The Epidemiology and 12-month outcomes of serious sport and active recreation injuries in Victoria, Australia

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General Declaration

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Declaration for thesis based or partially based on conjointly published or unpublished work

In accordance with Monash University Doctorate Regulation 17/ Doctor of Philosophy and Master of Philosophy (MPhil) regulations the following declarations are made:

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

This thesis includes three original papers published in peer reviewed journals and two unpublished publications. The core theme of the thesis is to describe the burden of serious sport and active recreation injuries. The ideas, development and writing up of all the papers in the thesis were the principal responsibility of myself, the candidate, working within the Department of Epidemiology and Preventive Medicine, Monash University under the supervision of Associate Professor Belinda Gabbe, Associate Professor Rory Wolfe and Professor Peter Cameron.

The inclusion of co-authors reflects the fact that the work came from active collaboration between researchers and acknowledges input into team-based research.

In the case of Chapters Three, Four, Five, Seven and Eight my contribution to the work involved the following:

Thesis chapter	Publication title	Publication status	Nature and extent of candidate's contribution
Chapter 3	Trends in sport and active recreation injuries resulting in major trauma or death in adults in Victoria, Australia	Published	Principal author responsible for the concept, design, statistical analysis, interpretation of results and writing up of the manuscript
Chapter 4	12-month outcomes of serious orthopaedic sport and active recreation related injuries admitted to Level 1 trauma centres in Melbourne, Australia	Published	Principal author responsible for the concept, design, statistical analysis, interpretation of results and writing up of the manuscript
Chapter 5	Evaluation of instruments for measuring the burden of sport and active recreation injury	Published	Principal author responsible for the concept, design, literature search, interpretation of results and writing up of the manuscript
Chapter 7	Return to pre-injury health status and function 12-months after hospitalisation for sport and active recreation related orthopaedic injury.	Returned for revision	Principal author responsible for the concept, design, data collection, statistical analysis, interpretation of results and writing up of the manuscript
Chapter 8	The impact of sport and active recreation injuries on physical activity levels, 12-months post-injury	Submitted	Principal author responsible for the concept, design, data collection, statistical analysis, interpretation of results and writing up of the manuscript

I have not renumbered sections of submitted or published papers in order to generate a consistent presentation within the thesis.

Signed: ……………………………………………………………………

Date: ………………………………

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Abbreviations

AIS	Abbreviated Injury Score
ACL	Anterior Cruciate Ligament
AIHW	Australian Institute of Health and Welfare
GOSE	Extended Glasgow Outcome Scale
HRQoL	Health Related Quality of Life
ISS	Injury Severity Score
IQR	Inter Quartile Range
ICD-10-AM	International Classification of Disease, Australia Modification
ICECI	International Classification of External Causes of Injury
ICF	International Classification of Function
IPAQ	International Physical Activity Questionnaire
LOAD	List of All Deficits
MCS	Mental Component Summary
MET	Metabolic Equivalents
NCIS	National Coroners Information Service
NIPP	National Injury Prevention Plan
PCS	Physical Component Summary
SF-12	Short Form 12
SF-36	Short Form 36
VAED	Victorian Admitted Episodes Data

VEMD	Victorian Emergency Minimum Dataset
VISU	Victorian Injury Surveillance Unit
VOTOR	Victorian Orthopaedic Trauma Outcomes Registry
VSTR	Victorian State Trauma Registry
WHO	World Health Organisation

Publications, conferences and awards

Publications

Andrew, NE, Gabbe, BJ, Wolfe, R, Williamson, OD, Richardson, MD, Edwards, ER and Cameron, PA. 12-month outcomes of serious orthopaedic sport and active recreation related injuries admitted to Level 1 trauma centres in Melbourne, Australia. Clinical Journal of Sports Medicine 2008, 18:387-393.

Andrew, NE, Gabbe, BJ, Wolfe, R and Cameron, PA. Evaluation of instruments for measuring the burden of sport and active recreation injury. Sports Medicine. 2010, 40:141-161.

Andrew, NE, Gabbe, BJ, Wolfe, R and Cameron, PA. Trends in sport and active recreation injuries resulting in major trauma or death in adults in Victoria, Australia, 2001-2007. Injury. 2011, doi:10.1016/j.injury.2011.01.031

Conferences

Andrew, NE, Gabbe, BJ, Wolfe, R, Williamson, OD, Richardson, MD, Edwards, ER and Cameron, PA. 12-month outcomes of serious orthopaedic sport and active recreation related injuries admitted to Level 1 trauma centres in Melbourne, Australia .The Australian Conference of Science and Medicine in Sport, Sixth National Physical Activity Conference and the Fifth National Sports Injury Prevention Conference. 2007, Adelaide. (oral presentation).

Andrew, NE, Gabbe, BJ, Wolfe, R and Cameron, PA. The epidemiology of major trauma and death during sport and active recreation in Victoria, Australia. 9th National Conference on Injury Prevention and Safety Promotion. 2009, Melbourne. (oral presentation).

Andrew NE, Gabbe BJ, Wolfe R, Cameron PA. Return to pre-injury health related quality of life and functional status twelve-months post serious orthopaedic sport and active recreation injury. IOC World Conference on Prevention of Injury & Illness in Sport. April 7 - 9, 2011, Monaco. (poster presentation).

Andrew NE, Gabbe BJ, Wolfe R, Cameron PA. The impact of orthopaedic sport and active recreation injury on physical activity levels 12-months post-injury. IOC World Conference on Prevention of Injury & Illness in Sport. April 7 - 9, 2011, Monaco. (poster presentation).

Andrew NE, Gabbe BJ, Wolfe R, Cameron PA The long term impact of hospitalised orthopaedic sport and active recreation injuries on health related quality of life and physical activity levels. Australian Conference of Science and Medicine in Sport. October 19-23, 2011, Freemantle. (oral presentation)

Awards

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Summary

Serious sport and active recreation injuries requiring hospitalisationare common with between 30-230 adult admissions per 100,000 participants per year, based on national and international data. The long-term consequences of these injuries can range from an inability to return to pre-injury sporting levels to severe disability, requiring long-term treatment and care, or even death. As those injured tend to be young, healthy and active contributors to society the potential long-term societal consequences can be great.

Sport and active recreation participation is an important means of promoting population physical activity. Though the public health benefits of physical activity participation are considerable, these benefits could be negated by injury. Despite this, there is little known about the trends and long-term consequences of serious sport and active recreation injuries at a general population level, including their impact on physical activity levels.

The first step in effective injury prevention and control is injury surveillance, in the form of incidence and outcome monitoring. This thesis investigated systems used to monitor serious sport and active recreation injuries in Victoria, Australia and identified potential injury surveillance and outcome monitoring systems for this group. Existing injury surveillance systems were used, both alone and in combination with purposefully collected data, to describe the trends in and outcomes of serious sport and active recreation injuries.

Results showed that there had been an increase, in the last decade, in both the number of life threatening injuries due to sport and active recreation participation and the risk of sustaining such an injury. Priority areas for injury prevention based on injury risk and trends were identified.

Outcome studies contained in this thesis demonstrated that, at 12-months post-injury, the majority of patients hospitalised with sport and active recreation related orthopaedic injuries had

not fully recovered and that large mean reductions in physical health had occurred. Priority areas for injury prevention and rehabilitation research were identified based on these results. Results from this thesis also showed that mean physical activity levels in this group were greatly reduced at 12-months post-injury, even in those who reported being fully recovered. This demonstrated the large impact that serious sport and active recreation injuries can have on participants' physical activity levels.

Information gained from this thesis is important for describing the burden of serious sport and active recreation injuries in Victoria, Australia. Priority areas for injury prevention research based on both incidence and outcome data have been identified and many of the broad health consequences associated with serious sport and active recreation injuries have been described. This is the first body of work to quantify the link between sport and active recreation injuries and their impact on physical activity levels. The results of this thesis are an important step towards improving our understanding of the burden of serious sport and active recreation injuries.

Chapter One: Introduction

1.1 Epidemiology of sport and active recreation injuries

1.1.1 Participation in sport and active recreation

Each year, large numbers of Australian adults participate in sport and active recreation. It was estimated that in Australia in 2009, approximately 12 million people aged over 15 years, or 70% of the population, participated in sport or active recreation at least once a week [1]. A multi-national survey found that more than half of the total physical activity reported by the Australian population was obtained through vigorous activities such as running, football cycling etc, a higher proportion than reported by the other 20 countries surveyed [2].

The health benefits associated with sport and active recreation participation are well established, with physical inactivity now considered to be the fourth leading risk factor for global mortality [3]. Participation in physical activity is associated with reducing the risk of cardiovascular disease, diabetes and some cancers [3], and has been associated with reduced rates of osteoporosis [4, 5], depression [6] [7] and obesity [8]. Consequently, the promotion of physical activity participation is a major public health priority both globally and nationally [3, 9].

A number of longitudinal and cross-sectional studies have shown that the prevalence of leisure-time physical activity has increased, whilst the prevalence of occupational and transport-related physical activity has decreased [10-12]. This suggests that sport and active recreation participation has become an important means of maintaining and increasing population physical activity levels, especially as other domains such as work, home and transport become increasingly sedentary [10].

Participation in sport and active recreation is not without risk, usually in the form of injury. The recent increase in the promotion of, and participation in, sport and active recreation is likely to result in a concomitant increase in the incidence of sport and active recreation injuries. Despite this, knowledge regarding the size or scope of this injury problem in Australia or elsewhere is limited.

1.1.2 Sport and active recreation injury as a public health priority.

Injury contributes significantly to Australia's overall burden of disease and has been a National Health Priority Area since 1986 [13]. Injury prevention strategies in Australia are guided by the National Injury Prevention Plan (NIPP) [14]. This plan was developed through a multi-organisational consultative process and is used to guide research and the development of programs and policies for injury prevention. The NIPP has identified priority areas for action to maximise limited economic resources. Selection of priority areas was based on: (i) economic and political factors; (ii) the potential for the injury prevention plan to demonstrate significant progress within a 3-5 year period; (iii) the potential for the area to be influential in the future; (iv) the maintaining of existing topics where significant spending and infrastructure has already occurred; (v) the availability of interventions; (vi) the frequency and severity of the injury; and (vii) data shortfalls in areas where there is a lack of surveillance infrastructure [15].

The International Classification of External Cause of Injury (ICECI) definition of sport and active recreation is "physical activity with a described functional purpose, eg. competition, practising for competition, improving physical health" [16]. This definition is used throughout the thesis to define sport and active recreation. Deficits in the current knowledge base and data collection systems used to describe the epidemiology of sport and active recreation injuries, may contribute to sports injury prevention not being specifically defined as a priority area in the NIPP. Features of sport and active recreation injuries such as low death rates compared to other injury areas, lack of cost data and societal attitudes towards the preventability of sport and active recreation injuries [17] mean that they may not fulfill the economic and political criteria of the NIPP. A limited evidence base for prevention due to insufficient numbers of community level randomised controlled trials, and insufficient information on how best to implement evidence based prevention [18], may also make this area of injury prevention less attractive to funding bodies and policy makers. The inability to effectively link trends in sport and active recreation injuries with increasing sport and active recreation participation means that its importance as a growing area of influence may not be recognised, further contributing to sport and active recreation injury prevention not being specifically defined as a NIPP priority area.

1.1.3 The incidence of sport and active recreation injuries

In order to monitor and quantify the magnitude of the sport and active recreation injury problem, the incidence and trends of these injuries need to be established. However, there is no specific system in place to provide ongoing monitoring of the incidence and associated trends of sport and active recreation injuries [19]. Most of the published data describing the incidence of sport and active recreation injuries describes specific injury types [20-23], specific sport or recreation activities [24-26], or a combination of both [27-29]. Published data describing the epidemiology of sport and active recreation injuries in general adult populations are less common and often focus on medically treated and hospitalised injuries [30-35]. A summary of published studies describing the incidence of general sport and active recreation injuries is provided in Table 1.1.

Table 1.1. Summary of incidence rates from population based sport and active recreation injury studies

	Data Source	Country	Population	Incidence per 10,000 population (95% CI)
Medically Treated (non-hospital)				
Conn et al 2003 [30]	Cross-sectional survey (3 month recall)	United States	Over 4 years of age	259 (244 to 274)
Mummery et al 2002 [36]	Cross-sectional survey (12 month recall)	Australia	Adults	1,660 (1,627 to 1,694)
Cassell et al 2004 [35]	General practitioner records	Australia	Over 4 years of age	187 (160 to 214)
Emergency Department Presentations				
Burt et al 2001 [37]	Emergency department records	United States	5-24 years of age	339 (303 to 375)
Anonymous 2001 [38]	Emergency department records	United States	Total population	154*
Cassell et al 2004 [35]	Emergency department records	Australia	Over 4 years of age	197 (123 to 255)
Hospital admissions				
Dempsey et al 2005 [23]	Hospital records	United States	Total population	3 (3 to 4)
Flood et al 2006 [39]	Hospital records	Australia	Total population	23*
Cassell et al 2004 [35]	Hospital records	Australia	Over 4 years of age	16 (14 to 42)
Finch et al 2009 [40]	Hospital records	Australia	Total population	19 (18.6-19.2)
Major trauma and death				
Gabbe et al 2008 [41]	Trauma registry and coronal	Australia	Adults over 15 years of age	Major trauma: 0.18* Death: 0.06*

*Confidence intervals not reported

Variations in methods for reporting and collecting injury incidence data and variations in definitions used to categorise sport and active recreation injuries means that incidence rates should be interpreted with caution. The results of cross-sectional population surveys will be influenced, in part, by variations in recall periods used, which varied between three months and 12-months. A decline in injury recall accuracy has been reported as the period of recall increases

[42, 43]. Hospital based rates reported by different countries or regions will also be influenced by the availability of public and private treatment facilities, differences in hospital systems and differences in sport and active recreation participation rates and definitions. Issues relating to the quality of data obtained from hospital based data systems will also impact on the accuracy of the incidence data obtained [44, 45]. This will be discussed in greater detail in Chapter Two. These variations make it difficult to gain a clear understanding of the extent of the sport and active recreation injury problem and mean that this type of data cannot be collated accurately to examine trends in sport and active recreation injuries over time.

In regards to the proportion of all injuries that can be attributed to sport and active recreation injuries, approximately 18% of adult emergency department presentations [46], 0.7% of total hospitalisations and 6-14% of injury admissions in Australian settings are due to sport and active recreation injuries [35, 40]. Similar figures are reported internationally, with sport and active recreation injuries accounting for 3.5% of all unintentional hospitalised injuries and 16% of emergency department visits in the United States [34]. In the United Kingdom, they account for 12.8% of fractures [23] and 8.7% of orthopaedic admissions [47]. These figures are likely to underestimate the true burden of sport and active recreation injuries, compared to other causes of injury, due to incomplete data collection systems and coding errors specifically associated with sport and active recreation cases within hospital data collection systems [48]. Furthermore, this information is often based on acute admission data and may not account for injuries that result in elective surgical admissions, such as anterior cruciate ligament (ACL) injuries or chronic injuries.

1.2 The long-term outcomes of sport and active recreation injuries

1.2.1 Describing the burden of sport and active recreation injuries

Whilst incidence data can provide a means of tracking and monitoring the occurrence of new sport and active recreation cases, it provides only a limited view of the burden imposed on health care, the individual and society by these injuries. In order to effectively measure the burden of sport and active recreation injuries, it is necessary to have an understanding of the long-term impact that injuries have on multiple aspects of participants' lives. Accurate measurement of long-term outcomes associated with sport and active recreation injuries is important to establish the effectiveness of injury prevention measures, to set priorities for future policy development and implementation, and to establish the magnitude of the sport and active recreation injury problem in relation to other injury and disease priority areas.

Conceptual frameworks are important for guiding and research and practice and can be a useful tool for describing the burden of injury. Common conceptual frameworks, used by the World Health Organisation (WHO) and the Australian Institute of Health and Welfare (AIHW) to measure the burden of injury, have their basis in predicting reductions in life expectancy and loss of function, eg. Disability Adjusted Life Years (DALYs) and Quality Adjusted Life Years (QALYs) [49, 50]. Whilst these conceptual frameworks include a temporal dimension that accounts for long-term effects, they only measure the direct injury-related impacts on the individual. The broader societal implications of injury or secondary adverse health issues that may occur after functional recovery are not accounted for. The high weighting given to mortality also means that DALYs and QALYs are likely to underestimate the burden of injury in groups with a high injury frequency but low levels of mortality, such as sport and active recreation injuries [51].

In recent years the List Of All Deficits (LOAD) framework has been developed from extensive expert consensus and is aimed at facilitating the measurement of the full burden associated with injury [52]. The LOAD framework provides a means of recognising the multidimensional nature of injury and the impacts that it has beyond the individual. This framework has the potential to describe the full spectrum of consequences for sport and active recreation injuries, from the most severe injuries requiring long-term treatment and care, to minor injuries that may impact on activities of daily living or restrict participation in physical activities or sports. Potential psychosocial issues around fear of re-injury and return to sport and recreation are included and societal issues around media coverage of elite sports injuries and their impact on fears of injury [53], can also be captured through the LOAD framework.

An additional dimension associated with sport and active recreation injuries, likely to influence a number of the sub-components of the LOAD framework, is related to the context of the injury. The psychosocial response to injury is complex and varies across different population and injury contexts [54]. Unlike many other forms of injury, sport and active recreation injuries occur whilst engaging in positive, health enhancing activities. The extent to which this impacts on outcomes associated with sport and active recreation injuries, as compared to other injuries that may occur during negative or health neutral behaviours, has not been explored. Furthermore, unlike work or transport, sport and active recreation may be viewed by society as a non-vital activity, despite the positive health benefits. Consequently, there is potential for sport and active recreation injuries to result in people avoiding the activity in which they were injured, especially if the injury consequences have impacted on other "more important" aspects of life such as activities of daily living, family or work. This is especially relevant to a sport and active recreation population as the burden of these injuries is disproportionately borne by males [32, 33] and those in the 15-24 year old age group [34, 41]. Those injured during sport and active recreation also tend to be employed and well educated compared to the general population [55, 56], increasing the potential for prolonged negative health consequences for the individual, their family and society. The extent to which this occurs has yet to be described for sport and active recreation injuries.

1.2.2 Outcomes of sport and active recreation injuries

Until recently there has been no unifying conceptual framework available to guide how best to measure the concepts outlined in the LOAD framework. The lack of a purposefully developed outcome measure for use in sport and active recreation populations has lead to an inconsistent use of measurement tools in this group. Consequently conceptual frameworks, such as those related to health related quality of life or function, used in sport and active recreation populations have been defined by the content of the measures used.

The International Classification of Function (ICF) has been developed by the World Health Organization (WHO) and provides a unifying framework to guide the selection outcome measures from the perspective of patients and clinicians [52]. The ICF covers the key domains of body functions, body structures, activity limitation and participation restrictions and the environment. Applying both the LOAD and ICF to sport and active recreation injury outcomes provides a framework for describing both what to measure as well as how best to measure it.

There is very little information available on the long-term outcomes of sport and active recreation injuries. At best there is only a fragmented view of how the LOAD components may be impacted at an individual level by sport and active recreation injuries. Figure 1.1 outlines the components of the load framework that cover the key ICF domains and the level two classifications that have the greatest relevance to those injured during sport and active recreation participation. These are mental function, pain, neuromusculoskeletal and movement related functions, muscle functions, mobility, community, social and civic life and environmental attitudes.

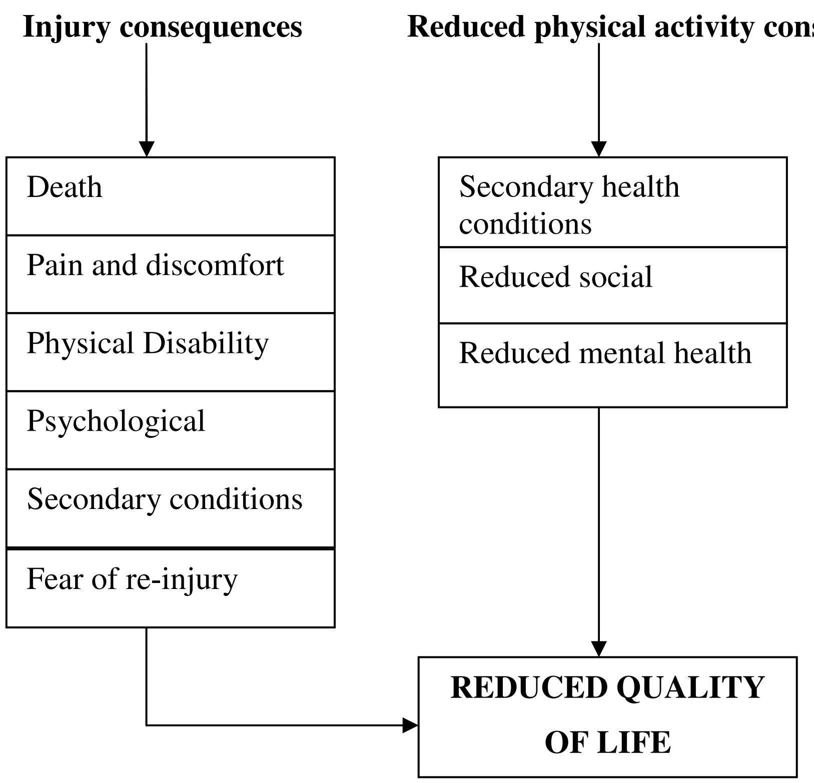

Figure 1.1 Individual level LOAD components most relevant to a sport and active recreation population, adapted from Lyons et al [51].

Only two studies were located in the published literature that have investigated long-term outcomes in general sport and active recreation populations [55, 56]. Methodologically the results of these studies were hampered by small study numbers and follow-up rates of between 50-75%. Outcome measures used by these studies failed to cover high levels of function and did not include many of the items considered to be meaningful to a sport and active recreation population, according to the ICF. The measures used were able to capture problems relating to low levels of health or function but did not capture aspects of recovery related to participation and activity limitation [52] and ignored important components of the LOAD framework such as Health Related Quality of Life (HRQoL), pain, mental health and physical activity levels [51].These studies also used a pre-determined cut-off point to define disability. The use of such cut-offs in sport and active recreations populations is likely to under-estimate the impact on injury in this group, as they are determined using population normative data. This is because sport and active recreation populations have been shown to have HRQoL and physical function above that of the general population [57, 58].

Despite the limitations, these studies addressed some of the LOAD components relating to long-term disability, tangible costs and reduced physical activity participation. They found that hospitalised injuries caused long-term disability in one third of participants and prolonged periods of time off work [56]. For non-hospitalised, medically treated injuries, 19% were unable to work for up to three months and 20% reported long-term disability [55]. Both studies reported large reductions (>50%) in sports participation.

The development of secondary conditions is another relevant component of the LOAD framework. Sport and active recreation injuries have the potential to impact on individuals over a lifetime through future injury risks and development of secondary co-morbidities [59, 60]. There are no published prospective long-term follow-up studies investigating the prolonged implications associated with sport and active recreation injuries. There is however empirical data to suggest that there may be negative long-term implications, even for those that fully recover. Having had a previous injury is the single greatest risk factor for sustaining a subsequent sports injury, with re-injury accounting for around 20% of all sports related injuries [59-61]. Participants will also be put at risk of developing secondary co-morbidities if their participation in physically active pursuits is reduced by the injury. To date there are no studies that have quantified the impact of sport and active recreation injuries on participants' physical activity levels. This information is important, as physical activity losses have the potential to cause long-term health harms that extend beyond the resolution of pain, discomfort and functional loss associated with injury.

1.3 Costs associated with sport and active recreation injuries

Costs associated with sport and active recreation injuries can include direct medical costs, secondary financial losses due to time off work or other costs incurred due to loss of function [62, 63]. Comprehensive costs can also include loss of quality of life or productivity and long-term costs related to the development of chronic disease due to reduced physical activity levels or development of osteoarthritis. The demographics of those that are more likely to be injured during sport and active recreation increases the overall cost implications, especially when secondary and lifetime costs and losses are taken into account.

Large variations in costs can occur for a given injury based on different health care systems as well as social, geographic and monetary inequalities that influence access to treatment. Variations in treatment protocols between health care providers, treatment seeking behaviours of individual patients and the level of function required to perform certain occupations will also influence cost. The proportion of the injury costs that are borne by the individual, and the proportion borne by families, employers and society, will also be influenced by these factors.

There were no cost estimate data identified in the published literature for sport and active recreation injuries in Australia, however broad estimates can be derived from a small number of international studies. A 2003 Dutch study calculated the direct medical costs for sport and active recreation injuries to be €170 (AU$225) million per year and additional costs due to work absences from sport and active recreation injuries to be €420 (AU$560) million [32]. Another study, using adolescent athletes, estimated direct costs to be approximately US$187 (AU$173) per athlete per year. It also estimated that once secondary cost variables were accounted for, such as loss of future earnings associated with time off school, parental time off work, transport costs and employment losses for those that were working, total cost increased by 4.5 times [62]. Even mild injuries such as ankle sprains are estimated to cost over €300 (AU$400) per injury once absenteeism from both paid and unpaid work are included in the costs, with these secondary costs making up over 85% of the total cost estimate [64]. There were also no studies identified in the published literature that estimated the long-term secondary costs associated with reduced physical activity levels or development of long-term health problems due to sport and active recreation injury.

1.4 Summary

Sport and active recreation injuries are a growing public health concern, especially in view of the increasing public health promotion of physical activity. Without clear, consistent and well defined data in this area it is difficult to establish the national importance of sport and active recreation injuries and the public health impact that increased sport and active recreation participation may have in regards to injury. High quality and comprehensive data relating to incidence trends and outcomes in this area is needed to provide the information necessary to inform the setting of research and intervention priorities and to establish links between sport and active recreation injuries and increasing population participation rates.

1.5 Thesis aims

The aims of this thesis therefore are:

i. To identify and review the current data collection systems used to monitor sport and active recreation injuries in a defined population, establish the strengths and limitations of these systems and where appropriate use data from these systems to examine the epidemiology, trends and outcomes associated with serious sport and active recreation injuries.

ii. To review outcome measures currently used to measure the burden and long-term consequences of sport and active recreation injuries, in regards to their suitability for use in sport and active recreation populations, with reference to the ICF.

iii. To quantify the 12-month HRQoL and functional outcomes of hospitalised orthopaedic sport and active recreation injuries with reference to outcomes described in the ICF and LOAD frameworks.

iv. To quantify the impact of serious orthopaedic sport and active recreation injuries on participants' overall physical activity levels at 12-months post-injury.

Chapter Two: Sport and active recreation injury surveillance systems.

2.1 Features of an effective injury surveillance system

Surveillance is the "ongoing, systematic collection, analysis, interpretation and dissemination of information" [65]. Effective injury surveillance can be used to: (i) assess the extent to which sport and active recreation injuries contribute to the burden of disease or injury; (ii) provide international comparisons; (iii) enable the calculation of incidence data; (iv) identify high risk populations and priority areas for injury prevention; (v) guide policy development and funding priorities for treatment and prevention; and (vi) monitor the effectiveness of injury prevention programmes.

The WHO recommends that a minimum core dataset be used for all injury surveillance systems to allow national, international and inter-system comparisons [65]. The proposed core minimum dataset includes five injury-specific variables, along with the basic demographic descriptors of age, gender and an identification code. The injury specific data items are outlined in Figure 2.1. Core optional data relevant to the population of interest and health systems used, can then be added. These core optional items are set out in Figure 2.1 and could include information such as detail regarding the specific type of sport and active recreation activity, the date and time of injury, residence of the injured person, race or ethnicity of the person injured, the severity of the injury and the disposition (ie. place of presentation) [19, 65].

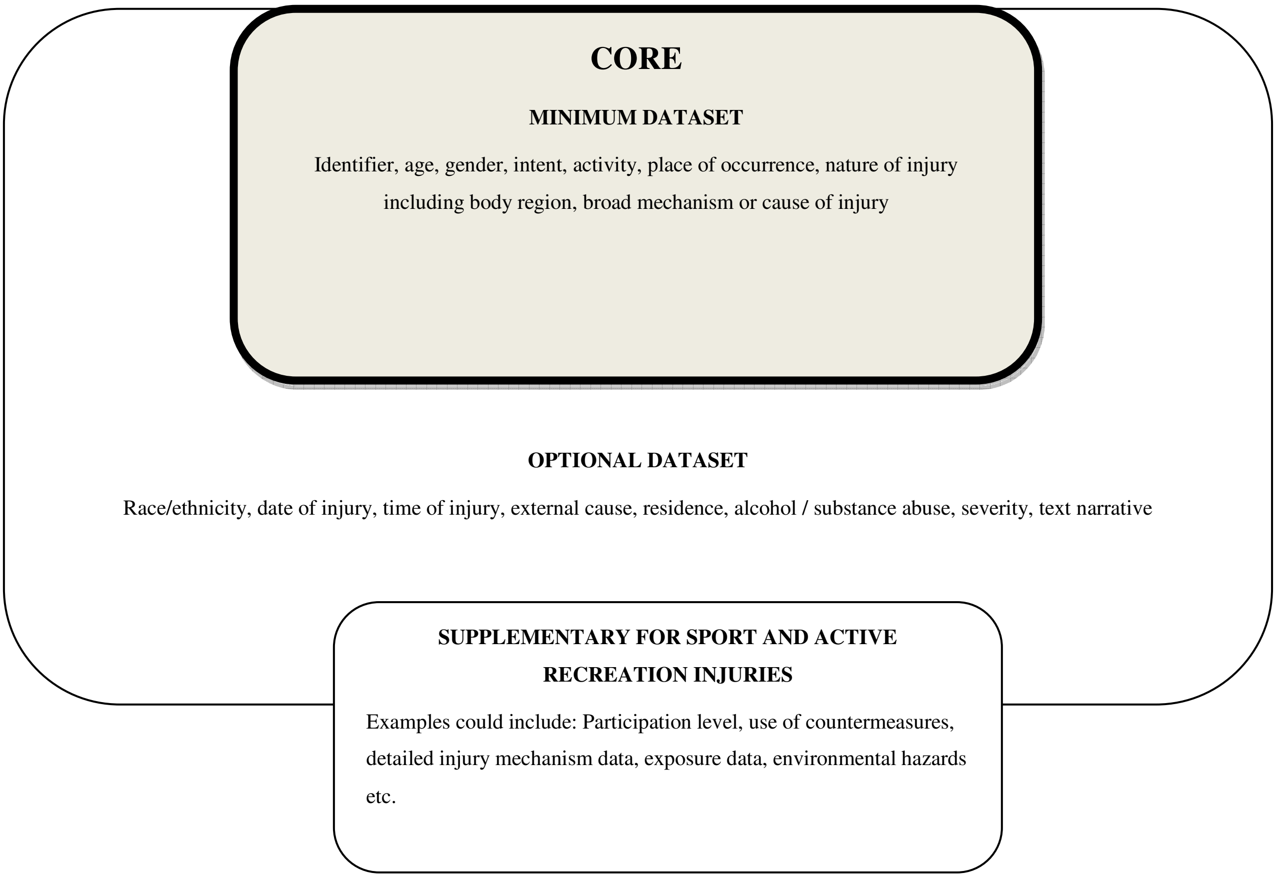

Figure 2.1. Features of an injury surveillance system adapted from Holder et al.[65]

Supplementary data are additional data that are unique to specific injury populations and provide the level of detail necessary for targeting specific intervention campaigns. For sport and active recreation injuries this could include information such as: (i) the level of participation; (ii) whether the person was injured during competition, training or recreation; (iii) the use of injury countermeasures such as protective equipment or modified rules; (iv) more specific information relating to the mechanism of the injury; and (iv) exposure data, such as the frequency of participation [19, 66].

The usefulness of a surveillance system ultimately depends on the quality and completeness of the data collected. Therefore it is essential that the system has a high level of case ascertainment, strong content validity, high reliability and low levels of bias [67]. This ensures that any hypotheses regarding changes in the surveillance data are an accurate reflection of change occurring in the population of interest, and not a result of changes in data collection procedures, case ascertainment, or data errors.

2.2 Sport and active recreation data collection systems

In Australia and internationally, a number of systems are in place for continuous monitoring of serious injuries requiring hospitalisation or medical treatment, predominantly through the use of medical records. These systems are used for a variety of reasons including epidemiological research, policy assessment and formulation, clinical research, quality assurance, patient management and national reporting obligations. The nature of the recording and reporting processes of these systems means that sport and active recreation injuries are often under-reported, misclassified or not reported at all [68]. To date there are no comprehensive systems available at a state, national or international level designed specifically for monitoring sport and active recreation injuries.

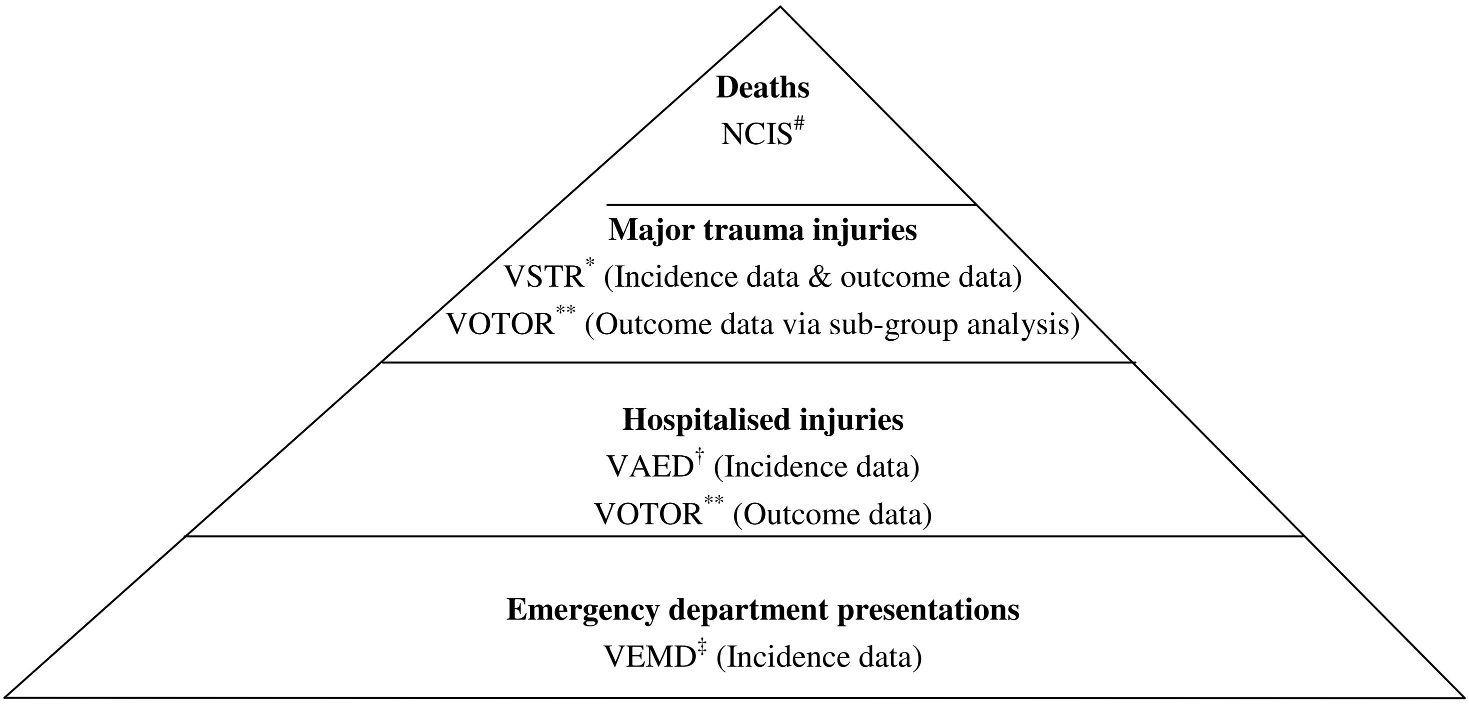

Figure 2.2 Injury Pyramid describing the data sources available at each level, from emergency department visits to deaths.
[#]NCIS, National Coroners Information Service; [*]VSTR, Victorian State Trauma Registry; [**]VOTOR, Victorian Orthopaedic Trauma Outcomes Registry; VAED[†], Victorian Admitted Episodes Data; VEMD[‡] Victorian Emergency Minimum Dataset

2.3 Description of Victoria, Australia

Victoria is Australia's most densely populated state, with a population of 5.6 million people (25% of the Australian population), of which 4.1 million (73%) reside in the capital city, Melbourne [69]. The population of Victoria is generally representative of that of Australia and similar to most developed western nations. In 2010, approximately 82% of the adult population was estimated to have engaged in sport or active recreation [1]. Throughout Victoria there are 110 public hospitals, of which 39 have 24-hour emergency departments [70] and there are 73 private hospitals, four of which have emergency departments [71]. Victoria also has a state trauma system. This is a regionalised system that was established following a ministerial review of Victoria's trauma and emergency services in 1997 [72]. The Victorian State Trauma System is divided into Major Trauma Services, which provide definitive care for the majority of major trauma patients (>80%) [73], Metropolitan Trauma Services and Regional Trauma Services. The effectiveness of this system is monitored through the Victorian State Trauma Registry (VSTR). The VSTR provides an additional source of injury surveillance for major trauma injuries in Victoria. At present, hospital data, registry data and information systems are used to monitor injuries in Victoria.

This chapter describes the administrative and registry data systems currently used to monitor injuries in Victoria. The comprehensiveness, accuracy and appropriateness of these systems were assessed for their effectiveness in monitoring trends and, where appropriate, outcomes in sport and active recreation injury populations.

2.4 Hospital Administrative datasets

Hospital administrative datasets are commonly used to describe the incidence and nature of sport and active recreation injuries as described in Chapter One. They have the capacity to provide information relating to emergency department presentations and hospital admissions within defined geographic areas, in the form of de-identified datasets. These data sets provide the majority of the data used to describe the lower end of the injury pyramid (Figure 2.2). The following section will describe the hospital based datasets used to describe the incidence of sport and active recreation injuries in Victoria.

2.4.1 The Victorian Emergency Minimum Dataset (VEMD)

The VEMD was established in 1995 as a means of monitoring and detailing emergency department presentations, though injury related emergency department data have been available from as early as 1989 through the Victorian Injury Surveillance Unit (VISU) [74]. The VEMD collects the minimum data required for monitoring and analysis purposes, relating to presentations from all Victorian public hospitals with 24-hour emergency departments [74].

The nature of the majority of sport and active recreation injuries means that many have the potential to be captured by the VEMD. The VEMD contains an injury surveillance subset which can aid in the collection of data relevant to a sport and active recreation population. The collection of this additional, injury-specific subset data is mandatory for all injury presentations and includes the core optional injury data items outlined in Figure 2.1. This injury subset information is sent to the VISU to be used for injury surveillance and other research purposes and has been used to report on the epidemiology of specific sport or recreation activities through short reports [75] and bi-annual newsletters [76].

2.4.1.1 Strengths of the VEMD

The VEMD uses standard definitions and collection protocols to ensure comparability over time and across geographical and agency boundaries. The "activity at the time of injury" codes used by the VEMD include a code specific to sport, which is described as "physical exercise with a described functional element". This definition includes both organised sports such as basketball or football and active recreation or non-organised sports such as jogging, trekking or skiing [74]. Diagnosis codes are recorded in International Classification of Diseases, Australian Modification (ICD-10-AM) format, allowing for comparability with other national and international data sources, including the Victorian Admitted Episodes Data (VAED) [74]. Other categories such as activity, place and cause of injury also use codes consistent with ICD-10-AM codes.

The VEMD contains a text narrative of the injury event that, when present, can aid in the identification of cases where codes are incorrect or not specified. The text narrative has the potential to provide an additional level of detail in regards to the type of sport or mechanism of injury.

2.4.1.2 Limitations of the VEMD

Whilst the collection of injury-specific subset data such as activity at the time of injury, cause of injury and place of injury codes is mandatory under the VEMD, the use of "other" and "unspecified" as coding options, often means that aspects of this data are missing, especially in cases where the text narrative does not provide this information. Missing data are also common. A validation study found that VEMD data had at least one error in 87% of injury cases [67] and that place of injury and activity at the time of injury codes, which are the primary method of identifying sport and active recreation cases, had the highest proportion of missing or invalid data [67, 77]. Cause of injury codes had lower error rates but can only be utilised for identifying certain subsets of sport and active recreation cases, such as cycling and horse-related activities [67].

The VEMD data are collected at the time of the emergency department presentation. Accordingly, the reliability and validity of the text narrative and coding data can vary in quality, accuracy and detail depending upon fluctuations in case load, staffing etc within the emergency department [67]. Sport and active recreation injuries are more likely to present at peak periods such as weekends and could be subject to greater degrees of error than other injury types. Also, it is not possible to tell from VEMD data if the injury is a primary presentation or a second or third presentation for the same injury

Despite the potential for the text narrative to provide additional injury detail, the information recorded is often poorly detailed. In one study, additional information beyond that included in the coded data was obtained from the narrative for only 14% of cases [67]. Another study found that only 45% of injuries coded as sporting injuries had sufficient detail in the narrative to identify the type of sport undertaken at the time of injury [78]. Also the VEMD only contains de-identified data and so cannot be used for follow-up purposes

The VEMD does not include private hospital emergency departments, of which there are four in Victoria, creating a potential source of bias in terms of coverage. The greatest difficulty in using the VEMD data as a method of continuous surveillance for sport and active recreation injuries is that there are no restrictions on the types of injuries that can present to emergency departments. Consequently, the decision to present for treatment to an emergency department can be influenced by a number of non-injury related factors such as cost of seeking treatment elsewhere, if the injury was sustained out of hours, availability of other medical or paramedical services and individual treatment seeking behaviours. These factors can fluctuate over time, making it difficult to attribute increases in emergency department sport and active recreation injury presentations to increases in population injury rates.

2.4.2 The Victorian Admitted Episodes Data (VAED)

The VAED has been in existence since July 1987, though inpatient hospital data are available from as early as 1979. The VAED collects demographic, administrative and clinical data about all patients admitted to Victorian public and private acute hospitals, rehabilitation centres, extended care facilities and day procedure centres. These data are used for health services planning, policy formulation, case-mix funding and epidemiological research [79]. Information obtained from hospital admission data such as the VAED plays an important role in morbidity monitoring and is the major source of data for establishing the National Health Priority Areas [13] and priority areas within the NIPP [15].

The VAED has comprehensive coverage within Victoria due to its inclusion of private hospitals, day hospitals and rehabilitation hospitals. Clinical data are coded from patient records by qualified coders using the ICD-10-AM. This is different to the VAED where basic level coding follows an ICD-10-AM format but is not necessarily recorded by trained coders. The ICD-10-AM coding that is performed for the VAED uses a hierarchical coding structure which has the potential to code to a high level of detail. Information relating to the core minimum dataset for injury surveillance is included within the broad ICD-10-AM coding levels. Information in the lower coding levels has the potential to cover many of the optional core dataset items and some of the supplementary items relevant to a sport and active recreation population. This includes information such as the actual sport or active recreation activity that the patient was participating in at the time of injury and the specific mechanism of injury. The ICD-10-AM codes have been used nationally since 1999 and form the basis of the national mortality and morbidity statistics used by the WHO member states [80].

2.4.2.1 Strengths of the VAED

As for the VEMD, standard definitions and collection protocols are used to allow comparability over time and between geographic areas. Specific admission criteria have been developed to standardise inclusion criteria for the VAED [79]. Both passive and active quality assurance measures are in place, in the form of extensive system checks included in the data entry software to minimise data entry errors, as well as independent auditing through external consultancy firms [79]. Its use of an internationally recognized coding system means that data obtained from the VAED can be used for both national and international comparisons.

2.4.2.2 Limitations of the VAED

In VAED cases that have been coded, accuracy has been reported to be around 68% for external cause of injury codes and 75% for place of injury codes [81]. The completeness of the data varies between coding categories. High levels of completeness have been reported for external cause of injury coding but not for coding of the activity at the time of injury, with completeness decreasing as the level of detail required increases [82]. As with the VEMD data, the provision of "other" and "unspecified" as coding options impacts heavily on the completeness of the data. Codes relating to the activity at time of injury account for the majority of missing data, with between 30% and 70% of activity data reported as either missing or "not specified" [68, 82]. This has important implications for sport and active recreation injuries, as the activity at the time of injury codes are the primary means of identifying these cases. Furthermore, the VAED data do not include a text narrative of the injury event, so case identification is reliant solely on the ICD-10-AM codes.

Incidence estimation using the VAED data can also be biased by the inability of the system to track patients between hospitals and to account for re-admissions. Methodologies have been employed to minimise double counting of between-hospital transfers but it is not yet possible to account for re-admissions, due to the absence of a national unique health identifier for patients [83].

Additional sources of bias can occur due to improved case ascertainment and changes in medical practice. Changes in fracture diagnosis rates with improved imaging techniques, and changes to fracture management through increases in surgical interventions are two examples where changes in sport and active recreation injury admissions can occur without an increase in the population rate of injury. As with the VEMD, there are no restrictions on the types of injuries that can be admitted. This means, that factors other than the injury type can influence whether or not a specific patient is admitted to hospital rather than being sent home, eg. an elderly person with a fracture is more likely to be admitted than a young person. Also, only a small proportion of all sport and active recreation injuries are severe enough to require hospitalisation, limiting the VAED's usefulness in capturing the full spectrum of injuries.

2.4.3 Summary

Emergency department and hospital admission data are commonly used both in Australia and overseas to describe the epidemiology of sport and active recreation injuries. This information has contributed to better understanding the burden of injury associated with these injuries in regards to incidence and types of injuries receiving hospital treatment. Limitations associated with these data sources, especially in regards to case definitions, case ascertainment and missing data means that they do not provide sufficient accuracy for the level of continuous monitoring required for analysis of incidence trends for sport and active recreation injuries. Other potential data sources used for injury surveillance are registries and information systems. These will be discussed in detail in the following section.

2.5 Registry data and information systems data

Clinical registries systematically collect data from a defined population and provide the most accurate method of collecting data for monitoring and benchmarking. As registries and information systems are set up for defined and specific purposes they tend to contain a high level of detail, specific to the population of interest. Unlike hospital data systems, they contain identifiable data which means that they can be accurately linked to other identifiable sources of data and that patient details are available for potential follow-up purposes.

2.5.1 The Victorian State Trauma Registry (VSTR)

The VSTR is a state-wide, population-based trauma registry that collects information about major trauma patients admitted to all trauma-receiving Victorian hospitals [72] as outlined in section 2.3. The VSTR has been collecting data on all major trauma cases since July 2001. The definition of a major trauma, that is used by VSTR, was established by a ministerial review and is defined as an Injury Severity Score (ISS) >15, injury requiring urgent surgery or an intensive care unit stay of over 24 hours [73].

Cases are identified prospectively by data coordinators at the three Major Trauma Services by checking the hospital information systems, emergency department and intensive care unit admission records and ward rounds, on a daily basis [84]. The remaining trauma-receiving services identify cases retrospectively by running reports using the VAED ICD-10-AM codes [84]. Data are extracted for the VSTR from the medical records, including emergency admission data, discharge data and pre-hospital data and further details about deaths are obtained from the National Coroners Information System (NCIS) [73]. All components of the core minimum and optional datasets are collected by the VSTR and the provision of a text narrative has the potential to provide some specific supplementary information about the injury event.

Effective injury control and prevention requires that we not only aim to prevent injuries but also aim to minimise the long-term consequences [85]. In order to measure these consequences, outcome data should be collected. Without this, important aspects of injury prevention can be missed and the burden of injury underestimated. The VSTR is unique in that it also monitors the effectiveness of the Victorian State Trauma System through changes in long-term outcomes [86, 87]. Functional outcome data using the Extended Glasgow Outcome Scale (GOSE) has been collected since 2005. Health status or HRQoL data using the Short Form 12 (SF-12), a numerical rating of pain and a global measure of disability, have been collected for the VSTR since 2006. Data are collected at 6 months, 12 months and 24 months post-injury [84]. There has been one publication to date using VSTR data to report the incidence of sport and active recreation major trauma injuries. Trends relating to sport and active recreation injuries have not been reported previously using this data.

2.5.1.1 Strengths of the VSTR

The main strengths of the VSTR are its comprehensive, state-wide coverage and its use of multiple data sources to provide a detailed and complete dataset for all major trauma patients in Victoria. For monitoring purposes, a robust and stable case definition was established at the commencement of the registry to ensure all major trauma cases were captured [72]. The linkage of episodes of care across health services enables the integration of multiple data sources to provide reliable tracking of patients, prevent double counting of patients and to maximise the completeness of the data collected [73]. The inclusion of a detailed text narrative provides an additional means of case identification for sport and active recreation cases and cross-checking of coding.

Numerous passive quality assurance processes are in place to minimise data entry errors and regular quality assurance procedures were implemented in 2004 to ensure that all incorrect or incomplete data were regularly updated [84]. The Major Trauma Services contribute over 80% of VSTR patients and so are required to submit an annual Data Governance Report, which includes a Data Completeness Report [84].

The use of routinely collected data provides access to large numbers of patients with a full set of demographic, injury, hospital and outcome data, across a number of years. Collecting injury and outcome data for general sport and active recreation participants via other methods can be difficult, especially for those participants who cannot be accessed through sporting clubs. Furthermore, the comprehensive nature of VSTR data means large numbers of variables are available for sub-group and multivariate analyses. As the data are already collected for other injury monitoring purposes, this provides a potentially cost effective means of studying trends in seriously injured sport and active recreation participants.

2.5.1.2 Weaknesses of the VSTR

The main limitation of the VSTR for sport and active recreation surveillance is that it captures the most severe end of the injury spectrum, which constitutes only a very small percentage of all sport and active recreation cases. Nevertheless these injuries should be a priority for injury surveillance and prevention due to their high costs and potential for long-term disability [73, 86].

A potential source of bias, common across all surveillance systems, is increased case ascertainment due to improved data collection processes, diagnostic procedures or changes in case definitions. In addition, unlike hospital databases, the VSTR uses an opt-out method of consent [88]. This means that patients are given the option of having their details removed from the VSTR system. Though this has the potential to impact on capture rates, only 0.2% of patients requested removal from the registry [86].

Only data routinely collected by the registries were available for analysis, with limited data available for particular subgroups. The VSTR does not contain a comprehensive measure of socio-economic status. However, it does collect information regarding level of education and occupation which are commonly used as indicators of socio-economic status. Also the VSTR uses an ISS cut off as one of the criteria for classifying an injury as a major trauma. The ISS is a threat to life measure. As such, the ISS does not take into account the level of disability associated with the injury.

Activity at time of injury codes include a section for sport and another for leisure activities and could potentially provide a quick and effective means of identifying sport and active recreation injuries. As with the hospital systems, 65% of cases from 2001-2006 were coded as "unspecified" or "other", though the extent to which this underestimates the incidence of sport and active recreation cases is unknown. With the VSTR this is can be overcome by using the text narratives, a more labor intensive method of case identification.

2.5.2 The Victorian Orthopaedic Outcome Registry (VOTOR)

The VSTR captures only the most severe orthopaedic trauma injuries. Consequently, the VOTOR was developed to provide a more comprehensive view of orthopaedic traumas and their outcomes [89]. The VOTOR collects detailed data on orthopaedic injuries admitted to participating hospitals, and so can provide outcome information at a hospital admission level. This provides outcome information that is not available through the VAED. The VOTOR commenced collecting data in August 2003 from the two adult major trauma hospitals in Victoria and has since expanded to include a regional, and more recently a metropolitan, trauma-receiving hospital. Outcome data is routinely collected at six and 12 months post-injury.

Information pertaining to treatment, complications and long-term outcomes of patients admitted to these hospitals is collected. As the VOTOR includes the adult Major Trauma Services, the majority of orthopaedic major trauma injuries are also captured by the VOTOR. The VSTR and the VOTOR are integrated so that outcome data are collected simultaneously to prevent doubling up of resources for patients that meet the criteria for both registries.

2.5.2.1 Strengths of the VOTOR

The benefits of using routinely collected data for monitoring outcomes in sport and active recreation injury populations, outlined in relation to the VSTR, also apply to the VOTOR. The VOTOR collects information on all orthopaedic hospital admissions and, unlike the VSTR, is not limited to major trauma cases. This means the VOTOR has the potential to capture many of the less severe hospitalised injuries, making it more applicable to a sport and active recreation population. Audits of the VOTOR have reported that data completeness is high with most (80-97%) data fields being 95% complete [90]. Follow-up rates are also high, with 6-month and 12-months rates reported at 87% and 86% respectively [91].

2.5.2.2 Weaknesses of the VOTOR

The VOTOR is not a population based registry but a sentinel site registry. As such it is not used for population based injury surveillance. The main value of the VOTOR is its ability to capture a broad range of orthopaedic injury management and outcome data. A text narrative of the injury event is often not available. Therefore cases within the VOTOR that are not classified as major trauma cases by the VSTR often need to rely on ICD-10-AM coding for case identification, reducing the ability to identify some sport and active recreation cases.

The other disadvantage of the VOTOR registry is that it does not include non-orthopaedic injuries. This means that outcome data cannot be generalised to those that suffer non-orthopaedic sport and active recreation injuries. Large numbers of sport and active recreation injuries will still be captured by the VOTOR however, as approximately 75% of all hospitalised sport and active recreation injuries have an orthopaedic or musculoskeletal injury as their primary diagnosis [39]. Limitations in regards to pre-determined variables and case identification associated with the VSTR also apply to the VOTOR

2.5.3 The National Coroners Information Service (NCIS)

The NCIS is a national data storage and retrieval system. Every death reported to the coroner in Victoria since July 2000 is stored within the system. Information within the NCIS can be utilised by approved research and government agencies to obtain details regarding the occurrence and circumstances of reported fatalities. Currently, in Australia there is mandatory reporting to the coroner of all deaths that result from accident or injury [92].

The NCIS records all items in the core minimum and optional datasets (Figure 2.1). Full text reports are available in the form of police narratives of circumstances, autopsy reports, toxicology reports and findings. These have the potential to provide additional information regarding injury mechanisms, exposures, the use of counter measures and environmental hazards.

2.5.3.1 Strengths of the NCIS

The main strengths of the NCIS are in its state-wide coverage and the high level of detail provided by the text narratives contained within the system. The text narratives allow all sport and active recreation injuries to be readily identified. Activity at the time of injury codes are entered by the NCIS staff, based on the narratives. Consequently these codes have a high level of completeness.

In Victoria, NCIS information can be used by the coroner to make recommendations in regards to public health and safety and provides sufficient detail to guide the development and implementation of specific injury prevention programmes [92]. Quality assurance is provided through both automated edits and warnings in the data entry system as well as through regular quality assurance audits [93].

2.5.3.2 Weaknesses of the NCIS

The low risk of death associated with sport and active recreation injuries means that, like the VSTR, only a small proportion of sport and active recreation injuries is captured by the NCIS. There are other issues inherent to the NCIS that impact on the completeness of the data. In general, external organisations are only given access to closed cases and most cases are not coded until they are closed. This means that, not only are open cases unable to be accessed, but it is not possible to estimate the number of specific sport and active recreation cases that may be open at any one time. In Victoria, it is estimated that approximately 15% of all cases are open at any one time [93].

The NCIS relies on hospitals and medical practitioners to report eligible cases. Despite mandatory reporting being in place for all injury related deaths, one study found that only 38% of eligible in-hospital deaths were reported to the coroner [92]. It is likely, however, to be less of a problem for sport and active recreation traumas as the majority of unreported cases related to the frail elderly [92]. As with any system, coding errors can occur. These have been reported to be between 15% and 30% nationally, according to the 2009/2010 quality assurance report [93].

2.5.4 Summary

The additional level of detail and robust case definitions provided by registries and information systems mean that injury incidence changes over time are able to be attributed to true incidence changes. When used in combination, the VSTR and the NCIS provide an effective injury surveillance tool for monitoring trends in sport and active recreation injuries at the high end of the injury pyramid. The use of satellite registries such as the VOTOR can provide additional valuable outcome data not provided by hospital databases.

2.6 Sport and Active Recreation Participation Data Souces

2.6 1 The Exercise Recreation And Sport Survey (ERASS)

The ERASS is a quarterly survey that has collected information on the frequency, duration, nature and type of activities that people aged 15 years and over participate in annually for exercise, recreation and sport since 2001. The ERASS collects information on both sport and active recreation activities, and surveys between 13,500 and 16,500 people per year. The data obtained from the surveys are extrapolated to calculate population participation rates both nationally and state-wide, as well as for individual sporting groups [94].

2.6.1.1 Strengths of the ERASS

The population rates derived using ERASS data provide a useful denominator for sport and active recreation injury surveillance, allowing calculation of injury rates which take into account fluctuations in participation. The provision of sport and active recreation and demographic sub-groups means that differences in activity levels between age and gender groups can be accounted for, and participation rates calculated for relevant sub-groups. Standard errors for common sport and active recreation are less than 25%. The ERASS has also been shown to have good correlation with physical activity surveillance measures such as the Active Australia measure, suggesting that the ERASS provides reliable estimates of population physical activity and sport and active recreation participation [95].

2.6.1.2 Limitations of the ERASS

Participation numbers are based on estimates obtained from random sampling and are subject to error. As mentioned, most activities have standard errors less than 25%. However, activities with low participation rates such as rock climbing or baseball have higher error rates and participation rates for uncommon sports such as aero sports are not reported [94]. The ERASS also lacks the necessary detail to differentiate within broad sporting categories or levels of participation and does not account for exposure time, limiting the ability to be used in studies where a more precise estimate of exposure time is required. The ERASS state data are not as comprehensive as the national data, which also limits the ERASS's ability to provide state level estimates for some categories.

2.6.2 Summary

The ERASS is an ongoing national survey of sport and active recreation participation in Australia. Though it is not a surveillance system per se, it provides a useful estimate of population participation rates for most sport and active recreation activities. Despite its limitations, the ERASS provides a more accurate denominator for sport and active recreation injury surveillance purposes than general population figures.

2.7 Conclusion

Hospital administrative data are important for state-wide injury surveillance in Victoria and elsewhere. They provide information across various levels of severity and have been the primary source of injury surveillance in Victoria since 1990. It is unlikely that a specific sports injury surveillance system, which provides an adequate level of information and coverage for accurately monitoring sport and active recreation injuries, will be developed at a state, national or international level in the near future. Until such a system is implemented, the primary source of routinely collected sport and active recreation injury surveillance data will continue to be from hospital administrative datasets [19].

The VSTR and the NCIS are the only available data systems at present, in Victoria, that provide the necessary detail, accuracy and features for the level of continuous surveillance of sport and active recreation injuries, necessary for trend analysis. In addition, registries such as the VSTR and the VOTOR provide valuable long-term outcome information that can be used to further describe the burden of sport and active recreation injuries. The following two chapters provide examples, in the form of published manuscripts, of how these data systems can be successfully used for injury surveillance to monitor trends in serious sport and active recreation injuries and report on the long-term outcomes of these injuries.

Chapter Three: The use of routinely collected data to measure trends in sport and active recreation injuries resulting in major trauma or death in Adults.

Overview

Chapter Two established that many of the routinely collected injury surveillance systems currently in place to monitor population injury rates are not ideal for the surveillance of trends associated with sport and active recreation injuries. However, the data sources described do contain strengths. In this chapter, data from the VSTR and the NCIS will be used to assess trends associated with sport and active recreation injuries. As mentioned in Chapter Two, these systems contain sufficient detail to accurately identify sport and active recreation injuries. The high level of reliability and case ascertainment associated with these data systems means that they contain a low level of bias. This is important when assessing trends in injury incidence, so that changes over time can be attributed to changes in the true incidence of sport and active recreation injuries, rather than occurring as a result of changes in the accuracy of the data collected or in the types of cases included in the datasets. Although data from the NCIS and VSTR only capture the most severe tip of the injury pyramid, it is these injuries that impact most on the burden of sport and active recreation and should be of the highest priority in terms of injury prevention. The availability of identifiable data from these two sources also means that data can be accurately linked to prevent double counting of cases and provide a more comprehensive view of the incidence of major trauma injuries and deaths in Victoria. This is important because changes in deaths alone may be a reflection of changes in the trauma system or improved treatment options occurring at the pre-hospital or hospital level. By combining these systems it was possible to establish rates and monitor trends in major trauma injuries and deaths, due to participation in sport and active recreation in Victoria.

The aim of the following paper was to examine patterns, rates and trends in major trauma injuries and deaths due to participation in sport and active recreation injuries in Victoria from July 2001 to June 2007. The following paper addresses the second part of aim number one of this thesis. Data from the VSTR and the NCIS were used and analysis was undertaken in Victoria using the most up to date data available at the time. As not all Victorians participate in sport and active recreation, denominator data, in the form of participation rates, were derived from the Exercise, Recreation and Sports Survey (ERASS) [94]. Participation data were established for all participants as well as for individual sporting activities, to establish the risk of major trauma and death associated with key sporting activities.

The following paper is the first to present trend analyses using state-wide data collection systems of seriously injured sport and active recreation participants, accounting for participation. The following paper was accepted for publication by Injury in January 2011 and is currently available as a "Published ahead of Print" article at the following weblink http://dx.doi.org.ezproxy.lib.monash.edu.au/10.1016/j.injury.2011.01.031

Monash University

Declaration for Thesis Chapter Three

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Declaration by candidate

In the case of Chapter-Three, the nature and extent of my contribution to the work was the following:

Nature of contribution	Extent of contribution (%)
Principle author responsible for the concept, design, statistical analysis, interpretation of results and writing up of the manuscript.	80%

The following co-authors contributed to the work. Co-authors who are students at Monash University must also indicate the extent of their contribution in percentage terms:

Name	Nature of contribution	Extent of contribution (%) for student co-authors only
A/Prof. BJ Gabbe	Contributed to the study design, analysis, writing and drafting of the manuscript	N/A
A/Prof. R Wolfe	Provided statistical advice and contributed to drafting of the manuscript	N/A
Prof. PA Cameron	Contributed to the design and drafting of the manuscript	N/A

Candidate's Signature	[redacted]	**Date** 25/8/2011

Declaration by co-authors

The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors.
(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
(4) there are no other authors of the publication according to these criteria;
(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location(s)	Department of Epidemiology and Preventive Medicine, Monash University, Alfred Campus

Co-authors signatures	**Date**

Signature 1	[redacted]	25/08/2011
Signature 2	[redacted] [redacted]	25/8/11
Signature 3	[redacted]	

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Trends in sport and active recreation injuries resulting in major trauma or death in adults in Victoria, Australia, 2001–2007

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ABSTRACT

Background: The purpose of this study was to describe patterns and rates of sport and active recreation injuries that result in major trauma or death and to examine trends in these rates for all sport and active recreation activities and key sporting groups, for the period July 2001–June 2007, in Victoria, Australia.

Methods: All sport and active recreation related major trauma cases and deaths were extracted from the Victorian State Trauma Registry (VSTR) and the National Coroners Information System, for the period July 2001–June 2007. Participation data from the Exercise Recreation and Sports Survey (ERASS) was used to establish incidence rates for the group as a whole and for key sporting groups. Poisson regression analysis was used to examine trends in major trauma and death due to participation in sport and active recreation across the six year study period.

Results: There were 1019 non-fatal major trauma cases and 218 deaths. The rate of major trauma or death from sport and active recreation injuries was 6.3 per 100,000 participants per year. There was an average annual increase of 10% per year in the major trauma rate (including deaths) across the study period, for the group as a whole (IRR 1.10, 95% CI, 1.06–1.14). There was no increase in the death rate (IRR = 0.94, 95% CI, 0.87–1.02; $p = 0.12$). Significant increases were also found for cycling (IRR 1.16, 95% CI, 1.09–1.24) off-road motor sports (IRR 1.10, 95% CI, 1.03–1.19), Australian football (IRR 1.21, 95% CI, 1.03–1.42) and swimming (IRR 1.16, 95% CI, 1.004–1.33).

Conclusion: The rate of major trauma inclusive of deaths, due to participation in sport and active recreation has increased over recent years, in Victoria, Australia. Much of this increase can be attributed to cycling, off-road motor sports, Australian football and to a lesser extent swimming, highlighting the need for co-ordinated injury prevention in these areas.

Introduction

The health benefits of maintaining a physically active lifestyle are well established.[22,25] Consequently, physical activity is widely encouraged as part of global public health initiatives.[26] In recent years, developed countries have demonstrated increases in population leisure-time physical activity, especially as other domains of life become more sedentary.[12] Unfortunately however these health benefits can be negated by injury with serious injuries having potential major long-term consequences for the individual and the whole of society.[1,6] It is therefore important to monitor trends, not only in population physical activity levels but also in the number and pattern of injuries associated with physically active pursuits. The first step in effective injury prevention is the development of ongoing, systematic, injury surveillance. The use of comprehensive registries and information systems such as The Victorian State Trauma Registry (VSTR) and the National Coroners Information System (NCIS) is one such method. These systems can monitor changes in injury patterns and priority areas for injury prevention over time and assess the effectiveness of injury prevention programs.

There are numerous studies on the patterns and rates of serious injuries that occur due to participation in sport and active recreation.[4,9,14] These studies provide useful information, however they afford only a snap-shot view of the situation. Examining injury trends provides additional information important in identifying research priorities and directions. The aim of this study therefore was to examine trends in major trauma and death rates for all sport and active recreation activities and individual key sporting groups, for the period July 2001–June 2007, in Victoria, Australia.

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Methods

Setting

The state of Victoria has a population of 5.4 million of which 3.8 million (70%) reside in the capital city, Melbourne.[2] In 2007, approximately 80% of the adult population was estimated to have engaged in sport or active recreation.[24]

Databases and procedures

Victorian State Trauma Registry (VSTR)

The VSTR is a state-wide population-based trauma registry that collects information about all major trauma patients admitted to trauma-receiving Victorian hospitals and is subject to rigorous quality assurance processes to ensure that all relevant cases are captured. Information on VSTR can be found at http://www.med.monash.edu.au/epidemiology/traumaepi/traumareg.html. Major trauma is defined as injury resulting in death, urgent life saving surgery, an intensive care stay of more than 24 h requiring mechanical ventilation, or an Injury Severity Score (ISS) > 15. Information relating to injury diagnosis codes, injury event details, injury management details and discharge information is collected from participants' medical records and hospital information systems. A text narrative of the injury event is collected. The VSTR uses an opt-off form of consent, so all eligible patients are included in the registry unless they request removal of their data. Approximately 0.3% of eligible cases have requested removal from the registry.[3]

Adult cases, aged over 14 years, were extracted from the VSTR database for the period July 2001–June 2007 if they met one or more of the following criteria:

i. Activity at the time of injury coded as either "sports" or "leisure".
ii. Place of injury coded as either "athletics and sports area" or "place for recreation".
iii. Cause of injury coded as "motorcycle driver", "motorcycle passenger", "pedal cyclist" or "horse related".

On-road motor cyclists and pillion passengers were excluded, as it was not possible to determine if they were riding for transport or recreation. However all pedal cyclists were included, as most on-road pedal cyclists choose to ride for sport or leisure/fitness.[5] The text narrative of the injury event was checked for all cases, to ensure comprehensive case identification. Each participant's sport or active recreation at the time of injury was determined from the relevant ICD-10-AM activity code and the injury event text narrative. The sport or active recreation was further categorised into sporting groups consistent with those used in the Exercise Recreation and Sport Survey (ERASS).[24]

National Coroners' Information System (NCIS)

The NCIS is a comprehensive national data storage and retrieval system. Information on the NCIS can be found at http://www.ncis.org.au/index.htm. Every Victorian death reported to the coroner since July 2000 is stored within the system. Closed cases were identified for adults aged over 14 years who died as a direct result of injuries sustained during participation in sport or active recreation activities, during the study period. Cases coded as "informal sport and active recreation", "organised sport and active recreation", or "leisure activity", were extracted for analysis. Road trauma deaths were checked to ensure that all cycling deaths were included. Event details were used to categorise cases into sporting groups consistent with those used in the ERASS. Data was extracted from the NCIS between October and November 2008. At the time of data retrieval approximately 13% of all cases for the 2006–2007 period were still open and not able to be accessed.[16]

The use of identifiable data from the VSTR and NCIS allowed cross-checking to prevent double counting of cases. The VSTR has been approved by the Human Research Ethics Committee at each of the participating hospitals and approval to access the NCIS was obtained through the ethics process of the NCIS.

Exercise, Recreation and Sport Survey (ERASS)

The ERASS collects information on the frequency, duration and type of activities that people aged 15 years and over participate annually for exercise, recreation and sport. Between 13,500 and 16,500 people are randomly surveyed annually. The data obtained is extrapolated to calculate state and national population participation rates. Sporting group participation rates used in this study had a relative standard error between 1% and 25%.[24]

Data analysis

Descriptive statistics were used to define the demographic profile, injury profile and injury severity of participants. Incidence rates were calculated for the whole group and the nine sporting groups with the highest frequency of major trauma and deaths, by dividing the number of major trauma and deaths by the ERASS annual participation numbers. This was expressed as a rate per 100,000 participants per year. The ERASS data, which follows calendar years, was adjusted by calculating the average participation numbers across the relevant time periods, to account for the VSTR data years, which followed a July–June period. Rates were not calculated for aero sports due to a lack of participation data.

Poisson regression was used to investigate changes in injury rates over the six-year period for the whole group and for individual key sports. Though all major trauma services were with VSTR from 2001 full coverage was not achieved until 2005 hence hospitals that were not part of the VSTR in 2001 were not included in these analyses. Models included number of injuries/deaths as the outcome variable, number of participants as the (log) offset, and were adjusted for age and gender. Due to limitations in the ERASS data, the percentage of males and females in each age group for the key sporting groups were taken from national participation figures. These percentages were then applied to Victorian participation numbers to obtain the figures used in the regression model. Our Poisson model was tested for effect modification using a likelihood ratio test with no significant interactions found. A negative binomial model was fitted to the data to test for over-dispersion. A moderate amount of over-dispersion was noted only for the Poisson model that included all the sporting groups. This over-dispersion was explained by the high level of variability between sporting groups. Ultimately the Poisson model was chosen over the binomial model as it was a more conservative model, in the sense of giving IRR estimates closer to the null. The incidence rate ratio (IRR) was calculated for the group as a whole and for individual sporting groups and a p-value of <0.05 was considered statistically significant.

Results

During the study period there were 1019 sport and active recreation non-fatal major trauma cases and 218 deaths (58 of which occurred in hospital). The average annual major trauma rate was 5.2, and the death rate was 1.1, per 100,000 participants per year from sport and active recreation injuries. The combined rate of major trauma and deaths was 6.3 per 100,000 participants per year. Off-road motor sports had the highest rate of major trauma and death at 118.9 per 100,000 participants per year, followed by

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Table 1
Numbers and rates for sport and active recreation major trauma and death cases in Victoria, Australia 1 July 2001–30 June 2007 (inclusive).

Sporting group	Major trauma cases		Deaths		Major trauma cases and deaths	
	n	Rate/100,000 participants/year	*n*	Rate/100,000 participants/year	*n*	Rate/100,000 participants/year
All sports	**1019**	**5.2**	**218**	**1.1**	**1237**	**6.3**
Off-road motor	247	108.7	23	10.1	270	118.9
Equestrian	155	52.2	4	1.3	159	53.5
Power boating/water skiing	30	12.4	7	2.9	37	15.2
Cycling	292	11.0	43	1.6	335	12.7
Fishing	0	0	35	9.5	35	9.5
Ice/snow	25	6.1	2	0.5	27	6.4
Australian football	67	5.7	0	0	67	5.7
Swimming	39	1.2	32	1.0	71	2.2
Aero sports	16	n/a	22	n/a	38	n/a
Other	148	1.3	50	0.4	198	1.8

Table 2
Rates of sport and active recreation major trauma and death cases in Victoria, Australia by age group and gender 1 July 2001–30 June 2007 (inclusive).

Age group (years)	Males rate/100,000 participants/year	Females rate/100,000 participants/year	Total rate/100,000 participants/year
15–24	16.6	3.3	10.2
25–34	11.5	2.1	6.9
35–44	9.2	2.5	5.8
45–54	9.2	2.5	5.8
55–64	8.0	1.4	4.6
≥65	5.7	0.7	3.0
Total	10.6	2.2	6.3

equestrian sports (53.5), power boating and water skiing (15.2), and cycling (12.7) (Table 1). Off-road motor sports demonstrated the highest death rate per 100,000 participants per year (10.1), followed by fishing (9.5). The rate of major trauma and death was higher for males than females across all age groups, with 15–24 year old males having the highest (Table 2). The major trauma and death rate declined steadily with increasing age.

There was a significant (10% per year) average annual increase in the rate of sport and active recreation-related major trauma, including deaths (IRR = 1.10, 95% CI, 1.06–1.14; $p < 0.001$) over the study period. This was predominantly due to increases in major trauma injuries, as the death rate remained constant (IRR = 0.94, 95% CI, 0.87–1.02; $p = 0.12$) (Fig. 1). Cycling (IRR = 1.16, 95% CI, 1.09–1.24; $p < 0.001$), motor sports (IRR = 1.10, 95% CI, 1.03–1.19; $p = 0.009$), Australian football (IRR = 1.21, 95% CI, 1.03–1.42, $p = 0.017$) and to a lesser extent swimming (IRR = 1.16, 95% CI,

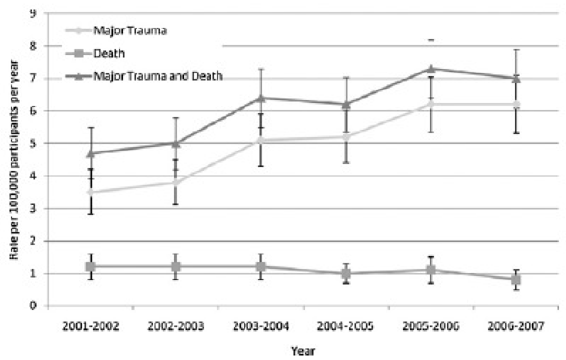

Fig. 1. Changes in rates of sport and active recreation related major trauma and death cases in Victoria, Australia 1 July 2001–30 June 2007 (inclusive), including 95% confidence intervals.

1.004–1.33; $p = 0.04$) also showed a significant increase in major trauma rates (including deaths) (Tables 3 and 4).

A total of 5037 injuries were sustained by 1063 hospitalised major trauma patients (including in-hospital deaths), with a median (range) of 4 (1–25) injuries per case. A head injury was the most common injury (21%), followed by injuries to the spine (16%) and thorax (15%) (Table 5). Head injuries were common in ice and snow sports (56%), cycling (57%), power boating and water skiing (52%), and off-road motor sports (50%). Thoracic injuries were prevalent in off-road motor sports (51%), while abdominal injuries were common in Australian football (49%). Spinal injuries were common in swimming (86%) and aero sports (72%) (Table 6). The most common cause of death was drowning (47%).

Discussion

The most important finding of this study was the increase in major trauma rates for sport and active recreation in Victoria, from July 2001 to June 2007. Much of this increase can be attributed to increases in rates associated with off-road motor sports, cycling and Australian football.

Cycling demonstrated an average annual increase of 16% per year in major trauma rates over the study period. This is consistent with another Victorian study which found a significant increase in cycling major trauma injuries, emergency department presentations and hospital admissions, between 2001 and 2006.[23] Hospitalised mountain bike injuries also tripled over a recent 10 year period in Vancouver, Canada.[11] These studies differed from the current study, in that they included children and used population rates as their denominator. Population rates may have contributed to the higher IRRs reported by Sikic et al.[23] and make it difficult to assess the extent to which increased participation contributed to the results. Collision with a motor vehicle and cycling at >15 mph have been associated with severe injury in cyclists.[5,20] Hence, changes in traffic conditions, increases in the

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Table 3
Incidence rate ratios and p-values for sport and active recreation major trauma and death cases in Victoria, Australia 1 July 2001–30 June 2007 (inclusive).

Sporting group	Major trauma injuries		Deaths		Major trauma cases and deaths	
	Incidence rate ratio(95% CI)	p-Value	Incidence rate ratio(95% CI)	p-Value	Incidence rate ratio(95% CI)	p-Value
All sports	**1.14 (1.09–1.18)**	**<0.001**	**0.94 (0.87–1.02)**	**0.12**	**1.10 (1.06–1.14)**	**<0.001**
Off-road motor	1.12 (1.03–1.21)	0.005	0.94 (0.74–1.20)	0.62	1.10 (1.03–1.19)	0.009
Equestrian	1.11 (1.01–1.22)	0.03	N/A[a]	N/A[a]	1.09 (0.99–1.20)	0.07
Power boating/water skiing	1.47 (1.14–1.88)	0.003	N/A[a]	N/A[a]	1.23 (0.99–1.53)	0.06
Cycling	1.16 (1.09–1.25)	<0.001	1.11(0.93–1.33)	0.23	1.16 (1.09–1.24)	<0.001
Fishing	N/A[a]	N/A[a]	0.87 (0.71–1.08)	0.21	0.87 (0.71–1.08)	0.21
Ice/snow	1.20 (0.93–1.55)	0.16	N/A[a]	N/A[a]	1.21 (0.95–1.55)	0.13
Australian football	1.20 (1.02–1.40)	0.02	N/A[a]	N/A[a]	1.21 (1.03–1.42)	0.017
Swimming	1.33 (1.09–1.61)	0.005	0.98 (0.79–1.21)	0.84	1.16 (1.0–1.33)	0.04
Other	1.03 (0.94–1.13)	0.52	0.93 (0.81–1.07)	0.30	1.00 (0.93–1.08)	0.99

[a] Insufficient numbers were present across years to calculate IRRs.

proportion of road cyclists or changes in the way that people ride are potential reasons for the results of this study.

Off-road motor sports also showed a significant increase in major trauma rates over the study period despite a slight reduction in death only rates. These results are supported by American studies[7,10,15] however comparisons are hindered by differences in vehicle types. Mullins et al. estimated that 60% of cases were due to four-wheeled all-terrain vehicles or quad bikes,[15] whereas our study contained mainly off-road motor-bikes (71%) with only 7% of injuries resulting from quad-bikes. Nevertheless the patterns of injury associated with both types of vehicles are similar.[7] These studies also differed from ours in that they included children[10,15] and used population rates as their denominator. One study however reported an increase, even when the number of off-road vehicles in use were accounted for.[10] Inexperience, riding in remote areas, larger engine sizes and increased participation leading to overcrowding in popular venues are risk factors for serious injury with all types of off-road motor vehicles.[15,21] Changes in these factors are possible contributors to the increase in major trauma rates for off-road motor sports reported in this study.

Australian football showed the highest significant (21%) increase per year in major trauma injuries. There were no recorded deaths due to injury during the study period. Though a long-term injury surveillance system is in place at the elite level, no such system is available at the community-level. The Australian football league (AFL) reported that, injury severity, as measured by number of games missed, has slowly increased over the last 10 years.[19] How the AFL results translate to community-level Australian football is unknown, however the total injury rate at community-level has been shown to be higher.[8] In this current study collisions were the cause of 99% of Australian football major trauma injuries. Game speed, player size and environmental factors such as ground hardness have increased over the last few decades and have been linked to an increased severity of collision injuries at the elite level.[17,18] However, whether similar changes have occurred at the community-level is unknown and the reasons for the increase in Australian football related major trauma in Victoria remains unclear.

There was a marginally significant increase in swimming-related major trauma rates despite a non-significant trend towards a decrease in deaths. Of the non-fatal major trauma injuries 90% were due to diving into pools or shallow water. Unlike other sporting groups the mechanisms for swimming related major trauma injuries and deaths are quite distinct. The results of this study suggest the need for further strategies and public health campaigns aimed at preventing serious diving-related injuries.

Though there had not been an increase in this area, the large number of fishing deaths is concerning. All of these deaths were due to drowning, with the majority occurring whilst fishing from small boats. Further research examining the detailed circumstances and potential prevention strategies relating to these deaths is strongly recommended.

The frequency of sport and active recreation major traumas is comparable to other areas of trauma. In the period July 2006–June 2007, sport and active recreation activities accounted for 9.7% of all hospitalised major traumas. This is less than the percentage of patients that sustained a major trauma as a result of being a driver in a motor vehicle accident (16.1%) but greater than the percentage that occurred in the workplace (9.3%).[13] The majority of sport and active recreation major traumas can be attributed to cycling, off-road motor sports and equestrian sports. The number of deaths due to sport and active recreation was less, accounting for 2.5% of trauma-related deaths for this period,[13] with the majority being due to fishing or swimming related drownings, cycling and off-road motor sports. The lack of change in the death rate over the study period may be due to improvements within the Victorian State Trauma system. The study results found a significant increase in the percentage of patients definitively managed at a major trauma hospital, a factor linked to lower preventable death rates in the most severe major trauma cases.[3]

The results of this study relate specifically to the state of Victoria, however many of the activities included in this study are common in other developed countries. The use of participation numbers took into account variations in the popularity of activities, allowing greater generalisability to other geographic areas and greater accuracy for comparing time points. Nevertheless, the ERASS has limitations. Participation numbers are based on population estimates and are subject to error with groups with low participation numbers being particularly vulnerable to large standard error values. Hence the results pertaining to these sporting groups should be interpreted with some caution. Activities not categorised in the ERASS could not be included in the analyses and there was insufficient detail to differentiate within broad sporting categories. Changes in the frequency of individual participation or exposure time could not be accounted for. Ideally hours of exposure time should be used as a denominator to establish accurate injury incidence data. There is no systematic collection of exposure time data for sport and active recreation. The use of existing databases such as the ERASS allows an overview of sport and active recreation trauma, from which priority areas for further research can be identified. The ERASS state data was not as comprehensive as the national data, so state estimates needed to be derived from national data for age and gender sub-categories. This is unlikely to have impacted on the results as the Victorian and national percentages were similar for categories where both were available, however this does introduce an additional degree of uncertainty to the denominator values.

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Table 4
Incident number (n), participation number (N) with relative standard error (RSE) bands, and rate per 100,000 participants for sport and active recreation major traumas and deaths in Victoria, Australia 1 July 2001–30 June 2007 (inclusive) overall and separately by sporting group.

Sport	Y1			Y2			Y3			Y4			Y5			Y6		
	n	N (in thousands) (RSE %)	Rate	n	N (in thousands) (RSE %)	Rate	n	N (in thousands) (RSE %)	Rate	n	N (in thousands) (RSE %)	Rate	n	N (in thousands) (RSE %)	Rate	n	N (in thousands) (RSE %)	Rate
All sports	**140**	**2982 (<5)**	**4.7**	**158**	**3172 (<5)**	**5.0**	**2134**	**3348 (<5)**	**6.4**	**210**	**3390 (<5)**	**6.2**	**245**	**3381 (<5)**	**7.3**	**231**	**3311 (<5)**	**7.0**
Cycling	34	416 (<10)	8.2	30	388 (<10)	7.7	61	433 (<10)	14.0	54	461 (<10)	11.7	72	474 (<10)	15.2	75	462 (<10)	16.2
Off-road motor	29	31 (<25)	93.5	39	39 (<25)	100	40	45 (<25)	88.9	44	34 (<25)	129.4	56	35 (<25)	160	53	44 (<10)	120.5
Equestrian	16	54 (<20)	29.6	19	50 (<20)	38	35	49 (<25)	71.4	32	46 (<25)	69.6	33	54 (<20)	59.3	22	45 (<25)	48.9
Swimming	8	520 (<5)	1.5	10	530 (<5)	1.9	9	598 (<5)	1.5	14	607 (<5)	2.3	18	517 (<5)	3.5	11	469 (<10)	2.3
Ice/snow	2	72 (<20)	2.8	2	75 (<20)	2.7	9	81 (<20)	11.1	4	86 (<20)	4.7	5	62 (<20)	8.1	4	43 (<25)	9.3
Australian football	9	174 (<15)	5.2	8	177 (<15)	4.5	8	203 (<10)	3.9	6	238 (<10)	2.5	17	227 (<10)	7.5	16	160 (<15)	10.0
Power boating /water skiing	4	36 (<25)	11.1	7	39 (<25)	17.9	6	54 (<20)	11.1	4	48 (<25)	8.3	8	38 (<25)	21.1	8	28 (<25)	28.6
Fishing	8	54 (<20)	14.8	4	63 (<20)	6.3	9	68 (<20)	13.2	6	65 (<20)	9.2	5	61 (<20)	8.3	3	55 (<20)	5.4
Other	30	1626 (<5)	1.8	39	1811 (<5)	2.2	36	1818 (<5)	2.0	46	1805 (<5)	2.5	31	1913 (<5)	1.6	39	2004 (<5)	1.9

Patients from hospital that were not included in the registry from year 1 were excluded $n = 40$.

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Table 5
Number of major trauma patients that sustained one or more injuries to various body regions in 1063[a] hospitalised sport and active recreation major trauma cases (including in-hospital deaths), in Victoria, Australia 1 July 2001–30 June 2007 (inclusive).

Body region	Number	% of all injuries	% of participants sustaining injury
Head	535	21	50
Spine	409	16	38
Thorax	380	15	36
Upper extremity	325	13	31
Abdomen	269	11	25
Lower extremity	265	11	25
Face	240	10	23
Other	67	3	6
Neck	26	1	2
Total	2516	100	

[a] $n = 14$ cases had missing injury data.

Table 6
Body regions injured, by sporting group and percentage of hospitalised major trauma patients (including in-hospital deaths) that sustained an injury to that body region in Victoria, 1 July 2001–30 June 2007 (inclusive).

Sporting group	Head (%)	Face (%)	Neck (%)	Thorax (%)	Abdomen (%)	Spine (%)	Upper limb (%)	Lower limb (%)	Other (%)
Off-road motor ($n = 258$)	130 (50)	59 (23)	8 (3)	131 (51)	82 (32)	100 (39)	121 (47)	69 (27)	17 (7)
Equestrian ($n = 155$)	69 (45)	28 (18)	1 (1)	54 (35)	32 (21)	49 (32)	33 (21)	39 (25)	6 (4)
Power boating / water skiing ($n = 31$)	16 (52)	6 (19)	1 (3)	13 (42)	7 (23)	17 (55)	9 (29)	8 (26)	3 (10)
Cycling ($n = 310$)	176 (57)	111 (36)	12 (4)	129 (42)	83 (27)	117 (38)	132 (43)	103 (33)	31 (10)
Ice/snow ($n = 25$)	14 (56)	7 (28)	1 (4)	3 (12)	1 (4)	11 (44)	2 (8)	5 (20)	0 (0)
Australian football ($n = 67$)	17 (25)	3 (5)	2 (3)	7 (10)	33 (49)	13 (19)	1 (2)	2 (3)	0 (0)
Swimming ($n = 37$)	7 (19)	1 (3)	0 (0)	3 (8)	1 (3)	32 (86)	0 (0)	0 (0)	1 (3)
Aero ($n = 18$)	8 (44)	3 (17)	0 (0)	8 (44)	1 (6)	13 (72)	2 (11)	8 (44)	2 (11)
Other ($n = 162$)	98 (60)	22 (14)	1 (1)	32 (20)	29 (18)	57 (35)	25 (15)	31 (19)	7 (4)
All ($n = 1063$)	535 (50)	240 (23)	26 (2)	380 (36)	269 (25)	409 (38)	325 (31)	265 (25)	67 (6)

$n = 14$ had missing injury data.

A major strength of our study is the detailed data and comprehensive coverage provided by the VSTR and NCIS. However limitations exist and are discussed here. The NCIS only provided access to closed cases. Therefore cases that were not captured by the VSTR and were still being investigated by the coroner were missed. These cases would have been from the latter years of the study period and may account for the slight decrease in deaths in 2007. The VSTR did not achieve full coverage until 2005. All major trauma services and the spinal service were part of the VSTR from the beginning hence hospitals that were not included from the first year contributed very few sport and active recreation cases in the latter years ($n = 40$ cases). These cases were excluded from the Poisson analyses to eliminate the impact of improved case ascertainment due to increased coverage of the VSTR. This reduced the comprehensiveness of the regression results however exclusion of these cases had little impact on the final IRR values.

Improved case ascertainment within the VSTR system is another possible confounder in our results. Improved diagnostic techniques or changes in case definition could have influenced the number of injuries diagnosed. To test for this the proportion of cases in the lower ISS bands were examined for each year. It was hypothesised that improved diagnostic techniques would lead to an increase in the number of minor injuries diagnosed increasing the number of cases in the lower ISS bands. Changes in case-mix over the study period were also examined. Both the proportion of cases across ISS bands and the case-mix remained constant, suggesting that these factors are unlikely to account for our results. Another way of assessing the role of improved case ascertainment is by using the "other" group as a benchmark. This group consisted of a wide range of activities from parachuting to walking and contained sufficient injury numbers to make it comparable to groups such as cycling and motor sports. The fact that this group showed no change over the study period suggests that there are factors other than improved case ascertainment driving the increases observed in some of the other sub-groups.

Conclusion

Severe life threatening injuries due to sport and active recreation have increased over recent years. However the death rate has remained unchanged. The increased major trauma rate is predominantly due to increased rates associated with off-road motor sports, cycling and Australian football. Changes in the environment in which these activities take place, or intrinsic mechanisms related to how they are undertaken are likely mechanisms and provide important opportunities for injury prevention. A co-ordinated injury prevention effort involving systematic identification of risk factors and the implementation of clinical trials of suitable injury prevention interventions in these areas should be implemented.

Conflict of interest statement

None of the authors involved in the production of the manuscript titled: Trends in sport and active recreation injuries resulting in major trauma or death in adults in Victoria, Australia, 2001–2007 have any financial, personal or other relationships with people or organisations that could inappropriately influence or bias their work.

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Summary

The findings of this paper demonstrated that the VSTR and NCIS datasets are able to be used to establish the incidence of, and monitor trends in, major trauma injuries and deaths that occur as a result of participation in sport and active recreation injuries. The inclusion of participation data has provided a means of establishing the likely risks of major trauma or death associated with participating in specific sporting activities. This paper has used this information to identify key sport and active recreation pursuits for injury prevention prioritisation based on both the risk of injury and trends in injury risks. This chapter has contributed to addressing aim number one of this thesis. The following chapter will address further aspects of aim number one by demonstrating how routinely collected injury data can be used to describe outcomes in sport and active recreation populations.

Chapter Four: The use of routinely collected trauma registry data to examine outcomes in serious sport and active recreation injuries.

Overview

Chapter Two reported that the VSTR and the VOTOR are unique, in that they routinely collect outcome data for injury patients. The importance of collecting outcome data for effective injury prevention and control and in describing the burden of sport and active recreation injuries was established in Chapters One and Two.

The following published paper used routinely collected outcome data to examine 12-month outcomes of serious orthopaedic sport and active recreation injuries. Data from the VOTOR were used for this paper instead of the VSTR. The decision to use VOTOR data was based on the longer timeframe of available outcome data (the VOTOR started collecting outcome data in 2003, whereas the VSTR started in 2006) and the higher number of sport and active recreation injuries predicted to be included in the VOTOR. This prediction was based on the VOTOR collecting data at a hospital admission level. Also, because the VOTOR includes the two adult Major Trauma Services in Victoria, which provide definitive care for over 80% of Victoria's major trauma cases [73], using the VOTOR to identify sport and active recreation cases meant that most of the major trauma cases were captured as well as a large number of non-major trauma cases.

This paper provides an opportunity to quantify 12-month outcomes in sport and active recreation injuries and examine the ability of routinely collected data to adequately describe outcomes in this population, thereby helping to address the second part of aim number one of this thesis. The following paper was accepted for publication in June 2008 by the Clinical Journal of Sports Medicine.

Monash University

Declaration for Thesis Chapter Four

Andrew NA, Gabbe BJ, Wolfe R, Williamson OD, Richardson MD, Edwards ER and Cameron PA. 12-month outcomes of serious orthopaedic sport and active recreation related injuries admitted to Level 1 trauma centres in Melbourne, Australia. Clinical Journal of Sports Medicine 2008, 18:387-393

Declaration by candidate

In the case of Chapter Four, the nature and extent of my contribution to the work was the following:

Nature of contribution	**Extent of contribution (%)**
Principle author responsible for the concept, design, statistical analysis, interpretation of results and writing up of the manuscript	80%

The following co-authors contributed to the work. Co-authors who are students at Monash University must also indicate the extent of their contribution in percentage terms:

Name	**Nature of contribution**	**Extent of contribution (%) for student co-authors only**
A/Prof. BJ Gabbe	Contributed to the study design, analysis, writing and drafting of the manuscript	N/A
A/Prof. R Wolfe	Provided statistical advice and contributed to drafting and analysis of the manuscript	N/A
Mr OD Williamson	Contributed to the design and drafting of the manuscript	N/A
A/Prof MD Richardson	Contributed to drafting the manuscript	N/A
A/Prof ER Edwards	Contributed to drafting the manuscript	N/A
Prof PA Cameron	Contributed to the design and drafting of the manuscript	N/A

Candidate's Signature	[redacted]	**Date** 11/8/2011

Declaration by co-authors

The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors.
(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
(4) there are no other authors of the publication according to these criteria;
(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location(s)	Department of Epidemiology and Preventive Medicine, Monash University, Alfred Campus.

	Co-authors signatures	Date
Signature 1	[redacted]	11 Aug 2011
Signature 2	[redacted]	13 OCT 2011
Signature 3	[redacted]	4 August 2011
Signature 4	[redacted]	13/9/11
Signature 5	[redacted]	
Signature 6	[redacted]	13/Oct/2011

Published paper: Twelve-month outcomes of serious orthopaedic sport and active recreation related injuries admitted to Level 1 trauma centres in Melbourne, Australia

Twelve-Month Outcomes of Serious Orthopaedic Sport and Active Recreation–Related Injuries Admitted to Level 1 Trauma Centers in Melbourne, Australia

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Objective: To describe and identify predictors of 12-month outcomes of serious orthopaedic injuries due to sport and active recreation.

Design: Prospective cohort study with 12-month follow-up.

Setting: Two Level 1 adult trauma centers in Victoria, Australia.

Participants: A total of 366 adults admitted to two Level 1 trauma centers for an orthopaedic sport and active recreation injury between August 2003 and March 2006. Patients were captured by the Victorian Orthopaedic Trauma Outcomes Registry (VOTOR), followed up at 12 months, and were free of moderate to severe disability prior to injury.

Assessment of risk factors: Independent variables assessed for predictors of outcome were sporting group, age, sex, marital status, education level, Injury Severity Score, injury patterns, and head injury status.

Main outcome measurements: The 12-item Short Form Health Survey and maximum pain scores.

Results: At 12 months postinjury, 22.8% of patients reported moderate to severe physical disability, 12.1% reported moderate to severe mental health disability, and 11.1% reported moderate to severe pain. There were significant differences in physical outcomes between sporting groups, with motor and equestrian sports reporting the worst physical outcomes. Multivariate analysis indentified increasing age ($P = 0.010$) and patterns of injury ($P = 0.040$) as significant predictors of a poor physical outcome at 12 months. No significant independent predictors of outcome for mental health and maximum pain at 12 months were identified.

Conclusion: Almost one-quarter of participants reported moderate to severe physical disability at 12 months postinjury. Increasing age and patterns of injury were found to be significant predictors of a poor physical outcome at 12 months.

Key Words: sport and recreation, injury, outcomes, orthopaedic, quality of life

(*Clin J Sport Med* 2008;18:387–393)

Serious injuries related to sports and active recreation are common, accounting for 0.7% of total hospital admissions in Australia during 2003 and 6.3% of admissions with an external cause.[1] Adjusting for rates of participation in the community, admission rates of 160 to 243 per 100,000 participants over a 12-month period have been reported in Australia.[1,2] For these injuries in the United States, between 32 and 80 hospital admissions per 100,000 population per annum were reported, based on total population admission rates.[3,4]

Despite the risk of serious injury associated with participation in sport and active recreation and the potential for ongoing disability, few studies have attempted to describe the long-term outcomes of sport and active recreation related injuries in adults. Prior studies focused on individual sports[5,6] or specific body regions,[7,8] used short follow-up periods,[5,6,9] or were retrospective.[10] Moreover, the outcomes used tended to focus on patients' length of stay, functional or medical status at discharge, or discharge to home versus rehabilitation.[5,6] To our knowledge, only three studies used functional or quality-of-life measures administered at 6 or more months postdischarge.[9–11] To date, no studies have investigated predictors of outcome in a seriously injured sport and active recreation orthopaedic trauma population.

At present, there is no formal system of injury surveillance in place to monitor sport and active recreation injuries in Australia. Trauma registries are a common method of collecting detailed information about injuries, their management, and outcomes, but most do not collect data beyond the hospital admission, thus limiting their usefulness for describing long-term outcomes following injury. In contrast, the Victorian Orthopaedic Trauma Outcomes Registry (VOTOR) captures detailed information pertaining to orthopaedic trauma admissions and their outcomes, providing a rare opportunity to investigate the outcomes of serious sport and active recreation orthopaedic injuries. While VOTOR focuses on the severe end

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of the sports injury spectrum, these injuries contribute significantly to the burden of injury[1] and are a high priority for injury prevention research and policy development. The purpose of this study was to describe and identify predictors of 12-month outcomes following serious orthopaedic injury associated with sport and active recreation participation.

METHODS

Patients

VOTOR collects information about all patients with orthopaedic injuries admitted to the two adult Level 1 trauma centers in Victoria, Australia who require management by an orthopaedic unit, require orthopaedic follow up, or have an injury involving the spine. Patients are excluded if they have sustained a pathological fracture related to metastatic disease and/or an isolated orthopaedic injury managed by another unit.[12,13] VOTOR has been approved by the Human Research Ethics Committee at each of the participating hospitals and Monash University.

For this study, participants who sustained a sport or active recreation–related injury, were aged between 15 and 74 years, and were admitted between August 2003 and March 2006 were included in the study. Potential sport and active recreation–related cases were identified if they met any of the following criteria: 1) activity at the time of injury, coded as either sports or leisure; 2) place of injury, coded as either athletic or sports area or place for recreation; 3) cause of injury, coded as motorcycle driver, pedal cyclist, or horse related.

Codes were cross-checked against each other and the text narrative of the injury event to ascertain if the injury was a direct result of participation in sport and active recreation. For cases in which the activity, place of injury, or cause of injury was not known, the text narrative of the injury event was checked to ensure that all relevant cases were identified. Only motorcycle injuries that occurred off road, such as motocross and trail biking, were included. However, all pedal cyclists were included because it has been shown that the majority of road cyclists choose to ride for sport or leisure.[5] Walking was only included if it was clear from the text narrative that it was being performed as a form of exercise. Cases that were covered by the workers' compensation scheme for Victoria, such as jockeys and professional athletes, were excluded. Each participant's sport or active recreation at the time of injury was determined from the relevant *International Classification of Diseases 10* Chapter XX activity code or the text narrative of the injury event. The sport or active recreation was further categorized into broad sporting groups.[14]

Procedures

VOTOR collected information from participants' medical records, hospital information systems, and patient interviews. Registration and admission data provided information relating to injury diagnosis codes, injury event details, severity of injuries including the injury severity score (ISS),[15] injury management details, and discharge information. An in-hospital interview was performed to obtain detailed demographic information. Twelve-month postinjury outcome information, including the 12-item Short Form Health Survey (SF-12) and maximum pain scores, were obtained by telephone interview. The SF-12 is a reliable and well-validated generic health-related quality of life (HRQL) measure, consisting of 12 items covering 8 domains.[16] Individual responses are used to calculate a score for each of the 2 summary scales: the Mental Component Summary (MCS-12) and the Physical Component Summary (PCS-12). For both summary scales, a higher score indicates a better outcome. Pain intensity was measured using an 11-point numerical scale, where a higher score indicates a greater level of pain. Information relating to preinjury disability was obtained from global disability scores obtained at the 12-month interview.

Data Analysis

The demographics of responders compared to non-responders were analyzed using chi-squared tests for categorical variables and Mann-Whitney U tests due to the skewed nature of the continuous variables. Baseline differences between sporting groups were analysed using chi-squared tests for categorical variables and the Kruskal-Wallis test for continuous variables.

For ease of interpretation in the general description of outcome, PCS-12 and MCS-12 scores were divided into none/mild disability (>40) or moderate/severe disability (≤ 40) and maximum pain scores into none/mild pain (<5) or moderate/severe pain (≥ 5). PCS-12 and MCS-12 scores were analysed as continuous variables using linear regression to assess the association between outcome and possible predictors. As the scores for maximum pain were highly skewed they were analysed in the categories described above using logistic regression.

Univariate analysis was used to assess the relationship between each outcome variable and the main demographic and injury event variables. Multivariate analysis was used to identify predictors of each outcome measure. Two sets of multivariate analyses were performed for each outcome: the first included only demographic variables and the second included demographic variables and injury event variables. Stata (version 9) and SPSS (version 15.0) were used for all analyses. A P value of <0.05 was considered to be significant.

RESULTS

During the study period, a total of 4,448 orthopaedic trauma admissions were recorded in the VOTOR database. Of these, 537 (12.1%) were related to sport and active recreation. Seven were excluded due to in-hospital deaths or a language barrier, leaving 530 eligible for 12-month follow-up at hospital discharge. One participant died postdischarge and 148 were lost to follow-up, resulting in 381 (71.9%) remaining participants. Of those patients who were followed up, 9 more were excluded because of a moderate to severe disability prior to injury and 6 because their disability status prior to injury was unknown, leaving 366 in the final analysis. A breakdown of sporting groups for the final sample is shown in Table 1.

There were no differences between participants successfully followed up and those lost to follow-up for the key population descriptors of sporting group, age, gender, marital

TABLE 1. Sport and Active Recreation–Related Injuries Registered on the VOTOR Database Between August 2003 and March 2006 (Inclusive) and Followed Up at 12 Months (n = 366)

Sport or Recreation Activity	n	Cases (%)
Wheeled		
Cycling	100	27.3
Skate boarding	10	2.7
Rollerblading	4	1.1
Mountain biking	3	0.8
BMX riding	2	0.5
Roller skating	1	0.3
Scooter	1	0.3
Motor		
Motor bike	65	17.8
Quad bike	5	1.4
Car racing	2	0.5
Four-wheel drive	1	0.3
Football		
Australian football	20	5.5
Rugby union	8	2.2
Soccer	15	4.1
Equestrian		
Horse riding	27	7.4
Horse handling	1	0.3
Horse driving	1	0.3
Ice and snow		
Snow skiing	15	4.1
Snow boarding	5	1.4
Tobogganing	1	0.3
Other sports	79	21.6
Total	366	100.2

status, level of education, ISS >15, injury profile, or head injury status (Table 2).

The demographic details and preinjury status of those successfully followed up at 12 months (n = 366) are shown in Table 3. The majority of participants were male with a median age of 33.5 years, were working prior to their injury, and were well educated. The highest number of cases (33.3%) resulted from participating in wheeled sports, followed by motor sports (21.0%), football (11.3%), equestrian sports (7.6%), and ice and snow sports (5.5%) (Table 1). There were significant differences among sporting groups for all key demographic variables, except for work status prior to injury. There were also differences among sporting groups for all injury details and discharge variables (Tables 3 and 4).

At 12 months postinjury, 22.8% reported moderate to severe physical disability, 12.1% reported moderate to severe mental health disability, and 11.1% reported moderate to severe pain. There were significant differences between sporting groups for PCS-12 scores ($P = 0.04$), with the worst physical outcomes reported by participants injured in motor and equestrian sports, followed by football, wheeled sports, and ice and snow sports. There were no significant differences in MCS-12 scores and maximum pain scores between sporting groups (Fig. 1).

TABLE 2. Demographic and Injury Details of Responders Versus Nonresponders

Variable	Nonresponders (n = 149)	Responders (n = 381)
Sporting group		
Football	12.8 (7.4, 18.2)	11.3 (8.1, 14.5)
Ice and snow	6.7 (2.7, 10.7)	5.5 (3.2, 7.8)
Equestrian	6.0 (2.2, 9.8)	7.6 (4.9 10.3)
Motor	18.8 (12.5, 25.1)	21.0 (16.9, 25.1)
Wheeled	31.5 (24.0, 39.0)	33.3 (28.6, 38.0)
Other	24.2 (17.3, 31.1)	21.3 (17.2, 25.4)
Age, median (IQR)	30.1 (24.5, 40.2)	33.5 (26.2, 45.8)
Sex		
Male	77.9 (71.2, 84.6)	78.7 (74.6, 82.8)
Female	22.1 (15.4, 28.8)	21.3 (17.2, 25.4)
Compensability		
Compensable	21.2 (14.6, 27.8)	25.7 (21.3, 30.1)
Noncompensable	78.8 (72.2, 85.4)	74.3 (69.9, 78.7)
Marital status		
Never married	51.9 (42.3, 61.5)	43.8 (38.3, 49.3)
Married/defacto	42.3 (32.8, 51.8)	47.6 (42.1, 53.1)
Previously married	5.8 (1.3, 10.3)	8.6 (5.5, 11.7)
Level of education		
Tertiary level and above	37.8 (28.2, 47.4)	31.1 (25.9, 36.3)
Certificate/diploma	16.3 (9.0, 23.6)	14.1 (10.2, 18.0)
Year 12	25.5 (16.9, 34.1)	20.3 (15.8, 24.8)
Years 9–11	15.3 (8.2, 22.4)	26.9 (21.9, 31.9)
Year 8 or below	5.1 (0.7, 9.5)	7.5 (4.5, 10.5)
ISS score>15		
Yes	16.2 (10.3, 22.1)	17.8 (14.0, 21.6)
No	83.9 (78.0, 89.8)	82.2 (78.4, 86.0)
Major head injury		
Yes	6.7 (2.7, 10.7)	7.6 (4.9, 10.3)
No	93.3 (89.3, 97.3)	92.4 (89.7, 95.1)
Injury profile		
Isolated extremities	43.0 (35.1, 50.9)	34.6 (29.8, 39.4)
Multiple upper limbs	6.7 (2.,7, 10.7)	11.5 (8.3, 14.7)
Multiple lower limbs	7.4 (3.2, 11.6)	7.1 (4.5, 9.7)
Isolated spinal injury	10.1 (5.3, 14.9)	9.4 (6.5, 12.3)
Multiple orthopaedic	6.0 (2.2, 9.8)	6.0 (3.6, 8.4)
Orthopaedic plus other	26.8 (19.7, 33.9)	31.2 (26.5, 35.9)

Data are percent (95% CI) unless noted.

Univariate regression analysis identified a significant relationship between PCS-12 scores and sporting group ($P = 0.04$), age ($P < 0.001$), marital status ($P \leq 0.001$), ISS >15 ($P = 0.005$), injury group ($P < 0.001$), and head injury status ($P = 0.02$). Multivariate linear regression analysis containing demographic variables identified no significant relationship between PCS-12 scores and sporting group ($P = 0.30$). Therefore, much of the variability between sporting groups was explained by the differences in participants' demographic characteristics. Increasing age, however, remained a significant predictor of poorer physical health outcomes according to the PCS-12. The addition of injury detail variables to the multivariate model had little effect on the sporting group coefficients.

TABLE 3. Demographic and Preinjury Details of VOTOR Sport and Active Recreation Population Followed Up at 12 Months

Variable	All cases (n = 366)	Football (n = 43)	Ice and snow (n = 21)	Equestrian (n = 29)	Motor (n = 73)	Wheeled (n = 121)	Other (n = 79)
Sex (%)							
Male	78.1	90.7	66.7	31.0	97.3	81.8	68.4
Female	21.9	9.3	33.3	69.0	2.7	18.2	31.6
Age group (%)*							
<25 years	23.1	38.1	23.8	21.4	27.8	16.5	22.5
25–34 years	32.5	42.9	33.3	14.3	23.6	33.1	40.5
35–44 years	18.2	14.3	19.1	17.9	31.9	15.7	11.4
45–54 years	15.2	4.8	4.8	28.6	13.9	21.5	10.1
55–64 years	7.7	0.0	14.3	14.3	0.0	9.1	12.7
65–74 years	3.3	0.0	4.8	3.6	2.8	4.1	3.8
Level of education (%)†							
Tertiary and above	31.9	37.5	58.8	21.7	7.0	43.0	30.7
Certificate/diploma	14.4	5.0	11.8	34.8	14.0	14.0	14.5
Year 12	19.5	27.5	17.7	21.7	17.5	17.2	19.4
Year 11 and below	34.3	30.0	11.8	21.7	61.4	25.8	35.5
Marital status (%)‡							
Never married	44.6	65.9	47.1	21.7	35.1	47.4	43.3
Currently married	47.3	34.2	47.1	60.9	59.7	37.9	53.7
Previously married	8.0	0.0	5.9	17.4	5.3	14.7	3.0
Working or studying prior to injury (%)¶							
Working	89.9	95.4	85.7	93.1	95.9	88.3	83.5
Not Working	10.1	4.7	14.3	6.9	4.1	11.7	16.5

*Data missing for n = 3.
†Data missing for n = 74.
‡Data missing for n = 66.
¶Data missing for n = 1.

In the final model, age and injury group were significant predictors of physical outcome. For every 1-year increase in age, there was a 0.1-unit decrease in PCS-12 score. For injury groups, those with multiple lower limb fractures scored 5.2 units lower than those with isolated extremity fractures (Table 5).

Variables that demonstrated a significant relationship to MCS-12 scores on univariate analysis were ISS >15 (P = 0.01) and head injury status (P = 0.04). There were no significant independent predictors of MCS-12 scores at 12 months postinjury (Table 4). Significant predictors of moderate to severe pain at 12 months on univariate analysis were age (P = 0.03), injury group (P = 0.02), and head injury status (P = 0.02), but no significant independent predictors of maximum pain at 12 months postinjury were identified by the multivariate analysis (Table 5).

DISCUSSION

This is the largest prospective cohort study to investigate the 12-month outcomes and predictors of outcome of serious orthopaedic injuries sustained during sport and active recreation. The main findings of this study were that, in a population that had little or no disability prior to injury, almost one quarter of participants who had sustained a serious injury during sport and active recreation were still experiencing moderate to severe physical disability at 12 months postinjury. Motor sports and equestrian sports demonstrated the worst physical HRQL outcomes. Moderate to severe mental health disability and moderate to severe pain was reported by 12.1% and 11.1% of participants, respectively, at 12 months postinjury.

These proportions were lower than those reported by previous studies of general trauma inpatients.[13,17,18] However, they are similar to the results of an outcome study involving sport and recreation inpatients.[10] The finding that almost one quarter of our study population still had moderate to severe physical disability at 12 months is important given that this was a sample of predominantly young, employed, well-educated, and productive members of society prior to their injury. As such, the long-term morbidity consequences for this group are high.

Severe sporting injuries create barriers to return to sport from both a physical and psychosocial perspective. Some people with good physical outcomes do not return to sport as a result of the psychosocial consequences of their injury.[19,20] Based on previous studies, it is likely that a large number of participants, especially those still experiencing moderate to severe physical or mental health disability, may not return to their previous level of physical activity.[9–11] Dekker et al found that of those who had suffered a severe injury relaying to sport and active recreation, nearly half had still not returned to sport

TABLE 4. Injury and Discharge Details of VOTOR Sport and Active Recreation Population Followed Up at 12 Months

Variable (%)	All cases (n = 366)	Football (n = 43)	Ice and snow (n = 21)	Equestrian (n = 29)	Motor (n = 73)	Wheeled (n = 121)	Other (n = 79)
ISS							
ISS ≤15	83.1	100.0	90.5	79.3	68.5	79.3	92.4
ISS >15	17.1	0.0	9.5	20.7	31.5	20.7	7.6
Injury profile							
Isolated extremities	35.0	74.4	33.3	20.7	9.6	32.2	45.6
Multiple UL	6.6	7.0	0.0	3.5	6.9	9.9	6.3
Multiple LL	11.9	14.0	14.3	6.9	16.4	5.8	16.5
Isolated spinal injury	9.6	0.0	28.6	27.6	9.6	3.3	12.7
Multiple orthopaedic	5.8	0.0	4.8	6.9	8.2	8.3	3.8
Orthopaedic plus other	31.1	4.7	19.1	34.5	49.3	40.5	15.2
Serious head injury							
No	92.4	100.0	95.2	96.6	86.3	89.3	96.2
Yes	7.7	0.0	4.8	3.5	13.7	10.7	3.8
Spinal cord injury*							
No	97.5	97.7	95.2	100.0	95.8	99.2	96.2
Yes	2.5	2.3	4.8	0.0	4.2	0.9	3.9
Hospital length of stay†							
Median (days)	4	3	4	5	8	4	4
Discharge destination‡							
Home	79.6	100.0	81.0	79.3	75.0	72.5	83.5
Rehabilitation	20.4	0.0	19.0	20.7	25.0	27.5	16.5

*Data missing for n = 6.
†Data missing for n = 1.
‡Data missing for n = 2.

at 12 months postinjury.[10] This can have serious long-term health consequences given the health benefits associated with physical activity.[21–24]

In our study, multivariate analysis identified age and pattern of injury as significant predictors of a poor physical outcome at 12 months. When compared to isolated extremity fractures, multiple lower-extremity fractures had the greatest risk of a poor physical outcome. A number of outcome studies in general trauma populations have identified patients with multiple lower-extremity fractures as having poorer HRQL outcomes at 12 months postinjury than other types of injuries.[7,18,25,26] Kiely et al[27] found that an extremity injury

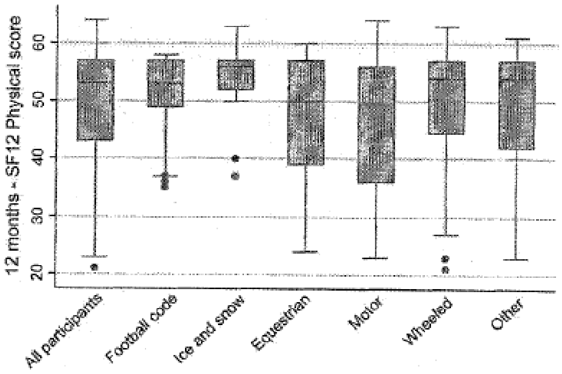

FIGURE 1. Distribution of PCS-12 scores of all participants and by sporting group (n = 366).

was predictive of a poor physical outcome at 1 month but not at 6 months. However, they did not separate lower-extremity from upper-extremity injuries or single-extremity injuries from multiple-extremity injuries. Another study that used multivariate analysis found that lower extremity and, more specifically, knee injuries were predictors of a poor long-term physical outcome in a sport and active recreation population.[11]

Studies that looked at the direct association between age and physical outcomes found increasing age to be associated with a poor physical outcome in trauma populations.[7,17,18,25] However, in studies that investigated predictors of outcome using multivariate regression in both general trauma and sport and recreation populations, increasing age was not found to be a predictor of a poor physical outcome.[10,11,27] This may be due to the different methodologies of the various studies, such as the predictor variables included in their models, or it may be that age has a greater predictive role in physical outcomes associated with severe orthopaedic injuries than in general trauma injuries. Although age was a significant predictor of outcome, the median age of those with a poor outcome was only 38.8 years.

There were significant differences between sporting groups for physical health outcomes but not for mental health outcomes or pain outcomes. Motor sports had the highest proportion of participants with multiple lower-extremity fractures, which may have contributed to their poorer physical health outcomes. As most of the motor sport injuries were due to off-road motor bike riding (88.8%), our study highlights the need for the development and implementation of injury prevention measures targeting this group.

TABLE 5. Multivariate Regression Results for SF-12 Outcomes, MCS-12 Outcomes, and Maximum Pain at 12 Months

	PCS-12		MCS-12		Maximum pain	
Variable	Coefficient (95% CI)	P value	Coefficient (95% CI)	P value	Coefficient (95% CI)	P value
Sporting group						
Football (ref)						
Ice/snow	5.2 (−0.3, 10.8)		−1.5 (−7.0, 3.9)		1.6 (0.1, 33.5)	
Equestrian	2.3 (−3.2, 7.9)		−3.5 (−8.9, 1.9)		0.6 (0.0, 13.1)	
Motor	0.2 (−4.1, 4.5)		−0.1 (−4.2, 4.1)		2.4 (0.2, 23.0)	
Wheeled	1.7 (−2.1, 5.5)	0.4	−2.3 (−6.0, 1.4)	0.6	4.2 (0.5, 38.0)	0.4
Other	2.4 (−1.5, 6.3)		−1.0 (−4.8, 2.8)		1.9 (0.2, 18.9)	
Age (years)	−0.01 (−0.2, −0.03)	0.01	−0.01 (−0.1, 0.05)	0.3	1.0 (1.0, 1.1)	0.4
Sex						
Male (ref)						
Female	−2.4 (−5.4, 0.7)	0.1	−1.6 (−4.6, 1.3)	0.3	1.1 (0.3, 3.4)	0.9
Level of education						
Tertiary plus (ref)						
Certificate/diploma	−0.9 (−4.4, 2.7)		3.0 (−0.5, 6.4)		2.1 (0.5, 8.2)	
Year 12	−1.6 (−4.9, 1.6)		2.3 (−0.8, 5.5)		2.8 (0.7,10.4)	
Year 11 and below	−2.2 (−5.1, 0.7)	0.5	1.4 (−1.4, 4.2)	0.3	2.3 (0.8, 7.3)	0.4
Marital status						
Never married (ref)						
Married	−1.8 (−4.5, 1.0)		0.9 (−1.8, 3.6)		2.0 (0.7, 6.1)	
Previously married	−2.3 (−7.1, 2.4)	0.4	−3.0 (−7.6, 1.7)	0.2	3.0 (0.7, 13.1)	0.3
ISS						
ISS ≤15 (ref)						
ISS >15	−0.04 (−3.9, 4.0)	1.0	−3.6 (−7.5, 0.2)	0.07	1.3 (0.4, 4.4)	0.7
Injury profile						
Isolated lower/upper limb (ref)						
Multiple upper limb	1.6 (−3.1, 6.3)		1.4 (−3.2, 6.0)		0.7 (0.7, 6.7)	
Multiple lower limb	−5.2 (−8.9, −1.4)		−2.4 (−6.1, 1.3)		2.3 (0.6, 9.3)	
Isolated spinal	0.2 (−3.9, 4.3)	0.04	0.5 (−3.4, 4.5)	0.6	1.4 (0.2, 7.9)	0.9
Multiple orthopaedic	−4.1 (−9.6, 1.4)		−0.8 (−6.2, 4.5)		1.5 (0.2, 9.3)	
Orthopaedic + other	−2.8 (−6.4, 0.7)		1.1 (−2.3, 4.6)		1.7 (0.5, 6.0)	
Serious head injury						
No (ref)						
Yes	−2.0 (−7.0, 3.0)	0.4	0.9 (−4.0, 5.7)	0.7	1.8 (0.5, 7.0)	0.4

The poorer physical health outcomes for participants in equestrian sports are most likely related to participants being older than those participating in other sports. Almost half (46.5%) of the equestrian participants were over 45 years of age. Hence, given the age of equestrian sports participants, the need for injury prevention programs aimed at reducing injury rates within this sport has been highlighted.

The ISS was not a predictor of disability outcomes, despite it being a measure of injury severity. The inability of the ISS to predict physical disability is potentially due to the purpose of the ISS. The ISS is based on the severity scores allocated to each individual injury using the Abbreviated Injury Scale system. This system allocates a severity score from 1 (minor) to 6 (maximum, essentially not survivable). To calculate the ISS, the sum of the squares of the highest severity scores for the three most severely injured body regions is taken. The ISS is a "threat to life" measure, rather than a "threat to disability" measure. Therefore, the inability of the ISS to predict disability outcomes is not surprising.

The main strengths of this study were the use of prospective data from a well-developed orthopaedic trauma registry, the large sample size, the availability of 12-month follow-up data for a general sport and active recreation population, and the use of a validated HRQL measure. Our follow-up rate, 71.9%, is comparable with other trauma outcome studies[8,26,28,29] and the finding that there were no differences in the baseline variables between responders and nonresponders suggest that our results are unlikely to be subject to a large amount of responder bias.

Some limitations warrant consideration. Our results relating to comparisons between sporting groups are likely to be affected by small numbers in some of the subgroups. Therefore, the lack of association for MCS-12 and pain outcomes might represent a type 2 error. Our study identified few significant independent predictors of outcome. This is potentially due to the outcome measures used in this study. The SF-12 has been validated in normal populations and does not include questions relating to high levels of function;

therefore, it may underestimate the impact of injury on a sport and active recreation population. For example, participants may not have been able to return to sport despite having the maximum SF-12 score. Therefore, information relating to participants' return to sport or active recreation and detailed high-level functional physical and mental outcomes relevant to a sport and recreation population would have been useful.

The generalizability of our study is limited by two factors. Firstly, VOTOR does not capture patients without orthopaedic injuries. Although the majority of serious injury following sport and active recreation are orthopaedic in nature,[30] other injuries such as isolated internal injuries and isolated head injuries are not captured by VOTOR. Secondly, VOTOR data are collected for admissions to Level 1 trauma centers and therefore includes some of the most severe orthopaedic injuries. Although anecdotally it could be expected that long-term disability would be prevalent, this is the first study to adequately quantify this burden. Overall, our results showed a general consistency with other hospitalized trauma studies,[8,26,28] which may allow extrapolation of our results to other similar settings. VOTOR is currently extending its catchment to include Level 2 metropolitan and regional trauma hospitals. This should not only improve the generalizability of VOTOR but also improve its ability to capture a wider range of sport and recreation injuries.

CONCLUSION

This large prospective cohort study investigated the 12-month outcomes of serious sport and active recreation related orthopaedic injuries and predictors of outcome in this group. Our findings show that at 12 months postinjury, almost one quarter of patients were still experiencing moderate to severe physical disability. This emphasizes the importance of further investigation into sports and recreation injury, given that our sample was a young, healthy, and productive group. Increasing age and patterns of injury were the main predictors of a poor physical outcome at 12 months. The description of sport and active recreation injuries in this study provides a basis for prioritization and planning of future research.

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Summary

This study addressed an important knowledge gap by quantifying some of the long-term consequences of sport and active recreation injuries. This is the first paper to use routinely collected outcome data to describe outcomes in a sport and active recreation injury population. It has demonstrated that this data can be used effectively to describe outcomes in this group, at a basic level, an important first step in describing the burden of sport and active recreation injuries. It has demonstrated that VOTOR data can be used effectively to identify sport and active recreation cases and that large numbers of cases are captured by the registry. Methodological information, relating to case ascertainment and identification of variables for inclusion in sub-group analyses, was also obtained from this study. This information was used to guide the development of the main cohort study associated with this thesis.

Limitations associated with using routinely collected VOTOR data to characterise outcomes in a sport and active recreation population were also identified. Limitations such as the inability to measure high levels of function or HRQoL, and the inability to capture many of the LOAD subsets important to this group, were identified. There is also no capacity within the VOTOR to determine the impact of injury on patients' physical activity levels. Consequently, this type of routinely collected general injury population data is likely to underestimate the impact of injury in sport and active recreation populations. This has highlighted the need for further, well designed research aimed at effectively measuring the long-term outcomes of sport and active recreation injuries. This gap in the current knowledge base will be addressed in the following chapters.

Chapter Five: Identification of outcome measures suitable for use in sport and active recreation populations.

Overview

As discussed in Chapter One of this thesis, measuring long-term outcomes is an important aspect of describing the burden of sport and active recreation injuries. Frameworks such as the LOAD model and the ICF provide guidance in terms of what to measure (LOAD) and how best to measure outcomes (ICF), in a specified population. At present there are no benchmarks or established guidelines as to how best to measure outcomes in a sport and active recreation population [96].

The previous chapter established that the outcome measures used by data systems that routinely collect outcome data in general injury populations, such as the VOTOR, are likely to underestimate the impact of injury in a sport and active recreation population. This chapter will address aim number two of this thesis by reviewing outcome measures currently used to measure the burden and long-term consequences of injuries, in regards to their suitability for use in sport and active recreation populations. Information from this chapter was used to guide the choice of outcome measures used for the main cohort study of this thesis. The following paper was accepted for publication by Sports Medicine in May 2009.

Monash University

Declaration for Thesis Chapter Five

Andrew NA, Gabbe BJ, Wolfe R and Cameron PA. Evaluation of instruments for measuring the burden of sport and active recreation injury. Sports Medicine. 2010, 40:141-161.

Declaration by candidate

In the case of Chapter Five, the nature and extent of my contribution to the work was the following:

Nature of contribution	Extent of contribution (%)
Principle author responsible for the concept, design, literature search, interpretation of results and writing up of the manuscript.	90%

The following co-authors contributed to the work. Co-authors who are students at Monash University must also indicate the extent of their contribution in percentage terms:

Name	Nature of contribution	Extent of contribution (%) for student co-authors only
A/Prof. BJ Gabbe	Contributed to the study design, writing and drafting of the manuscript	N/A
A/Prof. R Wolfe	Contributed to drafting of the manuscript	N/A
Prof. PA Cameron	Contributed to drafting of the manuscript	N/A

Candidate's Signature	[redacted]	Date 11/8/2011

Declaration by co-authors

The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors.
(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
(4) there are no other authors of the publication according to these criteria;
(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location(s)	Department of Epidemiology and Preventive Medicine, Monash University, Alfred Campus.

	Co-authors signature	Date
Signature 1	[redacted]	11 Aug 2011

Signature 2	[redacted]	[redacted]	25/8/14
Signature 3		[redacted]	

Published paper: Evaluation of instruments for measuring the burden of sport and active recreation injury

REVIEW ARTICLE

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Evaluation of Instruments for Measuring the Burden of Sport and Active Recreation Injury

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Contents

Abstract

Sport and active recreation injuries are common. Participants are generally young, healthy and physically active individuals and as a result their injuries can have long-ranging effects for both the individuals and society.

Accurate and appropriate measurement of the outcomes of sport and active recreation injuries is essential for understanding the time frame and quality of recovery, and quantifying the burden of these injuries. The WHO has developed a framework that can be used for studying health-related outcomes called the International Classification of Function (ICF). As such, the ICF is a useful tool for assessing the suitability of outcome measures for general sport and active recreation populations. This article provides a review of outcome measures that are potentially suitable for use in a general sport and active recreation injury population, assessed within the framework of the ICF.

An extensive literature search was performed to identify instruments used in sport and active recreation (and general) injury populations that would be suitable for measuring the outcomes and burden of sport and recreation injuries and return to physical activity. The search identified six health status and health-related quality-of-life (HR-QOL) measures and five functional outcome measures.

Of the outcome measures reviewed, the Short Form-36 was the most commonly used and covered many of the areas relevant to a sport and active recreation population. The comprehensiveness of the Sickness Impact Profile-36 meant that it contained many relevant items; however, its usefulness is limited by its high level of responder burden. The Musculoskeletal Functional Assessment provided a detailed measure of function, appropriate to a sport and active recreation population, and the Glasgow Outcome Scale-Extended can provide a suitable global measure of function. The Short International Physical Activity Questionnaire is a potential means of measuring return to physical activity for this group.

There are no outcome measures specifically designed to measure outcomes in a general sport and active recreation population. There are, however, existing measures that when used in combination have the potential to provide a comprehensive assessment of injury outcomes in this group. Future research should focus on validating existing measures suitable for a sport and active recreation population as well as developing an ICF sport and active recreation core set of items. An ICF core set would assist researchers and clinicians in selecting the combination of outcome measures most appropriate to their needs as well forming the basis for the development of a specific sport and active recreation outcome measure.

Sport and active recreation injuries are common,[1-3] and have the potential to result in long-term physical and mental health consequences ranging from an inability to return to pre-injury levels of sporting activity to severe disability requiring long-term treatment and care.[1,2] Nevertheless, few studies have assessed injury outcomes in an adult sport and active recreation population and how best to measure outcomes in this group remains unclear. Consensus on this issue is necessary to progress our understanding of the quality of recovery following sport and recreation-related injury, information critical for establishing the burden of sport and active recreation-related injury and informing injury prevention and safety promotion initiatives.

Sport and active recreation injuries can range from isolated ligament injuries to multiple traumas, with varying consequences. The WHO defines disability as an umbrella term that includes impairment, activity limitation and participation restrictions, and acknowledges that disability involves a complex interaction between features of a person's body and their environment.[3] The WHO has developed the International Classification of Function (ICF), which provides a unified, scientific framework that can be used for studying health and health-related outcomes. The ICF covers the key domains of body functions, body structures, activity limitation and participation restrictions and the environment.[4] Each domain is important for an injured participants' successful return to sport and active recreation. Outcome measures that cover the key domains of the ICF should provide the level of comprehensiveness needed to measure outcomes in the diverse sport and active recreation population.

The WHO is currently developing core sets of ICF items, developed through systematic review processes and extensive consultation with health professionals and patients, for various patient groups. A core set is yet to be developed for a sport and active recreation population. The ICF level two classifications that appear to be most relevant to sport and active recreation are those relating to mental functions, pain, neuromusculoskeletal and movement-related functions, muscle functions, mobility, community, social and civic life, and environmental attitudes.

This article provides an overview of commonly used and potentially useful measures of injury outcome with a specific focus on their validity, reliability, utility and usefulness for measuring outcomes of sport and active recreation injuries in adults, with reference to the ICF.

1. Assessing the Suitability of an Outcome Assessment Instrument

1.1 Population Demographics

Adults who participate in sport and active recreation differ from the general population. They tend to be young, physically active and healthy, with a high level of employment.[1,2,5] They also have higher levels of physical function, psychological function and perceived health than non-participants.[6-8] Hence, the morbidity consequences of their injuries can be high. Furthermore, sport and active recreation injuries that result in long-term reductions of physical activity levels in this already active group will potentially increase their risk of developing chronic diseases later in life.[9-12] Not only is it important to measure long-term outcomes for this group, but the measures used need to capture the full range of consequences, including changes in physical activity levels.

1.2 Stakeholders

Sport and active recreation involves a number of stakeholders, for whom the use of standardized outcome measures is important. These include patients, clinicians, researchers, coaches, trainers, sporting clubs, peak sporting bodies, health policy makers, funding bodies, health insurers and sports insurers. The selection of an outcome measure will depend on the purposes for which the outcome data will be used. Measures that are easy to understand, administer, score and interpret are more likely to aid in bridging the interface between the health sector and the sports sector.

1.3 Generic versus Specific

Outcome measures can be divided into generic and specific measures. Generic instruments allow broad comparisons to be made across different populations and often address multiple aspects of health.[13,14] They can be divided into health status and health-related quality-of-life measures (HR-QOL) and functional measures. The former focus on multiple dimensions of health such as physical, mental, social and functional health,[15] whereas functional measures focus on aspects of health related to the individual's ability to perform selected activities.

Specific instruments focus on health domains that are important to particular diseases or populations. They are more responsive than generic instruments,[13,14] but do not allow comparison across disease or injury groups. For a sport and active recreation population these comparisons are important for establishing the burden of injury, prioritizing research and funding, and guiding policy development,[16] especially given the low priority sport and recreation injuries currently receive and the paucity of information available on their outcomes.[17]

1.4 Reliability

Outcome measures are used to measure changes over time due to treatment or natural history[18] and therefore must fulfill the key psychometric properties of reliability, validity and responsiveness. Reliability is the ability of a measure to produce the same result when re-applied under conditions in which a change would not be expected.[13,18] High reliability means that we can be confident that any changes are a true reflection of change and not due to error. For measures that require administration by an interviewer, reliability between examiners or inter-rater reliability is also required. An intra-class correlation coefficient (ICC) is used to measure agreement for continuous measures, the Kappa statistic or weighted Kappa (Kw) is used for categorical measures and a Spearman correlation (ρ) can be used for ordinal variables. The lower limit of the 95% confidence interval (CI) should be ≥ 0.75.[18]

1.5 Validity

Key aspects of validity are content and construct validity. Good content validity means that the measure contains items that are relevant to the demographics and desired outcomes of a sport and active recreation population, will have minimal ceiling and floor effects, and does not restrict the range of measurement so as to capture the wide range of outcomes experienced by this group.[13] Construct validity enables quantification of the logical relationship between the instrument and other measurable characteristics of the patient group or other outcome measures.[13,18] For example, you would expect a good correlation or convergent validity between measures that are measuring similar aspects of disability but a low correlation or divergent validity between measures that are measuring different aspects of disability. Good agreement is generally accepted if $0.40 \leq r \geq 0.60$.[19-21]

1.6 Responsiveness

Responsiveness is the ability of the instrument to detect change over time and is established by correlating change scores with changes in other related measures or variables. Instruments that are responsive at the high end of function will be most appropriate as it is important to detect the subtle improvements that are important to sports participation, particularly in the later stages of recovery.[19] Responsiveness is usually measured using a standard response mean (SRM). An SRM of 0.5–0.7 represents a moderate effect and ≥ 0.8 a large effect.[19]

1.7 Accessibility and Acceptability

Measures need to be acceptable to both patients and researchers/clinicians. Completion time and the degree of difficulty of an instrument can impact on the completeness of the data obtained.[16,22] Completion time is important in sport and active recreation populations as younger, adult populations often have work and family commitments, which means that they have less free time than older, retired individuals.[16] Self-administration by mail or web delivery offers advantages in terms of costs and resources but often at the expense of quality and completeness.[13] Web delivery can provide a more reliable contact point than mail; however, it is limited to participants with web access. Those administered in person by trained interviewers can be more accurate and complete but are resource intensive.[13] Administration by phone interview can be an acceptable compromise.[13] Licensing costs associated with some outcome measures can also impact on their uptake.

2. Search Strategy and Selection Criteria for Reviewed Outcome Measures

Searches of Ovid, MEDLINE, PubMed and Cumulative Index to Nursing and Allied Health Literature (CINAHL) databases were performed using the key words 'sport', 'recreation', 'athletic', 'athlete', 'injury', 'disability', 'impairment', 'quality of life', 'function' and 'outcomes'. Searches were limited to English-language citations, from January 1950 to December 2007. A manual search was conducted of three sports medicine journals and three general injury journals that are known to publish papers using outcome measures in sport and recreation injuries from 2000 to 2007 inclusive. These were the *British Journal of Sports Medicine*, *American Journal of Sports Medicine*, *Clinical Journal of Sports Medicine*, *Injury Prevention*, *International Journal of Injury Control*, and *Safety Promotion and Injury*. The reference lists of key articles from the searches were checked for additional relevant articles.

The searches revealed 133 articles that reported outcomes in adult patients injured as a result of participation in sport or active recreation. Studies included a range of patients from elite athletes to active recreation participants. Fifty studies used disease-specific or joint-specific outcome measures.[23-73] As these studies focused on specific disorders such as anterior cruciate ligament injuries, the measures used were not appropriate for a general sport and active recreation population. Fifteen studies included a validated health status or functional outcome instrument[1,2,5,7,74-86] (table I). As our search strategy identified a small number of outcome measures for review, an additional MEDLINE search was performed to identify

Table I. Studies containing sport and active recreation populations that used generic outcome measures

Outcome measure	Study	Participants	Study type	Injury types/diagnosis	Mean follow-up period
SF-36	Peterson et al.[74]	Recreational athletes	Randomized control trial	Achilles tendinopathy	6, 12, 54 wk
	Guskiewicz et al.[75]	Retired professional footballers	Retrospective cohort	Concussion	NA
	Naal et al.[76]	Recreational athletes	Survey	Unicompartmental knee arthroscopy	18 mo
	Anandacoomarasamy and Barnsley[77]	Elite and recreational athletes	Case control	Inversion ankle injuries	29 mo
	Mazzocca et al.[78]	Collegiate and high school athletes	Case series	Anterior shoulder instability	37 mo
	Debnath et al.[79]	Elite and recreational athletes	Case series	Spondylolysis	2 y
	Williams et al.[80]	Competitive and recreational athletes	Retrospective case series	Traumatic posterior shoulder instability	5.1 y
	Finch et al.[5]	Competitive and recreational athletes	Prospective cohort	General outpatient injuries	6 wk
	Wang et al.[7]	Elite athletes	Case control	Lumbar discectomy	3.1 y
	Von Porat et al.[81]	Soccer players	Retrospective cohort	Anterior cruciate ligament injuries	14 y
	Nicholas et al.[82]	Retired American football players	Cross-sectional study	General injury	NA
SF-12	Meller et al.[83]	Competitive and recreational athletes	Retrospective cohort	Recurrent anterior shoulder instability	24 mo
SIP-68	Dekker et al.[1]	Competitive and recreational athletes	Retrospective cohort	General inpatient injuries	1–4 y
	Dekker et al.[2]	Competitive and recreational athletes	Retrospective cohort	General outpatient injuries	2–5 y
EuroQol	Turner et al.[84]	Professional footballers	Retrospective cohort	General injuries	4.7 y
GOSE	Lindsay et al.[85]	Competitive and recreational athletes	Retrospective cohort	Head injuries	6 mo
SMFA	Giza et al.[86]	Recreational footballers	Case series	Hip fracture-dislocations	12 mo

GOSE = Glasgow Outcome Scale Extended; **NA** = not available; **SF-12** = 12-item Short Form Health Survey; **SF-36** = Short Form-36 Health Survey; **SIP-68** = Sickness Impact Profile-68; **SMFA** = Short Musculoskeletal Functional Assessment.

common outcome measures used in general trauma populations, resulting in 24 studies and seven additional outcome measures.

For many sports participants, an important measure of recovery is return to pre-injury physical activity levels, highlighting the importance of valid measurement of this aspect of recovery. A few studies have used a graded system or a point of reference to assess changes in sporting or activity levels,[87-89] but none were validated measures. Physical activity questionnaires developed for use in general populations could be suitable for measuring return to physical activity following injury. Many of these questionnaires have undergone psychometric testing and have the advantage of capturing sport-related outcomes in situations where, for example, a person injured whilst cycling may be able to return to cycling but no longer be able to participate in their pre-injury level of football. Therefore, physical activity questionnaires that measure aspects of physical activity appropriate for a sport and active recreation population such as type, duration, frequency and intensity of activities within a suitable time frame were also reviewed.

Outcome measures identified from the above searches were reviewed for their use in general sport and active recreation populations.

3. Health Status and Health-Related Quality-of-Life Measures

The HR-QOL and health status measures identified in sport and recreation studies were the Short Form-36 Health Survey (SF-36),[5,7,74-82] the 12-item Short Form Health Survey (SF-12),[83] the Sickness Impact Profile-68 (SIP-68)[1,2] and the EuroQol (EQ-5D).[84] Other relevant measures used in general injury populations were the Sickness Impact Profile (SIP),[21,90-97] the Quality of Well-Being (QWB),[98,99] and the Assessment of Quality of Life (AQoL).[100,101]

3.1 The Quality of Well-Being

The QWB assesses over 25 symptoms and records functional limitations within the domains of mobility, physical activity and social activity (table II). The QWB can be used as a health utility measure in which quality-adjusted life-years (QALYs) can be calculated,[121,122] and is best suited to policy analysis and economic studies.[121] QALYs are the number of years lost from one's life expectancy as a result of dysfunction[123] and is an important concept when measuring the burden of injury associated with sport and active recreation injuries. The symptom-based approach of the QWB means the primary focus is on the ICF domains of body functions and structures, and to a lesser extent on activities and participation. The highest level of physical activity measured by the QWB refers to walking and stairs, reducing its usefulness for an active sport and recreation population.

3.2 The EuroQol

The EQ-5D has a measure of HR-QOL over five domains (table II) and a global health measure in the form of a visual analogue scale (VAS). It was designed for population health surveys and can be used to calculate QALYs.[124]

The most desirable features of the EQ-5D are its brevity and simplicity and its ability to be used in a wide variety of conditions.[124] The first three domains are related to activities and participation. Two of these do not address items specific to a sport and active recreation population, although the section on usual activities allows inclusion of sport and recreation activities. The other domains in the EQ-5D relate to body functions pertaining to mental health and pain. The EQ-5D was shown to have ceiling effects in a general population[125] reflecting its focus on low levels of function. The open-ended nature of the VAS in section two, which allows respondents to rate their health from a worst to best imaginable health state, may provide a global measure of HR-QOL appropriate for use in a sport and active recreation population.

3.3 The Assessment of Quality of Life

The AQoL contains 15 items over five domains (table II), each with four responses, increasing its sensitivity over the QWB and the EQ-5D.[126] Most of the items in the AQoL relate to ICF body

Table II. Summary of outcome measures

Outcome instrument	No. of items	Domains	Time to complete (min)	Injury populations where it has been validated	Advantages and disadvantages
QWB	14 plus assessment of >25 symptoms	Mobility Physical activity Social activity symptoms	10–30	Nil	Can be converted to QALYs Useful for policy development Only measures function or symptom-based problems Does not address high levels of function
EuroQol	6 plus a visual analogue scale	Mobility Self-care Usual activity Pain/discomfort Anxiety/depression	1	Nil	Brief and simple to administer Has wide applicability Can be used to calculate QALYs Large ceiling effects likely in a sport and active recreation population
AQoL	15	Illness Independent living Social relationships Physical senses Psychological well-being	5	General injury population[101]	Increased sensitivity over the EuroQol and QWB Can be used to calculate QALYs Likely to have large ceiling effects Only measures low levels of function
SF-36	36	Physical function Role-physical Bodily pain Social functioning General health Vitality Role-emotional Mental health	5–10	Athletic injuries[6,75,102,103] Traumatic brain injury[104,105] Multi trauma + head injury[106] Orthopaedic injury[107,108]	Only generic measure with some validation in a sport and recreation population Does not measure change in sport and recreation Poor responsiveness for mental health subscale
SF-12	12	Physical function Role-physical Bodily pain Social functioning General health Vitality Role-emotional Mental health	2	General trauma[109]	Brief and simple to administer Omits items most relevant to a sport and active recreation population
SIP-136	136	Sleep/rest Emotional behaviour Body care and movement Household management Mobility	20–30	Rehabilitation patients[110] General trauma[20,21] Lower extremity trauma[111]	Comprehensive measure Has questions specific to active recreation Ceiling effects demonstrated Long completion time

Continued next page

Table II. Contd

Outcome instrument	No. of items	Domains	Time to complete (min)	Injury populations where it has been validated	Advantages and disadvantages
		Social interaction Ambulation Alertness/behaviour Communication Recreation and pastimes Eating Work			
SIP-68	68	Somatic autonomy Mobility control Communication and psychological autonomy Social interaction Emotional behaviour Mobility range	10–15	Head injury[105]	Reduced responder burden compared to the SIP-136 Omits many of the questions considered to be most relevant to a sport and active recreation population
FIM and FAM	18 (FIM) +12 additional (FAM)	Motor Cognitive Behavioural Communication Community functioning	FIM + FAM =35	General trauma[112] Head injury[113,114]	Designed for use in inpatient rehabilitation programmes Only measures low levels of function Ceiling effects likely to be a problem
FCI	10	Excretory function Eating Sexual function Ambulation Hand/arm movement Bending/lifting Speech Auditory function Visual function	8	General trauma[21] Lower limb trauma[115]	Designed specifically for trauma patients Does not contain items specifically relevant to a sport and active recreation population Focuses on low levels of function
GOS and GOSE	7	Level of consciousness Independence in the home Independence outside the home Work Social and leisure activities Family and friends Return to normal life	<10	Head injury[116,117]	Simple to administer Global measure of function only Low sensitivity

Continued next page

Table II. Contd

Outcome instrument	No. of items	Domains	Time to complete (min)	Injury populations where it has been validated	Advantages and disadvantages
MFA	101	Activities using arms or legs Activities using hands Work around home Self care Sleep and rest Leisure and recreation Relationships Thinking Life changes and feelings Work	15	Orthopaedic trauma[20,118]	Good measure of injury impact on active recreation Designed for groups relevant to a sport and recreation population May not be appropriate for non-extremity injuries Potential ceiling effects
SMFA	46	Daily activities Emotional status Arm and hand function Mobility category Bother index	5–10	Orthopaedic trauma[119]	Reduced responder burden compared to MFA Developed in clinically relevant group Omits many items relevant to a sport and active recreation population
Short IPAQ	7	Work Domestic and gardening Leisure time Transport	5	Lower limb arthritis[120]	Measures physical activity across multiple domains High uptake for population surveillance in multiple countries Limited use in outcome studies Yet to be used in injury populations
PPAQ	3	Sport and leisure Stairs Blocks walked	Variable	Nil	Allows for detailed recording of sport and recreation activities Does not cover domains outside sport and recreation Time period over which sport and recreation is recorded would need to be modified
GLETQ	4	Leisure time	Variable	Nil	Easy and brief to administer Reduced accuracy as it only counts episodes of exercise of >15 min duration Does not cover domains outside leisure time

AQoL = Assessment of Quality of Life; **FAM** = Functional Assessment Measure; **FCI** = Functional Capacity Index; **FIM** = Functional Independence Measure; **GLETQ** = Godin Leisure-Time Exercise Questionnaire; **GOS** = Glasgow Outcome Scale; **GOSE** = Glasgow Outcome Scale Extended; **IPAQ** = Short International Physical Activity Questionnaire; **MFA** = Musculoskeletal Function Assessment; **PPAQ** = Paffenbarger Physical Activity Questionnaire; **QALYs** = quality-adjusted life-years; **QWB** = Quality of Well-Being; **SF-12** = 12-item Short Form Health Survey; **SF-36** = Short Form-36 Health Survey; **SIP-68** = the Sickness Impact Profile-68; **SIP-136** = Sickness Impact Profile-136; **SMFA** = Short Musculoskeletal Function Assessment.

functions such as senses, sleep, emotions and pain. Environmental factors relating to medications, devices and treatment are addressed, as are activities and participation, but with a focus on low levels of functioning. The AQoL can also be used to calculate QALYs using the items contained in the last four domains (table II).

The AQoL has been validated in an injury population.[101] However, its exclusion of activity and participation items and levels of function most relevant to a sport and active recreation population are likely to result in underestimation of the impact of injury in this group. This is reflected in a study in which 45% of a normal population reported scores in the highest decile.[127]

A later version of the AQoL (AQoL Mark 2) has been extended to 20 items. High level mobility functions such as running are included and vitality is assessed. Community roles are addressed with sporting groups included in the examples. Though this version is better suited to a sport and active recreation or injury population, it has yet to be validated or used in these groups.

3.4 Short Form-36

The SF-36 has been widely used in sport and active recreation populations.[5,7,74-80] It contains 36 items over eight domains (table II) and provides a separate score for each subscale and mental component summary (MCS) and physical component summary (PCS) scores. Many of the items in the SF-36 are applicable to a sport and active recreation population, especially in the ICF domains of activities and participation relating to mobility, recreation and leisure and mental functions. The lack of cognitive and upper limb subscales could result in underestimation of the impact of injury in these areas.

There is limited assessment of the psychometric properties of the SF-36 in sport and active recreation populations. A study of elite athletes found that serious injury was a predictor of lower PCS, MCS and subscale scores, and that mild injury was a predictor of lower PCS scores.[6] Another study on retired professional footballers found that those with clinical depression had lower MCS and PCS scores compared with those without depression.[75] These results, however, cannot readily be extrapolated to recreational athletes.

Criterion validity was assessed in knee-injured sporting populations.[102,103] Good correlations ($r = 0.57$–0.72) were found between physical function measured by the SF-36 and knee function tests, with divergent validity demonstrated between the other subscales of the SF-36 and the knee function tests.[102,103] Ceiling effects were noted in the SF-36 role physical subscale.[102] Good criterion validity was also demonstrated in general injury and traumatic brain injury (TBI) patients.[21,104,128]

The reliability of the SF-36 demonstrated high variability between subscales (ICC = 0.04–0.77) in a sport and active recreation population with patella dislocation;[102] however, there was a median interval of 21 days between tests and factors particular to patella dislocation such as fluctuations of symptoms could have affected the results, as could the inclusion of children.[102] In TBI patients, good reliability was demonstrated across all subscales of the SF-36 for one study[104] and in less than half the subscales in another.[105]

In sport and active recreation populations, improvements in the PCS and MCS have been demonstrated 2 years after surgery,[79] and changes in physical function, role function, bodily pain and social function subscales have been demonstrated as early as 5–6 weeks after injury.[5] High SRMs (0.5–1.1) were reported for the physical subscales but not the mental health subscales[128] in general injury patients. It is likely that the physical components of the SF-36 are more responsive than the mental components in this group.

The SF-36 is suitable for use in a sport and active recreation population. Its main limitations are the potential for ceiling effects in some subscales and the lack of responsiveness of the mental health subscales. The suitability of the SF-36 for upper limb injuries requires further investigation, and further psychometric testing is required in sport and active recreation populations.[129]

3.5 Short Form-12

The SF-12 was derived by selecting 12 items that provided a >90% correlation with the SF-36 and covered each of the eight subscales. Selection was based on predictions from US population data and validated in chronic medical patients.[130] Though the SF-12 appears to be a valid alternative to the SF-36 in general, trauma and medical populations,[109,130] its omission of items relevant to sport and active recreation populations such as vigorous activities and walking long distances are likely to underestimate the impact of injury in this group. Therefore, the SF-36 would be preferable to the SF-12 in sport and active recreation populations.

3.6 Sickness Impact Profile-136

The SIP-136 has not been used in specific sport or active recreation studies; however, it has been used in studies of injuries commonly seen in sporting populations.[131,132] The SIP-136 assesses sickness-related behaviours and is designed to have broad applicability across a variety of illnesses and demographics. The SIP-136 contains 136 questions over 12 domains giving it increased content validity over shorter measures,[133] and contains a large number of concepts that can be linked to the ICF.[134] Those most relevant to a sport and active recreation population are related to energy, psychomotor function, exercise tolerance, muscle function and physical recreation.[135,136] The SIP-136 can be scored to give physical, psychosocial well-being and individual category scores (table II).

The psychometric properties of the SIP-136 have been established in a range of patients, including rehabilitation patients, but have not been assessed in a sport and active recreation population. One study, however, found that certain aspects of the SIP-136 had a much higher degree of relevance to sporting populations, especially those aspects relating to pain and recreational activities.[132] In trauma patients, good convergent validity ($r > 0.60$) was demonstrated between the PCS of the SIP-136 and the Functional Capacity Index (FCI),[21] and a moderate correlation ($r = 0.41$) was demonstrated between the SIP-136 and clinical measures of physical impairment.[111] A ceiling but not a floor effect was also demonstrated in trauma patients.[20]

The SIP-136 was able to discriminate between treatment groups in conservatively managed ankle sprains[131] and was responsive to changes that occurred after anterior cruciate ligament reconstruction at 3 and 12 months.[132] The SIP-136 was also sensitive to improvements in function in trauma patients with lower limb fractures over 6, 12 and 30 months.[91,111] The comprehensiveness of the SIP-136 and its inclusion of relevant subscales make it suitable for a sport and active recreation population. The main disadvantage of the SIP-136 is its long completion time, and further psychometric testing is required in a sport and active recreation population.

3.7 Sickness Impact Profile-68

The SIP-68 has been used in two studies involving general sport and active recreation populations[1,2] and has reliability, validity and responsiveness similar to that of the SIP-136 in rheumatology and medical patients.[137-139] The main disadvantage of the SIP-68 is that it omits many of the questions that are most relevant to a sport and active recreation population.[91,111,132] Fourteen of the 24 questions in the SIP-136 considered to be most relevant to a sport and active recreation population are omitted,[132] limiting the potential usefulness of this instrument in a sport and active recreation population.

4. Functional Outcome Measures

Functional measures identified in our search and used in sport and active recreation populations were the Glasgow Outcome Scale (GOS)[85] and the Short Musculoskeletal Functional Assessment (SMFA).[86] Other suitable measures used in general injury studies include the Glasgow Outcome Scale Extended (GOSE),[140] Musculoskeletal Functional Assessment (MFA),[118,141-143] Functional Independence Measure (FIM) and Functional Assessment Measure (FAM),[112,113,144] and the FCI.[21,145,146]

4.1 The Functional Independence Measure and the Functional Assessment Measure

The FIM is an 18-item scale designed to measure change over the course of inpatient rehabilitation programmes and has motor and cognitive components. The FAM consists of 12 additional items and was designed for use with the FIM. The questions focus on performance of activities relating to self-care and independence and do not contain items relevant to high levels of function. This is reflected in follow-up studies involving general trauma and TBI patients in which ceiling effects were reported for between 80% and 95% of subjects.[100,112-114] Therefore, the FIM and FAM are unlikely to measure outcomes meaningful to a sport and active recreation population.

4.2 The Functional Capacity Index (FCI)

The FCI was initially designed to predict 12-month outcomes for the injury descriptions contained in the abbreviated injury scale (AIS). The AIS is primarily a threat-to-life scale and does not accurately identify injuries that have high morbidity. The FCI was developed to rectify this.[147] The FCI questionnaire was later developed as an evaluative tool, utilizing these predictive weights in its scoring system.[21] The FCI has the advantage of being specifically designed for use in injury populations and has been validated in this group,[21] though further psychometric evaluation is required.[148]

The FCI covers ten dimensions each with between three and seven categories of capacity that are weighted depending on their impact on everyday living[147] (table II). The FCI focuses on body functions with some dimensions such as ambulation and hand/arm movement also containing sub-categories relating to activities and participation and environmental factors. The FCI focuses on tasks necessary for everyday living and does not cover areas such as sport and active recreation.[21] As such, it is not suited to a sport and active recreation population.

4.3 Glasgow Outcome Scale and Glasgow Outcome Scale-Extended

The GOS was developed as a global measure of outcome following head injury, has been recommended for use in general injury studies,[149] and has been used in one study involving sport and active recreation participants.[85] The GOS is designed to reflect disability as defined by the WHO[150] and covers multiple aspects of the ICF relating mainly to activities and participation, across five domains.[116] The GOS is scored by allocating the patient to one of five broad categories ranging from dead to "resumption of normal activity despite minor deficits". The GOS contains a section on social and leisure activities but measures quantity, rather than quality, of participation.[150] This and the allowance of minor deficits in its highest category means that the impact of injury in a sport and active recreation population could be underestimated. Importantly, pre-injury status is considered when scoring the GOS.

An extended version of the GOS was developed to increase sensitivity and reduce ceiling effects.[151,152] The upper three categories of good recovery, moderate disability and severe disability are subdivided to provide eight categories (table II). The GOSE has greater suitability over the GOS for sport and active recreation populations due to additional categories and allowing qualification of whether or not a patient has returned to 'normal life'. Nevertheless, the GOSE has yet to be used in a sport and active recreation population.

The psychometric properties of the GOSE have only been assessed in head injured populations. Its content validity is evidenced by good correlations with other functional measures ($r=0.46$–0.89)[116,117,152] and the Beck depression inventory ($r=0.64$) for all patients except the most severely disabled.[116] Modest associations were also demonstrated with various cognitive tests.[116,153]

Administration by an interviewer using a structured interview is recommended for the GOSE to increase reliability.[150] Good intra-rater reliability was found for face-to-face versus telephone interviews ($Kw=0.92$).[154] Inter-rater reliability results were more variable. One study found low reliability ($Kw=0.56$–0.57) both at discharge and 12 months after injury,[105] whereas other studies found acceptable levels ($Kw=0.84$–0.98) through various modes of administration;[117,150,154] however, some studies were limited by small patient numbers.[154,155] Good reliability ($Kw=0.92$) was also demonstrated for postal interviews.[155] Agreement on the GOSE was slightly better for those with severe injuries compared with those with minor injuries,[154] which could reduce its reliability in a sport and active recreation population.

The GOSE was able to demonstrate change in a cohort of head-injured patients at 5–7 years after injury as compared with 12 months after injury.[117] Change was also demonstrated in a sample of TBI and general trauma patients at 3 and 6 months after injury,[151] and predicted increases in scores were also demonstrated over a 12-month period.[105] The categorical nature of the GOSE may reduce its sensitivity compared with continuous measures; however, this is yet to be established.

Though predominantly used in TBI populations, the use of the GOSE in general trauma populations and its inclusion of relevant items suggests that it may be a suitable global measure of function for sport and active recreation populations. Further psychometric evaluation of the GOSE is required in this population, especially for minor injuries. Further evidence of reliability of the GOSE is needed.

4.4 Musculoskeletal Functional Assessment

The MFA is a self-reported measure developed to assess musculoskeletal disorders of the extremities, including fractures and soft tissue injuries, making the MFA particularly relevant to sport and active recreation populations.[1,2,156] The MFA includes 101 items over ten categories. The MFA contains many ICF sub-categories relevant to a sport and active recreation population. Activities and participation, and to a lesser extent body functions and body structures, are covered and include items such as running, changes in physical recreation activities and changes in physical fitness due to disability[157] (table II). Scoring allows for a total score as well as category sub-scores.[20] Despite use in injury studies,[118,141-143] the MFA has not been used in sport and active recreation injury studies.

Validity of the MFA has been established in trauma patients.[20,118] Good correlations have been demonstrated between physician ratings of extremity function and MFA extremity function ($r=0.40$–0.66), but not between other subscores.[20,118] Convergent validity was demonstrated between various clinical measures and the relevant lower extremity and upper extremity MFA items, and between self-ratings of health and changes in activity.[20,118] Construct validity relating to injury and demographic characteristics and predicted MFA scores were also demonstrated.[118] The total score of the MFA does not have floor or ceiling effects,[20,157] though ceiling effects were noted within individual categories.[20]

The MFA has demonstrated good reliability ($ICC=0.70$–0.92) for self-administration and inter-rater reliability, with the MFA more reliable in injury than in arthritis groups.[20,157] Good responsiveness ($SRM=0.74$) has been demonstrated over a 6-month period for the overall MFA score, but was variable between categories with the categories of family relationships and mobility showing the lowest levels of responsiveness.[20]

The MFA could be an appropriate outcome measure for musculoskeletal sport and active recreation injuries. The ability of the MFA to accurately assess function in non-musculoskeletal sport and active recreation injuries is unknown; however, the inclusion of a cognitive component and general function questions suggest that it is likely to be acceptable for broader injury groups. Psychometric analysis of the MFA in a sport and active recreation population is needed.

4.5 The Short Musculoskeletal Functional Assessment

The SMFA was developed to reduce respondent burden for the MFA whilst maintaining important items. It has been used in one sport and active recreation study.[86] Though the SMFA has been shown to be reliable, valid and responsive in patients with extremity disorders,[119] the questionnaire does not include many of the MFA items most relevant to a sport and active recreation context such as those related to running and the category relating to leisure and recreational activities. As such, the SMFA is likely to be a less appropriate measure of function than the MFA in a sport and active recreation context.

5. Physical Activity Measures

5.1 The Short International Physical Activity Questionnaire

The short International Physical Activity Questionnaire (IPAQ) measures physical activity over the previous 7 days or a typical week over four domains (table II). Time spent in high-intensity, medium-intensity and walking activities and sitting is recorded and MET scores are obtained for each category where 1 MET is the resting metabolic rate during quiet sitting. A total score is derived as well as separate scores for each category except sitting. The questionnaire was designed for physical activity surveillance across a variety of cultures in response to the need for a standardized physical activity measure.

The short IPAQ has been validated in general populations across a number of countries. Validity has been assessed against accelerometers or motion detecting devices with only fair agreement ($p = 0.30$–0.39);[158-160] however, this may be due to accelerometers not measuring all aspects of physical activity and consequently underestimating physical activity in some people.[161] Good convergent validity ($r \geq 0.5$) was demonstrated between the IPAQ and other physical activity questionnaires and physical activity logs.[160,162,163] Though not validated in injury populations, one study showed that patients with greater severity of osteoarthritis of the knee and hip had lower activity levels as measured by the short IPAQ.[120] A similar relationship may exist between disability due to injury and the short IPAQ.

A large international study found good test-retest reliability ($p = 0.74$) for telephone-administered and self-administered questionnaires,[158] with lower reliability in rural and undeveloped areas. Another study found moderate reliability (ICC = 0.68);[164] however, two European studies found low reliability (ICC = 0.45–0.54).[160,165] Physical activity can vary from week to week, hence differences may be partly related to different administration periods as studies with longer re-administration periods reported lower reliability.[160,165]

The short IPAQ has the advantage of measuring physical activity across a number of domains and is suitable for use in a variety of cultures. The responsiveness of the short IPAQ in an injury context is unknown and consequently the developers do not recommend its use in small-scale intervention studies.[166] The variability of the results obtained from reliability studies suggests that further evaluation is required.

5.2 Paffenbarger Physical Activity Questionnaire

The Paffenbarger Physical Activity Questionnaire (PPAQ) or College Alumnus physical activity questionnaire was developed for use in exercise and chronic disease epidemiology studies. The PPAQ measures calories expended in sport, leisure and recreational activities, as well as flights of stairs climbed and city blocks walked. Sport and recreation activities are listed as weeks in the past year that each activity was performed, whereas other areas are recorded for the previous week (table II). This allows for variation in sporting participation habits but in the context of injury will limit the time frames for which it can be used. The PPAQ does not measure physical activity across multiple domains; however, it does allow time spent in each sport or recreation activity to be listed separately.[167]

Validity and reliability studies have involved general adult populations and university students. Only fair agreement was demonstrated between the PPAQ and accelerometer readings ($r = 0.29$–0.30)[168,169] and activity logs that measured total activity ($r = 0.31$).[168] However, when only the activity log items included in the PPAQ were compared, a high level of correlation was found ($r = 0.60$).[169] Another study found good agreement ($r > 0.50$) between the PPAQ and five of seven other physical activity questionnaires.[170]

Two studies found good test-retest reliability when administered within a time frame of 1 month,[168,169] whereas a study that used a time frame of 7–12 weeks found poor test-retest reliability ($r = 0.58$). When the reliability results were recalculated using only participants who reported no change in their activity levels, the correlation increased significantly (r = 0.69).[171]

The PPAQ appears to be valid and reliable in populations with similar demographics to a sport and active recreation population; however, the use of selected domains and activities means that some aspects of physical activity such as cycling to and from work or work-based activities may be missed. The 12-month time frame for recording sport and recreation activities is only appropriate for measuring recovery over very long periods. Nevertheless, the scoring system could be modified to cover activities over the last month or week.

5.3 Godin Leisure-Time Exercise Questionnaire

The Godin Leisure-Time Exercise Questionnaire (GLETQ) is a four-item questionnaire used to assess the number of times in an average week participants spend in strenuous, moderate and mild physical activity for more than 15 minutes[172] (table II). A score is obtained that can be converted to METs. Though not used specifically as an outcome measure, the GLETQ has been used to measure physical activity in patients with existing lower limb and spinal cord injuries.[173,174]

The GLETQ has undergone minimal psychometric testing. Accelerometer correlations were fair (r = 0.32–0.35).[168,175] Correlations between the GLETQ and a 4-week activity diary were lower than the other questionnaires (r = 0.36).[168] High test-retest reliability was reported (r = 0.75–0.82) when administered within a 2-week period.[175,176] The GLETQ has demonstrated changes in activity levels across phases of treatment and recovery in breast cancer patients[177] and could show changes in activity associated with injury and its phases of recovery.

The GLETQ measures aspects of physical activity relevant to a sport and active recreation population but it does not account for physical activity across other domains. The GLETQ measures exercise episodes per week greater than 15 minutes rather than actual time spent and thus may underestimate overall activity levels. The reliability of the GLETQ is good and its brevity is a desirable trait for a sport and active recreation population.

6. Conclusion

Despite the plethora of outcome measures available, none have been specifically designed to measure injury outcomes in a general sport and active recreation population. In the absence of a purpose-designed instrument, there are existing generic measures that could, alone or in combination with others, be useful for measuring outcomes in this group. The SF-36 covers many of the areas of HR-QOL relevant to a sport and active recreation population and enables comparison with other disease and injury populations. Where a detailed measure of function is required, the MFA could be useful, while the GOSE may have merit as a global measure of function. Physical activity measures present a standardized method for measuring return to activity in sport and active recreation populations with the short IPAQ appearing to be the most comprehensive of this group.

Ultimately, the choice of outcome measure will depend on the requirements of the users. So far there is no core set for sport and active recreation injury patients and though the ICF can provide a general framework in which to assess the appropriateness of existing measures, the development of a core set would assist researchers and clinicians in selecting the combination of outcome measures that would provide the most comprehensive assessment of disability and recovery in this group. Future research should focus on validating existing generic measures suitable for sport and active recreation populations as well as developing a measure specific to their requirements based on an ICF core set. Only through improved measurement of outcomes will gains be made in quantifying the burden of sport and active recreation injury outcomes.

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Summary

This paper has established that, within the currently available outcome measures, a single measure does not exist for assessing outcomes meaningful to a sport and active recreation population. In the absence of such a tool a small number of outcome measures have been identified and recommended for use, in combination, as a means of effectively measuring outcomes in this group. The combination of measures identified through this review address many of the outcomes identified through the LOAD framework that would be considered to be important to a sport and active recreation population, whilst also covering the core set of functions considered to be important through the ICF. These sets of measures also provide a means of measuring the impact of sport and active recreation injuries on patients' physical activity levels. The results of this paper confirm that the outcome measures used by data systems, designed to measure outcomes in general injury populations, such as the VSTR and the VOTOR, and the measures used in previous outcome studies [55, 56] are likely to underestimate the impact of injury on sport and active recreation participants.

This paper addressed aim number two of this thesis and was used to inform the choice of outcome measures used in the main cohort study of this thesis. Through the use of these carefully chosen outcomes measures, the results of the main cohort study of the thesis aimed to provide the most comprehensive view of the injury burden associated with hospitalised sport and active recreation injuries to date.

Chapter Six: Methodology for a prospective cohort study

6.1 Introduction

As described in previous chapters, many of the aspects of the LOAD framework that are likely to be important to a sport and active recreation population are not addressed by either published outcome studies performed in general sport and active recreation populations [55, 56] or outcome data obtained from routinely collected registry data. Chapter Five established that these systems used outcome measures that are likely to underestimate the long-term impact of sport and active recreation injuries and that there have been no attempts, to date, to measure the impact of sport and active recreation injuries on participants' physical activity levels. The following cohort study has been specifically designed, using a combination of routinely collected outcome data and purposefully collected outcome data, to address these knowledge gaps and better quantify the 12-month outcomes of sport and active recreation injuries, including their impact on physical activity levels. The results of this cohort study address aims three and four of this thesis.

This chapter describes, in detail, the rationale and methodology of the main prospective cohort study of this thesis. Chapters Seven and Eight report the results of the cohort study and an overview of the methodology is repeated in those chapters. Additional detail is provided in this chapter on how the information gained from the previous sections of this thesis informed the development of the novel methodological framework used in this study. A detailed explanation of the choice of statistical analyses used in the study is also provided.

6.2 Rationale, hypothesis and aims

6.2.1 Rationale

Long-term outcomes of serious sport and active recreation injuries have not been adequately described by previous research. To date, no studies have quantified the 12-month outcomes of sport and active recreation injuries using outcome measures considered appropriate for use in this population, including the impact of these injuries on physical activity levels. This information is important for understanding the burden of sport and active recreation injuries, identifying priorities for injury prevention and for setting priorities for treatment and rehabilitation. This cohort study was designed to help address this knowledge gap.

6.2.2 Hypothesis

Adults who sustain serious orthopaedic sport and active recreation injuries continue to report significant reductions in function, health status and physical activity levels at 12-months post-injury, compared to pre-injury levels.

6.2.3 Study Aim

The primary aim of this study was to quantify the 12-month health status, functional and physical activity outcomes of hospitalised orthopaedic sport and active recreation injuries. This addresses aims three and four of this thesis, as outlined in Chapter One.

6.3 Methods

6.3.1 Participants

Patients aged 18 to 74 years who were admitted to the participating hospitals with an orthopaedic injury due to participation in a sport or active recreation activity were eligible for inclusion. Patients admitted for pathological fracture related to metastatic disease or a with hospital stay less than 24 hours are excluded from the VOTOR and so were not included in this study. Eligible patients who were not capable of providing informed consent due to cognitive or language difficulties, who were homeless, in prison or had an overseas address, according to their details recorded on the VOTOR, were also excluded from the study.

The VOTOR originally included only the two adult Major Trauma Services in Victoria: The Alfred Hospital and the Royal Melbourne Hospital. In 2007, one of the five regional trauma services designated in the Victorian State Trauma System (Geelong Hospital) joined the VOTOR. The inclusion of Geelong Hospital provided the potential for a greater range of sport and active recreation injuries, both in terms of severity and variety of injury types, than was previously available from the Major Trauma Services alone.

6.3.2 Ethics approval

Approval for the project was granted by the Human Research Ethics Committees of each of the participating hospitals, and the VOTOR steering committee. Copies of the ethics approval certificates are provided in Appendix 1.

6.3.3 Definition of a sport and active recreation injury

Current research in this area is fragmented by the lack of a consistent definition of what constitutes a sport and active recreation injury [19]. To promote international consistency the International Classification of External Causes of Injury (ICECI) was used [16] to define a sport and active recreation injury. The ICECI was designed to assist in describing, measuring and monitoring the occurrence of injuries, using an internationally agreed classification. The ICECI also maintains consistency with other areas of injury research and classification to allow for comparisons between injury research areas. The ICECI definition specifically states that sport and active recreation is “physical activity with a described functional purpose, eg. competition, practising for competition, improving physical health” [16].

Based on the ICECI, off-road motor sports such as motorcross, trail-biking or four-wheel driving were included in the study, but on-road motorcycle riding was excluded. The ICECI specifically includes both on-road and off-road cycling. Walking was only included if it met the specifications outlined in the ICECI ie. power walking and walking for exercise [16].

6.3.4 Procedures for identifying eligible participants

Data collection and identification of potentially eligible participants were performed in close communication with the VOTOR staff. Hospital data cannot be transferred to the VSTR or the VOTOR until all clinical coding of patients, including ICD-10AM coding, has been completed by participating hospitals. Consequently, the VSTR and VOTOR patients are not confirmed on the database until approximately six months post-injury [86]. Data requests for this study were processed once the standard VOTOR 6-month follow-up interview had been commenced, so as not to interfere with the primary purpose of the registries.

Once data were made available, potentially eligible participants were identified from the database using the protocol outlined in Chapter Four page 44. In addition the activity at the time of injury was confirmed at the first participant interview.

6.3.5 Recruitment

Once identified, potentially eligible participants were sent a participant information sheet (Appendix 2) detailing the purpose of the study, the information that would be collected, how the information would be used and stored, and the follow-up procedures. An opt-off method of consent, similar to that used by the VOTOR [86], was approved for use in this study. For this study, the information sheet contained a number to call if participants did not wish to be contacted by the research team.

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Participants who did not choose to opt-off from the study were contacted 1-2 weeks after receiving the letter, and verbal consent was obtained prior to the collection of data. Consistent with the VOTOR follow-up procedures, four attempts at different times of day were made unless additional information at the fourth attempt indicated a likely successful contact, in which case additional attempts ensued [86].

6.3.6 Outcome measures

The outcome measures routinely collected by the VOTOR were supplemented by purposefully collected data, to provide a set of measures suitable for use in a sport and active recreation population. The set of measures used were the Short Form 36 (SF-36), the GOSE and the short International Physical Activity Questionnaire (IPAQ). This enabled relevant outcomes such as physical and psychological disability, general health, vitality, pain, social function, physical activity levels and whether or not participants had achieved a full recovery. Chapter Five explains these outcome measures in more detail and gives the rationale for the choice of measures used. The outcome measures are contained in Appendices 3-5.

6.3.7 Variables and Data Sources

Variables included in the study were obtained from multiple data sources and included:

i. Demographic and injury variables extracted from the VOTOR database for this study: age, gender, pre-existing medical conditions, pre-existing mental health conditions, in-hospital complications, ISS >15 (yes/no) and injury profile such as isolated lower limb injury or multiple orthopaedic injury.
ii. Variables obtained at the initial study interview: sport and recreation activity at the time of injury, retrospective, pre-injury SF-36 data and retrospective, pre-injury IPAQ data.
iii. Variables collected from participants as part of the VOTOR follow-up procedures and extracted for this study: pre-injury occupation, pre-injury work status, highest level of education attained, GOSE (12-months post-injury) and the SF-12 Version 1 (12-months post-injury).
iv. Additional information collected at the 12-month follow-up for this study: the 24 items of the SF-36 not included in the SF-12 and the short IPAQ.

6.3.8 Response shift and recall bias associated with the pre-injury interview

The aim of injury management and treatment is to return the person to their pre-injury state. The collection of pre-injury data is important for groups such as sport and active recreation participants who have health and physical activity levels that differ from the general population [58, 97], and for whom there are no reliable benchmarks to establish recovery.

Serious injury is infrequent and occurs without warning. The collection of retrospective pre-injury health data is therefore recommended in injury research [98], however it is unknown at what point post-injury this is best collected.

Recall bias and response shift are the main mechanisms that influence the reliability of retrospectively collected injury data. Response shift is a change in the internal standards, values or conceptualisations by which one judges their health [99]. In the occurrence of a traumatic event such as injury, this shift has the potential to elevate one's perception of their pre-injury health. Whether this is greatest immediately post-injury, when the patient is dealing with the immediate consequences of injury, or later in the recovery phase when they are in a more stable health state, is unknown.

As a way of examining the impact of response shift, Watson et al [100] compared the pre-injury SF-36 scores collected shortly after injury and the 12-month post-injury scores of those that had fully recovered in a cohort of general injury patients. The methodology described by Watson et al [100] was used to estimate the degree of response shift and recall bias present in the results of this study. In addition, the pre-injury scores of those that had recovered and those that had not recovered were compared to further estimate the impact of response shift.

6.3.9 Data analysis

6.3.9.1 Power calculations

Power calculations were based on the primary outcome measure, the SF-36. A three point difference in pre- and post-injury summary scores was considered clinically significant [101]. Based on this and using a standard deviation of 10 for the difference between mean pre- and post-injury scores [101], a minimum sample size of 117 was required to detect a clinically significant mean difference between pre- and post-injury SF-36 scores with a power of 0.9. Additional participants were recruited to allow data collection over a 12-month period for each hospital, to account for seasonal variations in sporting activities and to allow for an anticipated 80% 12-month follow-up rate.

6.3.9.2 Comparisons of eligible participants recruited and not recruited to the study.

Eligible participants recruited to the study were compared to those not recruited to the study. The high follow-up rates, and therefore low numbers of participants lost to follow-up, meant that it was not meaningful to compare those followed-up at 12-months post-injury and those lost to follow-up. All comparisons used chi-squared tests for categorical variables and Mann-Whitney U tests for continuous variables where data did not follow a normal distribution.

6.3.9.3 Scoring of outcome measures

(i) SF-36:

The pre- and post-injury Physical Component Summary (PCS), Mental Component Summary (MCS) and subscale scores were calculated according to the published guidelines, using the norm-based scoring system [101]. Missing data for the SF-36 were estimated using the "half scale rule" in which the missing item is given the average score of the completed items in the same scale [101].

(ii) GOSE:

The GOSE is scored by allocating patients to one of eight broad categories using a standardised structured interview [102]. The eight categories are: Dead (GOSE=1): Vegetative State (GOSE=2): Lower Severe Disability (GOSE=3), Upper Severe Disability (GOSE=4), Lower Moderate Disability (GOSE=5): Upper Moderate Disability (GOSE=6): Lower Good Recovery (GOSE=7): and Upper Good Recovery (GOSE=8). Participants were classified as “fully recovered" (GOSE=8) if they answered no to the question “Are there any other current problems relating to the injury which affect daily life?” Those with a GOSE score < 8 were classified as “not fully recovered”.

(iii) Short IPAQ:

Short IPAQ scores were calculated in Metabolic Equivalents (METS), where 1 MET is 1 kcal/kg/hour or the resting metabolic rate during quiet sitting, and were expressed as MET minutes per week. Continuous scores were truncated for analysis according to the IPAQ scoring protocol [103]. This meant that a maximum of three hours of activity per day could be scored for each category. This scoring method is recommended as a way of minimising the effect of over-estimation. Participants were also dichotomised into “low/moderate” or “high” activity groups based on their total amount of weekly physical activity, according to the IPAQ guidelines [103]. The “high” category represents the level of physical activity at which health enhancing benefits are believed to occur. This is defined as vigorous-intensity activity on at least 3 days a week, achieving at least 1,500 MET minutes per week or a combination of vigorous activity, walking and moderate activity over 7 days totalling 3,000 MET minutes per week [103]. This is consistent with the recent physical activity guidelines for healthy active adults [104, 105].

6.3.9.4 Choice of variables for use in analysis of outcomes

Variables obtained from the sources outlined in section 6.3.7 of this chapter and contained in the VOTOR database were reviewed for inclusion in the multivariate regression analyses. The choice of final variables was guided by already published studies [55, 56], the paper presented in Chapter Four and the ability of the variable to provide sufficient sub-group numbers. Some examples of variables not included were return to work (yes/no) and pain rating scores (0-10), as most had returned to work by 12-month post-injury. Pain rating scores were not included as the SF-36 pain subscale was considered to provide a better measure of pain for this study due to the inclusion of a functional component in its scoring system.

Individual sporting activities were categorised into key sporting groups based on the ICECI groupings [16]. Occupational groups were categorised according to the estimated amount of physical activity associated with the various occupation types, using the Compendium of Physical Activity [106]. Education groups were based on the highest level of education obtained. Injury groups were established based on logical groupings of types and areas of injuries that also allowed for sufficient numbers in each group.

The severity of the injury or injuries sustained was categorised using the ISS. The ISS is a derived variable based on an anatomical scoring system. Each injury is assigned an Abbreviated Injury Scale (AIS) score for one of six body regions. The three most severely injured body regions then have their score squared and added together to produce the ISS score [107]. Injury severity was categorised as an ISS >15 or ≤15 as this is how ISS is recorded by the VOTOR. Having an ISS>15 is commonly used to categorise a patient as having had a major trauma [88]. Days per week of vigorous physical activity was categorised into ≤ 3 days per week and > 3 days a week, based on physical activity recommendations in which >3 days of vigorous activity a week is above the current guideline recommendations [104, 105].

Participants who had a recorded pre-existing co-morbidity or in-hospital complication, were identified using the following ICD-10 codes:

i. Chapters I-III Codes A00 through to E90 and Chapters VI-XIV codes G00 through to N99 identified a physical disease.
ii. Chapter V codes F00-F99 identified a mental or behavioural disorder including drug or alcohol addiction.
iii. Chapter XIX codes T80-T88 and Chapter XX codes Y40-Y84 identified complications due to surgical or medical care.

6.3.9.5 Comparison of pre-injury and post-injury scores

The pre-injury scores for the PCS, MCS and the short IPAQ scores were approximately normally distributed. The post-injury scores for these outcomes were slightly skewed. Both parametric and non-parametric analyses were used to assess changes in pre-injury and post-injury scores. The final results from this study were based on the parametric tests as the conclusions from the parametric and non-parametric analyses were similar.

6.3.9.6 Linear regression analyses

Linear regression models were used to analyse the impact of the predictor variables on changes in the PCS, MCS and short IPAQ at 12-months post-injury. Analysis was first performed for each independent variable separately using univariate linear regression. To assess the combined impact of the independent variables on changes in outcome, three sets of multivariate analyses were performed. The first contained demographic variables only, the second contained demographic and injury variables and the third contained demographic, injury and hospital variables. Effect modification (interaction) was assessed between all pairs of demographic and injury variables in the multivariate models, using likelihood ratio tests.

Debate exists in the literature as to how best to account for change scores in linear regression [108, 109]. To investigate the most appropriate method, the data were modelled using two methods. The first method included the pre-injury score as a variable in the model to account for changes in pre- and post-injury scores at 12-months, and the 12-month score was used as the outcome. The second method subtracted the pre-injury scores from the post-injury scores and used this derived variable as the outcome. Pre-injury scores were not included as a variable in this second model. The PCS and the MCS produced similar results using both methods but the short IPAQ produced considerably different results. Theoretical models reported by Dugravot et al [108] and Glymore et al [109] were used to explain the possible differences and guided the final choice of models used for the different outcome measures.

The results of the prospective cohort study are reported in the next two chapters in the form of submitted papers.

Chapter Seven: Return to pre-injury health status and function 12-months after hospitalisation for sport and active recreation related orthopaedic injury.

Overview

The 12-month health status and functional outcomes associated with serious sport and active recreation injuries are reported in this chapter. The outcomes reported cover many of the outcomes described in the LOAD framework that are important to a sport and active recreation population. The long-term implications of these results for participants are also discussed in this manuscript. The paper contained in the chapter following this one reports the physical activity outcomes. The following manuscript has been submitted for publication.

Monash University

Declaration for Thesis Chapter Seven

Andrew NE, Wolfe R, Cameron PA, Richardson, M, Page, M Bucknill, A and Gabbe, BJ. Return to pre-injury health status and function 12-months after hospitalisation for sport and active recreation related orthopaedic injury. Submitted

Declaration by candidate

In the case of Chapter Seven, the nature and extent of my contribution to the work was the following:

Nature of contribution	**Extent of contribution (%)**
Principle author responsible for the concept, design, data collection, statistical analysis, interpretation of results and writing up of the manuscript.	80%

The following co-authors contributed to the work. Co-authors who are students at Monash University must also indicate the extent of their contribution in percentage terms:

Name	**Nature of contribution**	**Extent of contribution (%) for student co-authors only**
A/Prof. R Wolfe	Provided statistical advice and contributed to drafting of the manuscript	N/A
Prof. PA Cameron	Contributed to the design and drafting of the manuscript	N/A
A/Prof. MD Richardson	Contributed to drafting the manuscript	N/A
A/Prof. R Page	Contributed to drafting the manuscript	N/A
A/Prof. A Bucknill	Contributed to drafting the manuscript	N/A
A/Prof. BJ Gabbe	Contributed to the study design, analysis, writing and drafting of the manuscript	N/A

Candidate's Signature	[redacted]	**Date** 11/8/2011

Declaration by co-authors

The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors.
(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
(4) there are no other authors of the publication according to these criteria;
(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location(s)	Department of Epidemiology and Preventive Medicine, Monash University, Alfred Campus

	Co-authors signatures	Date
Signature 1	[redacted]	19|9|11
Signature 2	[redacted]	19/9/11
Signature 3	[redacted]	13 / 9 /11
Signature 4	[redacted]	18Aug 2011.
Signature 5	[redacted]	25/8/11
Signature 6	[redacted]	11 Aug 2011

Return to pre-injury health status and function 12-months after hospitalisation for sport and active recreation related orthopaedic injury.

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Abstract

Background: Sport and active recreation injuries can require hospitalisation with potentially serious long-term consequences. Despite this, few studies have examined the long-term outcomes of these injuries.

Purpose: To establish whether patients hospitalised with orthopaedic sport and active recreation injuries, have returned to their pre-injury levels of health status and function, 12-months post-injury and to identify factors associated with poor outcomes.

Study Design: Cohort study with retrospective assessment of pre-injury status and prospective assessment of outcome at 12-months post-injury.

Methods: Adults with orthopaedic sport and active recreation injuries admitted to two major trauma centres and a regional hospital, and captured by the Victorian Orthopaedic Trauma Outcomes Registry, were recruited to the study. Pre-injury and 12-month outcomes were assessed using the 36-item Short Form Health Survey and the extended Glasgow Outcome Scale. Differences in pre- and post-injury SF-36 scores were assessed for all participants and for key sporting groups. Demographic, injury, hospital and physical activity variables were assessed for associations with outcome using multivariate linear regression.

Results: In total 324 participants were recruited and 98% were followed-up at 12-months post-injury. At 12-months, participants reported a mean 7.0 point reduction in physical health (95%CI 5.8, 7.8) and a 2.1 point reduction in mental health (95%CI 1.2, 3.0), with 58% (95%CI 52.6%, 63.4%) reporting reduced function. Sporting group (p=0.001), Injury Severity Score >15 (p=0.007) and high pre-injury vigorous activity levels (p=0.04), were related to poorer physical health outcomes through multivariate analysis. Presence of a co-morbid medical condition (p=0.03) or pre-morbid psycho/behavioural condition (p=0.003) were associated with poorer mental health outcomes.

Conclusions: At 12-months post-injury, most patients reported large reductions in physical health and reduced function. This information is important for furthering our understanding of the burden of sport and active recreation injury and setting priorities for treatment and rehabilitation.

Key Words: Sport and recreation; injury; outcome, health status, health related quality of life, function

Introduction

Participation in sport and active recreation is widely encouraged as part of global public health initiatives to increase population physical activity levels [110]. Though the health benefits of physical activity are well established [3], the long-term consequence of the associated injury risks are rarely acknowledged in the evaluation and promotion of physical activity [110].

Most of the literature aimed at describing the burden of sport and active recreation injuries has focused on injury rates, numbers and severity [30, 34, 35, 47]. Accurate collection of this type of information is important, however effective injury control and prevention requires that the long-term impact of these injuries, are also monitored [85]. Despite this, few studies have measured long-term outcomes of seriously injured general sport and active recreation participants.

Most studies reporting long-term outcomes relating to health status and function in adult sport and active recreation populations have been limited to specific injury types [111-116], specific sports[117], or both[118, 119]. Only three studies to date have reported long-term outcomes for general sport and active recreation populations [55, 56, 120]. These papers reported the percentage of patients still experiencing disability, using cut-offs and outcome measures not validated in, or suitable for, sport and active recreation populations. Consequently these studies are likely to have underestimated the impact of injury in this group [121].

The aim of this study was to quantify the 12-month outcomes of serious sport and active recreation-related injury, including return to pre-injury levels of health and function. A further aim was to identify sporting groups with poor outcomes and investigate factors related to poor outcomes.

Methods

Setting

Eligible participants were identified from the Victorian Orthopaedic Trauma Outcomes Registry (VOTOR). At the time of this study, VOTOR collected detailed demographic and injury information about all patients with orthopaedic injuries, admitted to two adult metropolitan hospitals and one regional hospital in Victoria, Australia. The metropolitan hospitals are the two adult, major trauma services for the state of Victoria and the regional service is one of five regional trauma services, designated in the State trauma system.

Patients were included on VOTOR if they were admitted to one of the participating hospitals with an orthopaedic injury requiring a length of stay >24 hours. Patients admitted for pathological fracture related to metastatic disease are excluded from VOTOR.

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Participants

Patients admitted to the two major trauma services and injured between March 2008 and March 2009, and patients admitted to the regional hospital and injured between June 2008 and June 2009, were included in the study. The different data collection periods for the hospitals were related to the separate ethics approval timeframes.

Data for participants aged between 18 and 74 years of age, were extracted from the VOTOR database if they met one or more of the following criteria:

I. Activity at the time of injury coded as either "sports" or "leisure".
II. Place of injury coded as either "athletics and sports area" or "place for recreation".
III. Cause of injury coded as "motorcycle driver", "motorcycle passenger", "pedal cyclist" or "horse related".

In cases where the VOTOR activity, place or cause code were not specified, the International Classification of Diseases 10^{th} revision (ICD-10) Chapter XX codes and, where available, the text narrative of the injury event were checked. This ensured that all relevant coded cases were identified. Activities defined as sport and active recreation by the International Classification of External Causes of Injuries (ICECI) [16] were included in the study. Hence off-road motor sports such as motor-cross, trail-biking or four-wheel driving were included but on-road motorbike riding was excluded. Both on-road and off-road cycling were included. Walking was only included if the activity or place code met the previously mentioned criteria and if at the first participant interview, walking was confirmed as being performed specifically for exercise.

Participants who were not capable of providing informed consent due to cognitive or language difficulties, or who were homeless, in prison or had an overseas address were excluded from the study. Approval for the project was granted by the Human Research Ethics Committees of each of the participating hospitals, and the VOTOR steering committee.

Procedures

All eligible patients were first contacted by mail. They were sent a participant information sheet and informed that they would be contacted by telephone within the next two weeks. Patients were given a phone number to call if they did not wish to be contacted by the research team. At the first telephone interview, informed consent was obtained, the activity at the time of injury was confirmed, and retrospective pre-injury data were collected.

Participants were contacted by telephone again at 12-months post-injury. At this interview, the VOTOR 12-month follow-up assessment was completed, [86] along with additional questionnaire items specific to this study.

The ICD-10 codes were used to identify pre-existing co-morbidities and in-hospital complications:

Chapters I-III Codes A00-E90 and Chapters VI-XIV codes G00-N99 identified a physical disease

Chapter V codes F00-99 classified a mental or behavioural disorder including drug or alcohol addictions

Chapter XIX codes T80-T88 and Chapter XX codes Y40-Y84 identified complications due to surgical or medical care.

Questionnaire Measures.

The choice of questionnaire-based measures used in this study was informed by a review.

Short Form 36 (SF-36) Version 2.

The SF-36 is a health status measure that contains 36 items measured over eight domains. Items cover a range of physical activities from self-care to participation in strenuous sports, and covers areas relevant to a sport and active recreation population. The SF-36 provides separate subscale scores, as well as a mental component summary (MCS) score and a physical component summary (PCS) score. A higher score indicates better health. Though not specifically validated in a general sport and active recreation population, it has been widely used in a number of studies containing sport and active recreation participants [112, 122-124]. The standard SF-36 was administered at the first participant interview with reference to their health in the 4-weeks prior to injury. The standard form is recommended in situations where the survey is administered only once or there are more than 4-weeks between administration periods. The acute version was used for the 12-month follow-up interview to maintain consistency with the VOTOR follow-up procedures. The two versions have a very high level of comparability and are suitable for comparing time points in a single study [101].

Glasgow Outcome Scale Extended (GOSE)

The GOSE is a global measure of function covering a range of domains including social and leisure activities. The GOSE is scored by allocating patients to one of eight broad categories using a standardised structured interview [102]. The 8 categories are: Dead, Vegetative State, Lower Severe Disability, Upper Severe Disability, Lower Moderate Disability, Upper Moderate Disability, Lower Good Recovery, and Upper Good Recovery. Those without any injury related disability are assigned to the "Upper Good Recovery" category. Its focus on return to pre-injury status makes it suitable for a sport and active recreation population [121].

The Short International Physical Activity Questionnaire (IPAQ)

The IPAQ asks about time spent doing vigorous activity, moderate activity and walking in a typical week across the domains of work, home and sport and recreation. The IPAQ was designed as a population surveillance tool and has been shown to have acceptable measurement properties in many settings. Scores were calculated in Metabolic Equivalents (METS) where 1 MET is 1 kcal/kg/hour or the resting metabolic rate during quiet sitting, and were expressed as MET minutes per week. Truncated scores were used in the analyses, in which a maximum of three hours of activity per day could be scored for each category to minimise the effect of over-estimation [103].

Variables and Data Sources

Multiple data sources were used to obtain the variables included in the study. Demographic and injury variables extracted from the VOTOR database for this study were: age, gender, pre-existing medical conditions, pre-existing mental health conditions, in-hospital complications, Injury Severity Score (ISS) and type of injury. Variables obtained at the initial study interview were: sport and recreation activity at the time of injury, retrospective pre-injury SF-36 data and retrospective pre-injury IPAQ data. Variables collected from participants as part of the VOTOR follow-up procedures and extracted for this study were occupation, pre-injury work status, highest level of education attained, GOSE (12-months post-injury) and the Short Form-12 (SF-12) version 1 (12-months post-injury). Additional information collected at the 12-month follow-up for this study were: the SF-36 and the IPAQ.

Data Analysis

Eligible participants recruited to the study were compared to those not recruited to the study using chi-squared tests for categorical variables and Mann-Whitney U tests for continuous variables. High follow-up rates meant that it was not feasible to compare those followed-up at 12-months post-injury and those lost to follow-up. Participants were categorised into broad sporting groups, according to the (ICECI) [16].

Missing data for the SF-36 were estimated using the “half scale rule” in which the missing item is given the average score of the completed items in the same scale [101]. The pre- and post-injury PCS, MCS and subscale scores were calculated according to the published guidelines using the norm-based scoring system [101]. Participants were classified as “fully recovered " (GOSE=8, upper good recovery) or not fully recovered (GOSE score less than 8) To explore the potential for recall bias to impact pre-injury SF-36 scores, pre-injury and post-injury scores were compared for participants that had reported a full recovery [100].

Univariate linear regression analysis was used to assess differences between pre- and post-injury SF-36 subscale and summary scores. The relationships between changes in SF-36 summary scores and demographic and injury variables were also investigated using univariate linear regression. Multivariate linear regression analyses were used to identify the combined impact of baseline variables on outcome at 12-months post-injury for the PCS and the MCS. Independent variables used in the multivariate analyses were sporting group, age, sex, education level, ISS>15, injury patterns, pre-existing health problems, pre-existing mental health problems, in-hospital complications and days spent engaging in pre-injury vigorous activity. These variables were chosen as they are considered to impact on outcomes in sport and active recreation populations [56, 120].

Stata (Version 10, StataCorp, College Station, TX) statistical software was used for all analyses and a p-value of <0.05 was considered significant. A three point difference in pre- and post-injury summary scores was considered clinically significant [101]. Based on this, with a standard deviation of 10 [101], a minimum sample size of 117 was required to detect a clinically significant difference in pre- and post-injury SF-36 scores with a power of 0.9. Additional participants were recruited to allow data collection over a 12-month period for each hospital, to account for seasonal variations in sporting activities and to allow for an 80% 12-month follow-up rate.

Results

Recruitment and follow-up

During the study period 455 potentially eligible patients were identified from VOTOR, of which 432 were confirmed eligible for the study. Of these, 49 (11%) were not able to be contacted, 37 (9%) had incorrect contact details or were overseas at the time and 22 (5%) chose not to participate, resulting in 324 (75%) being recruited (Figure 7.1). The majority n=317 (98%) were followed up at 12-months. Of those lost to follow-up, four declined to undertake the 12-month interview and three were unable to be contacted (Figure 7.1).

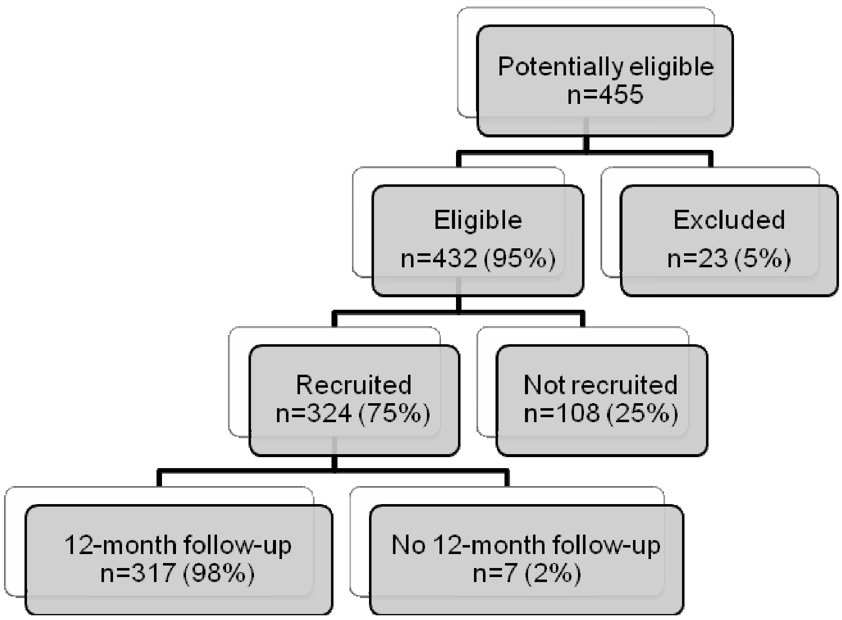

Figure 7.1. Flow diagram identifying participants meeting inclusion criteria, recruited to the study, and followed up at 12-months post-injury.

The median time between injury and initial interview was nine months (range: 7-11 months) and the median (Inter Quartile Range (IQR)) time between injury and final follow-up was 12-months (11.6-12.4 months). All participants were followed up between 11 and 14 months except for one patient who was overseas and not followed up until 17 months post-injury. This participant was included in the analyses as further gains in recovery are considered to be minimal between 12- and 18-months post-injury [125]. There were no significant differences between eligible patients recruited to the study and eligible participants not recruited to the study for the key demographic variables of employment status (p=0.23) and injury severity (p=0.14). However, a higher proportion of non-participants were male (p=0.01), younger (p<0.001), and less educated (p=0.03) than participants.

Demographic Characteristics

The majority of participants were male (73%) and the median (IQR) age was 39 (29-51) years. Most were employed or studying prior to injury, and 60% reported a university-level of education (Table 7.1). Participants were highly active prior to injury with 93% participating in vigorous activity and 92% categorised as performing high levels of activity according to the IPAQ (Table 7.1). A summary of the activities in which participants were injured is provided in Table 7.2. The activity with the most injured participants was cycling (35%) followed by off-road motorcycle riding (15%).

Table 7.1. Demographics, pre-injury and in-hospital details of VOTOR sport and active recreation population followed up at 12-months post injury (n=317)

Variable		All sports n=317	Wheeled n=128	Motor n=55	Team ball sports n=45	Equestrian n=34	Other n=55
Sex	% Male	73	73	91	84	29	73
Age	Mean (SD)	40(13)	45(13)	35(12)	28(8)	42(13)	42(13)
Education Level *	%						
	Degree+	34	53	14	26	18	26
	Diploma	27	26	29	28	30	24
	High school	18	11	19	30	21	22
	Did not finish high school	21	10	39	16	30	30
Pre-injury METS '1000/week	Mean (SD)	7.6(4.2)	6.9(3.8)	9.2(4.3)	7.2(4.0)	8.7(4.7)	7.4(4.6)
Days/week of vigorous activity	% >3 days/week	65	69	67	67	65	55
Pre-injury SF-36	Mean (SD)						
	PCS	58.5(4.0)	58.9(3.7)	58.4(3.9)	58.8(2.2)	57.0(4.7)	58.2(5.0)
	MCS	55.0(6.9)	54.3(6.5)	56.6(4.6)	56.1(4.4)	56.5(3.8)	53.1(10.9)
Injury Profile	%						
	Isolated upper limb	23	34	7	29	15	16
	Spinal	8	6	4	4	27	9
	Isolated lower limb	28	18	24	51	15	46
	Orthopaedic plus other	23	27	38	0	27	16
	Multi-orthopaedic	18	16	27	16	18	13
Injury Severity Score (ISS)>15*	% ISS>15	19	21	35	0	24	9
Co-morbidities	% At least one	19	17	35	7	24	16
Mental health disorder	% Yes	7	8	6	0	15	4
In-hospital complications	% Yes	9	6	18	4	9	7

*Data missing n=2

Table 7.2 sport and active recreation activities resulting in injuries of VOTOR population recruited to the study and followed up at 12-months post-injury (n=317)

Sport or recreation activity	No.	%
Wheeled	**128**	**40.4**
Cycling	112	35.3
Mountain biking	10	3.2
Other wheeled	6	1.9
Motor	**55**	**17.4**
Motor bike	49	15.5
Quad bike	3	0.9
Other Motor	3	0.9
Team ball sports	**45**	**14.2**
Australian football	20	6.3
Rugby union	2	0.6
Soccer	9	2.8
Basketball	7	2.2
Netball	3	0.9
Touch football	3	0.9
Equestrian	**34**	**10.7**
Horse riding	32	10.1
Other Equestrian	2	0.6
Other	**55**	**17.4**
Total	317	99.5

Recall Bias

The majority (58%, 95%Confidence Interval (CI): 52.6%, 63.4%) of participants still reported some degree of disability at 12-months, according to the GOSE. Those that reported a full recovery (n=133) had a statistically but not a clinically significant difference between their pre-injury and post-injury mean PCS scores (PCS difference: 1.2 points, 95%CI: 0.6, 1.7) and similar pre- and post-injury mean MCS scores (MCS difference: 0.4 points, 95%CI: -0.9, 0.7). There were similar mean pre-injury PCS scores of those that had fully recovered at 12-months post-injury and those that had not. The same was true for mean MCS scores.

Health Status Outcomes at 12-months

There was a seven point reduction in the mean PCS score at 12-months post-injury (95%CI: 5.8, 7.8) and a 2.5 point reduction in mean MCS scores (95%CI: 1.2, 3.0), compared to pre-injury scores. There were significant reductions in all of the SF-36 sub-scale scores, with the "role physical" and "bodily pain" subscales reporting the greatest reductions (each 11 points) (Table 7.3).

Table 7.3. Short Form-36 summary scale and subscale results for VOTOR sport and active recreation population followed up at 12-months. Means and standard deviations reported for the pre- and post-injury scores

	Physical Component Summary	Mental Component Summary	SF-36 subscales							
			Physical function	Role physical	Bodily pain	General health	Vitality	Social function	Role emotional	Mental health
All sports n=317										
Pre-injury	58.5(4.0)	55.0(6.9)	56.5(2.4)	56.2(3.5)	59.5(5.8)	59.6(5.8)	59.2(7.6)	55.7(5.0)	54.8(4.5)	55.2(7.4)
Post-injury	51.5(9.7)††	52.5(10.0)††	51.9(7.7)†	49.8(10.2)	52.4(9.8)††	55.1(9.5)††	52.3(10.2)†	51.9(9.9)†	53.3(7.4)†	52.3(9.1)†
Team ball sports n=45										
Pre-injury	58.8(2.2)	56.1(4.4)	56.9(0.7)	56.6(1.1)	60.7(4.2)	59.8(4.1)*	59.8(6.6)	56.7(0.8)	55.7(1.2)*	56.4(6.7)*
Post-injury	55.5(5.1)	54.7(5.4)	54.9(3.8)	53.9(6.4)	56.7(6.9)	58.0(6.6)*	54.7(7.4)	54.5(6.4)	54.6(4.5)*	55.6(5.7)*
Cycling n=128										
Pre-injury	58.9(3.7)	54.3(6.5)	56.5(2.0)	56.4(2.8)	59.5(5.5)	60.0(6.2)	58.7(6.8)	55.4(5.8)	54.6(4.2)	54.4(7.0)
Post-injury	53.4(7.3)	52.5(9.1)	53.6(5.0)	51.0(8.9)	53.4(8.4)	55.2(8.5)	53.2(9.3)	53.4(8.1)	53.2(7.2)	51.6(9.2)
Off-road motor sports n=55										
Pre-injury	58.4(3.9)	56.6(4.6)	56.6(1.4)	56.1(4.5)	60.2(5.4)	60.3(5.8)	61.1(7.3)	55.9(4.3)	55.5(1.8)	57.2(5.8)
Post-injury	46.7(10.8)	51.4(10.7)	48.2(10.1)	44.9(12.6)	47.3(11.5)	52.3(10.9)	49.9(12.0)	46.4(13.6)	52.1(8.6)	50.5(11.1)
Equestrian sports n=34										
Pre-injury	57.0(4.73)	56.4(3.8)	56.0(4.4)	55.9(2.5)	57.2(7.3)	59.9(5.7)	58.6(7.6)	56.5(1.3)	55.7(0.9)*	56.6(4.4)
Post-injury	47.3(15.7)††	49.1(16.7)††	48.6(11.2)†	46.6(12.9)	50.9(11.9)††	55.9(10.7)††	50.0(11.0)†	48.7(12.7)†	52.8(10.7)†*	52.8(7.5)†
Other sports n=55										
Pre-injury	58.2(5.0)	53.1(10.9)	56.3(3.3)	55.7(5.2)	59.1(6.5)	57.5(8.0)	58.1(9.7)	54.9(6.8)*	53.3(8.2)*	53.3(10.4)*
Post-injury	51.3(8.9)	53.9(8.3)	51.3(8.0)	50.3(9.0)	52.9(9.9)	54.5(10.7)	52.4(11.3)	53.7 (7.5)*	53.8(6.1)*	52.9(9.5)*

*P-value>0.05 (not statistically significant) for univariate linear regression comparison of pre- and post-injury scores.
†Data missing n=1
††Data missing n=2

Univariate analyses identified sporting group ($p<0.001$), having an ISS greater than 15 ($p<0.001$), injury type ($p=0.005$), pre-existing medical problems ($p=0.01$), in-hospital complications ($p=0.008$) and performing vigorous activity >3 days a week ($p=0.009$) as being associated with a poorer PCS outcome. Sporting group ($p=0.01$), ISS>15 (0.004), injury type ($p=0.02$), having a pre-existing medical condition ($p=0.002$), and having a pre-existing psycho/behavioural problem ($p<0.001$) were associated with poorer MCS scores.

After adjusting for other key factors, sporting group was associated with a lower PCS score, with those injured during equestrian or motor sports having significantly lower scores than those injured during ball sports. Participants with an ISS>15, and those participating in vigorous activity more than 3 days a week prior to injury, compared to those participating less than 4 days a week, were also associated with poorer PCS outcomes (Table 7.4). Having a co-morbid medical, or psycho/behavioural condition, was associated with a poorer MCS outcome through multivariate analysis (Table 7.4).

Table 7.4. Multivariate linear regression results for Short Form-36 Physical Component Summary (PCS) score outcomes and Mental Component Summary (MCS) score outcomes for VOTOR sport and active recreation population followed up at 12-months

Variable		PCS Coefficient (95% CI)	P-value	MCS Coefficient (95% CI)	P-value
Sporting group	Team ball (ref)				
	Wheeled	-1.7(-5.2, 1.7)	0.001	-0.1(-3.0, 2.9)	0.2
	Motor	-7.1(-10.8, -3.4)		-1.9(-5.9, 1.3)	
	Equestrian	-5.2(-9 7, -0.7)		-0.5(-4.4, 3.3)	
	Other	-3.6(-7.2, 0.02)		1.8(-1.3, 4.9)	
Age (per year)		0.00(-0.09, 0.09)	1.0	0.01(-0.08, 0.07)	0.9
Sex	Male (ref)				
	Female	-0.3(-2.6, 2.0)	0.8	0.7(-1.3, 2.7)	0.5
Level of education	Degree+ (ref)				
	Diploma	1.6(-1.0, 4.2)	0.4	-0.3(-2.5, 2.0)	0.3
	Finished high school	-0.7(-3.8, 2.2)		0.3(-2.3, 2.9)	
	Did not finish high school	0.1(-2.8, 3.1)		-2.2(-4.7, 0.4)	
Injury severity score (ISS)	ISS ≤15 (ref)				
	ISS >15	-4.9(-8.5, -1.4)	0.01	0.2(-3.2, 2.9)	0.9
Injury Profile	Isolated upper limb (ref)				
	Spinal	-2.4(-6.5, 1.8)	0.2	-0.9(-4.5, 2.6)	0.3
	Isolated lower limb	-1.8(-4.6, 1.0)		0.8(-1.6, 3.2)	
	Orthopaedic plus other	0.8(-3.0, 4.5)		-0.8(-4.0, 2.4)	
	Multiple Orthopaedic	-3.0(-6.2, 0.2)		-0.4(-3.1, 2.4)	
Behavioural disorder	No (ref)				
	Yes	0.1(-4.2, 4.3)	1.0	-5.7(-9.4, -1.9)	0.003
Disease diagnosis	No (ref)				
	Yes	-0.4(-3.1, 2.3)	0.8	-2.6(-4.9, -0.3)	0.03
Complications	No (ref)				
	Yes	-1.8(-5.4, 1.7)	0.3	2.1(-0.9, 5.2)	0.2
Total METS '000 (1 MET is the resting metabolic rate)		-0.1(-0.4, 0.2)	0.4	0.0(-0.2, 0.3)	0.9
Vigorous Days	0-3 (ref)				
	>3	-2.5(-4.9,-0.1)	0.04	-0.8(-2.8, 1.3)	0.5

Discussion

This cohort study described the impact of serious sport and active recreation injuries on health status and function at 12-months post-injury. At 12-month post-injury, there was a large reduction in physical health and over half of the participants reported reduced function. Being injured during motor sports or equestrian sports, having an ISS greater than 15 and participating in vigorous activities more than three times a week were found to be important predictors of a poorer physical outcome.

This study confirmed the findings of others that injured sport and active recreation participants tend to be young, healthy members of society, [56, 120] with high levels of employment and education. Hence the poor outcomes reported in this study are concerning. Injury in this group can have substantial consequences in terms of lost work time, productivity and reduced physical activity levels. Content-based interpretation of the SF-36 uses population data to predict the percentage of people that will have limitations in activities or roles based on their subscale and summary scores [101]. Using this method of interpretation, our study participants who had not recovered at 12-months post-injury had reductions in PCS that equated to a 9.2% risk of job loss and 9.8% risk of hospitalisation over the following six months. The large impacts on participants "role physical" and "bodily pain" subscale scores, suggest that many were still experiencing reduced productivity at work and home, and were having difficulty performing heavy activities. Social functioning was the most affected of the mental health subscales, highlighting the relationship between physical roles and social networks in this group [57, 126]. These outcomes are likely to have large economic and social costs at both an individual and whole of society level, especially when viewed in the context of the high pre-injury function and health of this group.

There is little known about factors associated with poor outcomes in those injured during sport and active recreation. Previous studies using multivariate analyses found gender and sporting group, [56] or increasing age and injury types [120] to be associated with poorer outcomes. These are consistent with the results of this study in which sporting group and having an ISS greater than 15 were associated with poorer physical health outcomes, even when additional variables such as pre-injury health status, pre-injury physical activity levels and co-morbidities were accounted for. Unlike previous studies, our results did not find age to be associated with pre-injury health or poorer outcome, despite 25% of participants being over 50. This suggests that for those able to remain physically active with increasing age, the long term consequences of injury are no greater than for younger participants.

An unexpected finding was that participating in vigorous activity more than three days a week was associated with reduced physical health at 12-months post-injury. These results are inconsistent with studies involving whiplash and ACL deficient patients [127, 128] in which high pre-injury physical activity levels were associated with improved outcomes. One study however found that those in the highest category of pre-injury physical activity did not do as well as those with more moderate levels of pre-injury activity [127]. One explanation is that patients that are highly active prior to injury require a higher level of function to fully resume their pre-injury activities. Such outcomes are likely to be more apparent when patient oriented measures such as the SF-36 and GOSE, which rely on patients' perceptions of their outcome or provide reference to their pre-injury status, are used [121]. These results have important implications for injury rehabilitation in regards to treatment goals and resource allocation, if we are to return patients to their pre-injury status. The study results also highlight the importance of using patient reported measures suitable for active populations when assessing outcomes.

The study identified that motor and equestrian sports are associated with poorer outcomes when compared to other sporting groups. These sports have also been shown to have a higher incidence of injury [41, 129]. Despite these findings, there have been few attempts to implement injury prevention strategies specific to these sports[130, 131]. The severity and patterns of injuries sustained by equestrian and motor sports participants potentially explains some of the poorer outcomes of these groups. The multivariate results however suggest that there are characteristics inherent to these sports, not accounted for in our analyses that contributed to poorer outcomes. Features shared by these activities that were not accounted for in the analyses, are the location (often performed in remote bushland or rural settings), and the high speeds and jumping manoeuvres often employed. These factors may impact on the specific nature of the injuries sustained and their management. Further investigation into the impact of the injury setting, injury mechanisms, pre-hospital care and access to rehabilitation on outcomes in these groups is warranted.

The strengths of this study were the high follow-up rate, the use of outcome measures identified as appropriate for a sport and active recreation population and the inclusion of pre-injury data. There are, however some limitations that need to be addressed. Serious injury is uncommon and occurs without warning, making the collection of prospective pre-injury data difficult. The retrospective pre-injury levels of physical and mental health reported by study participants were high when compared to age-matched population normative data[132]. This is consistent with previous research examining SF-36 scores in young athletic [58, 126] and physically active populations [97, 132] . Nevertheless the retrospective collection of pre-injury data is subject to recall bias and response shift. Response shift is a change in the internal standards, values or conceptualizations by which one judges health [99]. In the occurrence of a traumatic event such as injury, past and current perceptions of patient health may be altered. In an attempt to quantify aspects of recall bias and response shift, the pre- and post-injury PCS and MCS scores were compared with fully recovered patients (as measured by the GOSE). Also, the pre-injury scores of those who had recovered and those who had not recovered were compared. The lack of differences in these group comparisons suggest that the role of recall bias and response shift are likely to be small and not sufficient to negate the large seven point difference in PCS scores reported in this study.

Eligible patients not recruited to the study were more likely to be young, poorly educated and male implying that the study results may not generalise as well to this group. The generalisability of the findings is also limited by VOTOR including only orthopaedic injuries. Although most sport and active recreation injuries are orthopaedic, [41] the results cannot be extrapolated to injuries such as isolated head or internal injuries. Furthermore, the inclusion of only hospitalised injuries meant that sports that were likely to cause fractures or multiple injuries were over-represented. Nevertheless, there were still a number of isolated muscle and ligament injuries in the study and the inclusion of a large regional hospital increased the range of injuries included in this study compared to previous studies [56, 120].

Conclusion

This study investigated the 12-month outcomes of hospitalised orthopaedic sport and active recreation injuries. Most participants had not fully recovered and there were large deficits in physical health at 12-months post-injury. Those with the most severe injuries, those who engaged in high levels of vigorous activity prior to injury and those injured during motor and equestrian sports reported poorer outcomes. The information gained from this research is important for furthering our understanding of the burden of sport and active recreation related injury, identifying target areas for injury prevention and setting priorities for treatment and rehabilitation. Sport and active recreation injuries need to become a priority for injury prevention, research and implementation if we are to maintain the health and activity levels of those who are already physically active.

Summary

This chapter has furthered our understanding of the burden of sport and active recreation injuries. The subscales contained in the SF-36 addressed, either directly or indirectly, many of the aspects of the LOAD framework relevant to a sport and active recreation population. Outcomes related to pain, social function, physical capacity, mental health and pain were addressed and the impact of injury these were reported. This paper has provided important insights into the degree to which sport and active recreation injuries impact on multiple aspects of participants' lives.

This paper has also demonstrated the effectiveness of both the GOSE and SF-36 as outcome measures in this population and has highlighted the appropriateness of using patient perceived measures such as these in sport and active recreation populations. This chapter has successfully addressed aim number three of the thesis and confirmed the choice of outcome measures identified as part of aim number two.

Chapter Eight: The impact of sport and active recreation injuries on physical activity levels at 12-months post-injury.

Overview

The change in physical activity levels experienced, at 12-months post-injury, by those that are seriously injured during sport and active recreation participation are reported in this chapter. The published paper in this chapter is from the study reported in Chapter Seven, but focuses on the physical activity outcomes. The implications of these results are discussed from a public health perspective and highlight the need for strong injury prevention policy to accompany physical activity promotion. This is the first study to quantify the extent to which physical activity levels are affected by injury in physically active populations. The following manuscript has been submitted for publication.

Monash University

Declaration for Thesis Chapter Eight

Andrew NE, Wolfe R, Cameron PA, Richardson, M, Page, M Bucknill, A and Gabbe, BJ. The impact of sport and active recreation injuries on physical activity levels, 12-months post-injury. Submitted

Declaration by candidate

In the case of Chapter Eight, the nature and extent of my contribution to the work was the following:

Nature of contribution	**Extent of contribution (%)**
Principle author responsible for the concept, design, data collection, statistical analysis, interpretation of results and writing up of the manuscript	80%

The following co-authors contributed to the work. Co-authors who are students at Monash University must also indicate the extent of their contribution in percentage terms:

Name	**Nature of contribution**	**Extent of contribution (%) for student co-authors only**
A/Prof. R Wolfe	Provided statistical advice and contributed to drafting of the manuscript	N/A
Prof. PA Cameron	Contributed to the design and drafting of the manuscript	N/A
A/Prof. MD Richardson	Contributed to drafting the manuscript	N/A
A/Prof. R Page	Contributed to drafting the manuscript	N/A
A/Prof. A Bucknill	Contributed to drafting the manuscript	N/A
A/Prof. BJ Gabbe	Contributed to the study design, analysis, writing and drafting of the manuscript	N/A

Candidate's Signature	[redacted]	**Date** 11/8/2011

Declaration by co-authors

The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors.
(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
(4) there are no other authors of the publication according to these criteria;
(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location(s)	Department of Epidemiology and Preventive Medicine, Monash University, Alfred Campus

	Co-authors signatures	Date
Signature 1	[redacted]	19/9/11
Signature 2		19/9/11
Signature 3		13/9/11.
Signature 4		18 Aug 2011
Signature 5		25/8/11
Signature 6		11 Aug 2011

The impact of sport and active recreation injuries on physical activity levels at 12-months post-injury

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Abstract

Objectives: The aim of this study was to evaluate the impact of serious sport and active recreation injury on 12-month physical activity levels.

Methods: Adults admitted to hospital with sport and active recreation-related injuries, and captured by the Victorian Orthopaedic Trauma Outcomes Registry were recruited to the study. Changes between pre-injury and 12-month post-injury physical activity, was assessed using the short International Physical Activity Questionnaire (IPAQ). Independent demographic, injury and hospital variables were assessed for associations with changes in physical activity levels, using multivariate linear regression.

Results: 324 patients were recruited, of which 98% were followed-up at 12-months. Mean short IPAQ scores decreased from 7,650 METS (95% CI: 7,180, 8,120) pre-injury to 3,880 METS; (95% CI: 3,530, 4,250) post-injury, independent of functional recovery. Education level and occupation group were the only variables independently associated with changes in physical activity levels post-injury.

Conclusions: Sport and active recreation injuries lead to significant reductions in physical activity levels. Hence, the prevention of sport and active recreation injuries is important when considering promotion of activity at a population level.

Introduction

Physical inactivity is the fourth leading risk factor for global mortality and an independent risk factor for diabetes, cardiovascular disease and a number of cancers [3]. Consequently, promoting and maintaining population physical activity levels has become a major global public health priority [110]. For many, participation in sport and active recreation activities is an important avenue for achieving health enhancing physical activity, especially as other domains of life, such as work and home become more sedentary [10]. Unfortunately participation in sport and active recreation is not without the risk of injury.

From a public health perspective, it is important to consider the negative health costs of sport and active recreation injuries against the positive health gains associated with sport and active recreation participation. Negative injury consequences include not only those that impact on the individual and society through disability and loss of health [56, 120], but the long-term health losses associated with the potential for injury to disrupt sport and active recreation participation and reduce physical activity levels [133, 134]. Despite this, the extent to which sport and active recreation injuries impact on participants' physical activity levels is unknown.

The aim of this study was to quantify the extent to which participants, seriously injured during participation in sport and active recreation activities, had returned to their pre-injury levels of physical activity, at 12-months post-injury. A secondary aim was to identify factors associated with reduced physical activity levels in this group.

Methods

Setting

Participants were recruited from the Victorian Orthopaedic Trauma Outcomes Registry (VOTOR). This registry routinely collects demographic, injury and follow-up information about patients admitted to participating hospitals with orthopaedic injuries and requiring a length of stay greater than 24 hours. Patients with pathological fractures related to metastatic disease are excluded from VOTOR. At the time of this study, VOTOR collected information from the two adult major trauma services (Level 1 trauma centre equivalent) and one of five regional trauma services for the state of Victoria, Australia.

Participants

Patients aged 18 to 74 years were recruited from each participating hospital. To account for seasonal variations in sport and active recreation activities, recruitment occurred at each site over a 12-month period. Potential participants injured between March 2008 and March 2009 were recruited from the two major trauma hospitals, while those injured between June 2008 and June 2009 were recruited from the regional hospital. Ethics approval was granted by each of the participating hospitals and the study was approved by the VOTOR steering committee. The variation in data collection periods for the hospitals was related to different ethics approval timeframes.

Only injuries that occurred as a result of participating in the sport and active recreation activities outlined in the International Classification of External Causes of Injuries (ICECI), [16] were included in the study. Hence, off-road motor sports were included but on-road motorcycle riding was excluded. Both on-road and off-road cycling were included. Walking was only included if it met the specifications outlined in the ICECI ie. power walking and walking for exercise.

Eligible participants were identified from the VOTOR database if they met one or more of the following criteria.

i. Activity at the time of injury coded as either “sports” or “leisure”.
ii. Place of injury coded as either “athletics and sports area” or “place for recreation”.
iii. Cause of injury coded as “motorcycle driver”, “motorcycle passenger”, “pedal cyclist” or “horse related”.

Where available, the International Classification of Diseases 10th revision (ICD-10) Chapter XX codes and text narrative of the injury event were also checked to ensure that all relevant cases were identified. Once identified cases were screened to make sure they met the ICECI inclusion criteria, outlined above and the activity at the time of injury was confirmed, in relation to these criteria, at the first participant interview. Participants were also excluded if they were not capable of providing informed consent due to cognitive or language difficulties were homeless, in prison, or had an overseas address.

Procedures

Once identified from the database, eligible participants were sent an information sheet and provided with a telephone number to call if they did not wish to be contacted by the research team. If the participant had not refused participation within 7 to 14 days of sending the information, they were contacted for the first telephone interview.

At the first interview, the interviewer explained the purpose of the study and participants provided verbal consent. Once consent was obtained, the activity at the time of injury was confirmed, and retrospective pre-injury physical activity data was collected. Participants were contacted by telephone again at 12-months post-injury to complete the VOTOR 12-month follow-up assessment and provide additional physical activity information.

Questionnaires

The choice of questionnaire-based measures used in this study was informed by a review [121]. The following questionnaires were chosen based on this review.

(i) The International Physical Activity Questionnaire (IPAQ), short version

The short IPAQ asks about time spent doing vigorous activity, moderate activity and walking, in a typical week, across the domains of work, home and sport and recreation. The short IPAQ was designed primarily as a population surveillance tool but has been used as an evaluation tool in orthopaedic populations [135, 136]. Validity has been assessed against accelerometers or motion detecting devices with only fair agreement (intraclass correlation coefficient (ρ) = 0.30-0.39) [137, 138], and against physical activity questionnaires and physical activity logs with good convergent validity ($\rho \geq 0.5$) [138, 139]. The “usual week” reference period was used for recall of physical activity [140]. Processing and analysis of the short IPAQ data was performed according to the published guidelines [103].

(ii) Glasgow Outcome Scale Extended (GOSE)

The GOSE is a global measure of function and is scored by allocating patients to one of eight broad categories [141]. The eight categories are: (i) dead; (ii) vegetative state; (iii) lower severe disability; (iv) upper severe disability; (v) lower moderate disability; (vi) upper moderate disability; (vii) lower good recovery; and (viii) upper good recovery. The GOSE is considered suitable for use in sport and active recreation populations [121] and has a strong focus on return to pre-injury status. Participants were categorised as “recovered” (GOSE=8, upper good recovery) and “not recovered” (GOSE<8) for analysis.

Variables and Data Sources

Variables collected from hospital medical records, extracted from the VOTOR database and used in this study were: age, gender, pre-existing medical conditions, pre-existing mental health conditions, in-hospital complications, Injury Severity Score (ISS) >15 (yes/no) and injury profile. Variables collected from participants as part of the VOTOR follow-up procedures and extracted for this study were occupation, highest level of education attained and the GOSE (12-months post-injury). Additional information obtained specifically for this study that was not part of the standard VOTOR follow-up procedure, included: confirmation of the activity at time of injury; and pre-injury and 12-months post-injury short IPAQ data.

Data Analysis

Recruited participants were compared with eligible but not recruited participants using chi-squared tests for categorical variables and Mann-Whitney U tests for continuous variables where data were not normally distributed. Participants were categorised into broad sporting groups, according to the ICECI [16]. Participants were also categorised into occupation groups based on the estimated amount of physical activity associated with the various occupation types [106].

Short IPAQ scores were calculated in Metabolic Equivalents (METS) where 1 MET is 1 kcal/kg/hour or the resting metabolic rate during quiet sitting, and were expressed as MET minutes per week. Continuous scores were truncated for analysis according to the IPAQ scoring protocol [103]. This meant that a maximum of three hours of activity per day could be scored for each category and is recommended as a way of minimising the effect of responder over-estimation.

Participants were dichotomised into “low/moderate” or “high” activity groups based on the IPAQ guidelines [103]. The “high” category represents the level of physical activity at which health enhancing benefits are believed to occur, and is consistent with the recent physical activity guidelines for healthy active adults [104, 105]. The high category is also recommended for setting population targets, when using measures such as the short IPAQ, which reports physical activity across all domains [103].

The pre-injury short IPAQ scores were approximately normally distributed but the post-injury scores were slightly skewed. Both parametric and non-parametric analyses were used to assess changes in pre-injury and post-injury scores. Parametric test results are reported here as the conclusions from the two sets of analyses were similar.

Linear regression models were used to analyse the difference between pre and post-injury short IPAQ scores and there was no adjustment for pre-injury scores [108, 109]. Univariate models were estimated with the following variables; sporting group, age, sex, education level, ISS>15, occupation group, injury patterns, pre-existing health problems, pre-existing mental health problems and in-hospital complications. The choice of variables was based on factors shown to be associated with health related outcomes in sport and active recreation populations [56, 120]. Three sets of multivariate analyses were performed to identify factors associated with changes in physical activity levels. The first contained demographic variables only, the second contained demographic and injury variables and the third contained demographic, injury and hospital variables. Effect modification was assessed between pairs of relevant variables from the list above in the multivariate models using a likelihood ratio test. Effect modification was detected between age and occupation. We therefore included an interaction term between these two variables. Stata (Version 10, StataCorp, College Station, TX) statistical software was used for all analyses and a p-value of <0.05 was considered significant.

Results

Recruitment and follow-up

Data from 317 participants, for whom complete baseline and follow-up data was obtained, were analysed. Figure 1 illustrates the flow of participants in the study. A total of 455 potentially eligible patients were identified from the VOTOR database, of which 432 were confirmed eligible. Of these 324 (75%) were recruited to the study and 317 (98%) were followed up at 12-months. Of those lost to follow-up, four declined to undertake the 12-month interview and three were unable to be contacted (Figure 8.1).

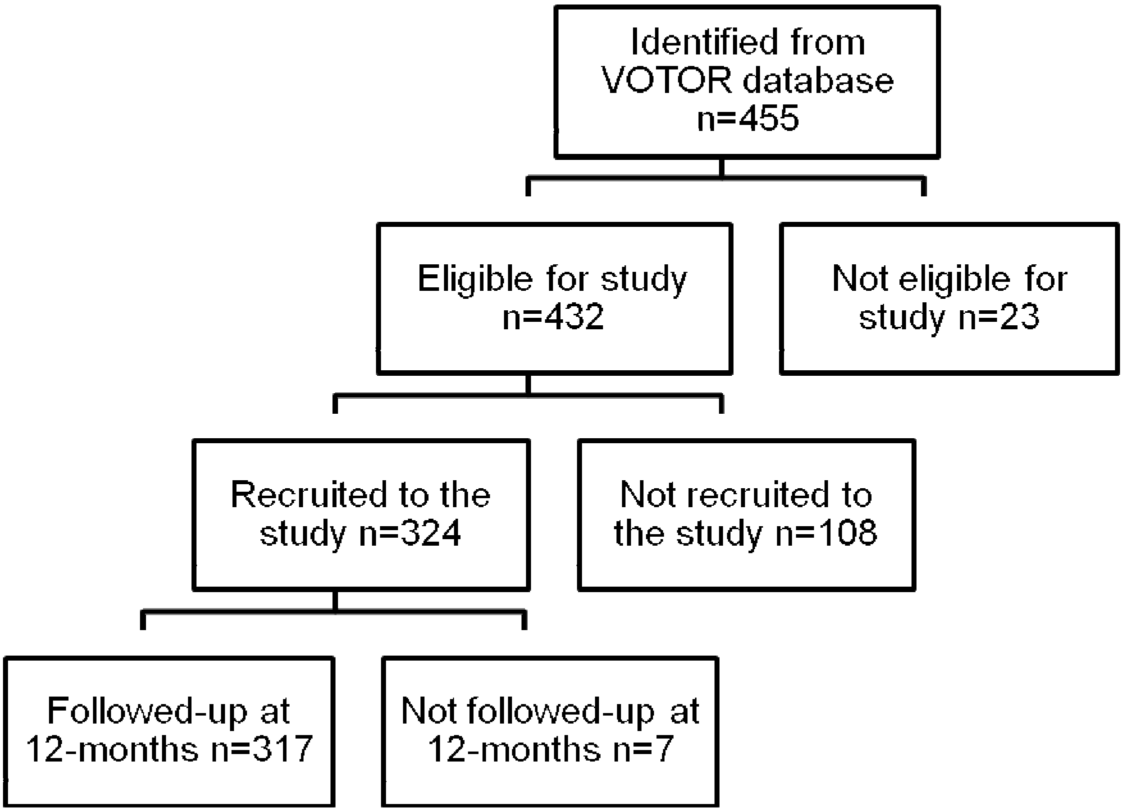

Figure 8.1. Flow diagram showing the numbers of participants meeting inclusion criteria, recruited to the study, and followed up at 12-months post-injury.

The initial patient interview was completed a median (range) of 9 (7-11) months post-injury and the median (range) time between injury and final follow-up was 12 (11-17) months. Eligible patients that did not take part in the study were younger with median age (inter quartile range) 29 years (22-41) compared to 39 years (29-51) for participants ($p<0.001$). They were also less educated; 43% of non-participants had a diploma or degree as compared to 60% of participants ($p=0.03$), and 85% of non-participants were male compared to 73% of participants ($p=0.01$). The groups had similar proportions employed; 86% for non-participants and 90% for participants ($p=0.23$) and similar levels of injury severity, 12% of non-participants had an ISS>15 compared to 19% of participants ($p=0.14$).

Demographic Characteristics

Table 8.1 shows the demographic and injury characteristics of participants and the mean pre- and post-injury short IPAQ scores, in METS, for all participants and for those that reported a full recovery. Most participants were highly active prior to injury with 93% participating in vigorous activity at least once a week and 92% performing high levels of activity according to the short IPAQ.

Table 8.1. Short Physical Activity Questionnaire results for VOTOR sport and active recreation population followed up at 12-months post-injury. Means (standard deviations) reported for the pre- and post-injury scores in METS (1 MET is the resting metabolic rate).

Variable		Total METS'00 / week All participants			Total METS'00 / week Fully recovered participants		
		n (%)	Pre-injury	Post-injury	n(%)	Pre-injury	Post-injury
All		317 (100)	76.1 (42.4)	38.3 (32.2)††	133 (100)	72.1 (43.4)	39.0 (31.2)†
Sex	Male	231 (73)	78.8 (43.2)	38.4 (32.3)†	95 (71)	75.0 (44.5)	38.2 (31.4)†
	Female	86 (27)	69.0 (39.7)	40.5 (32.2)†	38 (29)	64.6 (40.2)	41.1 (30.8)
Age group (years)	18-30	81 (26)	89.1 (42.0)	42.0 (35.9)	42 (32)	89.7 (40.8)	41.0 (32.3)
	30-39	80 (25)	72.4 (45.0)	39.3 (32.0)	28 (21)	54.2 (46.1)	37.7 (33.6)
	40-49	74 (23)	71.5 (41.8)	35.2 (26.1)†	29 (22)	59.7 (39.4)	35.9 (21.4)†
	50-75	82 (26)	71.1 (38.9)	38.6 (33.8)†	34 (26)	75.6 (40.1)	40.4 (35.3)
Education Level ‡‡‡	Degree+	105 (34)	57.9 (33.4)	39.0 (33.3)†	46 (36)	54.8 (35.4)	36.3 (28.6)†
	Diploma	83 (27)	82.1 (46.3)	35.8 (28.5)	37 (29)	77.3 (49.9)	36.9 (30.3)
	Finished high school	56 (18)	89.7 (38.4)	41.9 (37.7)	21 (16)	86.0 (37.2)	44.7 (38.4)
	Did not finish high school	66 (21)	87.5 (45.2)	40.0 (29.2)†	25 (32)	88.3(43.2)	44.7 (32.1)
Occupation Group ‡‡	Office work	56 (18)	58.7 (36.9)	39.9 (34.5)	24 (18)	45.4 (24.2)	35.8 (22.2)
	Health education & service	96 (31)	65.2 (38.8)	40.3 (32.1)†	39 (30)	59.0 (38.5)	41.1 (33.5)†
	Trades and manufacturing	93 (30)	97.2 (41.3)	34.9 (28.7)	45 (34)	100.9 (41.1)	38.7 (34.4)
	Other	66 (21)	77.0 (417)	42.6 (34.4)†	24 (18)	66.2 (43.1)	41.2 (29.9)
Injury Profile	Isolated upper limb	74 (23)	66.1 (34.6)	41.7 (29.2)†	45 (34)	63.0 (34.7)	38.1 (23.5)
	Spinal	25 (8)	75.1 (40.3)	35.0 (29.5)	8 (6)	77.0 (43.2)	33.8 (30.0)
	Isolated lower limb	88 (28)	75.5 (46.0)	36.2 (30.7)†	40 (30)	76.5 (46.2)	38.0 (31.1)†
	Orthopaedic plus other	74 (23)	82.9 (46.7)	42.8 (38.3)	30 (23)	73.6 (49.4)	40.3 (38.8)
	Multiple orthopaedic	56 (18)	81.9 (39.7)	36.0 (30.8)	10 (8)	86.3 (49.4)	47.6 (41.2)
Injury Severity Score (ISS) >15‡	ISS≤15	256 (81)	75.0 (41.3)	38.1 (30.7)††	114 (86)	73.5 (42.7)	39.5 (29.9)†
	ISS>15	59 (19)	80.7 (47.9)	42.0 (38.7)	18 (14)	62.2 (48.9)	37.0 (39.8)

† IPAQ data missing n=1, †† IPAQ data missing n=2,

‡Variable data missing n=2, ‡‡ Variable data missing n=6, ‡‡‡ Variable data missing n=7

Changes in physical activity levels

At 12-months post-injury most participants reported significant reductions in physical activity levels. Mean levels reduced from 7,650 METS (95% CI: 7180, 8120) pre-injury to 3,880 METS; (95% CI: 3530, 4250) post-injury. Those reporting no disability at 12 months, as measured by the GOSE, reported similar reductions, with mean short IPAQ scores being reduced from 7,250 METS (95% CI: 6510, 8000) pre-injury to 3,900 METS (95% CI: 3370, 4440) post-injury. Vigorous and moderate activity levels reduced substantially (Figure 8.2). The proportion of participants participating in any vigorous activity decreased from 93% (95% CI: 90%, 96%) pre-injury to 67% (95% CI: 62%, 72%) post-injury. Those meeting health enhancing levels of physical activity according to the short IPAQ also decreased from 92% (95% CI: 89%, 95%) pre-injury to 62% (95% CI: 57%, 67%) post-injury. There was little difference between pre-injury and post-injury short IPAQ walking scores.

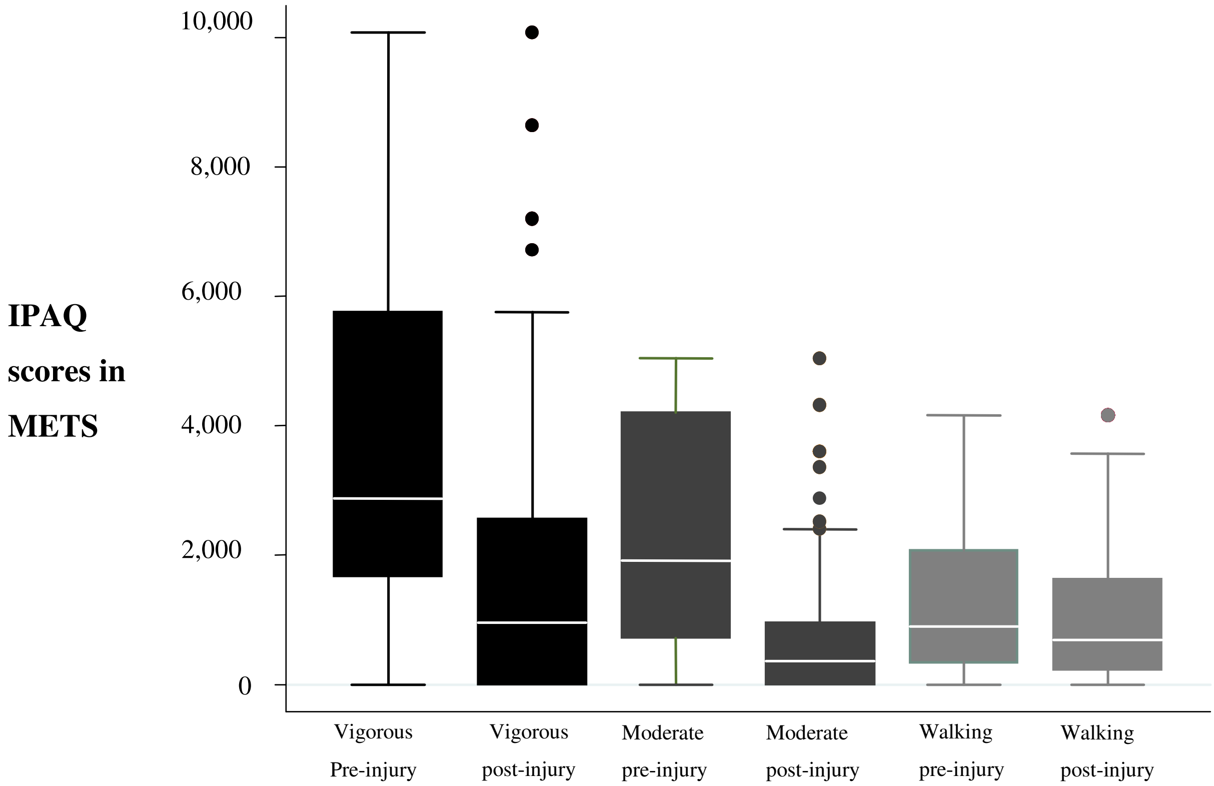

Figure 8.2. Distribution of pre-injury and post-injury short International Physical Activity Questionnaire (IPAQ) scores in METS (1 MET is the resting metabolic rate) for each short IPAQ category

Results from the univariate analyses, found that those with a university education had significantly lower mean reductions in physical activity levels (mean: 1930 METS, 95% CI: 1030, 2830) compared to those without (mean: 4730 METS, 95% CI: 3990, 5470), and that those employed in trades and manufacturing had significantly larger reductions (mean: 6230 METS, 95% CI: 5170, 7290) compared to other occupation groups (mean: 2660 METS, 95%CI: 2010, 3320). Those who reported a full recovery had similar mean reductions in physical activity levels (mean: 3350 METS, 95%CI: 3270, 4827) compared to those who did not report a full recovery (mean: 4050 METS, 95%CI: 2460, 4240).

In multivariable analysis of demographic variables, occupation group was independently associated with reduced short IPAQ scores at 12-months post-injury (Table 8.2). Those working in a trade or manufacturing had greater reductions in short IPAQ scores compared to other occupation groups. Having a diploma or having finished school, compared to having a degree was also associated with greater reductions in short IPAQ scores. Additional adjustment for injury variables and hospital diagnoses had little impact on the coefficients or 95% confidence intervals of the demographic variables. In the final model, working in a trade or manufacturing job and having a diploma and finishing school compared to having a university degree, were the only variables significantly associated with reduced short IPAQ scores at 12-months post-injury (Table 8.2).

Table 8.2. Three multivariate linear regression models for the International Physical Activity Questionnaire change scores for VOTOR sport and active recreation population followed up at 12-months.

Variable		Model including demographic variables			Model including demographic and injury variables			Model including demographic, injury and hospital variables		
		Coefficient	**(95% CI)**	**P-value**	**Coefficient**	**(95% CI)**	**P-value**	**Coefficient**	**(95% CI)**	**P-value**
Sporting group	Team ball (ref)			0.8			0.8			0.9
	Wheeled	10.3	(-9.0, 29.6)		12.9	(-7.5, 33.4)		11.8	(-8.8, 32.4)	
	Motor	10.9	(-9.9, 31.6)		8.4	(-13.5, 30.2)		7.4	(-14.8, 29.6)	
	Equestrian	14.4	(-10.3, 39.0)		13.0	(-13.0, 39.0)		10.9	(-15.4, 37.1)	
	Other	7.8	(-13.1, 28.7)		7.9	(-13.3, 29.2)		7.4	(-13.9, 28.8)	
Age (per year)		-0.2	(-1.3, 0.9)	0.8	-0.2	(-1.3, 0.9)	0.7	-0.1	(-1.3, 1.0)	0.8
Sex	Female	-8.1	(-22.0, 5.9)	0.3	-7.5	(-21.6, 6.6)	0.3	-7.3	(-21.5, 6.9)	0.3
Level of education	Degree+ (ref)			0.1			0.1			0.1
	Diploma	16.6	(0.9, 32.3)		16.6	(0.6, 32.6)		17.1	(0.9, 33.3)	
	Finished high school	19.5	(1.1, 38.0)		19.4	(0.8, 38.0)		20.1	(12.9, 38.9)	
	Did not finish high school	15.7	(-2.3, 33.7)		17.5	(-0.9, 35.8)		16.9	(-16.1, 35.4)	
Occupation group	Office work (ref)			<0.001			0.001			<0.001
	Education, health & service.	11.3	(-50.7, 73.2)		15.5	(-47.2, 78.2)		18.3	(-45.0, 81.6)	
	Trade & manufacturing	68.2	(10.2, 126.3)		71.7	(12.7, 130.6)		75.0	(15.5 134.5)	
	Other	-26.0	(-84.8, 32.7)		-23.6	(-83.4, 36.2)		-22.0	(-82.1, 38.1)	
Injury severity score	ISS >15				0.5	(-20.0, 20.9)	1.0	-2.0	(-22.9, 18.9)	0.9
Injury Profile	Isolated upper limb (ref)						0.5			0.5
	Spinal				7.7	(-16.6, 32.0)		5.7	(-18.9, 30.4)	
	Isolated lower limb				8.6	(-8.2, 25.5)		7.9	(-9.0, 24.9)	
	Orthopaedic plus other				7.6	(-14.0, 29.2)		4.9	(-17.2, 26.9)	
	Multiple Orthopaedic				17.8	(-0.8, 36.5)		16.9	(-1.9, 35.7)	
Behavioural issues	Yes							14.4	(-10.1, 38.9)	0.2
Diagnosed disease	Yes							4.3	(-11.9, 20.5)	0.6
Complications	Yes							3.8	(-17.1, 24.7)	0.7

*Co-efficients are reported in METS'00 (1 MET is the resting metabolic rate) with 95% confidence intervals and p-values.

Discussion

This is the first study, to our knowledge, to examine the impact of orthopaedic sport and active recreation injuries requiring hospitalisation on patients' physical activity levels. The main findings were that serious sport and active recreation injuries have large, negative, persistent impacts on participants' physical activity levels, independent of functional recovery. Being employed in a trade or other manual occupation, and not having a university degree, were significantly associated with greater reductions in physical activity levels.

Only 67% of study participants were meeting health enhancing physical activity levels post-injury compared to 92% prior to injury, with participation in vigorous activity being affected the most. Though participation in vigorous activity is not necessary in order to meet physical activity guidelines, emerging evidence suggests that it may play an important role in the prevention of weight gain [142] and provide additional health advantages not afforded by moderate activities [143] [144]. Furthermore, a dose-response relationship has been reported between activity levels and health [103]. Consequently, the large reductions in physical activity levels from injuries requiring hospitalisation reported in this study could result in long-term health harms. The fact that moderate activity and walking did not increase post-injury to compensate for the reductions in vigorous activity levels highlights the role that vigorous activity has in achieving population physical activity recommendations in this group.

Despite a lack of literature examining the impact of injury on physical activity levels, a small number of studies have reported return to sport rates following serious knee injuries and fractures. At 12 or more months post-injury or surgery, only 40-65% of patients in these studies had returned to pre-injury sports participation, despite good functional recovery [145-148]. Psychosocial issues such as fear of re-injury or self-determination have been suggested as potential factors influencing return to sport [145] [146]. Other factors such as younger age, being female and not having had a previous injury experience were also associated with failure to return to sport, in functionally recovered elite athletes[149]. How these factors translate to general sport and active recreation participants is not known.

Our results suggest that return to physical activity post-injury is more likely to be influenced by fundamental issues such as the degree to which the injury impacts on the participant's ability to work and the resulting loss of productivity and income. This is evidenced by the strong association between occupation and reduced physical activity levels reported in this study. Despite this study including a range of injuries severe enough to require hospitalisation, the severity, type or mechanism of injury was not associated with physical activity levels at 12-months post-injury. It is therefore possible that non-hospitalised injuries that are severe enough to significantly interfere with paid and unpaid work could have similar impacts on physical activity levels. Not having a university education was also associated with persistent reductions in physical activity. Education level is a strong predictor of population physical activity levels [150, 151]. Hence education level may also play an important role in whether or not people return to pre-injury physical activity levels, following injury.

Longitudinal studies have identified that physical activity behaviour changes throughout life [152]. These changes are often triggered by key life events such as transition from school to work, change in residential, employment or relationship status or change in physical state due to pregnancy or illness [152]. It is plausible that significant injury would impact on physical activity levels in a similar way to these key life events. The exact mechanisms by which key life events affect physical activity patterns are unknown. Interruption of exercise habits may be one mechanism. Habit formation has been shown to be more important for the ongoing performance of vigorous activities, especially during leisure time, as it often requires a higher degree of planning than incidental physical activity [153]. This may account, in part, for the large reductions in vigorous activity observed in our study.

The strengths of this study are the high follow-up rate and the novel nature of this research. There are however, some limitations that must be acknowledged. The collection of retrospective pre-injury data is subject to recall bias and response shift [100]. Response shift is a change in the internal standards, values or conceptualizations by which one judges their health [99] and can occur following a traumatic event such as injury. It is possible that this could also occur with recall of pre-injury physical activity levels. To explore this, we examined the pre-injury physical activity levels of those that reported being recovered and those that did not. There was no difference in mean scores, suggesting that response shift is likely to be low. As with most self-report physical activity questionnaires, the short IPAQ is subject to over-reporting of physical activity levels [154]. To minimise this, interviewers were trained to clarify, with the participant, potential over-reporting in situations where excessively large scores were reported. The IPAQ scores were also truncated to further minimise over-reporting of physical activity levels. To what extent over-reporting contributed to our results is unclear.

Another limitation is the use of the short IPAQ as an outcome measure. To our knowledge there are no physical activity measures that have been validated for use as a measure of outcome in injury populations. Based on a literature review we felt that the short IPAQ was the best available physical activity questionnaire for the purposes of this study. The short IPAQ is however, subject to large standard errors [103]. To account for this, we did not adjust for baseline short IPAQ scores in our linear regression models. Theoretical models suggest that when using outcomes with similar properties to the short IPAQ, not including baseline scores provides a less biased estimate of the association between the outcome and the variables of interest [108, 109]. The high levels of variance associated with the short IPAQ would also mean that estimates of association will tend to be biased towards the null [155]. The presence of statistically significant differences between pre and post-injury scores despite this, attest to the robustness of the overall results. The high levels of variance, along with small sub group numbers, may however have contributed to a lack of association between some variables and the short IPAQ results in our regression analyses. Finally, the generalisability of the findings are to orthopaedic injuries. Although most sport and active recreation injuries are orthopaedic, [41] the results cannot be extrapolated to isolated non-orthopaedic injuries.

Conclusion

Promotion of physical activity at a population level needs a multi-faceted, innovative and co-ordinated public health approach. This study has demonstrated the large negative impacts that sport and active recreation injuries can have on physical activity levels 12-months post-injury. Consequently the prevention of sport and active recreation injuries is important when considering promotion of activity at a population level.

Summary

As outlined in Chapter One, developed countries have reported increases in leisure-time physical activity levels over recent years. The number of serious sport and active recreation injuries and the risk of being injured in certain activities have also been shown to have increased in the last decade, in Chapter Three.

This chapter demonstrated the large impact that sport and active recreation injuries can have on participants' physical activity levels, independent o functional recovery. This emphasises the importance of sport and active recreation injury prevention, if the benefits of physical activity promotion are to be optimised. The large reductions in physical activity reported in this study suggest that sport and active recreation injuries can become a pathway for the development of secondary co-morbidities associated with physical inactivity and have furthered our understanding of the burden of sport and active recreation injuries.

Chapter Nine: Conclusion

9.1 Introduction

This thesis has used a combination of routinely collected registry data and purposefully collected data to improve our understanding of the epidemiology and 12-month outcomes of serious sport and recreation injuries. This thesis has aimed to identify gaps in the current knowledge base in regards to trends and long-term outcomes associated with serious sport and active recreation injuries. The results have enabled this improved understanding of trends and outcomes to be examined within the context of physical activity promotion.

9.2 Key Findings in relation to the aims of the thesis

9.2.1 Aim number one:

To identify and review the current data collection systems used to monitor sport and active recreation injuries in a defined population, establish the strengths and limitations of these systems and where appropriate use data from these systems to examine the epidemiology, trends and outcomes associated with serious sport and active recreation injuries.

The review of data systems in Chapter Two established that although routinely collected hospital data are important for monitoring the overall injury burden, they do not contain sufficient information or accuracy to provide the level of injury surveillance necessary for monitoring trends in sport and active recreation injuries. When data sources such as the VSTR and the NCIS were linked, they contained sufficient detail, accuracy and reliability, to monitor trends in deaths and major trauma injuries resulting from sport and active recreation participation. The use of these existing systems provides a cost effective and reliable means of monitoring the effects of injury prevention efforts aimed at targeting this most severe end of the sport and active recreation injury spectrum.

Chapters Three and Four demonstrated how data from these systems could be used to examine the epidemiology, trends and outcomes associated with serious sport and active recreation injuries. Key sporting activities for injury prevention were identified based on incidence, trends and outcomes reported in these studies. Limitations associated with using routinely collected data for more comprehensive analyses of outcomes, with reference to the LOAD framework, were also addressed.

9.2.2 Aim number Two

To review outcome measures currently used in sport and active recreation populations and general injury populations, in regards to their suitability for use in sport and active recreation populations.

The published paper included in Chapter Five reviewed outcome measures commonly used in injury populations, to assess their appropriateness for use in a sport and active recreation population. This review was used to identify a set of measures that could effectively measure many of the outcomes that are important to sport and active recreation participants. Outcome measures were reviewed with reference to the ICF definition of disability, therefore giving preference to measures that focused on broad health related outcomes such as those outlined in the LOAD framework.

9.2.3 Aim number three

To quantify the 12-month HRQoL and functional outcomes of hospitalised orthopaedic sport and active recreation injuries with reference to outcomes described in the ICF and LOAD frameworks.

This aim was addressed through a prospective cohort study that used a combination of routinely collected registry data and purposefully collected data to measure 12-month outcomes in a sport and active recreation population.

Chapter Seven quantified the 12-month health related outcomes associated with sport and active recreation injuries using outcome measures identified in Chapter Five. The results reported in Chapter Seven helped further our understanding of the extent to which sport and active recreation injuries can impact on multiple aspects of participants' lives and found that participants were still reporting large mean reductions in physical health at 12-months post-injury. Priority areas for injury prevention were identified based on outcomes, and information important for guiding treatment goals, rehabilitation and future research was reported.

9.2.4 Aim number four

To quantify the impact of serious orthopaedic sport and active recreation injuries on participants' overall physical activity levels at 12-months post injury.

Chapter Eight contained the second paper from the cohort study and focused on the physical activity outcomes. That chapter demonstrated the large impact that sport and active recreation injuries can have on participants' physical activity levels. Results also found that these changes were independent of functional recovery and that decisions to resume physical activity participation are most likely influenced by psychosocial factors. This information highlighted the need for strong sport and active recreation injury prevention policy to accompany physical activity promotion if the benefits of physical activity participation are to be optimised.

9.3 General Limitations

The specific limitations associated with each individual study have been outlined in the relevant chapters. This section focuses on the general limitations of this thesis.

This thesis has used existing databases, in conjunction with purposefully collected data, to provide information on the epidemiology and 12-month outcomes of serious sport and active recreation injuries. At present databases containing routinely collected data only exist for the more serious end of the injury spectrum. Consequently, only hospitalised injuries were addressed in this thesis. Hospital presentations account for only a small proportion of the total number of sport and active recreation injuries but it is these injuries that contribute the most to the injury burden in terms of costs and long-term consequences. Further research using alternate methodologies is needed to establish the overall epidemiology and outcomes of sport and active recreation injuries.

Using VOTOR limited outcome data to orthopaedic injuries. However, as discussed in this thesis, orthopaedic injuries account for the majority of sport and active recreation injuries. Nevertheless the outcome results of this thesis cannot be generalised to non-orthopaedic sport and active recreation injuries.

Outcome measurement was limited to 12-months post-injury. This time point was chosen as further gains in recovery have been shown to be minimal after this time point in a general injury population [125]. To what extent this applies to sport and active recreation populations is unknown, especially with regards to regaining the high levels of pre-injury health and function reported by this group. Furthermore how this applies to return to physical activity is unknown, given the complex psycho-social issues associated with physical activity participation.

9.4 Recommendations

Monitoring the incidence of sport and active recreation injuries and their long-term consequences is important if we are to optimise the effectiveness and health benefits associated with physical activity participation and promotion. Reliable incidence and outcome information, including physical activity outcomes, is needed to identify priority areas for injury prevention, to measure the effectiveness of injury prevention and treatment strategies and for promoting government support and funding for sport and active recreation injury prevention.

The following recommendations are based on the results of this thesis:

i. Provide ongoing monitoring of major trauma injuries and deaths due to sport and active recreation injuries, through data systems such as VSTR and NCIS, using the methods reported in Chapter Three. Results should be regularly reported to government bodies to help inform decisions pertaining to priority areas for injury prevention.

ii. Establish an ICF core set for sport and active recreation injury populations, to guide the development of a patient oriented outcome measure specific to sport and active recreation injuries and assist clinicians and researchers in their choice of measures. Ideally this would incorporate a measure of physical activity. This would assist in the development of benchmarks and standards for future sport injury outcome research.

iii. Prioritise off-road motor bike riding and equestrian sports for future injury prevention action. These activities are popular forms of physical activity and improving the safety of these activities would reduce the overall burden of sport and active recreation injuries, as it is these activities that have the greatest long-term costs per participant, at both an economic and social level as a consequence of their poor long-term outcomes.

iv. Make injury prevention part of physical activity promotion. The results of this thesis have demonstrated the large impact that serious injury can have on participants' overall physical activity levels, even once they have fully recovered. The promotion of physical activity should be accompanied by strong injury prevention policy across all sectors, to maximise the benefits of physical activity participation.

9.5 Conclusion

The full burden of sport and active recreation injuries is largely unknown, despite many of these injuries impacting on the healthiest and most productive members of society. Gaps in the current data systems currently used to monitor the incidence of serious sport and active recreation injuries in Victoria, and elsewhere were highlighted. Information contained in this thesis is an important step in improving our understanding of the burden of sport and active recreation injuries in terms of outcomes, their impact on physical activity levels and trends associated with these injuries. Based on this improved understanding of the burden of sport and active recreation, priorities for future research and action have been identified.

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Appendix 1: Ethics approval forms

ETHICS COMMITTEE CERTIFICATE OF APPROVAL

This is to certify that

Project No: 132/08

Project Title 12-month outcomes of hospitalised orthopaedic sport and active recreation injuries in adults in Victoria, Australia.

Principal Researcher: Dr Belinda Gabbe

Project Proposal: 132/08

Participant Information and Consent Form version 4 **dated:** 2-Jun-2008

was considered by the Ethics Committee on 22-May-2008 and ***APPROVED*** *on* 01-Jul-2008

It is the Principal Researcher's responsibility to ensure that all researchers associated with this project are aware of the conditions of approval and which documents have been approved.

The Principal Researcher is required to notify the Secretary of the Ethics Committee, via amendment or progress report, of

- Any significant change to the project and the reason for that change, including an indication of ethical implications (if any);
- Serious adverse effects on participants and the action taken to address those effects;
- Any other unforeseen events or unexpected developments that merit notification;
- The inability of the Principal Researcher to continue in that role, or any other change in research personnel involved in the project;
- Any expiry of the insurance coverage provided with respect to sponsored clinical trials and proof of re-insurance;
- A delay of more than 12 months in the commencement of the project; and,
- Termination or closure of the project.

Additionally, the Principal Researcher is required to submit

- A Progress Report on the anniversary of approval and on completion of the project *(forms to be provided)*;

The Ethics Committee may conduct an audit at any time.

All research subject to the Alfred Hospital Ethics Committee review must be conducted in accordance with the National Statement on Ethical Conduct in Human Research (2007).

The Alfred Hospital Ethics Committee is a properly constituted Human Research Ethics Committee in accordance with the National Statement on Ethical Conduct in Human Research (2007).

SPECIAL CONDITIONS

None

SIGNE[redacted]

Chair, Ethics Committee (or delegate)

Please quote Project No and Title in all correspondence

R. FREW
SECRETARY
ETHICS COMMITTEE

PO Royal Melbourne Hospital
Parkville Victoria 3050
Telephone 61 3 9342 8530
Facsimile 61 3 9342 8548
Email: research.directorate@mh.org.au
Website: www.mh.org.au/research/research_directorate/
ABN 73 802 706 972

MELBOURNE HEALTH

RESEARCH DIRECTORATE Research Directorate - Human Ethics Committee Approval Form

Telephone: 9342 8530 Facsimile: 9342 8548

This is to certify that

HREC Project No: 2008.094 **Approval date: 16/07/2008** **Expiry date: 16/07/2011**

Project Title: 12-month outcomes of hospitalised orthopaedic sport and active recreation injuries in adults in Victoria, Australia.

Principal Investigator: Dr. Belinda Gabbe
Department of Epidemiology and Preventative Medicine
Central and Eastern Clinical School
Alfred Hospital
MELBOURNE VIC 3004

Sponsored by: N/A

Protocol No: N/A

Participant Information Form: Version 3 dated 03/06/2008

Investigator Brochure: N/A

Other enclosures: (please describe eg advertisement etc.) Your Health and Well Being Questionnaire Version 2, Glasgow Outcome Scales Interview, International Physical Activity Questionnaire Short Last 7 Days Telephone Format, Invitation Letter, Procedures to take if a patient becomes distressed during follow-up

Conducted at: Royal Melbourne Hospital **has been approved**

This proposal meets the requirements of the *NHMRC National Statement on Ethical Conduct in Human Research 2007.*

It is now your responsibility to ensure that all people conducting this research project are made aware of which documents have been approved.

This approval is subject to ongoing, current and valid insurance coverage throughout the duration of the conduct of the study.

You are required to notify the Secretary of the Human Research Ethics Committee of

- Any change in the protocol and the reason for that change together with an indication of ethical implications (if any) by submitting an amendment to the study.
- Serious adverse effects on subjects and the action taken to manage them, including amended Plain Language Statement and Consent Form where appropriate.
- Any unforseen events.
- Your inability to continue as Principal Investigator, or any other change in research personnel involved in the study
- A delay of more than 12 months in the commencement of the project.
- The actual date of commencement of the study.

You are required to submit to the Human Research Ethics Committee

- An Annual Report every twelve months for the duration of the project.
- A detailed Final Report at the conclusion of the project.

The Human Research Ethics Committee may conduct an audit at any time.

An extens[redacted]lusion date should be sought from the Human Research Ethics Committee.

Signed: [redacted]
Dr. Angel[redacted]
Secretary[redacted]

HUMAN RESEARCH ETHICS COMMITTEE

Telephone: 03 5226 7978
Facsimile: 03 5226 7306
e-mail: BERNICE@BarwonHealth.org.au

Barwon Health

The Geelong Hospital,
Ryrie Street P.O. Box 281
Geelong Victoria 3220

ETHICS COMMITTEE APPROVAL STATEMENT: low risk

Project Number	**08/66**
Site	Barwon Health/Melbourne Uni
Principal Investigator:	**Dr Belinda Gabbe**
Title:	**12-month outcomes of hospitalised orthopaedic sport and active recreation injuries in adults in Victoria**
Co investigators	Prof Peter Cameron Monash University A/Prof Rory Wolfe Monash University Richard Page Barwon health
Student names	Ms Nadine Andrew PhD student, Monash University

Thankyou for submitting your application with the Research and Ethics Advisory Committe

Full approval was granted on 23/02/2009 for three years or until the anticipated completion date, 1/01/2011 ,whichever is the closer.

In addition any items approved in support of this project are listed below:

	Date Approved	***Item***		
1	23/02/2009	Participant Information Sheet	ver 1	21/10/2008
2	23/02/2009	Glasgow outcome scales interview		
3	23/02/2009	International Physical Activity questionnaire	Short Last 7 days telephone Revised August 2002	
4	23/02/2009	Verbal Consent (Phone)		

Approval is granted on the basis that this is a low risk project and /or has been considered by another Human Research Ethics Committee.

Your obligations under this approval include notifying the Committee of intent to deviate from the approved protocol and of the occurrence of any untoward events.

Please note that your final report is due on completion and, in the interim , progress reports are due on an annual basis.

Should you require any further information concerning the Committee's approval of your research or have any concerns regarding the reporting requirements please contact the HREC secretary, on 52267978.

In all future correspondence regarding your study please quote your project number and full title of your research project.

Yours sincerely,

[redacted]

Research and Ethics Advisory Committee

Dr. T. Ca:laly

FRANZCP, MRCPsych, MBL, FAAQHC, BSc, H.Dip in Ed

Chair: Review Committee

Appendix 2: Participant Information and Consent Form

Participant Information Sheet

The Alfred Hospital

Full Project Title: 12-month outcomes of hospitalised orthopaedic sport and active recreation injuries in adults in Victoria, Australia.

Principal Researcher:

Dr Belinda Gabbe - NHMRC Research Fellow, Monash University

Associate Researchers:

Prof Peter Cameron – Monash University

A/Prof Rory Wolfe – Monash University

Ms Nadine Andrew – PhD student, Monash University

1. Introduction

You are invited to take part in this research project. You were identified through the Victorian State Trauma Registry as having recently been admitted to the Alfred Hospital after sustaining an injury as a result of participating in sport or active recreation. You are therefore eligible to participate in our study on the long term outcomes of hospitalised orthopaedic sport and active recreation injuries. The research project aims to investigate the long term consequences of injuries sustained during participation in sport and active recreation including the impact on quality of life, function and participation in physical activity.

This Participant Information sheet tells you about the research project. It explains what is involved to help you decide if you want to take part.

Please read this information carefully. Ask questions about anything that you don’t understand or want to know more about. Before deciding whether or not to take part, you might want to talk about it with a relative, friend or your local health worker.

Participation in this research is voluntary if you do not wish to take part you do not have to.

If you decide you want to take part in the research project you will be asked at your first telephone interview to give verbal consent. By agreeing to answer the questions during the telephone interview, you are telling us that you:

- Understand what you have read;
- Consent to take part in the research project;
- Consent to be involved in the process described;
- Consent to the use of your personal and health information, in the confidential manner described below;

2. What is the purpose of this research project?

The aim of the study is to assess the 12-month health related quality of life, functional and return to activity outcomes in patients admitted to Victorian hospitals with orthopaedic injuries sustained while participating in sport and active recreation activities.

Despite sport and active recreation injuries being common, few studies have attempted to look at the long term outcomes of these injuries and the degree of recovery following injury, including the impact on the injured person's ability to return to sport and recreation participation. Previous studies have tended to focus on short term outcomes only. The information gained from this project will assist in understanding the course of recovery following injuries related to sport and active recreation, planning of future research designed to enhance care and improve outcomes for people injured during sport and active recreation.

We hope to recruit a total of 300 people from three hospitals in Victoria, including The Alfred hospital.

The results of this research will be used by the researcher Nadine Andrew to obtain a PhD degree.

3. What does participation in this research project involve?

- Most of the data that will be used in this research study is already routinely collected by the Victorian State Trauma Registry (VSTORM). You should have been provided with information on VSTORM and the type of information they collect in a separate letter.
- Approximately six months after your injury you will be contacted by telephone and asked about your health prior to your injury, your physical activity levels prior to your injury, and some questions about your injury. This will take between 10 and 15 minutes.
- At 12 months after your injury, we will telephone you again. At this interview we will ask you

about your recovery, any continuing problems and your current physical activity levels. This should take an additional 5 minutes to the VSTORM follow-up.

- As many of the questions that we will ask are the same as the VSTORM follow-up questions you will not be contacted for the VSTORM 12-month follow-up if you participate in the 12-month interview for this project.

4. What are the possible benefits?

The data provided by you will allow us to determine the course of recovery for participants injured in sport and recreation activities, issues faced by this group, and identify areas of sport and active recreation for prioritisation in injury prevention research. Also by identifying areas and injury types in which outcomes are poor, our research can assist in guiding improvements in the level of care provided to those injured as a result of participation in sport and active recreation, and help with establishing appropriate rehabilitation goals for this group.

5. What are the possible risks?

As this research project only requires you to answer some questions over the phone, we do not anticipate any adverse events. In the unlikely event that you do become upset or distressed as a result of your participation in the research, the researcher is able to arrange for counselling or other appropriate support. Any counselling or support will be provided by someone who is not a member of the research team.

6. Do I have to take part in this research project?

Participation in any research project is voluntary. If you do not wish to be contacted for either or both of the telephone interviews please notify a member of the research team. Please note that this will only withdraw you from this particular study. If you do not want to be contacted by the VSTORM registry you will need to contact the relevant research co-ordinator for this project. Their details will be provided on the VSTORM information sheet.

You will also be given the opportunity to withdraw prior to either of the interviews when you are contacted by telephone. If you agree to participate you have the right to refuse to answer any of the questions. Once you have completed the interview it will not be possible to withdraw the data that you have submitted.

Your decision whether to take part or not, will not affect your relationship with the researchers or the Alfred Hospital.

7. How will I be informed of the final results of this research project?

Participants will be sent by mail a summary of the results when the research project is completed. This should be in early 2011. The results of the study will also be published in academic journals and will form part of a PhD thesis.

8. What will happen to information about me?

Any information obtained in connection with this research project that can identify you will only be used for the purpose of this research project and will remain confidential.

The data obtained will be coded so that people involved in analysing and writing up the data will not have access to any of your personal details. In any publication and/or presentation, information will be provided in such a way that you cannot be identified

The data will be stored on a computer database in the Department of Epidemiology and Preventive Medicine, at the Alfred Hospital and only the research staff involved in the study will have access to your data. It will be retained indefinitely in a secure storage facility, according to Alfred Hospital policy.

9. Can I access research information kept about me?

In accordance with relevant Australian and/or Victorian privacy and other relevant laws, you have the right to access the information collected and stored by the researchers about you. Please contact one of the researchers named at the end of this document if you would like to access your information.

10. Is this research project approved?

The ethical aspects of this research project have been approved by the Human Research Ethics Committee of the Alfred Hospital.

This project will be carried out according to the *National Statement on Ethical Conduct in Human Research (2007)* produced by the National Health and Medical Research Council of Australia. This statement has been developed to protect the interests of people who agree to participate in human research studies.

11. Who can I contact?

The person you may need to contact will depend on the nature of your query. Therefore, please note the following:

For further information:

If you want any further information concerning this project or if you do not wish to be contacted for the 6 month pre-injury interview and/or the 12 month post-injury interview you can contact the principal researcher Dr Belinda Gabbe on 9903 0951 or Nadine Andrew on 9903 0053

For complaints:

If you have any complaints about any aspect of the project, the way it is being conducted or any questions about being a research participant in general, then you may contact:

Name: Ms Rowan Frew

Position: Ethics Manager, Research and Ethics Unit

Telephone: 9076 3848

Appendix 3: Short Form 36

Your Health and Well-Being

This questionnaire asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities. ***Thank you for completing this survey!***

For each of the following questions, please mark an ☒ in the one box that best describes your answer.

1. In general, would you say your health is:

Excellent	Very good	Good	Fair	Poor
▼	▼	▼	▼	▼
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

2. <u>Compared to one year ago</u>, how would you rate your health in general <u>now</u>?

Much better now than one year ago	Somewhat better now than one year ago	About the same as one year ago	Somewhat worse now than one year ago	Much worse now than one year ago
▼	▼	▼	▼	▼

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

3 The following questions are about activities you might do during a typical day. Does <u>your health now limit you</u> in these activities? If so, how much?

		Yes, limited a lot	Yes, limited a little	No, not limited at all
a	Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports	☐ 1	☐ 2	☐ 3
b	Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	☐ 1	☐ 2	☐ 3
c	Lifting or carrying groceries	☐ 1	☐ 2	☐ 3
d	Climbing several flights of stairs	☐ 1	☐ 2	☐ 3
e	Climbing one flight of stairs	☐ 1	☐ 2	☐ 3
f	Bending, kneeling, or stooping	☐ 1	☐ 2	☐ 3
g	Walking more than a kilometre	☐ 1	☐ 2	☐ 3
h	Walking several hundred metres	☐ 1	☐ 2	☐ 3
i	Walking one hundred metres	☐ 1	☐ 2	☐ 3
j	Bathing or dressing yourself	☐ 1	☐ 2	☐ 3

4. During the <u>past 4 weeks</u>, how much of the time have you had any of the following problems with your work or other regular daily activities <u>as a result of your physical health</u>?

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a Cut down on the amount of time you spent on work or other activities	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b Accomplished less than you would like	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c Were limited in the kind of work or other activities	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
d Had difficulty performing the work or other activities (for example, it took extra effort)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

5. During the <u>past 4 weeks</u>, how much of the time have you had any of the following problems with your work or other regular daily activities <u>as a result of any emotional problems</u> (such as feeling depressed or anxious)?

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a Cut down on the amount of time you spent on work or other activities	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b Accomplished less than you would like	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c Did work or other activities less carefully than usual	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

6. During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbours, or groups?

Not at all	Slightly	Moderately	Quite a bit	Extremely
▼	▼	▼	▼	▼
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

7. How much bodily pain have you had during the past 4 weeks?

None	Very mild	Mild	Moderate	Severe	Very severe
▼	▼	▼	▼	▼	▼
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6

8. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?

Not at all	A little bit	Moderately	Quite a bit	Extremely
▼	▼	▼	▼	▼
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

9. These questions are about how you feel and how things have been with you <u>during the past 4 weeks</u>. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the <u>past 4 weeks</u>…

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a Did you feel full of life?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b Have you been very nervous?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c Have you felt so down in the dumps that nothing could cheer you up?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
d Have you felt calm and peaceful?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
e Did you have a lot of energy?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
f Have you felt downhearted and depressed?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
g Did you feel worn out?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
h Have you been happy?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
i Did you feel tired?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

10. During the <u>past 4 weeks</u>, how much of the time has your <u>physical health or emotional problems</u> interfered with your social activities (like visiting with friends, relatives, etc.)?

All of the time	Most of the time	Some of the time	A little of the time	None of the time
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

11. How TRUE or FALSE is <u>each</u> of the following statements for you?

	Definitely true	Mostly true	Don't know	Mostly false	Definitely false
a I seem to get sick a little easier than other people	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b I am as healthy as anybody I know	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c I expect my health to get worse	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
d My health is excellent	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Thank you for completing these questions

Appendix 4: Extended Glasgow Outcome Scale

GLASGOW OUTCOME SCALES INTERVIEW

Consciousness

1. Is the person able to obey simple commands? No ☐ Yes ☐

Anyone who shows ability to obey even simple commands, or utter any word or communicate specifically in any other

way is no longer considered to be in the vegetative state. Eye movements are not reliable evidence of meaningful responsiveness. Corroborate with nursing staff.

Independence in the home

2a. Is the assistance of another person at home essential every day for some activities of daily living? No ☐ Yes ☐

For a 'No' answer they should be able to look after themselves at home for 24 hours if necessary, though they need not actually look after themselves. Independence includes the ability to plan for and carry out the following activities: getting washed, putting on clean clothes without prompting, preparing food for themselves, dealing with callers, and handling minor domestic crises. The person should be able to carry out activities without need prompting or reminding, and should be capable of being left along overnight.

2b. Do they need frequent help or someone to be around at home most of the time? No ☐ Yes ☐

For a 'no' answer they should be able to look after themselves at home for up to 8 hours during the day if necessary, though they need not actually look after themselves.

2c. Was assistance at home essential before the injury? No ☐ Yes ☐

Independence outside the home

3a. Are they able to shop without assistance? No ☐ Yes ☐

This includes being able to plan what to buy, take care of money themselves, and behave appropriately in public. They need not normally shop, but must be able to do so.

3b. Were they able to shop without assistance before the injury? No ☐ Yes ☐

4a. Are they able to travel locally without assistance? No ☐ Yes ☐

They may drive or use public transport to get around. Ability to use a taxi is sufficient, provided the person can phone for it themselves and instruct the driver.

4b. Were they able to travel without assistance before the injury? No ☐ Yes ☐

Work

5a. Are they currently able to work to their previous capacity? No ☐ Yes ☐

If they were working before, then their current capacity for work should be at the same level. If they were seeking work before then the injury should not have adversely affected their chances of obtaining work or the level of work for which they are eligible. If the patient was a student before injury then their capacity for study should not have been adversely affected.

5b. How restricted are they? ☐ Reduced work capacity

☐ Able to work only in a sheltered workshop or non-competitive job, or currently unable to work

5c. Were they either working or seeking employment before the injury? No ☐ Yes ☐

Social & Leisure Activities

6a. Are they able to resume regular social and leisure activities outside the home?

No ☐ Yes ☐

They need not have resumed all their previous leisure activities, but should not be prevented by physical or mental impairment. If they stopped the majority of activities because of loss of interest or motivation then this is also considered a disability.

6b. What is the extent of restriction on their social and leisure activities?

☐ Participate a bit less: at least half as often as before

☐ Participate much less: less than half as often

☐ Unable to participate: rarely, if ever, take part

6c. Did they engage in regular social and leisure activities outside home before the injury?

No ☐ Yes ☐

Family and friendships

7a. Have there been psychological problems which have resulted in ongoing family disruption or disruption to friendships? No ☐ Yes ☐

Typical post-traumatic personality changes: quick temper, irritability, anxiety, insensitivity to others, mood swings, depression, and unreasonable or childish behaviour.

7b. What has been the extent of disruption or strain?

☐ Occasional – less than weekly

☐ Frequent – once a week or more, but tolerable

☐ Constant – daily and intolerable

7c. Were there problems with family or friends before the injury? No ☐ Yes ☐

If there were some problems before injury but these have become markedly worse since injury then answer 'No' to Q7c.

Return to normal life

8a. Are there any other current problems relating to the injury which affect daily life?

No ☐ Yes ☐

Other typical problems reported after head injury: headaches, dizziness, tiredness, sensitivity to noise or light, slowness, memory failures, and concentration problems.

8b. Were similar problems present before the injury? No ☐ Yes ☐

If there were some problems before injury but these have become markedly worse since injury then answer 'No' to Q8b.

Epilepsy

Is the head injured person on any epilepsy medication? No ☐ Yes ☐

Since the injury has the head injured person had any epileptic fits? No ☐ Yes ☐

Appendix 5: Short International Physical Activity Questionnaire

Short Last 7 Days Telephone IPAQ

READ: I am going to ask you about the time you spent being physically active in the last 7 days. Please answer each question even if you do not consider yourself to be an active person. Think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

READ: Now, think about all the *vigorous* activities which take *hard physical effort* that you did in the last 7 days. Vigorous activities make you breathe much harder than normal and may include heavy lifting, digging, aerobics, or fast bicycling. Think only about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities?

   _____ Days per week [VDAY; Range 0-7, 8,9]

   8. Don't Know/Not Sure
   9. Refused

[**Interviewer clarification**: Think only about those physical activities that you do for at least 10 minutes at a time.]

[**Interviewer note**: If respondent answers zero, refuses or does not know, skip to Question 3]

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

   __ __ Hours per day [VDHRS; Range: 0-16]

   __ __ __ Minutes per day [VDMIN; Range: 0-960, 998, 999]

   998. Don't Know/Not Sure

   999. Refused

   [**Interviewer clarification**: Think only about those physical activities you do for at least 10 minutes at a time.]

   [**Interviewer probe**: An average time for one of the days on which you do vigorous activity is being sought. If the respondent can't answer because the pattern of time spent varies widely from day to day, ask: "How much time in total would you spend **over the last 7 days** doing vigorous physical activities?"

   __ __ Hours per week [VWHRS; Range: 0-112]

   __ __ __ __Minutes per week [VWMIN; Range: 0-6720, 9998, 9999]

   9998. Don't Know/Not Sure

   9999. Refused

READ: Now think about activities which take *moderate physical effort* that you did in the last 7 days. Moderate physical activities make you breathe somewhat harder than normal and may include carrying light loads, bicycling at a regular pace, or doubles tennis. Do not include walking. Again, think about only those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities?

_____ Days per week [MDAY; Range: 0-7, 8, 9]

8. Don't Know/Not Sure

9. Refused

[**Interviewer clarification**: Think only about those physical activities that you do for at least 10 minutes at a time]

[**Interviewer Note**: *If respondent answers zero*, refuses or does not know, skip to Question 5]

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

__ __ Hours per day [MDHRS; Range: 0-16]

__ __ __ Minutes per day [MDMIN; Range: 0-960, 998, 999]

998. Don't Know/Not Sure

999. Refused

[**Interviewer clarification**: Think only about those physical activities that you do for at least 10 minutes at a time.]

[**Interviewer probe**: An average time for one of the days on which you do moderate activity is being sought. If the respondent can't answer because the pattern of time spent varies widely from day to day, or includes time spent in multiple jobs, ask: "What is the total amount of time you spent over the **last 7 days** doing moderate physical activities?"

__ __ __ Hours per week [MWHRS; Range: 0-112]

__ __ __ __Minutes per week [MWMIN; Range: 0-6720, 9998, 9999]

9998. Don't Know/Not Sure

9999. Refused

READ: Now think about the time you spent walking in the last 7 days. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____ Days per week [WDAY; Range: 0-7, 8, 9]

8. Don't Know/Not Sure

9. Refused

[**Interviewer clarification**: Think only about the walking that you do for at least 10 minutes at a time.]

[**Interviewer Note**: *If respondent answers zero*, refuses or does not know, skip to Question 7]

6. How much time did you usually spend **walking** on one of those days?

__ __ Hours per day [WDHRS; Range: 0-16]

__ __ __ Minutes per day [WDMIN; Range: 0-960, 998, 999]

998. Don't Know/Not Sure

999. Refused

[**Interviewer probe**: An average time for one of the days on which you walk is being sought. If the respondent can't answer because the pattern of time spent varies widely from day to day, ask: "What is the total amount of time you spent walking over **the last 7 days**?"

__ __ __ Hours per week [WWHRS; Range: 0-112]

__ __ __ __Minutes per week [WWMIN; Range: 0-6720, 9998, 9999]

9998. Don't Know/Not Sure

9999. Refused

READ: Now think about the time you spent sitting on week days during the last 7 days. Include time spent at work, at home, while doing course work, and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television.

7. During the last 7 days, how much time did you usually spend ***sitting*** on a **week day**?

__ __ Hours per weekday [SDHRS; 0-16]

__ __ __ Minutes per weekday [SDMIN; Range: 0-960, 998, 999]

998. Don't Know/Not Sure

999. Refused

[**Interviewer clarification**: Include time spent lying down (awake) as well as sitting]

[**Interviewer probe**: An average time per day spent sitting is being sought. If the respondent can't answer because the pattern of time spent varies widely from day to day, ask: “What is the total amount of time you spent *sitting* last **Wednesday**?”

__ __ Hours on Wednesday [SWHRS; Range 0-16]

__ __ __ Minutes on Wednesday [SWMIN; Range: 0-960, 998, 999]

998. Don't Know/Not Sure

999. Refused