]. The decision to target coaches was made on both pragmatic and evidence grounds. Firstly, delivering RugbySmart to approximately 10,000 coaches presented significantly less of a challenge than delivering it to over 130,000 players, which was considered unfeasible. Secondly, rugby coaches have been identified by both players and coaches in New Zealand as having an important role in the communication of injury prevention information and attitudes to player safety [77]. In addition referees, who play a major role in preventing avoidable injuries during matches, were targeted by NZRU [77]. To enforce the annual compulsory nature of RugbySmart for all levels of the game from under-6 grade to senior adults, rugby teams are audited and withdrawn from competition for non-compliance of their coach or a representative in attending annual workshops. Referees who did not complete RugbySmart were not assigned matches.

RugbySmart involves coaches and referees participating in a workshop setting with focus around the RugbySmart video. The video is produced to assist consistent delivery of the messages throughout the country. The video and other resources can be taken home by coaches after the workshop. The emphasis given to different areas has varied from year to year, with the greatest attention given to physical conditioning, technique (specifically tackling and scrummaging) and injury management. Other areas covered have included warm-up/cool-down, protective equipment (specifically mouthguards in contact situations) [53] and injury reporting.

While RugbySmart has helped to achieve a reduction in serious scrum-related spinal injuries [36] the aim of the current review was to provide a more detailed evaluation of RugbySmart in terms of the effect of RugbySmart on reducing injury rates (ACC injury incidence data combined with NZRU participation data) and resulting behaviours (ACC survey data). Currently there is little information available as to what a worthwhile change in injury rate or injury prevention behaviour for sport may be for a population based study as there are few large prospective population based studies in the literature [100]. This chapter addresses the need for a prospective intervention study of sufficient size that can provide evidence of the effectiveness of a specific injury prevention programme.

Methods

Injury data were collected by ACC, a New Zealand government taxpayer-funded monopoly. The coverage by ACC provides compensation for injury costs including medical treatment, income replacement, social rehabilitation and vocational rehabilitation, and ancillary services such as transport and accommodation. A claim is made when a person seeks medical treatment from one of the 30,000 registered health professionals throughout New Zealand. When making a claim, information about the injury is collected using a standard form to ensure levels of

consistency for data analysis i.e. the registered health professional makes the diagnosis. The claim is then filed with ACC and details entered into a central database. There is no disincentive for making a claim; people are not discriminated against, risk rated, or penalised for the number of claims made. The guarantee of personal injury coverage is offset by the restriction in ability to sue for personal injury (except in rare circumstances for exemplary damages).

There are two major categories of claims made to ACC, moderate to serious injuries claims (MSC) and minor claims. In the 2005/06 financial year (July to June) there were 58,264 rugby claims costing ACC \$NZD40,385,034. MSC represented 7.4% (4,384) of the number of claims, but 77.9% (\$NZD31,472,702) of the cost for 2005/06. For this review we focused on MSC, rather than minor claims, to evaluate RugbySmart because of the high relative cost of MSC and the greater level of information collected. For its evaluation of its prevention programmes, ACC also uses MSC rather than minor claims to evaluate its prevention programmes.

The injury sites that RugbySmart targets represent approximately 65% of the new rugby MSC and 73% of the cost to ACC in 2005/06 financial year. Specifically:

- Neck/spine – (including neck/back of head/vertebrae, upper back/spine, back/spine and lower back/spine) contributing 4.2% in number and 5.4% in cost;
- Shoulder (including clavicle/blade) contributing 19% in number and 20% in cost;
- Knee contributing 25% in number and 31% in cost;
- Leg (upper and lower, excluding knee and ankle) contributing 6.4% in number and 7.1% in cost; and
- Ankle contributing 10% in number and 9.1% in cost.

A specific type of injury that has received attention is concussion. In this paper we focused on injury sites rather than diagnosis such as concussion. Head injuries in general (e.g., injuries to the face, scalp, eye, ears and nose) were not specifically targeted, but a concussion-specific initiative was introduced in 2003/04. This initiative was implemented through RugbySmart; a decrease in concussion MSC was observed and is reported elsewhere [38].

Injury claims were extracted from the ACC database on 4th September 2006 and were classified by date of injury. This extraction date allowed for injuries that may have occurred late in 2005 to be included. Typically the New Zealand community rugby season occurs between March and August. There could still be players yet to seek treatment for their injury, but this is less likely, and if there are any outstanding claims, the number will be small. Since the inception of ACC in April 1974, there has been no time limit on when someone can make a claim to ACC.

To report the effect of RugbySmart using claims data, we have presented the rate of injury claims per 100,000 players per year. Player numbers were provided by the NZRU player registration system. Before 2001, player numbers were estimated from a combination of registered players and number of teams enrolled in competitions. From 2001 onwards, numbers were taken solely from the NZRU player registration database. Although the player registration

system used by NZRU was changed at the start of 2001 [35] the same year as RugbySmart was implemented, this was the baseline for the purposes of measuring the impact RugbySmart had on MSC.

A goal of NZRU was to increase the number of people playing rugby. Assuming no change in injury rate, an increase in playing numbers that occurred would increase the absolute number of MSC to ACC.

A central part of the RugbySmart programme was using coaches as a medium to impart information in the RugbySmart workshops to players. To evaluate if this strategy of targeting coaches was successful, we surveyed adult players (males over 19), to determine if information from the RugbySmart programme was being disseminated to them. In 1996, 1997, 1998 and 2005, ACC undertook surveys of self-reported behaviour of players. The effects of the RugbySmart programme were determined comparing 2005 with the 1996-1998 data (noting that there were differences in methodology between the 2005 and 1996-1998 surveys). Table 12 shows the main variables collected in each survey and the survey participant characteristics.

In the surveys conducted in 1996-1998 (all pre RugbySmart intervention) the rugby development officers (RDO's), of which there was at least one in each of the 27 regions, each visited three randomly selected clubs and players. RDO's surveyed no more than five players from each club (player self-completed survey forms). The response rate to individual survey questions varied from 30-82% with an average response rate per question over the three years of 64% (see Table 12).

The 2005 survey repeated some questions related to safe tackle, rucking and scrumming technique from the 1996-1998 surveys. Some methodological changes occurred between the surveys; typical over such a time period due to refinement of questions (see Table 12). While there were a number of areas explored in the various questions, we chose to focus on the parts that were used by both ACC and NZRU to evaluate RugbySmart and were key in determining continual involvement.

To examine the linear trend in claim rate per 100,000 players from 2001 to 2005, a simple Poisson regression model was developed using the GENMOD procedure in SAS (version 9.1, SAS Institute, Cary NC.). Estimated changes in claim rates were calculated as percentage changes along with 90% confidence intervals (CI) over the five year period [121]. We considered a worthwhile decrease in claim rates to be $\geq 10\%$ (0.90) on the rationale that this would represent a noticeable decrease in injuries for both health service providers and individuals playing the sport. This met the goals for the programme for NZRU and ACC. To determine the effect for self-reported behaviour, we have presented the percentage of responses (90% CI) for each category.

Table 12: Characteristics of the self-reported behaviour surveys undertaken in rugby union in 1996, 1997, 1998, 2001 and 2005.

Year of survey	1996 (Pre RugbySmart)	1997 (Pre RugbySmart)	1998 (Pre RugbySmart)	2005 (Post RugbySmart)
n	203	135	216	571
Compliance : Mean response to individual questions in each survey per year (range)	57% (30 to 82%)	67%	68%	83% (56 to 100%)
Selection criteria and administration	RDO's visited three randomly selected clubs. Five players randomly selected from each club were surveyed. Self-completion forms.	RDO's visited three randomly selected clubs. Five players randomly selected from each club surveyed. Self-completion forms.	RDO's visited three randomly selected clubs. Five players randomly selected from each club surveyed. Self-completion forms.	Random sample with no more than 4 players from one team at games.
Size	10 page A4 booklet	10 page A4 booklet	10 page A4 booklet	Double sided A4 questionnaire
Player characteristics	Male players over the age of 19 years	Male players over the age of 19 years	Male players over the age of 19 years	Male players over the age of 19 years
Level of rugby played	Senior amateur club	Senior amateur club	Senior amateur club	Senior amateur club
Example of variables collected	<ul style="list-style-type: none"> • Basic demographics - 5 questions including forward or back position • Activities undertaken at practice – 1 questions with 5 parts • Activities undertaken at games – 1 questions with 5 parts • Mouthguard use 1 question • Pre-season training – 7 questions • Pre-season training guides - 5 questions • Injury management & reporting – 8 questions • Knowledge of ACC advertising material – 5 questions 	<ul style="list-style-type: none"> • Same as 1996 	<ul style="list-style-type: none"> • Same as 1997, except did not ask if player was forward or back and 7 questions on Alcohol & Rugby 	<ul style="list-style-type: none"> • Basic demographics - 5 questions including forward or back position • Attitudes towards key strategies of injury prevention – 1 question with eight parts • I.C.E. knowledge & behaviour – 13 questions • Activities undertaken at practice – 1 question with 6 parts • Injury prevention information 1 question with 9 parts • Roles in injury prevention 1 question with 3 parts • Mouthguard use 1 question • Training guides - 2 questions • Rating of injury prevention information mechanisms – 1 question with 9 parts

Results

Table 13 presents the injury rates per 100,000 players by rugby season. The season is concordant with the calendar year in the southern hemisphere. The injury rates in 2005 in general decreased compared to 2001 for targeted injuries and dental claims, however, non-targeted areas did not decrease by 2005. There was a worthwhile effect for targeted MSC and dental claims overall, but not for non-targeted MSC.

When rates for specific injury sites were analysed and grouped by similar sample sizes, some sites that were targeted, such as the knee, neck/spine and leg (excluding knee and ankle), had decreased by 2005. Although ankle injuries were targeted, the change in claim rates was negligible. Shoulder injuries fell just short of the threshold for a worthwhile effect. Injury sites that were not targeted, however, did not decrease - for example, foot/toe injury claim rates increased over the evaluation period. The rate of increase for one non-targeted injury site, finger/thumb/hand/wrist exceeded the 10% (0.90) threshold.

The 2005 survey data on practice behaviour and injury management supported the change observed in injury sites reported in Table 13. Behaviour at practice as reported by players (see Table 14) showed worthwhile effects for safe tackle, safe ruck, safe scrum and cool-down when comparing 2005 with 1996-98. The only behaviour area that did not show an effect was warm-up which had already achieved 100% in 1998 and was 98% in 2005.

Table 13: Changes in ACC rugby moderate to serious injury claim rates from 2001 to 2005.

Injury site	Rate per 100,000 players					5 year trend in injury rate (90% CL)
	2001	2002	2003	2004	2005	
Neck/Spine ^a	122	106	108	110	93	0.77 (0.62 to 0.97)
Shoulder ^a	473	455	486	496	412	0.91 (0.82 to 1.01)
Knee ^a	675	654	623	583	565	0.79 (0.72 to 0.87)
Leg (excluding knee & ankle) ^a	175	154	182	166	137	0.81 (0.68 to 0.97)
Ankle ^a	244	261	273	262	243	0.99 (0.86 to 1.14)
All ^a	1689	1629	1671	1616	1449	0.85 (0.81 to 0.91)
Finger/Thumb/Hand/Wrist ^b	376	385	399	369	342	0.89 (0.79 to 1.00)
Arm/Elbow ^b	153	169	161	168	156	1.01 (0.84 to 1.21)
Head/Face/Eye/Ear/Nose ^b	131	124	141	153	142	1.20 (0.98 to 1.46)
Chest/Abdomen/Pelvis ^b	83	86	93	80	79	0.91 (0.71 to 1.17)
Foot/Toe ^b	26	36	34	44	54	2.29 (1.57 to 3.34)
All ^b	770	800	828	815	773	1.01 (0.93 to 1.09)

^a = Targeted body site – moderate to serious claims

^b = Non-targeted body site – moderate to serious claims

Table 14: Behaviour at practice as reported by players.

	1996			1997			1998	2005		
Behav iour	Fwds	Back	Total (90%CI)	Fwds	Back	Total (90%CI)	Total (90%CI)	Fwds	Back	Total (90%CI)
n	105	96	203	79	55	135	216	318	250	573
Warm -up	84%	84%	84% (80 to 88%)	84%	82%	83% (78 to 88%)	100% (100 to 100%)	98%	98%	98% (97 to 99%)
Cool- down	49%	48%	48% (42 to 54%)	66%	53%	61% (54 to 68%)	67% (62 to 72%)	78%	83%	80% (77 to 83%)
Safe tackle	45%	46%	45% (39 to 51%)	48%	51%	49% (42 to 56%)	56% (50 to 62%)	84%	87%	86% (84 to 88%)
Safe ruck	39%	40%	39% (33 to 45%)	39%	36%	38% (31 to 44%)	41% (36 to 46%)	69%	68%	68% (65 to 71%)
Safe scrum	70%	50%	61% (55 to 67%)	73%	45%	62% (55 to 69%)	59% (54 to 64%)	93%	59%	78% (75 to 81%)

Fwds = Forwards; Back= Backs

Discussion

Educational strategies have been used in a number of public health areas, such as diabetes and cardiovascular disease, to reduce the risk of illness by changing participants' knowledge and consequent behaviours. For example, Kirk and colleagues [122] reported that exercise consultation was more effective in stimulating exercise behaviour change in the short term than a standard exercise leaflet in people with Type 2 diabetes. Within rugby there has been literature published on injury incidence at both community and professional level of the sport, but few papers have evaluated the effect of injury prevention programmes. The RugbySmart programme provided a unique opportunity to evaluate the impact of an educational strategy for sports injury prevention that was focused at the community level and implemented throughout a country. We are unaware of any other programmes around the world that have combined a nationwide injury prevention intervention with nationwide injury data collection. As well as injury data, surveys of the knowledge, attitudes and behaviours of participants have been conducted, which has permitted the effect of RugbySmart to be evaluated at various levels. While the RugbySmart evaluation has limitations that need to be mitigated, the RugbySmart programme has been designed so that its impact can be continually evaluated.

Analysis of the injury rates per 100,000 players has shown worthwhile reduction in claims for targeted areas, but little impact on non-targeted claims. This provides a useful comparison; if non-targeted areas had decreased at a similar rate to targeted areas then the likelihood of factors other than RugbySmart contributing to the decrease would be higher. This was further supported when injury sites were analysed. In an ideal setting player exposure would have been used to calculate rates. However, we don't believe the exposure has changed markedly over the study period [36]. The cost of determining exposure for community level injury prevention, particularly across an entire country covering multiple grades and competitions would make such regular collection of exposure data prohibitively expensive. The benefit of the ACC system is that claims are collected as its business requirement required by government and as such can be used for analysis of injury prevention initiatives.

The self-reported survey results of players indicated a level of success for the RugbySmart programme in increasing injury prevention behaviour i.e., the players, led by the coach, incorporated more of the desired prevention behaviours into training and matches. The injury sites targeted (see Table 13) are parts of the body associated with the contact aspects of the game (such as scrums as shown in Table 14) and we presume decreases in injuries to these areas reflect improvements in player technique. The increases in self-reported behaviour are consistent with the material provided in RugbySmart.

In hindsight the evaluation of RugbySmart would have benefited from a baseline established in 2000 just prior to RugbySmart being introduced in 2001, consistent methodologies between studies and not having a change in player registrations in 2001. Inconsistent methodology has been widespread across community intervention programmes. The challenge for the

RugbySmart programme is to keep the same methodology for the next five years to allow valid comparisons to be made.

In conclusion there has been an observed decrease in injury claims per 100,000 players in areas RugbySmart specifically targeted. This decrease is supported by the improvement in injury prevention behaviour of players.

CHAPTER 8.

EFFICACY OF INJURY PREVENTION RELATED COACH EDUCATION WITHIN NETBALL AND FOOTBALL

This chapter comprises the following paper published by *Journal of Science and Medicine in Sport*:

Gianotti, S.M., Hume, P.A. and Tunstall, H. *Efficacy of injury prevention related coach education within netball and soccer*. *Journal of Science and Medicine in Sport*, 2008: Volume 13, Issue 1, January 2010, Pages 32-35. (Author contribution percentages: SG: 90%, PH: 5%, HT: 5%).

Overview

In 2004, Netball New Zealand and New Zealand Football adapted a generic 10-point action plan for sports injury prevention, SportSmart, to create NetballSmart and SoccerSmart, as part of their coach education programmes. A small-size descriptive study was conducted in both sports, to assess the efficacy of integrating sports injury prevention into coach education. NetballSmart was evaluated at the end of 2005, via a telephone survey of 217 coaches (53% response rate) who had attended a NetballSmart course earlier in the year. SoccerSmart was evaluated at the start of 2007, via an Internet questionnaire completed by 71 coaches (20% response rate) who had attended a SoccerSmart course in 2006. The evaluations focused on the quality and use of the course resource material, as well as assessing the extent to which coaches had incorporated injury prevention behaviours into player practices. After attending a NetballSmart course, 89% of coaches changed the way they coached, with 95% reported using knowledge from the course and passing it on to players. Ninety-six percent of football/soccer coaches also changed the way they coached, with most change relating to warm-up/cool-down and stretch (65%), technique (63%), fitness (60%) and nutrition/hydration (58%) practices. Although this was a descriptive study in nature, with a small sample size, we conclude that integration of injury prevention content within coach education courses and resources may be a viable and effective strategy to help community coaches – and therefore community players – help reduce their risk of injury.

Introduction

As the field of sports injury prevention develops, particularly at the community/amateur level, effective delivery mechanisms are required. The use of coach education to deliver injury prevention messages has received little attention in the literature. Indeed, the effectiveness of coach education in general has not been fully determined. Although coaches repeatedly cite coaching experience as the primary source of their coaching knowledge, researchers have yet to examine the process of how this experience is transferred into knowledge [123]. One paper considered general themes of coaching research during the period 1970-2001 [124] and subsequent research by the same authors covered the period 2001-2005 [125]. For both periods, only 2% of articles related to the assessment of coach education.

In New Zealand (NZ), the Accident Compensation Corporation (ACC), a government agency, invests in coach education, as a strategy to reduce injuries in sport and recreation. Almost all sport and recreation claims to ACC are derived from participation in community based amateur sport, therefore this is the focus of ACC's sport injury prevention programmes.

The ACC recognised early that the causes of sports injuries are usually multifactorial and that a single preventive action or strategy may not be successful in isolation. Rather, a combined strategic approach is required that can cover a variety of possible situations [126]. The ACC elected to address sport and recreation injuries through coach education and in 1999, developed SportSmart, the 10-point action plan for sport injury prevention [127]. Each action point was determined from a combination of existing literature and best practice at the time (further information can be obtained from ACC or www.acc.co.nz/sportsmart). Following the successful development of a rugby-specific version of SportSmart, in 2004 ACC in association with Netball New Zealand (NNZ) and New Zealand Football (NZF), created NetballSmart and SoccerSmart respectively, alongside a sport-specific coach education course and resources. The impact of sport injury prevention programmes in general on ACC claims and costs has been reported elsewhere [39]. In this study, we were interested in determining if coaches found the information provided by coach education of sufficient use and relevance, that they subsequently incorporated it into their coaching.

Methods

Netball

The NetballSmart resources consisted of (i) a booklet providing netball specific information (e.g., landing and passing technique and dynamic stretches); and (ii) a wallet card (similar information but in a format that could be folded to fit into a pocket). While both resources were designed for distribution to coaches and subsequently players, without the need to attend a course, for the purpose of this evaluation, we surveyed only coaches who had attended a course.

Netball coaches received NetballSmart education and resources from a trained presenter/facilitator between March 2005 and June 2005. Evaluations were conducted in October 2005 via telephone interview. Names and telephone numbers ($n = 404$) of individuals who had attended courses were obtained from four NNZ regions - Southland, Otago, Tasman and Waikato. Trained telephonists undertook the interviews and at least one attempt at contact was made. A total of 217 coaches participated in the interviews, providing a response rate of 53%.

The netball evaluation concentrated on recall of the NetballSmart resources, whether coaches had used the resources and if so, to what extent they had passed on the information to their players. Over half of the coaches ($n = 155$) were also asked to recall specific information from the resources.

Football

As part of the SoccerSmart programme, New Zealand Football also created a booklet and wallet card that addressed all 10 of the SoccerSmart action points. In addition, a DVD of FIFA's training programme "The 11" [128], a poster of "The 11" and adapted versions of the Sideline Concussion Card [38] and associated poster were also included in the SoccerSmart course pack.

Football coaches received SoccerSmart education and the above resources from a trained presenter/facilitator between March 2006 and June 2006. Evaluations were conducted in March 2007, much later than in the netball evaluation, as we were interested in determining if and what coaches were implementing in the subsequent season, what they found useful and how the information had changed their behaviour. We also wanted to establish whether coaches were using "The 11".

When coaches attended a SoccerSmart workshop, they were asked to provide an email address. Of the 350 coaches attending courses delivered by the same trainer, email addresses for 250 coaches were collected. A message was sent to these addresses describing a proposed evaluation and providing the link to an online survey. A follow-up email was sent to the same email addresses, one month later. In total, as a result of this email communication, 71 individuals completed the online survey. Unfortunately, over 100 email addresses were found to have been mis-spelt or could not be read and so 'bounced' back. Despite this limitation, a response rate of almost 50% was achieved. Of the 71 respondents, 9 were administrators, players or referees. These non-coach replies were removed from subsequent analysis.

Analysis

For the purpose of analysis, we used 95% confidence intervals (CI). While an accurate number of active netball and football coaches are difficult to quantify, NNZ and NZF approximate that they have 10,000 and 15,000 coaches respectively. This number was used to determine CI.

Results

Netball

Of the 217 netball coaches in the survey, 89% (95% CI=86-92%) changed the way they coached: 38% (33-43%) "a lot"; 32% (27-37%) "somewhat"; and 19% (15-23%) "a little". Coaches also indicated that as a result of their coaching, at least 70% (65-75%) of their players had changed their landing and stopping techniques, dodging ability and cool-down/recovery procedures.

Table 15 presents the results for recall and use of the NetballSmart resources. About half of all coaches recalled the booklet and wallet card respectively, with more being likely to have read the wallet card than the booklet. Nearly all coaches reported using the wallet card information

and passing it on to players. The contents of the booklet and wallet card are similar, so it is not surprising that the results in Table 15 are similar and have overlapping CI.

Table 15: Use and usefulness of NetballSmart responses as reported by coaches.

		Booklet (95% CI)	Wallet Card (95%CI)
N		217	217
Recall ¹	Yes	49% (43-55%)	53% (47-59%)
	No	51% (45-57%)	47% (41-53%)
Read ²	Yes	79% (75-83%)	90% (87-93%)
	No	21% (17-25%)	10% (7-13%)
Used information ³	Not at all	6% (3-9%)	10% (7-13%)
	A little	33% (28-38%)	34% (29-39%)
	Some	24% (19-29%)	24% (19-29%)
	A lot	36% (31-41%)	29% (24-34%)
Passed information to players ³	Yes (total)	90% (87-93%)	91% (88-94%)
	A little	44% (39-49%)	37% (32-42%)
	A lot	46% (41-51%)	54% (49-59%)
	No	10% (7-13%)	9% (6-12%)
¹ Percent of all coaches. ² Percent of those who had seen it. ³ Percent of those who had read it.			

With respect to specific knowledge gained from the resources, awareness of the need to replace fluids and treat injuries was very high among coaches and large numbers identified light aerobic activity, static stretching and refuelling with carbohydrates and protein as activities that should be included after training and games, in the cool-down and recovery phase (see Table 16). Coaches were asked to identify three important things to remember about landing safely, with no prompts provided. The coaching booklet identifies several recommended activities, of which “bending at the hips and knees” was by far the most frequently identified, followed by “keeping feet shoulder width apart” and “maintaining balance”. Interestingly, balance, as a general concept, is not mentioned in the resources. Rather, specific factors relating to balance are described. Coaches also reported information that was not in the resources at all, such as landing on two feet, but not information that could be considered to cause injury.

Table 16: Recall by coaches of cool-down, recovery and safe landing information from the NetballSmart booklet.

Percentage of coaches who provided each response (95% CI)		
Reply to question regarding	N	155
Cool-down	Light aerobic activity*	75% (69-81%)
Cool-down	Replace fluids*	99% (98-100%)
Cool-down	Sprint session	3% (1-5%)
Cool-down	Static stretching*	81% (76-86%)
Cool-down	Dynamic stretching ^a	45% (38-52%)
Recovery	Refuel with carbohydrate/protein*	88% (84-92%)
Recovery	Treat injuries*	96% (93-99%)
Safe landing	Feet shoulder width apart*	37% (31-43%)
Safe landing	Bend at hips & knees*	72% (66-78%)
Safe landing	Knees in line with feet*	9% (5-13%)
Safe landing	Trunk upright*	24% (18-30%)
Safe landing	Soft landing*	5% (2-8%)
Safe landing	Two feet	8% (4-12%)
Safe landing	Balance	37% (31-43%)
Safe landing	Head upright*	3% (1-5%)
Safe landing	Miscellaneous	17% (12-22%)
Safe landing	Don't know	15% (10-20%)
*Recommended activities.		
^a = recommended activity for warming-up in the NetballSmart resources		

Football

Table 17 presents the feedback data for the SoccerSmart resources. Coaches considered the booklet the most useful resource, followed by the DVD, concussion card and wallet card. Fewer coaches commented on the posters and these were rated 'neutral' in terms of their usefulness. Not all coaches chose to answer all aspects of this question.

Although 78% (95% CI 69-87%) of coaches considered "The 11" DVD useful, when asked if they were using it, only 47% (36-58%) of these coaches responded "Yes", 40% (29-51%) "No", and surprisingly, 15% (7-23%) responded "Not sure".

Table 17: Coaches' perceptions of the usefulness of SoccerSmart resources.

(95% CI)	Not useful	Neutral	Useful	N
SoccerSmart booklet	0%	19% (10-28%)	81% (72-90%)	52
Wallet Card	4% (0-8%)	30% (20-40%)	66% (56-76%)	56
FIFA's "The 11" DVD	3% (0-7%)	19% (11-27%)	78% (69-87%)	58
FIFA's "The 11" Poster	18% (9-27%)	42% (31-53%)	40% (29-51%)	50
Sideline Concussion Checklist	7% (0-14%)	24% (13-35%)	68% (56-80%)	41
Concussion poster	21% (9-33%)	42% (28-56%)	36% (22-50%)	33

For each aspect of SoccerSmart, coaches were asked what they included in their coaching sessions, what they had previously included and what they had changed/added as a result of the SoccerSmart training (see Table 18). This identification of pre-existing knowledge was not part of the netball evaluation.

Overall, only two coaches (3%) believed that they had been addressing all points of the SoccerSmart plan before they attended the education session. Most coaches considered "Fair Play" and "Protective Equipment" to be areas that they had been addressing, in the recommended way, before they attended the SoccerSmart course. "Player Profiling" was the area that coaches had least undertaken activity in. Between a quarter and a third of coaches indicated that they had previously been addressing the remaining seven SoccerSmart action points, to some degree.

The area where most behaviour change was affected was "Player Profiling", with 26% of coaches responding "I am now including this". Notable numbers of coaches also implemented content from the "Environmental factors"; "Fitness"; "Nutrition/Hydration" and "Injury Surveillance" action points. "Protective equipment" and "Fair Play" content had least impact on coaches' behaviour and were considered areas that coaches were already doing before they attended a SoccerSmart session.

Some aspects of SoccerSmart were being addressed by coaches before attending the session, but were improved upon afterwards. In particular, large numbers of coaches improved their "Warm-up/Cool-down"; "Technique"; "Fitness" and "Nutrition/Hydration" practices. When the responses "I am now including this" and "I was already doing this but made improvements" were combined, reflecting positive uptake of SoccerSmart information, the action points with the largest degree of change were "Warm-up/Cool-down" (65%); "Technique" (63%); "Fitness" (60%), and "Nutrition/Hydration" (58%).

The SoccerSmart action points that coaches were still not undertaking, despite receiving education ("I still don't do this"), related to "Player Profiling" and "Environmental Factors".

Table 18: Self-reported behaviour of coaches post-course in relation to each component of SoccerSmart.

n = 62 (95% CI)	I am now including this	I was already doing this but I've made improvements	I was already doing this	I still don't do this.
Player profiling	26% (17-35%)	23% (14-32%)	15% (8-22%)	37% (27-47%)
Warm-up & Cool-down	11% (4-18%)	53% (43-63%)	32% (22-42%)	3% (0-7%)
Fitness	18% (10-26%)	42% (32-52%)	32% (22-42%)	8% (2-14%)
Technique	11% (4-18%)	52% (42-62%)	35% (25-45%)	2% (0-5%)
Fair Play	3% (0-7%)	18% (10-26%)	76% (67-85%)	3% (0-7%)
Protective Equipment	5% (0-10%)	21% (13-29%)	68% (58-78%)	6% (1-11%)
Nutrition/Hydration	18% (10-26%)	40% (30-50%)	29% (20-38%)	13% (6-20%)
Injury Surveillance	16% (8-24%)	31% (21-41%)	27% (18-36%)	26% (17-35%)
Environmental Factors	18% (10-26%)	21% (13-29%)	29% (20-38%)	32% (22-42%)
Injury Management	11% (4-18%)	31% (21-41%)	35% (25-45%)	23% (14-32%)

Discussion

The results of this study would suggest that coach education is a viable mechanism for the implementation and delivery of injury prevention in community sport, if there is an existing infrastructure. Most coaches found the course they attended beneficial and supporting resources appear to be valued by the community coach, as evidenced by their usage. Uptake and application of information in subsequent coaching sessions was high. In the case of football, coaches were still using the resources and/or information the following season, showing long-term retention and effectiveness.

There is no requirement for coaches to incorporate NetballSmart or SoccerSmart information in to their coaching. Therefore, implementation of knowledge by coaches in both sports indicates that coaches considered the information suitable. This is supported by the high ratings for the course booklets and wallet cards.

Football coaches gained the greatest benefit from the action points relating to core aspects of their sport, e.g., warming-up, technique and conditioning. This might suggest that these areas must be addressed in any education process before coaches will adopt other action points. Awareness of "Fair Play" and "Protective Equipment" was already high, before the education sessions, suggesting that these aspects may require less emphasis in the future.

Unfortunately, the number of participants in the SoccerSmart survey was small, partly due to email address errors and partly due to only one trainer delivering courses during the analysis period. The timing of the evaluation (several months after the course) may also have affected the response rate, although this was essential to evaluate longer-term knowledge retention and behaviour change.

Both evaluations (netball and football) provide insights but also have limitations. In the netball evaluation, there was no pre-assessment of the knowledge or behaviour of the netball coaches, which if present, would affect the results. No increase in knowledge could be due to: i) the course not being delivered as intended; or ii) pre-existing coach knowledge base [129]. This was partially mitigated in football, as all coaches involved in the evaluation were educated by the same trainer. In addition, these coaches were asked about their behaviour change in relation to each action point. Notwithstanding this, 89% of the netball coaches did indicate that they had changed the way they coached as a result of the course.

It is unfortunate that an accurate number of coaches is not known for either sport. This makes it difficult to determine confidence intervals and the effective reach of the injury prevention programme. This is a problem in most sports in New Zealand.

Early on in the development of SportSmart, there was an expectation from ACC that NSOs would adapt the model to their sports. It became clear, very quickly, that while the NSO had the intention of doing this, it needed ACC support and funding to translate this intention into action. Having a model isn't enough for community sport. There needs to be a clear implementation plan, including funding mechanisms, if the models developed are to be incorporated by community sport in more than a handful of cases. Partnership with the respective NSOs has, in our experience, been key to the implementation of NetballSmart and SoccerSmart.

Conclusion

Integrating injury prevention into coach education courses and resources appears to be a viable mechanism for the implementation and delivery of injury prevention in community sport, if there is an existing infrastructure. The uptake of key injury prevention messages was demonstrated by coaches in both netball and football and information continued to be recalled and implemented in training, a significant time period after the course.

CHAPTER 9.

THE FREED FRAMEWORK FOR COMMUNITY SPORT INJURY PREVENTION IMPLEMENTATION IN NEW ZEALAND

This chapter comprises the following paper that has been re-submitted to the *British Journal of Sports Medicine*:

Gianotti, S. and Hume, P.A. 2009. The FREED framework for community sport injury prevention implementation in New Zealand. Submitted to *British Journal of Sports Medicine*. (Author contribution percentages: SG: 95%, PH: 5%).

Overview

The aim was to document the FREED (Funding, Resources, Environment, Evaluation and Delivery) model of community sport injury prevention implementation developed through experience of sport injury prevention implementation in New Zealand. New Zealand community sports organisations and recreational athletes were the participants in the implementation of the FREED framework. The FREED framework uses a nation-wide approach and was developed based on our experience and theoretical knowledge. The main outcome measures were number, severity, duration, work and sporting time lost, and cost of injuries reduced, behaviour change for reducing risk of injury, and increased return on investment for injury prevention programmes. Examples from sports injury prevention interventions in New Zealand, specifically rugby league are provided. In conclusion, the FREED framework outlines how community sports injury prevention implementation can be effective in reducing injury.

Introduction

Models of injury prevention

Van Mechelen et al.'s 'sequence of injury prevention' model [25] is a framework to describe an approach to sport injury prevention [8, 10, 30]. When first published, aspects of the first (extent and severity of injury) and second stages (aetiology) of this model were the focus [25]. Further development of stage two by Meeuwisse [7] then Bahr and Krosshaug [130] had a focus on injury causation [131]. Finch [2] provided the "Translation of Research into Injury Prevention Practice" (TRIPP) framework to provide a synthesis between research and a 'real world' approach, and was the first to start addressing implementation. Two further developments by van Tiggelen et al.'s [34] and Finch and Donaldson [47] occurred for stage three (implementation). Van Tiggelen et al. [34] focused on overuse injuries and based implementation in relatively controlled settings of military and professional sport. This model has greater control over compliance which is unlikely in the community setting. Finch and Donaldson [47] adapted Glasgow's [48] RE-AIM model used to evaluate health promotion interventions, to include a sport setting matrix termed the RE-AIM SSM [47]. While RE-AIM can be used to design programs it is more commonly used to report results or compare interventions [49, 50]. Care is needed when directly applying the RE-AIM framework to interventions

implemented in the community sport setting because the definition for each dimension will depend on the specific level being targeted [47].

The FREED framework of injury prevention implementation

The need for sport injury prevention on a national scale is well recognised particularly in 'real world' settings [47]. Hume and Potts [132] developed in consultation with 20 national sports organisation coaches and researchers the 10-point action plan for sport injury prevention for the Accident Compensation Corporation (ACC). The resulting educational resources and model named *SportSmart* formed the cornerstone of ACC's sports injury prevention work (see Figure 10). The ACC expected that sports would adapt the model given the collaboration of national sports in development of *SportSmart*, but it became clear that while sports had the intention of doing this, it needed ACC support and funding to translate this intention into action [44]. There needs to be clear implementation plans and funding mechanisms if models are to be incorporated by community sport.



Figure 10: The SportSmart 10-point plan for community sports injury prevention.[132]

Sport injury prevention needs to be acceptable, adopted and complied with by athletes, coaches, and sports administrators [131] or the adoption of prevention measures will fail [2]. In New Zealand we have focused on implementation of sport injury prevention (stage three of the sequence of injury prevention model). In developing the FREED framework (Funding, Resources, Environment, Evaluation and Delivery) for community sport injury prevention implementation (see Figure 11) we took into account published theoretical approaches [2, 7, 25, 130, 131] and drew from our successful [5, 35-45] and unsuccessful attempts in implementation of sports injury prevention.

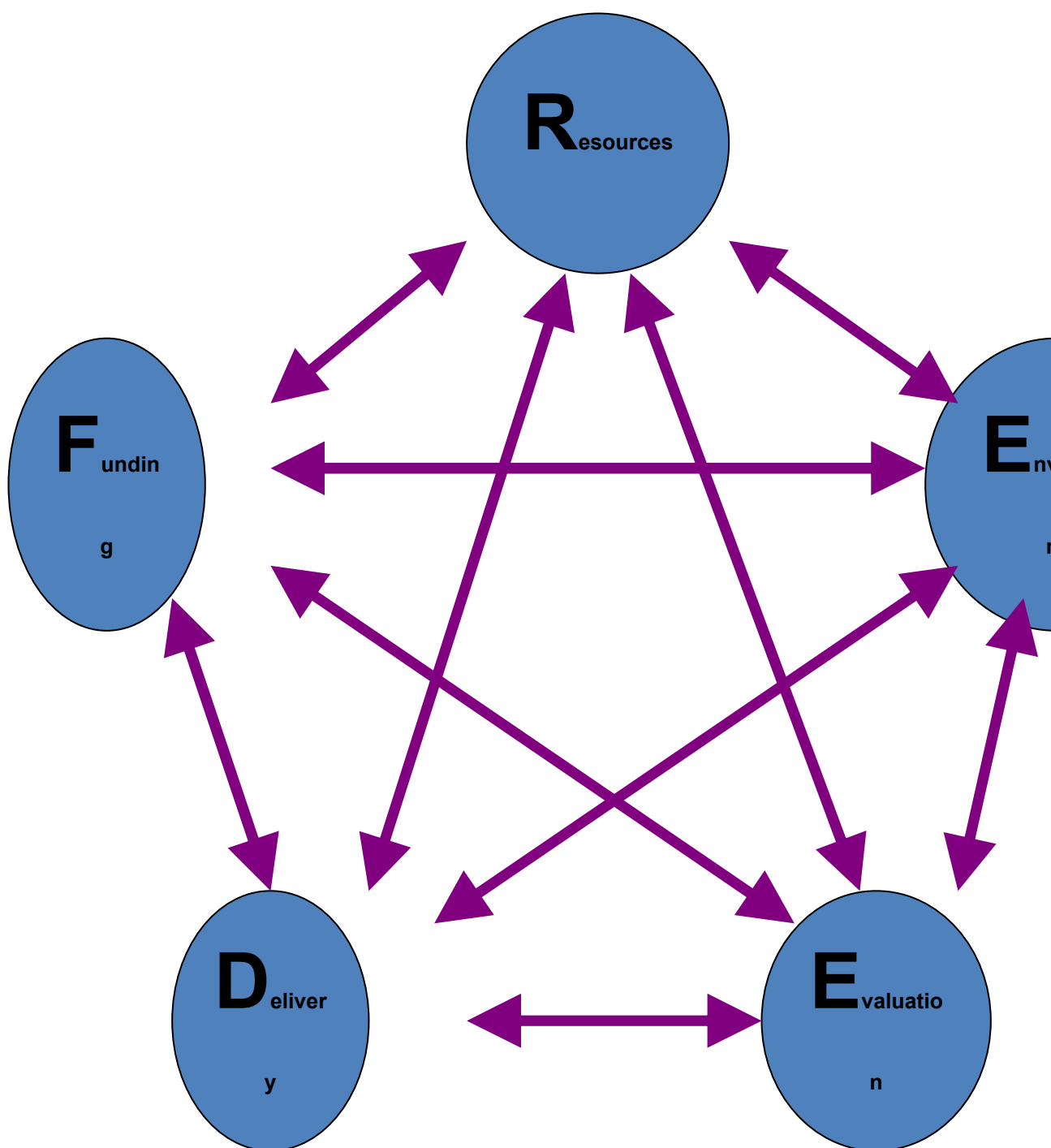


Figure 11: The FREED framework of community sports injury prevention implementation.

Methods

This section outlines some of our successful and unsuccessful experiences in guiding community sports injury prevention implementation, and the effects in reducing injuries, with the application of the FREED framework.

The FREED framework factors can be considered in any order but we recommend the Environment, Funding, Delivery, Resources and Evaluation order. Each factor of FREED has equal value and all five factors have to be present otherwise there is reduced likelihood of success in the 'real world'. Table 19 outlines FREED framework factors, key questions and examples from published literature.

Table 19: Factors in the FREED framework, key questions and examples from published literature.

Factor [Examples from published studies]	Key questions
Funding [39]	<ul style="list-style-type: none"> How much funding should be invested? How long will funding be available? What are the criteria for whether investment should be increased or reduced? What will happen if funding no longer occurs? Should social cost or insurance costs be used? What is an acceptable return on investment?
Resources [5, 36, 38, 40-42]	<ul style="list-style-type: none"> What type of resources will be used? Are these sufficient to reinforce the prevention message? Are the resources relevant for the target audience? Are we using too many resources and overloading the target audience? How will messages once delivered, be retained? What is the most effective way that messages can occur? Are resources being used for areas where awareness is high? Are the resources straight forward to use? What will work for the end user?
Environment [5, 38, 40-42]	<ul style="list-style-type: none"> What is the perception of prevention in the sport, by the NSO, by the participants? Who are partners that can be help ensure the success of the programme? Is there an impetus, crisis or need from within the sport? What is the attitude to injury prevention? What can partners bring? What is the level of buy-in?
Evaluation [5, 40, 41]	<ul style="list-style-type: none"> What baseline data have been collected and when? What is the cost of evaluation compared to implementation? What is to be evaluated? What is the benchmark that currently exists? Is there evaluation of behaviours as well as injuries?
Delivery [5, 36, 38, 40-42, 133]	<ul style="list-style-type: none"> What delivery channels currently exist? Are there delivery channels suitable to carry the injury prevention message? Is there a project champion or driver? Will there be sufficient reach to be effective? Who is the target audience?

Environment

One of the first aspects to understand from the environment is the perception of what injury prevention is or is not. Injury can be seen as an inevitable consequence of participation in sport [30]. Engaging with stakeholders within sport and the community allows an understanding of behavioural aspects and norms of the environment in which sport and injury occur [131].

The majority of the sport sector, in our experience, view injury prevention as changing the rules/the essence of the game, or stopping people participating. It is difficult if partners needed for implementation have this view. An argument needs to be made that removing the injury barrier will help to increase participation in sport and help improve performance [126]. We have shown that injury prevention can occur without changing the rules by working within the sport [41]. For example, the scrum in rugby union is still a dominant aspect of the game, yet by educating players how to scrum correctly serious spinal injuries have decreased [36].

At an individual/team level we have observed that people view injury prevention as a mechanism to obtain things for free that might not be linked to prevention. For example, when

ACC implemented a strains and sprains course [40] attendance was high because of the free medical kit. Drink bottles are another regular injury prevention request to ACC.

When analysing the environment the development of partnerships with research institutions, government agencies, and sporting organisations is important [39]. There might not be a national sporting organisation (NSO), or if there is it might not be responsible for the entire sport. For example, people who run for physical activity might not belong to the local athletes/running club. For touch rugby the NSO doesn't have a majority of touch players affiliated to it, so we changed our focus to how we would implement a touch programme [42].

Partners can provide guidance and advice regarding the environment within the sport. Partnership with the respective NSO has, in our experience, been key to implementation [40]. In rugby union [36] a crisis, in the form of increasing permanent spinal injuries, was central to their involvement. Alternatively, without crises, our programmes in netball, soccer and rugby league, took more than 18 months for the NSO to become involved even though ACC provided funding for full time staff positions with resources focused on injury prevention [5]. Timing plays a crucial element to implementation. ACC data can be used to establish the extent of the injury incidence and severity [39, 43, 52] but it does not mean that it will be addressed easily by the sport or the sport will be cognisant of the injury issue. As part of implementation with sport we identify the range of topics to address and prioritise them to help balance the needs of all and maintain momentum.

Understanding the environment will give important insight to successful implementation. Undertaking an analysis, identifying partners, attitudes and factors, provides necessary aspects to determine what if any the implementation programme will look like.

Funding

Ensuring injury prevention funding is available is central to enable implementation [39]. Funding levels should be commensurate to the number and cost of injuries that the programme will be preventing. This might be easy to establish in other countries what do not have a system such as the ACC in NZ.

At the early stage of planning for implementation funding avenues need to be obtained, as well as how long funding will continue, and whether the programme would continue after initial implementation without additional funding. If these aspects are not identified early on there is the perception that funding levels will remain or increase. There are also consequences of withdrawing funding. For example, as claims were reducing in basketball and hockey a decision was made that the programme was effective and would continue without funding. Subsequently claims increased and made it difficult to re-engage with these NSOs.

Dedicated funding allows a programme to be ring fenced and free from competing interests within the sport. When a NSO is in financial difficulty it is likely to cut the injury prevention

programmes first. This is more likely in NZ given that ACC covers the cost of injuries and the no-fault system reduces any legal redress for participants who incur a personal injury. Sports injury prevention is a good investment as we have shown using insurance costs [39] rather than social costs.

Delivery

Understanding the environment and funding available will help determine delivery and resources. Delivery carries the prevention message/behaviour to the target audience identified in the environment. The delivery channel will vary depending on who the target audience is. Injury prevention can be woven into existing delivery channels in sport [37, 38, 40, 41]. A delivery channel doesn't have to be restricted to formalised coach education, although organisations considering promoting injury prevention should investigate community coach education as an option to reach large numbers of community level players [44]. This is effective as it makes use of an existing infrastructure (coach education) through a partner, in this case the NSO. It gets more challenging when there isn't an existing channel, or the channel does not reach the desired target. In delivering other prevention initiatives we have utilised a database for coaches and referees [37, 38], sporting participants [42] and managers [40]. For touch rugby where the majority of players are found in social competitions, focusing on touch rugby coaches resulted in an estimated 20% of teams coming into contact with the prevention programme [42].

For our unsuccessful mountain biking injury prevention initiative, delivery was not established and largely ignored. Instead of delivery being directly to participants via registration for a large mountain biking event, it occurred after competitors had crossed the finishing line. Competitors were tired and muddy at this time rendering the delivery of any prevention messages ineffective.

Within delivery there needs to be a project champion or driver within the sport. The ACC increased its investment fund for key sports to employ injury prevention managers [39]. This allowed NSOs to focus on injuries and 'sell' the prevention programme from within the sport. Having a sport injury prevention manager meant the crafting of sport specific initiatives and utilising/evaluating existing channels for the purposes of delivery. It also helped determine the environment and change it. Central was ensuring injury prevention manager funding was ring fenced.

In developing delivery channels the key is ensuring that initiatives affect enough people to get the desired outcome of a reduction in injuries. This can be determined in part in stage one of the sequence of prevention [25] or TRIPP [2] where both models advocated for determining the injury severity and incidence. . We use a pre-implementation calculation [39] which can be used as a target to ensure enough delivery thereby allowing for resources to be effective.

Resources

While delivery gets prevention programmes to the desired audience, resources ensure the quality of the initiative with the right messages to reduce injuries. At the community level there is a small opportunity, due to perception and control, to have people engaged with an injury prevention programme. If the delivery reaches the target, it is the quality of the resources that allows for the prevention programme to continue past initial engagement.

Resources can take different forms but must be perceived as adding value to the target audience. Understanding the environment allows the right resources to be developed. Van Mechelen reported 90% of participants were already performing warm-up, cool down and stretching [25] and our data supported this [40, 41] so they are no longer a key focus of our programmes. We have used a variety of resource formats (e.g., posters, video, wallet cards, website etc) with the key being understanding the environment and focusing on the end user and what would work best for them. For example, for concussion in sport in general we used a small wallet card [37, 38] to cover key aspects of the concussion prevention programme [42]. We also used the wallet card concept in snow and touch but extended this to a website where the user could tailor their own card by entering personal details and then printing it out. This concept dovetailed aspects that a sport undertakes (e.g., draws, contact details) with the injury prevention messages reducing resistance to use, adding value to the sport and increasing delivery.

Getting the right number of resources rather than overloading a person is critical. We consider that for the short amount of time we might have to engage a person with prevention programmes they need to understand the relevance of our message, determine that it is important to them by showing how it will benefit them and not labouring the detail of what is in the resources. Our work in soccer and netball showed that our resources were being used again the following season meaning that we had achieved our goal of developing suitable resources [40].

Coach and athlete friendly language for injury prevention materials are required. We found when we implemented 'Screening' (see Figure 10) where we intended to describe physical assessment for the purpose of establishing baseline measures and potential injury risk, it was viewed by some players as a tool to 'screen' them out of a team. Players were tending to hide things that they thought could count against them for selection. To increase the likelihood of accurate completion we replaced the term 'Screening' with the phrase 'Player profiling'.

Evaluation

Evaluation needs to include analysis of injury claims and injury prevention behaviours to help determine whether delivery and resources are working. In the past a baseline for some of our injury prevention programmes had not been established. For example, in initial netball evaluation there was no pre-assessment of knowledge or behaviours of netball coaches which if

present, could affect results [40]. In rugby union initial baseline information collection occurred at the same time as the implementation [41].

Behavioural evaluations are important if you don't have a participation rate. A behavioural study could supplement the lack of a participation rate available to determine if the programme has had an effect. While the ACC system can provide claims data, few sports can provide the playing numbers making an injury rate calculation difficult [39, 44]. A change in claims to ACC could be the result of a change in playing numbers, so having behaviour evaluation provides additional insight into programme effectiveness where a rate is unavailable.

Evaluation can be expensive - some evaluation costs have dwarfed costs of implementation several times. For the pure researcher this is irreverent, but for the practitioner money spent on evaluation could be spent on implementation. This dynamic needs a middle ground. Using the internet as a survey tool is cost effective, but does have limits [44].

Results

This section shows how we have applied the FREED framework to injury prevention with New Zealand Rugby League (League). League was one of the first sports in New Zealand to have an injury prevention programme. From 1998/99 when the programme started until 2002/03 when the programme officially stopped, there was a 37% decrease (from 587 to 376) in annual new moderate to serious claims (MSC) to ACC. However, new league MSC claims increased dramatically since 2003 (485 in 2003/04; 763 in 2004/05; 813 in 2005/06; 906 in 2006/07; and 1,027 in 2007/08). Re-engaging League was difficult and although discussions started in 2005/06 the programme was not re-instigated until early 2008. This delay did however give time for the components of the FREED framework to be worked through. Baseline *Evaluation* of injury prevention behaviour was started in 2006 in addition to evaluation of ACC claims. Another study was conducted in 2007 to provide additional information regarding behaviour at trainings and games.

While *Resources* and *Delivery* could be developed from the previous league prevention programme, or from what had been successful for other sports, an analysis of *Environment* factors showed that some barriers to adoption within league were the attitudes of community players who were inspired by antics of professional players in big tackles (e.g. a shoulder charge is allowed under international rule but not at the community level) [134]. To overcome barriers the injury prevention manager role was combined with a community programmes role to enable a project champion. This person was based in the region that had the greatest number of players (estimated at 40%). League is a team based sport and most teams have a coach/organiser so coach education was chosen for the *Delivery* and a combination of different *Resources* specific to league were developed focusing on key areas for the sport (e.g., concussion, tackle) [39]. Resources were tested on the target audience and were positioned promoting performance enhancement through correct technique rather than for preventing injuries through correct technique.

League wanted ACC to guarantee a level of *Funding* for the first three years so that the revised prevention programme had time to be established and further investment decisions could be made after this time. Developing return on investment and levels of funding was difficult as there were no reliable numbers [135]. While player numbers varied there was no doubt that the increase in MSC claims was not matched by an increase in playing numbers. Levels of funding were based upon claim costs to ACC for similar sports and were set for three years. Years two and three had performance measures that funding was linked to.

The FREED framework indicated the necessary factors could be put in place and in 2008/09 there was a 7.2% decrease (953 in 2008/09) in MSC.

Discussion

The FREED framework has been successful because it draws from a range of sports and from real life implementation experience at the community level on a national scale.

The RE-AIM SSM model [47] identified some implementation factors, however it has not been the approach taken in New Zealand. We have placed more emphasis on aspects such as funding. The application of cost is addressed via the RE-AIM website, rather than in published literature, where it is acknowledged that cost influences several RE-AIM dimensions in addition to adoption; Cost is usually related to intensiveness of intervention which is often related (positively) to efficacy and (negatively) to implementation. Positioning cost or funding in this way gives greater weighting to RE-AIM being more suited to evaluation rather than implementation.

Finch [2] argued before successful prevention efforts can be implemented, the determinants and influences of sports safety behaviours of the sports people and sports organisations need to be understood [30]. If a prevention programme is biologically appropriate, but not appropriate within the context of sport, it has little hope of being adopted and therefore little likelihood of being effective [131]. In our experience understanding the environment allows for tailoring of the programme. Finch [2] also noted unsuccessful attempts at injury prevention are hard to publish, which is unfortunate as practitioners and researchers can learn from both positive and negative examples.

It might seem out of place to have evaluation in our implementation model when it is considered a separate stage in the sequence of prevention [25], TRIPP [2] and van Tiggelen et al's models [34], however, in our experience consideration needs to be given to what and how the programme is evaluated before implementation starts.

NZ is ideally suited to advance sport injury prevention, largely due to the unique national system for injury collection and no-fault insurance for all acute injuries managed by ACC [52]. Between

1 July 2008 to 30 June 2009 the incidence of acute sport and recreation injury claims was 488,000 costing \$NZD486 million for a NZ population of 4.2 million. These injuries can be segmented into five of the six criteria used by van Mechelen et al. [25] to describe injury severity: nature of the sports injury [35, 37, 38, 43]; duration and nature of treatment [5, 35, 37, 38, 40, 43]; working time lost [5, 35, 39, 41, 45]; permanent damage [35, 39]; and cost [37-39, 43]. The remaining criteria, sporting time lost [25], can only be classified by the ACC database into three categories: minor, moderate to serious, and serious. To offset injury cost, ACC funds sport injury prevention programmes with a focus on community sports throughout the country as these represent the incidence and severity as well as the scarcity of professional sports in NZ. How NZ has addressed sports injury prevention has earned praise [52].

Conclusion

The FREED framework has guided community sports injury prevention implementation in New Zealand, and has been effective in reducing injury.

CHAPTER 10

CONCLUSIONS

The overarching aim of the thesis has been to develop a framework that will assist researchers and practitioners to implement strategies to assist in preventing sports injuries. The approach has been novel, drawing on a unique national database maintained by New Zealand's Accident Compensation Commission. Although the framework emerged from research on a series of specific issues and sports, the framework is not case-study dependent. The database has allowed for the linking of injury prevention interventions to outcomes at the scale of populations of sports players rather than selected samples and case studies. The nature of the data maintained by the ACC has also allowed for a much more powerful assessment of the impact of injury prevention programmes because the costs of rehabilitation after different types of sports injury are fully documented. This has allowed us to place much greater emphasis in our research, and in the resulting FREED framework, on costs and funding in the implementation of sports injury prevention. This, in turn, differentiates this research from other approaches which acknowledge the importance of funding, but which are not in a position to measure and monitor the impact of costs directly.

The thesis started with what was to become the first key component of the FREED framework – funding; by using a cost-outcome approach. Chapters 2 and 3 (Section 1) focused on the ACC's database and its potential for the analysis of sports injury prevention implementation. The cost-outcome approach in Chapter 2 was used to determine the feasibility of a prevention programme by outlining how many injury claims were needed to break even. This can result in a number that exceeds what is possible by way of injuries. In some cases it would be better to undertake no prevention programme if the aim is to more than cover costs of its implementation. This type of analysis can assist in determining whether a specific injury prevention programme should be scaled up from a randomised control trial to a national programme. Chapter 2 showed that based on ACC insurance costs, as opposed to the more expensive social costs, sports injury prevention is a good investment. The approach developed for this chapter continues to be used at ACC for workplace injury prevention, road injury prevention and home injury prevention.

Chapter 3 demonstrated that the ACC database enabled population injury rates to be determined for the first time for community sports. This was illustrated with reference to a population-based knee ligament injury. The ACC data underscore the high level of short-term disability associated with knee ligament injuries, particularly those that result in surgery, in the general population. Anterior cruciate ligaments (ACL) injuries are particularly significant in this regard, since 80% of all knee ligament surgeries involved ACL surgery. Sports activities are the primary source (65%) of ACL injuries resulting in surgery. It became clear in this study that there was a need to develop interventions designed to reduce the risk of ACL and other knee ligament injuries, particularly in sports. Using the ACC database for this type of analysis also illustrated the importance of understanding the environment component of the FREED

framework, particularly given the study suggested males had higher knee ligament injury rates than females in the general population.

Chapters 4 to 7 addressed specific sports injuries and the findings provided evidence that supported the development and articulation of several components of the FREED framework including resources, delivery and evaluation. Chapter 4 focused on serious spinal injuries. The introduction of RugbySmart programme coincided with a reduction in the rate of disabling spinal injuries arising from scrums in rugby union. This chapter exemplifies the benefit of educational initiatives in injury prevention and the need for comprehensive injury surveillance systems for evaluating injury prevention initiatives in sport. Chapter 5 focused on the concussion programme. The programme showed a decrease in moderate to serious injury claims, provided a positive return on investment and reduced the time that players with a suspected concussion where delaying seeking professional medical treatment. A number of aspects have since been replicated into other concussion tools for medical practitioners (e.g., Sideline Concussion Assessment Tool) [136].

Chapter 6 presented prevention programmes on neck/beck injuries. While targeting these injuries it examined the role of rule and policy changes. The analysis in Chapter 6 showed that the new law change appears to have had the intended effect of reducing scrum-related head and neck injuries. An important finding in this chapter was that rule changes can be used to prevent injuries without interfering with how the game is played.

Chapter 7 focussed on rugby union and demonstrated that the rugby prevention programme was associated with a decrease in injury claims per 100,000 players in most areas the programme targeted.. The decrease in injury claims numbers was supported by results from the player behaviour surveys pre- and post-implementation. There was an increase in safe behaviour in the contact situations of tackle, scrum and ruck.

Chapter 8 initiated the development of the model subsequently reported in Chapter 9. Chapter 8 focused on coaches as mechanisms for delivering the prevention programme, with soccer and netball being the focus. The integration of injury prevention messages into coach education courses and resources appears to be a viable mechanism for the implementation and delivery of injury prevention strategies in community sport. Organisations considering promoting injury prevention should investigate community coach education as an option to reach large numbers of community level players. Although this was a descriptive study in nature, with a small sample size, we concluded that integration of injury prevention content within coach education courses and resources may be a viable and effective strategy to help community coaches, and therefore community players, to reduce their risk of injury.

Sections 2-4 (covering Chapters 4-8) provided the basis of the FREED framework, particularly regarding Resources, Environment and Delivery. It was evident that these chapters would have benefited from baselines established before implementation; the second 'E' in the FREED

framework. This point is highlighted in Chapter 9 in the final of the five sections where the model is used to draw together many of the ideas presented in earlier chapters in the thesis.

Some reflections and future directions

The development of the research that is reported in this thesis, and the articulation of its major conceptual contribution – the FREED framework, has followed a rather unusual pathway. Instead of starting with the framework and the testing it via a number of experiments or case-studies, the thesis emerged from numerous studies of specific issues related to sports injury prevention carried out by the author, often in association with his supervisors and fellow students. The studies were published in a range of international and journals, and the findings were presented at numerous conferences. Over the course of the period of enrolment for a PhD it became apparent from the specific studies, especially the ones reproduced as chapters 2-9, that there were the elements of a more comprehensive framework for addressing implementation of strategies and interventions to prevent injury in community sports. These became the key components of the FREED framework – funding, resources, environment, evaluation and delivery. This framework, in turn, became the subject of the final substantive chapter rather than the framework that guided the preparation of the substantive thesis chapters.

There are some important caveats that need to be acknowledged with regard to both the research reported in chapters 2-9 of this thesis as well as the application of the FREED framework to sports injury prevention research in other countries. Most of these caveats relate to the database that has provided the empirical evidence that has been analysed in studies reported in chapters 2-9 – the ACC data. These data are not readily accessible by researchers – access is restricted to ACC staff members whose work requires them to draw on the database to manage claims for compensation. It is possible for external researchers to apply to the ACC Ethics Committee for access to the data, but the information they receive is limited. Internationally there is no other country that has such comprehensive data on injuries generally and on the costs of rehabilitation at a national scale and for all types of injuries. This does not mean the FREED framework cannot be used in other jurisdictions, but it does mean that directly comparable findings from replication of studies done for this thesis are impossible to generate.

There are some limitations to the ACC data – the injuries claims information used in chapters 2-9 do contain some data entry errors, especially as the personal details are self-reported as is the information on the sport the individual was undertaking when injured. There are also variations in the way injuries classified as ‘minor’, ‘moderate’, and ‘serious’ have been reported. Before 2004, for example, only claims that had the potential to be moderate to serious had the details of the sport entered. All other details such as name, address and medical diagnosis were entered, but sport-specific information was not. This started to change in the 2003/04 financial year and has seen the number of minor sport claims dramatically climb from 40,000 in 2002/03 to 440,000 in 2008/09. We have limited our analysis to claims classified as moderate to serious because of the changes ACC made to the way it entered sport minor claims. The focus is on

claims for accident compensation and we are well aware that not all sports injuries are followed up by a claim lodged with ACC.

Looking ahead further research is needed to determine if the FREED framework can be implemented to assist with injury prevention in sports other than the major team sports addressed in chapters 2-9. There is scope for extending the analysis of injury prevention implementation strategies to individual sports both in New Zealand as well as overseas. There are also some broader questions that could form the basis of future research on this topic. For example, does the framework have the potential to be generalised along the lines of the 'sequence of injury prevention' framework [25] that was developed into the Translation of Research into Injury Prevention Practice (TRIPP) framework [2]. The specific focus on implementation in the FREED framework takes us beyond the focus on injury causation that is emphasized by Meeuwisse [7] and Bahr and Krosshaug [130]. The chapters that have been published, along with other papers prepared during the course of this thesis project, have made an important contribution to the body of knowledge about sports injury prevention. Chalmers [30] has stated that there has not been progress beyond the initial stages of the sports injury prevention frameworks. On the basis of findings from this thesis, it is our view that the FREED framework has the potential to address the implementation stage where so much of the earlier research into sports injury prevention either stalled or terminated.

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