Faculty of Health Sciences

Group Riding in Western Australia:
An Examination of Crashes, Outcomes and Behaviour

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Doctor of Philosophy
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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number: HR 189/2013

Signature: …………………………….

Date: 15 March 2019

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Abstract

INTRODUCTION

Non-professional group riding is a unique type of cycling that takes place on public roads and is rapidly gaining popularity in Australia. While there has been extensive research into cycling safety, it has focused almost exclusively on individual, often commuter cyclists. Evidence suggests that group of riders may experience quite different safety issues compared to individual riders. The likely under-reporting of group riding crashes to Police, coupled with the lack of recording of whether a cyclist was riding in a group at the time of the crash, makes it difficult to examine group riding crashes using Police or hospitalisation data. In-depth crash investigation methods may overcome these challenges and provide valuable insights into the circumstances and contributing factors surrounding group riding crashes that occur on-road. Naturalistic cycling research using bicycle-mounted video cameras and Global Positioning System (GPS) data is still in its infancy and again, has focused largely on individual cyclists. A naturalistic study of group riding would provide invaluable detail on the types of unsafe events and violations experienced, as well as group and road environment-related risk factors.

AIM AND OBJECTIVES

The overall aim of this study was to gain an understanding of the safety issues affecting group riders in Perth, WA. The study consisted of two Phases and the specific objectives were to:

Phase 1: In-depth bicycle crash study

Part A: Baseline crash study

1. Compare the characteristics (rider, road-environment and crash-related) of group rider and individual rider on-road crashes resulting in hospitalisation in Perth WA, between September 2014 and December 2016.
2. Determine the human, environmental and vehicle factors contributing to group rider and individual rider on-road crashes resulting in hospitalisation in Perth WA.

Part B: 12-month follow-up

3. Examine the association between group riding participation and reduced cycling exposure 12 months after a hospitalisation crash in Perth, WA.

Phase 2: Naturalistic group riding study

Part A: Unsafe events involving a motor vehicle

4. Describe the unsafe events involving a motor vehicle that occurred while group riding on-road in Perth, WA between March 2015 and April 2017, using naturalistic video and GPS data.
5. Determine the road environment and group position-related factors associated with unsafe events involving a motor vehicle that occurred while group riding on-road, using a case-crossover study.

Part B: Unsafe events not involving a motor vehicle

6. Describe the unsafe events not involving a motor vehicle that occurred while group riding on-road in Perth, WA between March 2015 and April 2017, using naturalistic video and GPS data.
7. Determine the road environment and group position-related factors associated with unsafe events not involving a motor vehicle that occurred while group riding on-road, using a case-crossover study.

Part C: Group rider traffic violations

8. Describe the traffic violations that occurred while group riding on-road in Perth, WA between March 2015 and April 2017, using naturalistic video and GPS data.
9. Identify group and trip-related characteristics associated with the rate of group rider traffic violations, using a cross-sectional study.

PHASE 1: METHODS

Phase 1 involved an in-depth longitudinal study of 108 cyclists hospitalised in Perth, WA due to an on-road crash, between September 2014 and December 2016. Participants were recruited consecutively from four public hospitals. Data collected at baseline consisted of a researcher-administered questionnaire, crash information from the Integrated Road Information System, injury information from the State Trauma Registry and a virtual crash site inspection using Google Maps and Nearmap. A detailed examination of factors contributing to the crash was also undertaken. The follow-up 12 months after the crash involved a telephone questionnaire examining pain, function and cycling exposure, cessation and reduction. For the baseline data, the participant and road environment characteristics of the crashes were described and compared for group rider (crashes that occurred while group riding) and individual rider crashes using t-tests, chi-square tests, Fisher's exact tests and Fisher-Freeman-Halton Exact tests. To determine whether group rider crashes were more likely to involve *'road-related factors'* than individual rider crashes, two multivariate binary logistic regression models were undertaken for all crashes (n=108) and for crashes which did not involve a motor vehicle (n=61). For the follow-up data a multivariate binary logistic regression model was used to determine the association between *'group riding participation'* and *'reduced cycling exposure'* at follow-up.

PHASE 1: RESULTS

For the 108 crashes in the study, 34% were group rider crashes and 66% were individual rider crashes. Only 16% of group rider crashes involved a motor vehicle, compared to 58% of individual rider crashes. Group rider crashes commonly involved another rider in the group (45%), a loss of control (26%) or a collision with an object (23%). Road-related factors were involved in 54% of group rider crashes compared to 27% of individual rider crashes. These included road maintenance issues, slippery roads and temporary traffic hazards or objects on the carriageway. The results of the multivariate models found that *'road-related factors'* were over three times more likely to be present for group rider than individual rider crashes, for all crashes (OR: 3.19, 95% CI: 1.26-8.04, p=0.014) and those not involving a motor vehicle only (OR: 3.31, 95% CI: 1.05-10.49, p=0.042). A total of 83 participants completed the follow-up questionnaire approximately 12 months after the crash. Overall, 60% of participants had *'reduced cycling exposure'* and 33 (39.8%) had *'no reduction in cycling exposure'* at follow-up. The results of the multivariate model found that those who did not participate in group riding before the crash had nearly four times the likelihood of reduced cycling exposure at follow-up (OR: 3.8, 95% CI: 1.23-11.78, p=0.021), compared to group riders.

PHASE 2: METHODS

Phase 2 involved a naturalistic study of unsafe events and traffic violations observed among group riders in Perth, WA. Participants consisted of a convenience sample of 52 group riders recruited between March 2015 and April 2017. Data collection involved an online survey, naturalistic group riding video footage and GPS data recorded during 126 group riding trips, using bicycle-mounted cameras and a researcher-administered questionnaire.

Part A consisted of a case-crossover study examining road environment and group position-related risk factors for unsafe events involving a motor vehicle. Cases were the sites where unsafe events occurred and the controls (sites where no unsafe event occurred) were randomly selected from within the same group-riding trip as the cases. Temporal, group rider and motorist behaviour characteristics were recorded for each case and control and road environment characteristics obtained through a virtual site inspection. A multivariate Generalised Estimating Equations (GEE) logistic regression model was undertaken to examine the association between road environment and group position-related factors and the risk of an unsafe event (case).

Part B involved a case-crossover study examining road environment and group position-related risk factors for unsafe events that did not involve a motor vehicle. A multivariate GEE logistic regression model was undertaken to examine the association between road environment and group position-related factors and the risk of an unsafe event which did not involve a motor vehicle

Part C consisted of a cross-sectional study examining group and trip-related factors associated with group rider traffic violations. *'Red light violations'*, *'stop sign violations'* and *'other violations'* (*one-way sign'*, *'right of way'*, *'wrong side of road'*, and *'riding more than two-abreast' violations*) were identified from the footage. In addition, group and trip characteristics were obtained from the researcher-administered questionnaire and the video. A multivariate GEE negative binomial regression model was undertaken to examine the association between group and trip-related factors and the rate of *'other violations.'*

PHASE 2: RESULTS

Part A: There was a total of 108 unsafe events (cases) involving a motor vehicle, which occurred during 60 group riding trips. The majority of these unsafe events involved a passing manoeuvre by a motorist (66%). Motorists were at fault for 82% of the unsafe events but they were predominantly due to errors or misjudgements. Obvious aggressive behaviour from motorists or group riders was present for 15% of unsafe events. Results of the case-crossover study found that roundabouts (OR: 3.63, 95% CI: 1.57-8.42, p=0.003), traffic islands (OR: 2.30, 95% CI: 1.41-3.78, p=0.001), posted speed limits of 60 km/h or higher (OR: 2.45, 95% CI: 1.55-3.86, p<0.001) and group rider violations (OR: 2.51, 95% CI: 1.14-5.53, p=0.022) significantly increased the risk of an unsafe event involving a motor vehicle. Compared to riding single file in the traffic lane, riding two abreast in the traffic lane (OR: 0.50, 95% CI: 0.32-0.76, p=0.002) or having all riders in the bicycle lane (OR: 0.14, 95% CI: 0.04-0.51, p=0.003), significantly reduced the risk of an unsafe event involving a motor vehicle.

Part B: There was a total of 59 unsafe events (cases) not involving a motor vehicle, which occurred during 40 group riding trips. The most common types of unsafe events involved a conflict between two or more riders in the group (41%) or a conflict with an obstacle or object on the road (39%). Results of the case-crossover study found that curved roads (OR: 3.29, 95% CI: 1.22-8.83, p=0.018) and construction zones (roadworks) (OR: 8.67, 95% CI: 1.72-41.92, p=0.007) significantly increased the risk of an unsafe event not involving a motor vehicle. Riding staggered significantly reduced the risk (OR: 0.16, 95% CI: 0.03-0.90, p=0.037), compared to riding in close proximity.

There was a total of 64 '*red light violations*', 103 '*stop sign violations*' and 232 '*other violations*' observed in the footage from 91 trips. Group riders committed a violation at 12% of red lights and did not come to a complete stop at 80% of stop signs. The most common '*other violations*' were '*riding more than two abreast*' (67%) and '*riding on the wrong side of the road*' (19%). Results of the cross-sectional study found that formal riding groups (e.g. clubs) had less than half the rate of '*other violations*' (IRR: 0.46, 95% CI: 0.29-0.73, p=0.001), compared to semi-formal riding groups (e.g. bike shop rides). There were no significant differences for informal groups (e.g.

friends). In addition, groups which had sprint points (informal racing points) had over twice the rate of *'other violations'* (IRR: 2.28, 95% CI: 1.38-3.78, p=0.001), compared to groups which did not have sprint points.

CONCLUSION

This study provided a comprehensive picture of the safety issues surrounding on-road group riding. Phase 1 highlighted crashes that occurred while group riding as a significant issue and also revealed important differences in the characteristics of group rider and individual rider crashes. Phase 2 provided new information on the types of unsafe events and traffic violations that occur while group riding, as well the road environment and group-related risk factors for these. Since the WA government is actively promoting participation in cycling, it is essential to improve safety for all types of riders, including group riders. The findings of this study suggest that interventions targeting the road environment have the potential to improve group rider safety in Perth. These include road surface repair/ maintenance and clearing of on-road hazards, the provision of wider bicycle lanes that allow for riding two abreast, treatments that encourage riders to claim the lane at single lane roundabouts and improved safety for riders around construction sites. In addition, the findings suggest that interventions targeting the road user may also have safety benefits for group riders. Group rider training addressing safe rider practices, avoiding conflicts with other riders, detection and calling of hazards, negotiating curves safely, road sharing with motorists and acceptable behaviour in terms of traffic violations has the potential to reduce group rider crashes, unsafe events and violations. Finally, motorist education to improve knowledge, attitudes and behaviours surrounding group riders, through mass media campaigns and the driver training curriculum could be effective for reducing motorist frustration, aggressive behaviour, unsafe events and crashes involving group riders.

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List of Abbreviations

ACEM	Association of European Motorcycle Manufacturers
ACT	Australian Capital Territory
AIS	Abbreviated Injury Scale
AR(1)	Autoregressive
ARC	Australian Research Council
BMI	Body Mass Index
CI	Confidence Interval
C-MARC	Curtin-Monash Accident Research Centre
ED	Emergency Department
FSH	Fiona Stanley Hospital
GEE	Generalised Estimating Equations
GLMM	Generalised Linear Mixed Models
GOS-E	Glasgow Outcome Scale-Extended
GP	General Practitioner
GPS	Global Positioning System
HRQOL	Health-Related Quality of Life
ICC	Intra-class correlation coefficient
IQR	Interquartile Range
IRIS	Integrated Road Information System
IRR	Incidence Rate Ratio
ISS	Injury Severity Score
km	Kilometres
km/h	Kilometres Per Hour
ln	Natural Log
MAIDS	Motorcycle Accidents In Depth Study
NISS	New Injury Severity Score
NSW	New South Wales
OR	Odds Ratio
PIS	Participant Information Sheet
PSP	Principal Shared Path
PTSD	Post-Traumatic Stress Disorder
QIC	Quasi Likelihood Under Independence Model Criterion

QICC	Corrected Quasi Likelihood Under Independence Model Criterion
RPH	Royal Perth Hospital
RUM	Road Use Movement
SCGH	Sir Charles Gairdner Hospital
SD	Standard Deviation
SHRP 2	Strategic Highway Research Program 2
SPSS	Statistical Package for the Social Sciences
UK	United Kingdom
USA	United States of America
USB	Universal Serial Bus
vpd	Vehicles Per Day
WA	Western Australia

CHAPTER 1

Introduction

1 INTRODUCTION

1.1 Background

The concept of riding a bicycle as part of a group originated in road bicycle racing in countries such as France, Belgium and Italy (Mignot, 2016a). The most well-known road bicycle race, The Tour de France started in 1903 (Ritchie, 2011). More recently, group riding has evolved from the exclusive domain of racing to become mainstream and popular in Australia, with non-professional riders taking part in group riding for the purposes of training, fitness and also for recreation (O'Connor & Brown, 2007).

While no minimum group size or standard definition currently exists for group riding, it commonly involves a group riding in formation, often in rows of two, on a pre-determined route. (Burridge, Lajbcygier, & Lema, 2003; Johnson, Oxley, & Cameron, 2009). The term *'group riding'* is used in this thesis to encompass all the types of riding referred to as *'group'*, *'bunch'* or *'peloton'* riding in the literature and by group riders themselves. In Australia, groups of riders are often informal, self-organised and internally-regulated (O'Connor & Brown, 2007). Group riding also takes place on public roads, where there may be minimal infrastructure provision for this type of riding (Johnson et al., 2009).

In Perth, Western Australia (WA), group riding predominantly takes place on roads shared with traffic. This is because shared paths and footpaths in Perth, are usually unsuitable and often unsafe for group riding. These paths are shared with pedestrians, children, dogs and other riders, require slower travelling speeds than roads and riding two abreast is prohibited on all paths. In addition, riding on-road for recreation or fitness is very popular among individual riders in Perth, with 85% of cyclists riding for recreation in the past month, compared to only 35% for transport (Austroads/ Australian Bicycle Council, 2017). Currently, very little is known about non-professional on-road group riding in WA or the associated safety issues. This represents a significant gap in the evidence for the safety of these unique riders.

1.2 Rationale

The increasing participation in group riding in WA is coupled with a reported growth in anti-cycling sentiment among segments of the community, likely fuelled by the media's promotion of a *'war on our roads'* between cyclists and motorists (Fulton, 2017; Strutt, 2015). This means that a comprehensive examination of the safety issues surrounding on-road group riding is both relevant and topical.

A large body of research has examined risk factors for bicycle crashes within Australia and internationally. However, whether a cyclist was riding alone or in a group is not recorded in Police or hospital crash data, meaning very little is known about the circumstances and contributing factors for group riding crashes specifically. While it is likely that there are important differences between individual rider and group rider crashes that occur on-road (Albert, 1999), studies describing the latter group to date have been limited by small sample sizes and uncertainty surrounding whether the included crashes actually involved group riding (Biegler et al., 2012; Johnson et al., 2009). Since group riding is growing in popularity in WA, detailed knowledge of the circumstances and contributing factors to these specific on-road crashes is essential for guiding crash prevention efforts surrounding road user behaviour and road infrastructure design.

In terms of crash outcomes, there is also a significant gap in the evidence surrounding the impact of on-road crash involvement on return to cycling, cycling cessation and cycling avoidance. In order to continue increasing cycling participation in Australia and prevent cycling cessation where possible, it is essential to understand how on-road crash involvement affects participation in cycling long term for different types of cyclists, including group and non-group riders.

Finally, naturalistic road safety research involves the unobtrusive observation of road users in their natural environment (Dingus et al., 2006). These methods commonly use video and Global Positioning System (GPS) data and have become popular in the last decade as they provide detailed information on unsafe events (crashes, near crashes and crash-relevant events) as well as traffic violations that occur on the road. The majority of cycling studies to date using this methodology have examined individual, usually commuter cyclists (Dozza & Werneke, 2014; Gustafsson & Archer, 2013; Hamann & Peek-Asa, 2017; Johnson, Charlton, Oxley, & Newstead, 2010). Currently, there is very limited information on the prevalence or type of unsafe events and traffic violations that occur while group riding on roads in Perth, WA or the road environment and group-related factors associated with these. This information would greatly enhance the understanding of the safety issues surrounding group riding in Perth.

Since the majority of group riding takes place on roads in Perth, WA, the decision was made to examine only crashes and unsafe events which occurred on-road in this thesis. In addition, the unique features of group riding which distinguish it from individual riding (e.g. riding in close proximity, riding two abreast and '*rolling*') are only possible when groups are riding on roads and not on paths in Perth. These features of group riding and how they affect safety are of particular interest for this research. Phase 1 and 2 of this study also included only those who were group riding for recreational, social, fitness or training purposes on roads open to traffic. Group riders who were racing were excluded from Phase 1 and 2 of the study, since in Perth, all bicycle racing takes place on closed or traffic- controlled roads.

Phase 1 and 2 of this Thesis consist of two completely separate studies using different participants and study designs. It is envisaged that the information gained from these two different methodologies will complement each other and provide in-depth information on safety issues surrounding group riding in Perth. The Phase 1 crash study includes individual cyclists because it aims to compare the characteristics and factors contributing to group rider and individual rider crashes. In contrast, the Phase 2 naturalistic study aims to determine which road environment and group-related factors increase the risk of unsafe events for group riders. Therefore, individual cyclists are not included in Phase 2.

1.3 Study objectives

The overall aim of this study was to gain an understanding of the safety issues affecting group riders in Perth, WA. The study consisted of two Phases and the specific objectives were to:

Phase 1: In-depth bicycle crash study

Part A: Baseline crash study

1. Compare the characteristics (rider, road-environment and crash-related) of group rider and individual rider on-road crashes resulting in hospitalisation in Perth WA, between September 2014 and December 2016.
2. Determine the human, environmental and vehicle factors contributing to group rider and individual rider on-road crashes resulting in hospitalisation in Perth WA.

Part B: 12-month follow-up

3. Examine the association between group riding participation and reduced cycling exposure 12 months after a hospitalisation crash in Perth, WA.

Phase 2: Naturalistic group riding study

Part A: Unsafe events involving a motor vehicle

4. Describe the unsafe events involving a motor vehicle that occurred while group riding on-road in Perth, WA between March 2015 and April 2017, using naturalistic video and GPS data.
5. Determine the road environment and group position-related factors associated with unsafe events involving a motor vehicle that occurred while group riding on-road, using a case-crossover study.

Part B: Unsafe events not involving a motor vehicle

6. Describe the unsafe events <u>not</u> involving a motor vehicle that occurred while group riding on-road in Perth, WA between March 2015 and April 2017, using naturalistic video and GPS data.
7. Determine the road environment and group position-related factors associated with unsafe events <u>not</u> involving a motor vehicle that occurred while group riding on-road, using a case-crossover study.

Part C: Group rider traffic violations

8. Describe the traffic violations that occurred while group riding on-road in Perth, WA between March 2015 and April 2017, using naturalistic video and GPS data.

9. Identify group and trip-related characteristics associated with the rate of group rider traffic violations, using a cross-sectional study.

1.4 Significance of the study

Despite significant health, transport-related and environmental benefits of cycling (de Hartog, Boogaard, Nijland, & Hoek, 2010; Oja et al., 2011), cyclists are vulnerable road users who are at risk of death or serious injury in the event of a crash (Shinar, 2012). In Australia, road trauma represents a significant burden to the community, costing an estimated $22 billion per year (Australian Automobile Association, 2017). Since the popularity of cycling is increasing and the WA government is actively promoting participation in cycling (Department of Transport, 2014), a thorough understanding of the safety issues surrounding all types of cycling is essential for reducing crashes and injuries.

Group riding is a unique type of cycling that is also rapidly gaining popularity in Australia (Johnson et al., 2009). While a large amount of research has been published on cyclist safety issues, this has focussed almost exclusively on individual, often commuter cyclists. Therefore, very limited information exists on safety issues surrounding group riding including on-road crashes, crash outcomes, unsafe events and traffic violations. This represents a significant gap in the evidence as it is likely that on-road crash characteristics, risk factors and road user behaviour differ considerably for group rider and individual rider crashes. Police, State and Local Governments, cycling advocacy groups and cyclists themselves have expressed interest in optimising group riding safety (Johnson et al., 2009). Currently however, evidence is insufficient to make any direct recommendations for this.

The proposed study will be the first to provide important, in-depth information on the characteristics, contributing factors and outcomes of serious on-road crashes that occur while group riding and compare this to individual rider crashes. It will also be the first to use bicycle-mounted video cameras and GPS technology to provide a detailed understanding of the unsafe events and traffic violations that occur while group riding specifically.

Recommendations will be made from these findings that could inform government road safety campaigns targeting both group rider and motorist behaviour. In addition, findings on road environment features associated with crashes, unsafe events and violations could be used to guide road authorities such as Main Roads WA in the design of safer road infrastructure on popular group riding routes. This information will also assist group ride organisers in choosing the safest possible cycling routes.

Finally, in 2017, WestCycle, a not-for-profit peak body for cycling in WA published a best practice guide to riding safely in a group (WestCycle, 2017a). In addition, riding groups sometimes have their own written and unwritten codes of conduct governing rider behaviour. However, while these are based on rider experience, there is currently no objective research on which to base these guides and codes. This comprehensive study will provide this evidence. Overall, it is envisaged that the findings of this study will be used to reduce the burden of crashes involving group riders in Australia.

1.5 Outline of the thesis

Chapter 2: Literature review – Chapter 2 presents existing literature on safety issues surrounding non-professional, on-road group riding. This includes the characteristics of group riding crashes, long-term outcomes of bicycle crashes, as well as studies which have used naturalistic data to examine unsafe events and road rule violations among individual riders and group riders.

Chapter 3: Methods (Phase 1) – Chapter 3 details the methodology of the in-depth bicycle crash study of hospitalised cyclists. It describes the study design, participant recruitment, inclusion and exclusion criteria, sample size, data collection, crash classification, contributing factors, statistical analyses, ethical considerations and data management for Parts A and B.

Chapter 4: Results (Phase 1) – Chapter 4 presents the results of the in-depth bicycle crash study. Part A describes the baseline results including cyclist, injury, crash and road environment characteristics for group rider and individual rider crashes. It also examines the association between group rider crashes and road-related contributing factors. Part B presents the results of the follow up study including cycling history, recovery from injury and cycling cessation/ reduction. It also examines the association between participation in group riding and reduced cycling exposure at follow-up.

Chapter 5: Methods (Phase 2) – Chapter 5 details the methodology of the naturalistic group riding study. It describes the study design, participant recruitment, inclusion and exclusion criteria, sample size, data collection, data reduction and statistical analysis for Parts A, B and C.

Chapter 6: Results (Phase 2) – Chapter 6 presents the results of the naturalistic group riding study. Part A describes the unsafe events involving a motor vehicle and examines risk factors for these events using a case-crossover study. Part B describes the unsafe events not involving a motor vehicle and again determines risk factors for these events using a case-crossover study. Part C describes group rider traffic violations and examines group and trip-related risk factors for these using a cross-sectional study.

Chapter 7: Discussion – Chapter 7 discusses the results of Phases 1 and 2 in detail and compares findings with other published research. Interventions that may improve group rider safety are suggested throughout the chapter. Strengths and limitations of Phase 1 and 2 are also discussed.

Chapter 8: Conclusion and recommendations – Chapter 8 summarises the main funding of the study. It also presents a set of recommendations for interventions and further research, in relation to the relevant components of the Safe System Framework.

CHAPTER 2

Literature review

2 LITERATURE REVIEW

This literature review provides current evidence on the safety issues surrounding group riding. Relevant published scientific literature was accessed using a range of search engines and databases, available through the Curtin University library service. The main databases and search engines that were used were: Transport databases - TRID: TRIS and ITRD; ProQuest; ScienceDirect; Web of Science, PubMed and the Cochrane Library. A range of keywords and their combinations were included in the search (e.g. bicycle, cycling, group riding, bunch riding, peloton, safety, crashes, crash outcomes, infrastructure, behaviour, naturalistic studies, collisions, near-collisions, road rule violations). Grey literature (reports produced by government departments, universities and industry) was also searched using the Curtin University library database and Google Scholar. Full-text, English language studies published before February 2019 only were included in the review.

The review is divided into four sections:

- Section 2.1 provides background information on cycling and group riding in Western Australia (WA) and describes the Safe System Framework which underpins this study.
- Section 2.2 reviews available evidence on the circumstances of crashes that occur while group riding and discusses how in-depth crash investigation methods could be used to examine the specific factors contributing to group riding crashes.
- Section 2.3 reviews current literature on the long-term physical, psychological and social outcomes of bicycle crashes as well as the impact on return to cycling and cycling cessation.
- Section 2.4 reviews studies conducted to date that have used naturalistic data to examine unsafe events and/ or road rule violations among individual riders and group riders.

2.1 Background: Group riding in Western Australia

2.1.1 Cycling in Western Australia

Cycling is growing in popularity in WA with the number of people cycling increasing more than five-fold in the past 15 years (Department of Transport, 2014). In 2017, an estimated 19% of WA residents cycled in a typical week and 42% cycled in the previous year, a level of participation significantly higher than the national average (Austroads/ Australian Bicycle Council, 2017). Cycling has a number of important individual and community benefits including improved health and well-being, social interaction, reduced traffic congestion, environmental benefits and increased social capital (Austroads, 2010; de Hartog et al., 2010; Oja et al., 2011). Consequently, the WA Bicycle Network Plan 2014-2031 (Department of Transport, 2014) aims to double the number of people cycling or the number of cycling trips made.

It is important to recognise however, that cyclists are vulnerable road users (Wegman, Zhang, & Dijkstra, 2012). The increase in cycling in Australia in recent years has also been accompanied by an increase in the number of bicycle crashes (Henley & Harrison, 2011). In 2017, seven cyclists were killed on WA roads (Road Safety Commission, 2018). The most recent available statistics also indicate that in 2014, 761 cyclists were hospitalised in WA, representing 18% of hospitalised road users (Road Safety Commission, 2016).

The popularity of non-professional on-road group riding (also called bunch or peloton riding), has anecdotally increased in Australia (O'Connor & Brown, 2007). Despite this, group riding has been largely ignored in the literature, in government strategies and in cycling participation surveys. For example, the WA Road Safety Strategy (Road Safety Council, 2009), the WA Bicycle Network Plan (Department of Transport, 2014) and the National Cycling Participation Survey (Austroads/ Australian Bicycle Council, 2017) make no specific reference to group riding. The National Cycling Strategy (2011-2016) only mentions group riding in the context of the social benefits offered by cycling clubs (Austroads, 2010). Police-reported crash and hospitalisation data also does not currently specify whether a cyclist was riding alone or in a group at the time of a crash. As a result, currently there is minimal information about group riding in WA and Australia or the associated safety issues.

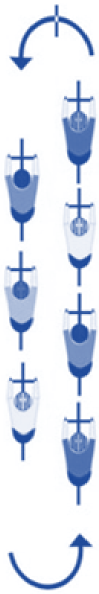
2.1.2 The evolution of group riding: From professional racing to serious leisure

As previously described, group riding originated in the sport of professional road bicycle racing (Mignot, 2016a). In races such as the Tour de France, the main pack of riders is known as a *'peloton'*. According to Trenchard (2013) *'peloton'* is defined as "*two or more cyclists riding in sufficiently close proximity to be located either in one of two basic positions 1) behind cyclists in zones of reduced air pressure, referred to as 'drafting, or 2) in zones of highest air pressure, described here alternately as 'riding in the front', 'in the wind', or in 'non-drafting positions*" (p. 194).

Riders who are *'drafting'* in the peloton (directly behind or beside at angles to others) use less energy while maintaining the same speed as riders in the front positions (Trenchard, 2013). It has been calculated that when drafting a single rider at 32 kilometres per hour (km/h), energy expenditure is reduced by around 18% (McCole, Claney, Conte, Anderson, & Hagberg, 1990). When drafting at 40 km/h in a group of eight riders, energy expenditure is reduced by as much as 39% (McCole et al., 1990). Therefore, professional riders use their position in the peloton for both co-operative and competitive purposes to advance their position in the race (Mignot, 2016b).

As group riding has evolved from the exclusive domain of racing to become more mainstream and popular in Australia, many of the groups use the concepts of aerodynamics learnt from professional racing such as reduction of energy expenditure, and apply them to non-competitive group riding (O'Connor & Brown, 2007). For example, groups of non-competitive riders often use the technique of *'rolling through'* (also called *'rotating the lead'* or *'pace lining'*), where two columns of riders take turns at the front in an orderly rotation, in order to share the energy expenditure and increase the speed the group can travel at. This manoeuvre involves a constant rotation of the lead riders in an anti-clockwise direction in a rolling formation (WestCycle, 2017a) (Figure 2.1).

Figure 2.1 *'Rolling through'* in group riding



A small number of qualitative studies using interviews and focus groups have described the nature of group riding which takes place outside of formal organised races in Australia and the USA. These have revealed that the individuals who participate in group riding vary in age, cycling ability and motivations for participation (Burridge et al., 2003; O'Connor & Brown, 2007). There is also great diversity in the type of groups who take to the road in terms of size, structure, leadership, purpose, codes of behaviour and exclusivity (Albert, 1999; O'Connor & Brown, 2007). Group riding on open roads may take place in the form of training rides within formal cycling clubs, rides organised by bike shops, regular rides with friends/ workmates, informal rides that form by word of mouth or even ad hoc assemblies of riders who form on the road (Albert, 1999; O'Connor & Brown, 2007). While some groups have formalised membership, fees and organising committees, others are reported to be informal, self-organised and internally regulated (O'Connor & Brown, 2007).

O'Connor and Brown (2007) termed this less formal type of group riding that takes place outside of traditional club racing as *'serious leisure'* cycling. These groups are described as informal communities of like-minded individuals without a formalised club structure but who share perspectives, language, ritual, dress and common values (O'Connor & Brown, 2007).

O’Connor and Brown (2007) also noted that each group in their study combined training, informal competition and socialisation and placed value on each of these elements. However, different groups placed more emphasis on some of these elements than others. For example, while some groups emphasised the social elements of group riding by riding at a steady pace that allowed for mid-ride conversation, others emphasised the informal competition and training elements and pushed themselves hard, with conversation and socialisation predominantly occurring after the ride, rather than during (O'Connor & Brown, 2007). Currently, there is minimal information about how these different group characteristics influence safety outcomes.

2.1.3 Safe System Framework

The Safe System Framework is a road safety philosophy originating in the Netherlands and Sweden that was adopted nationally in Australia in 2004 (Australian Transport Council, 2011). This Framework provides the basis for the current WA Towards Zero Road Safety Strategy, 2008-2020 and views the road transport system holistically, representing a shift from a road user-based to a system-based approach to road safety (Road Safety Council, 2009). It acknowledges that human error is inevitable within the transport system and that the system should allow for these errors and minimise the risk of death or serious injury (Organisation for the Economic Co-Operation and Development (OECD)/ International Transport Forum, 2008). The four key components of the approach include; safer road users, safer roads and roadsides, safer vehicles and safer speeds (Australian Transport Council, 2011; Organisation for the Economic Co-Operation and Development (OECD)/ International Transport Forum, 2008). It is recognised that these four elements interact to influence crash risk and severity for all road users in the system.

While the current WA Road Safety Strategy makes no mention of group riders, for cyclists in general it acknowledges the importance of: promoting in-vehicle technology that reduces the likelihood and severity of a crash, appropriate speed limits and dedicated bicycle paths or shared paths (Road Safety Council, 2009). The focus on providing bicycle and shared paths as the main infrastructure-related strategy in WA is unlikely to improve safety for the majority of group riders, for whom it is not appropriate or safe to ride on paths and instead use roads.

For the current study, the Safe System Framework was used as a basis to holistically examine the unique safety issues for on-road group riders. The components of most relevance to this analysis of group riding safety are *'safer road users'* and *'safer roads and roadsides.'*

2.2 Group riding crashes

2.2.1 Background

Crash studies are essential for understanding the causes, circumstances and consequences of bicycle crashes, in order to guide appropriate crash prevention measures. A large number of studies have reported on risk factors for involvement in a bicycle crash or increased injury severity in the event of a crash. For example, inexperience with cycling (Heesch, Garrard, & Sahlqvist, 2011) and multi-lane roundabouts (Reynolds, Harris, Teschke, Cripton, & Winters, 2009) have been shown to increase the risk of a bicycle crash, while on-road bicycle lanes (Reynolds et al., 2009) and use of conspicuity aids (Tin Tin, Woodward, & Ameratunga, 2013a) decrease risk. Selected risk factors for bicycle crashes in general are summarised in Table 2.1.

It is very likely however that the characteristics and risk factors for crashes that occur while riding in a group differ considerably from individual rider crashes. For example, qualitative evidence suggests that rider/ rider crashes, pile ups and crashes involving road hazards are likely to be more common amongst group riders (Albert, 1999). To date, very limited evidence exists on the risk of crashes and circumstances surrounding crashes that occur while group riding specifically. This is because whether a cyclist was riding alone or in a group at the time of the crash is not commonly recorded in either Police or hospitalisation crash records.

This section reviews studies examining the risk or circumstances of crashes that occur while group riding. In addition, the use of in-depth crash investigation methods to determine contributing factors for all types of bicycle crashes is discussed.

Table 2.1 Factors associated with risk or severity of bicycle crashes

Risk factor category	Increased risk or severity	Decreased risk or severity
Road infrastructure	• Increased speed limit • Intersections • Multi-lane roundabouts • Increased traffic density • Presence of parking facilities • Presence of public transport facilities • Increased number of traffic lanes	• On road bicycle lanes (except in combination with roundabouts) • Raised medians between lanes of opposing traffic • Street lighting • Low-angled grades
Cyclist characteristics	• Males • Inexperience with cycling • Alcohol or drug consumption • Use of electronic devices • Recreation cycling	• Use of conspicuity aids • Helmet use • Transport cycling
Crash characteristics	• Motor vehicle involvement • Van, truck or sport utility vehicle involvement • Right angle crashes	• Fall from bike (no collision)

(Amoros, Chiron, Thelot, & Laumon, 2011; Boufous, de Rome, Senserrick, & Ivers, 2012; Brude & Larsson, 2000; Cripton et al., 2015; Daniels, Brijs, Nuyts, & Wets, 2009; DiGioia, Watkins, Xu, Rodgers, & Guensler, 2017; Harris et al., 2013; Heesch, Garrard, et al., 2011; Kaplan, Vavatsoulas, & Prato, 2014; Kim, Kim, Ulfarsson, & Porrello, 2007; Klop & Khattak, 1999; Moore, Schneider, Savolainen, & Farzaneh, 2011; Poulos et al., 2015a, 2015b; Prati, Marín Puchades, De Angelis, Fraboni, & Pietrantoni, 2017; Reynolds et al., 2009; Robartes & Chen, 2017)

2.2.2 Risk of crashes while group riding

The recent prospective Taupo Bike Study involving over 2500 cyclists in New Zealand, used a survey and data linkage to determine that *'ever'* riding in a bunch (group) was associated with a higher risk of involvement in crashes (including Police-reported, hospitalisation and insurance claim crashes) (Tin Tin et al., 2013a). Further analysis also revealed that a higher percentage of bunch riding increased the risk of on-road bicycle crashes (Tin Tin, Woodward, & Ameratunga, 2013b). The authors suggest this may be due to riders being more likely to take risks and not notice hazards while riding in a bunch (Tin Tin et al., 2013b). A major weakness of these studies however, is that it was unknown whether the cyclist was actually riding in a bunch at the time of the crash, only whether they participated in bunch riding.

Similarly, a survey of over 700 male sport cyclists in The Netherlands reported that those involved in bunch riding had higher self-reported crash involvement during the previous year (OR:1.79, 95% CI: 1.26-2.54) than those who mostly cycled alone (Wijlhuizen, van Gent, & Stipdonk, 2016). Since this study did not collect data on the proportion of total cycling that bunch riding comprised however, the authors were unable to compare the actual crash risk for bunch vs non-bunch sport cycling.

Another study of over 2000 cyclists in New South Wales (NSW) compared the crash and injury experiences of transport and recreational riders (Poulos et al., 2015a). In a retrospective analysis, transport riders self-reported a higher proportion of crashes involving motor vehicles than recreational riders (Poulos et al., 2015a). A prospective follow-up study using crash diaries, found that the rate of crashes was significantly higher for those who rode mainly for transport than those who rode mainly for recreation (Poulos et al., 2015b). While this study did not separate riders by group and non-group riders, the majority of group riding is recreational, rather than for transport. Therefore, in contrast to the other two studies, results suggest that group riders could possibly have a lower crash risk than transport cyclists.

Currently, only limited and conflicting evidence exists on the risk of crashes while group riding.

2.2.3 Group riding crash circumstances

A small number of studies have attempted to describe the circumstances of crashes that occur while group riding. The findings of these studies are presented in Table 2.2 by crash circumstance. A recent study of riders hospitalised due to a crash in Victoria reported that 19% of the 128 on-road crashes involved bunch riding. Among these injured riders, 71% reported that another rider contributed to the crash (B. Beck et al., 2016). It should be noted that *'bunch'* was not defined in this study. A report from the same study also analysed eight bunch riding crashes that occurred on Beach Road in Melbourne, Victoria (a very popular bunch riding route) and revealed that the mechanisms of the crashes were diverse (Biegler et al., 2012). The number of riders in the groups ranged from three to 20-30, with three crashes occurring at intersections and five at midblocks. Six of the crashes involved a rider hitting another rider or crashing as a result of avoiding a rider and two crashes involved hitting an object or falling. Five of the crashes occurred while riding two abreast, two while riding single file and one was undefined (Biegler et al., 2012).

An earlier report from Victoria examined all bicycle crashes which occurred on weekends between 6.30am and 10.30am, since this is the most common time for bunch riding to occur (Johnson et al., 2009). Of the 97 serious injury cases, 84% involved a collision with a vehicle and 71% were in speed zones up to 60 km/h (Table 2.2). A major weakness of this study was that it was unable to determine which crashes occurred while riding in a bunch, so would also have included many non-bunch riding crashes that occurred on weekend mornings in the analysis.

The authors of the same report also examined 89 serious injury crashes that occurred along Beach Road in Melbourne (Johnson et al., 2009). They determined that more crashes occurred on weekend days than weekdays and that the most common collision types were rider hitting a parked vehicle (19%) and rider colliding with a right turning vehicle (12%). The majority of crashes occurred at midblocks (57%) or T-intersections (36%) but it should be noted that there are only T-intersections along the portion of Beach Road analysed (Johnson et al., 2009) (Table 2.2). Again, it was impossible to determine what proportion of crashes analysed in this study actually involved bunch riding.

Finally, one study examined the mechanisms of injuries on a multi-day recreational bicycle tour in Iowa, USA over several years. In this event, participants rode in groups on roads where traffic was limited but not blocked (Boeke, House, & Graber, 2010). For the 148 participants where the mechanism of incident was documented, 77% were attributed to rider-related factors (fall/ loss of balance, contact or avoidance of other rider and excessive speed), 20% to road-related factors (cracks, rumble strips, bumps) and 3% to bicycle-related factors. There was also a disproportionate amount of injuries to the upper half of the body and the authors suggest this may be due to clipping of shoes into pedals, which is common among serious group riders. Since this study examined a cycling event and was conducted in the USA, the findings are unlikely to be generalisable to group riding in WA.

Overall, very preliminary evidence suggests that crashes that occur while group riding may be likely to involve another rider, occur at midblocks, while riding two abreast, involve a motor vehicle, occur on roads with speed limits up to 60 km/h, on weekend days and result in upper body injuries (Table 2.2).

Table 2.2 Summary of literature describing group riding crashes

Crash circumstance	% of crashes	Sample size	Country	Study
Involve another rider	71%	24 bunch crashes	Australia	(B. Beck et al., 2016)
Involve motor vehicle	84%	97 weekend morning crashes	Australia	(Johnson et al., 2009)
Riding two abreast	63%	8 bunch crashes	Australia	(Biegler et al., 2012)
At midblock	63%	8 bunch crashes	Australia	(Biegler et al., 2012)
	57%	89 crashes on Beach Rd, Victoria	Australia	(Johnson et al., 2009)
Speed limit up to 60 km/h	71%	97 weekend morning crashes	Australia	(Johnson et al., 2009)
Weekend crash	47%	89 crashes on Beach Rd, Victoria	Australia	(Johnson et al., 2009)
Upper body injuries	68%	148 cycling event crashes	USA	(Boeke et al., 2010)

2.2.4 In-depth crash investigation methods

To date, the majority of studies examining bicycle crashes and the small number examining group riding crashes have used Police-reported crash data. Since lower severity bicycle crashes and those not involving a motor vehicle are rarely reported to Police (Watson, Watson, & Vallmuur, 2015), these types of crashes would not be represented in this review. In WA, cyclists are required to report crashes to the Police if they resulted in bodily harm or property damage was more than $3000 (Insurance Commission of WA/ WA Police, 2017). However, the online crash reporting facility, a joint initiative of the Insurance Commission of WA and the WA Police only allows the reporting of crashes involving a motor vehicle. For these reasons, it is likely that a very small proportion of group riding crashes actually appear in Police-reported crash records. While hospital admission data captures more bicycle crashes than Police data (Meuleners, Gavin, Cercarelli, & Hendrie, 2003), neither sources record information on whether the crash occurred while individual or group riding. In addition, crash and hospital statistics are only able to provide information on a set of pre-defined variables that are included in the databases (Møller & Haustein, 2016). However, the simple presence of a risk factor does not necessarily mean it contributed to the crash and it is impossible to explore the complex interplay between multiple contributing factors using crash data alone (McLaughlin, Hankey, Klauer, & Dingus, 2009; Møller & Haustein, 2016). Therefore, in-depth crash investigation methods present a potential means for determining the specific factors contributing to crashes that occur while group riding.

In-depth crash investigations examine individual crashes in great detail in order to determine the likely factors contributing to the crash and injuries which occurred (Allen et al., 2017; Campbell, Smith, & Najm, 2003). Such methods are suitable for examining a smaller number of crashes than database studies and to date have predominantly been used to examine motor vehicle and motorcycle crashes (Allen et al., 2017; Association of European Motorcycle Manufacturers (ACEM), 2004; McLaughlin et al., 2009). These investigations may include a combination of road user interviews, vehicle inspections, crash site inspections, video footage of crashes, as well as available hospital or Police-reported crash records. This data is then used to determine the primary and secondary contributing factors for each crash with most studies categorising these into *‘human’*, *‘vehicle’* and *‘environment-related’* factors (Allen et al., 2017; Association of European Motorcycle Manufacturers (ACEM), 2004; McLaughlin et al., 2009; Møller & Haustein, 2016).

2.2.4.1 In-depth bicycle crash studies

In-depth crash investigation methods have only recently been used to investigate the specific contributing factors to bicycle crashes. A recent study in Belgium analysed 164 adolescent bicycle crashes using data from schools and insurance companies and followed up each rider with an online questionnaire (Vanparijs, Int Panis, Meeusen, & de Geus, 2016). Primary and secondary contributing factors for each crash were determined and divided into 6 categories. The main primary contributing factors were rider distraction (29%) and poorly maintained infrastructure (21%) and overall, human factors were the primary contributing factor in 79% of crashes (Vanparijs et al., 2016). A weakness of this study was that there were no inspections of the crash site in order to assist with determining contributing factors. In addition, this study was retrospective and required participants to recall details of the crash several months after it occurred, meaning it was susceptible to recall bias.

A study from the Netherlands analysed 41 single bicycle and bicycle/ bicycle crashes involving riders aged 50 years and over (Boele-Vos et al., 2017). Data included hospitalisation records, interviews, bicycle inspections and crash site inspections. Human, vehicle and environment-related contributing factors were identified with the most common being *'behaviour of another road user'* (46-49%), *'carriageway too narrow'* (29%) and *'distraction'* (12-27%) (Boele-Vos et al., 2017).

Finally, Beck et al. (2016) conducted an in-depth analysis of 186 bicycle crashes in Victoria using trauma registry data and cyclist interviews. However, while crash type, road user movement and injury information were described in detail, no in-depth analysis of contributing factors was undertaken (B. Beck et al., 2016).

2.2.5 Group riding crashes: gaps in the literature

To date, extremely limited evidence exists on the circumstances and risk factors for bicycle crashes that occur while group riding. This is due to the under-reporting of group riding crashes to Police and the lack of recording of whether a cyclist was individual or group riding in Police and hospital crash data. While anecdotal evidence suggests there may be important differences between individual rider and group crashes, studies describing group riding crashes to date have been limited by extremely small sample sizes and the likely inclusion of crashes that did not involve group riding in the analyses. Use of in-depth crash investigation methods would overcome these challenges and provide a thorough understanding of the contributing factors (human, environment and bicycle-related) to group riding crashes resulting in hospitalisation in Perth, and how these differ to individual rider crashes. While group and individual riders may share many of the same risk factors for crashes, it is also likely that group riding presents some unique risks or hazards. Group riding differs from individual riding in that it often involves periods of riding two abreast, *'rolling'* (rotating the lead), riding in close proximity to other riders and at high speeds. These features of group riding may present unique hazards which are not present for individual riding, in particular the risk of experiencing a collision with another rider in the group. Since group riding is growing in popularity in WA, this knowledge and understanding is essential for guiding crash prevention efforts surrounding group rider behaviour, motorist behaviour and road infrastructure design.

2.3 Long-term outcomes of bicycle crashes

2.3.1 Background

Since the prevalence of bicycle crashes is increasing, it is important to understand the long-term impact of crash involvement on physical, psychological and social outcomes for both group and non-group riders. In addition, since State and Federal governments in Australia aim to encourage cycling as a form of transport and as a fitness/ leisure activity (Austroads, 2010; Department of Transport, 2014), it is essential to understand how crash involvement affects participation in cycling, for different types of riders. To date, very few studies have examined the long-term outcomes of bicycle crashes. This section summarises current evidence on the physical, psychological and social outcomes of bicycle crashes, cycling participation after a crash and risk factors for negative outcomes for group and non-group cyclists.

2.3.2 Physical, psychological and social outcomes of bicycle crashes

The long-term impact of crash involvement for motor vehicle occupants has been extensively studied with outcomes including physical (e.g. pain), psychological (e.g. post-traumatic stress disorder (PTSD), anxiety, depression, travel phobia) and social (e.g. employment and financial difficulties) effects (Craig et al., 2016; Ehring, Ehlers, & Glucksman, 2006; Mayou & Bryant, 2003; Üzümcüoğlu et al., 2016).

Only a small number of studies have examined long-term crash outcomes for cyclists specifically. A United Kingdom (UK)-based study of road users admitted to the Emergency Department (ED) included 146 cyclists and found that one year after their crash, 19% had PTSD, 6% had an episode of depression, 18% had an episode of anxiety and 17% had travel phobia (Mayou & Bryant, 2003). The second study of French road users included 101 cyclists and found that two years after the crash, 57% reported a good physical recovery, 39% reported negative impact on leisure or sport activities, 27% reported negative impact on occupation or studies, 23% on family life and 12% reported financial difficulties (Tournier et al., 2014). A third study which included over 400 injured cyclists in Sweden found that 44% reported problems in health-related quality of life (HRQOL) with the most common problems being in the pain/ discomfort and anxiety/ depression domains (Ohlin, Berg, Lie, & Algurén, 2017).

Finally, a recent Australian study of 186 cyclists hospitalised due to a crash in Victoria, found that by 12 months post-crash, the majority (95%) had returned to work but 54% did not report a complete functional recovery (B. Beck et al., 2016).

Three of these studies also compared the outcomes of cyclists injured in a crash to other road users and agreed that overall, the types of negative outcomes experienced by cyclists, were very similar to other road users (Mayou & Bryant, 2003; Ohlin et al.; Tournier et al., 2014). Interestingly, injured cyclists reported significantly better physical recovery (Mayou & Bryant, 2003; Tournier et al., 2014), less problems in HRQOL (Ohlin et al., 2017) and less negative impact on leisure or sports activities (Tournier et al., 2014) than other road users, even after controlling for injury characteristics. This is likely due to cyclists having a higher level of health and fitness than other road users, promoting better recovery from their injuries (Ohlin et al., 2017). It should also be noted that Mayou et al. reported that a higher proportion (17%) of cyclists experienced travel phobia one year after the crash, than drivers and pedestrians, but this proportion was lower than for passengers and motorcyclists (Mayou & Bryant, 2003). The term *'travel phobia'* has been used to describe an avoidance or reduction in travel, with necessary travel causing marked discomfort (Taylor, Deane, & Podd, 2002). This suggests that travel phobia may be a particular issue for cyclists following a crash that could impact on their return to cycling.

2.3.3 Return to cycling, cessation and avoidance after a crash

While research suggests that driving avoidance may commonly occur following a crash (Taylor et al., 2002), the impact of bicycle crashes on return to cycling, cycling cessation and cycling avoidance have not yet been investigated.

An early prospective study conducted in the UK found that among motorcyclists involved in a crash, only 38% had returned to motorcycling one year post-crash, 36% had returned to car driving but not motorcycling and 27% had not returned to either (Mayou & Bryant, 1994). In contrast, most car drivers in the same study had returned to driving but several restricted or avoided travel following the crash (Mayou & Bryant, 1994). Avoidance of driving/ riding following a crash has been reported to range from occasional reluctance in particular situations (e.g. bad weather, heavy traffic) to complete avoidance altogether (A. E. Stewart & St Peter, 2004).

While evidence suggests that the physical, psychological and social outcomes of crash involvement are quite similar among road user groups (Ohlin et al., 2017), it is possible that the impact on return to cycling may be greater than return to driving. Since riding a bicycle requires a much higher level of physical ability and exertion than driving, the remaining effects of injuries may impact more on return to cycling. In addition, there are likely to be other transport options available to cyclists that are perceived to be easier, convenient and less risky such as driving or using public transport. Since cyclists participate for a variety of different reasons (e.g. commuting, fitness, training, social), it is possible that certain types of cyclists may be more likely to return to cycling following a crash than others. Group riders who participate more for social/ enjoyment reasons for example, may be more likely to return to cycling that commuters who can choose other transport options. This requires further investigation.

2.3.4 Risk factors for negative outcomes after bicycle crash

Risk factors for poor psychological and social outcomes have been extensively examined following motor vehicle crashes. For example, a systematic review found that consistent predictors of PTSD after a crash included perceived threat to life, lack of social support, higher Acute Stress Disorder symptom severity, persistent physical problems, previous emotional problems, previous anxiety disorder and involvement in litigation/ compensation (Heron-Delaney, Kenardy, Charlton, & Matsuoka, 2013). While little research has examined risk factors for negative outcomes for cyclists, it is reasonable to think they would be similar to other road users.

To date, studies which included cyclists and examined risk factors for negative outcomes of crashes have found that younger people showed better physical recovery, collision with a motor vehicle predicted negative impact on physical recovery, occupation/ studies and familial/ affective life and a history of psychological problems related to financial impact two years post-crash (Tournier et al., 2014). In addition, females reported more problems in HRQOL after crash involvement than males (Ohlin et al., 2017).

No information exists on risk factors for cycling cessation or avoidance after a crash. Anecdotal evidence suggests that for more serious group riders, involvement in a crash may be a normalised or expected part of participation and even serve as a rite of passage into the sport (Albert, 1999). The group also often assumes the rider will return when possible (Albert, 1999). It is therefore possible that group riders are at a lower risk of cessation or avoidance following a crash. It would be useful to determine whether factors such as demographics, crash characteristics, injury type and severity, cycling experience and type of rider (group/ non-group rider) are associated with return to cycling, so that those at risk of cessation could be supported to make a safe return to cycling where possible.

2.3.5 Long-term outcomes of bicycle crashes: gaps in the evidence

Overall, long-term physical, psychological and social outcomes of road traffic crashes have been extensively investigated in the literature. While there is limited information on these outcomes for cyclists specifically, current evidence supports that cyclists experience the same type of negative outcomes as other road users following a crash, but that they may actually recover better in several areas.

There is a major gap in the evidence surrounding the impact of crash involvement on return to cycling, cycling cessation and cycling avoidance. Since the WA government aims to increase cycling participation rates, cycling cessation or avoidance following a crash are important negative outcomes. In order to prevent cycling cessation where possible, it is essential to understand how crash involvement affects cycling cessation and avoidance for different types of riders, including group and non-group riders.

2.4 Naturalistic cycling studies

2.4.1 Background

Naturalistic road safety research involves the unobtrusive observation of road users in their natural environment (Dingus et al., 2006). This may involve the placement of fixed video cameras at specific locations on the road or the instrumentation of motor vehicles or bicycles. Fixed cameras allow observation of road user behaviour at a specific location and have been commonly used to observe traffic violations.

The second method involving instrumented vehicles has become popular in the last decade, pioneered by the *'100 Car Study'* in the USA (Dingus et al., 2006). In these studies, vehicles are unobtrusively fitted with devices such as video cameras, GPS, accelerometers and various sensors and driven by ordinary drivers who are given no instructions or controlled in any way, for an extended period of time (Dingus et al., 2006; Hallmark, Tyner, Oneyear, Carney, & McGehee, 2015). More recently, this methodology has also been adapted for naturalistic cyclist observation.

A major advantage of naturalistic methods is that they allow the examination of all crashes, including those of lower severity which do not appear in crash data. This is particularly beneficial for bicycle safety research, since only a small proportion of crashes are reported (Watson et al., 2015). Importantly, they also allow the analysis of near crashes (any circumstance requiring a rapid evasive manoeuvre) and crash-relevant events (circumstances requiring crash avoidance that is less severe than a rapid evasive manoeuvre), which are far more common than crashes (Dingus et al., 2006). Analyses using the *'100 Car Study'* data have also concluded that near-crashes are a valid surrogate for crashes with positive relationships found between the frequencies of contributing factors for crashes and near crashes (Guo & Fang, 2012; Guo, Klauer, Hankey, & Dingus, 2010).

Other advantages of using vehicle/ bicycle instrumentation for data collection include allowing analysis of events leading up crashes, near-crashes and crash-relevant events and the provision of detailed information on driver/rider exposure to road, traffic and environmental factors that may be associated with crashes (Dingus et al., 2006; Regan, Williamson, Grzebieta, & Tao, 2012). The following section provides a summary of naturalistic cycling studies which have examined various unsafe events and traffic violations.

2.4.2 Naturalistic cycling studies examining unsafe events

2.4.2.1 Studies using bicycle/ helmet instrumentation

A total of seven published studies were identified which involved collecting data from video cameras and other technology attached to bicycles/ helmets, for the purpose of observing unsafe events (Table 2.3). In this review *'unsafe event'* is used to encompass the range of terminology used in the literature including *'safety critical event', 'safety problem', 'safety relevant event', 'cyclist driver event'* and *'traffic conflict'*. The studies either described the unsafe events or determined factors associated with increased risk of an event.

The first study was conducted in Melbourne, Victoria with video cameras being attached to the helmets of 13 commuter cyclists which recorded 127 hours of footage (Johnson et al., 2010). The authors identified 54 on-road *'events'* described as collisions, near collisions or incidents involving motor vehicles (Johnson et al. 2010). The majority of events occurred at intersections (70%), where there was no designated bike lane (56%) and the most frequent event involved sideswipes (41%). Drivers were determined to be at fault in 87% of events (Johnson et al., 2010). Cross-tabulations showed that event severity was significantly associated with the driver turning/ merging too close in front of cyclist, cyclist braking, cyclist head check (left), sideswipes and no driver reaction to the event (Johnson et al., 2010). Since GPS data was not collected, this study was unable to control for cycling exposure or analyse speed data of the cyclists (Table 2.3).

A similar study by the same authors in Canberra, Australian Capital Territory (ACT) attached GPS-enabled cameras to the helmets of 36 commuter cyclists, recording 466 hours of footage (Johnson, Chong, et al., 2014). Again, *'cyclist-driver events'* that occurred on-road were examined (n=91) and revealed that driver behaviour led to the majority of events (93%). The most common event involved a left turn by the driver

(37%) and opened vehicle doors made up 18% of events (Johnson, Chong, et al., 2014) (Table 2.3).

A study in Sweden attached one forward facing camera and GPS to the bikes of 16 commuter cyclists who were asked to ride assigned routes in order to identify *'safety problems'* on 17 major cycling routes in Stockholm (Gustafsson & Archer, 2013). A total of 240 hours of footage was collected and 220 safety problems identified on paths and roads. Overall, the most common conflicting interactions were with cars (33%), other cyclists (20%) and pedestrians (9%) and the most common other problems involved road/ facility design (50%) and road/ facility surface issues (22%). It should be noted that this study was not strictly naturalistic since participants were asked to cycle on assigned (though familiar) routes, which may have affected cyclist behaviour (Gustafsson & Archer, 2013) (Table 2.3).

Most recently, a study in the USA used a helmet camera and GPS to compare the *'safety relevant events'* of 10 adult and 10 child cyclists (Hamann & Peek-Asa, 2017). A total of 57 hours of footage was recorded and 179 safety-relevant events identified. This study included traffic violations as well as crashes, near-crashes and errors that occurred on roads or paths, meaning the majority of events were traffic violations. Overall, children had a lower rate of events than adults and for both adults and children, the highest rate occurred on paved roadways with no bicycle facilities (77.7%) (Table 2.3).

Another study from Germany instrumented bicycles with two cameras (one forward facing and another pointing towards the participant's face), GPS and speed sensors. A total of 372 hours of footage was recorded and 77 *'safety critical events'* (interaction between cyclist and another road user on roads or paths) identified (Schleinitz, Petzoldt, Franke-Bartholdt, Krems, & Gehlert, 2015). Less than 35% of events occurred on-road and 43% involved motor vehicles. Interestingly, this study found that the risk of an event was two times higher on bicycle infrastructure (bike path or bike lane not shared with traffic) than on the roads (Schleinitz et al., 2015). A further analysis compared this data with that collected from 49 electric bike (e-bike) riders. From 1030 hours of footage, 175 *'traffic conflicts'* (interaction between cyclist and another road user on roads or paths) were identified and compared to 350 random controls where no traffic conflict occurred (Petzoldt, Schleinitz, Heilmann, & Gehlert, 2016). Overall, there was no difference in risk of conflicts found for bicyclists and e-bike riders. The risk of a conflict decreased when riding on a carriageway and increased when riding on bicycle infrastructure, on paving stones and when riders infringed traffic rules (Petzoldt et al., 2016) (Table 2.3).

Other studies have had participants use instrumented bikes, rather than their own bikes for the study. In Sweden bikes were instrumented with two cameras (one forward facing, the other pointed at the cyclist's face), GPS, brake force sensor, inertial measurement unit and a push button to press for critical events (Dozza & Werneke, 2014). The extra instrumentation meant this was the first naturalistic bike study that allowed researchers to use kinematic triggers and data from the push button to identify events. A total of 16 cyclists rode the five instrumented bikes, returning 114 hours of footage. *'Critical events'* were defined as any situation which made the cyclist feel uncomfortable and 63 events were identified. These were matched with 126 random control events. Overall, 80% of events involved another vehicle, pedestrian, animal or bicycle and 20% involved road or infrastructure conditions (Werneke, Dozza, & Karlsson, 2015). The risk of a critical event was calculated and found to increase with poorly maintained road surfaces, intersections, intersections with visual occlusion, pedestrian threat and other bicycle threat. (Dozza & Werneke, 2014). More recently, the same authors followed this methodology to examine the risk of *'critical events'* for 12 e-cyclists and found that risk of a critical event increased at intersections and when a motor vehicle was parked in the bicycle lane (Dozza, Bianchi, Giulio, & Werneke, 2016) (Table 2.3).

Lastly a small number of studies have used quasi naturalistic methods involving the attachment of cameras and ultrasonic distance sensors to instrumented bikes, to specifically examine factors affecting the passing distance of motor vehicles from individual cyclists (Chuang, Hsu, Lai, Doong, & Jeng, 2013; Llorca, Angel-Domenech, Agustin-Gomez, & Garcia, 2017; Walker, 2007; Walker, Garrard, & Jowitt, 2014). These studies are outside the scope of this review.

2.4.2.2 Identification of unsafe events

It is clear that the seven studies reviewed defined events quite differently (Table 2.3). Most have based their coding schemes on previous methodologies from naturalistic driving studies and adapted them for the needs of the specific study. There are currently no established standards for definitions or coding among naturalistic cycling studies. While two only included on-road events (Johnson et al., 2010; Johnson, Chong, et al., 2014), the others examined events that occurred on both roads and off-road bicycle infrastructure. While some included only events involving interactions with motor vehicles (Johnson et al., 2010; Johnson, Chong, et al., 2014), or other road users (Petzoldt et al., 2016; Schleinitz et al., 2015), others also included single rider events (Dozza et al., 2016; Dozza & Werneke, 2014; Gustafsson & Archer, 2013; Hamann & Peek-Asa, 2017) and one combined traffic violations with events (Hamann & Peek-Asa, 2017).

In terms of the methods for identifying events, five studies simply viewed the footage (Johnson et al., 2010; Johnson, Chong, et al., 2014; Petzoldt et al., 2016; Schleinitz et al., 2015), two requested that participants fill in a diary of events after each ride (Gustafsson & Archer, 2013; Hamann & Peek-Asa, 2017), as well as reviewing the footage. Gustaffson et al. noted however, that on viewing the footage, a large number of events were identified that were not included in the participants' diaries (Gustafsson & Archer, 2013) The studies by Dozza et al. using instrumented bikes and e-bikes installed a push button for participants to use when they felt uncomfortable about their safety and also interviewed them about events. Since the push button is not a naturalistic method of collecting data however, it is possible that its inclusion affected cyclist behaviour. The additional sensors installed on the instrumented bikes also meant these were the first naturalistic bike studies which were able to use kinematic triggers (e.g. harsh braking) to identify events (Dozza et al., 2016; Dozza & Werneke, 2014). Kinematic triggers were present in only 10 of the 63 identified events, indicating that this method may not be as useful in naturalistic cycling as driving research or that it needs to be refined further.

2.4.2.3 Unsafe events: gaps in the evidence

Overall, seven studies were identified which collected naturalistic data from cyclists by attaching video cameras and other technology to bikes, in order to identify unsafe events. They used a variety of definitions and coding schemes for unsafe events, making it difficult to compare the results of the studies. Findings on the type of events and risk factors for events observed differed substantially between studies. This variation in findings is likely due to the differing definitions of events, methodologies and variation in cycling environments and exposures in the different countries where the studies were conducted.

A weakness of several studies was the use of only one forward facing camera (Gustafsson & Archer, 2013; Hamann & Peek-Asa, 2017; Johnson et al., 2010; Johnson, Chong, et al., 2014). This meant it was impossible to examine events occurring to the rear of the cyclist and may have resulted in certain issues being missed. Another weakness is that the analyses of current studies consisted only of descriptive data, comparisons of rates or univariate analyses, with no multivariate modelling of risk factors for unsafe events.

Lastly, all studies to date using this methodology have examined individual, usually commuter cyclists. No study has examined the unsafe events or risk factors for these events that occur while group riding, presenting a significant gap in the evidence.

Table 2.3 Naturalistic studies using bicycle-mounted cameras to examine unsafe events

Study	Country	Participants/ Naturalistic data analysed	Instrumentation	Outcome measures	Findings
(Dozza & Werneke, 2014; Werneke et al., 2015)	Sweden	• 16 participants • 332 trips • 1549 km • 114 hours	***Instrumented bikes*** • 2 cameras (forward facing and cyclist's face) • Inertial measurement unit (accelerometer, compass and gyroscope) • GPS • Brake force sensor • Push button for critical event	Safety critical events[a] (n=63) Baseline events (n-126)	***Event descriptives*** • 80% of events involved another vehicle, pedestrian, animal or bicycle • 20% of events involved road or infrastructure conditions ***Risk of event increased with:*** • Poorly maintained road surface • (OR: 10.3, 95% CI: 2.16-49.4) • In proximity to intersections • (OR: 4.44, 95% CI: 2.30-8.60) • In proximity to intersections with visual occlusion (OR: 3.12, 95% CI: 1.19-8.21) • Pedestrian threat (OR: 2.33, 1.15-4.72) • Other bicycle threat (OR: 2.4, 1.21-4.78)
(Dozza et al., 2016)	Sweden	• 12 e-cyclists • 410 trips • 1474 km • 86 hours	***Instrumented e-bikes*** • 2 cameras (forward facing and cyclist's face) • Inertial measurement unit (accelerometer, compass and gyroscope) • GPS • Brake force sensor	Critical events[a] (n=88) Baseline events (n=176)	***Event descriptives*** • 78% of events involved another vehicle, pedestrian, animal or bicycle • 9% of events involved road or infrastructure conditions ***Risk of event increased with:*** • In proximity to intersections • (OR: 2.18, 95% CI: 1.28-3.74) • Motor vehicle parked in bicycle lane • (OR not calculated)

Study	Country	Participants/ Naturalistic data analysed	Instrumentation	Outcome measures	Findings
			• Pedal sensor • Current sensor • Push button for critical event		
(Gustafsson & Archer, 2013)	Sweden	• 16 commuter cyclists on assigned routes • 438 trips • 4910 km • 240 hours	***Participant's bike*** • GPS • 1 camera (forward facing)	Safety problems [b] (n=220)	***Event descriptives*** • 68% of events occurred in the morning • Most common conflicting interaction events were with cars (33%), other cyclists (20%) and pedestrians (9%) • Most common other events involved road/ facility design (50%), and road/ facility surface issues (22%)
(Hamann & Peek-Asa, 2017)	USA	• 10 child cyclists • 10 adult cyclists • 261 trips • 670 miles • 57 hours	***Participant's bike helmet*** • 1 GPS enabled camera (forward facing)	Safety-relevant events[c] (n=179)	***Event descriptives*** • Majority of events occurred at intersections for child (78%) and adult (85%) cyclists • Highest safety-relevant event rates occurred on paved roadways with no bicycle facilities present for adults (8.6 per 100 mins of riding) and children (7.2 per 100 mins of riding)
(Johnson et al., 2010)	Australia (Victoria)	• 13 commuter cyclists • 127 hours	***Participant's bike helmet*** • One camera (forward facing)	Events[d] (n=54)	***Event descriptives*** • Most frequent event involved sideswipes (41%) • Drivers determined to be at fault in 87% of events • 70% of events occurred at intersections

Study	Country	Participants/ Naturalistic data analysed	Instrumentation	Outcome measures	Findings
					• No designated bike lane at 56% of event sites ***Event severity associated with:*** • Cyclist reaction, cyclist post-event manoeuvre, pre-event driver behaviour, other vehicle involved, driver reaction, visual obstruction, cyclist head check, event type and vehicle location ($p<0.05$)
(Johnson, Chong, et al., 2014)	Australia (ACT)	• 36 commuter cyclists • 466 hours • 8986 km	***Participant's bike helmet*** • One GPS enabled camera (forward facing)	Cyclist- driver events[e] (n=91)	***Event descriptives*** • Driver behaviour led to 93% of events • Most common event types were left turn by driver (37%), driver turning across cyclists' path from adjacent direction (33%) and opened vehicle doors (17.6%)
(Schleinitz et al., 2015)	Germany	• 31 participants • 1667 trips • 5280 km • 372 hours	***Participant's bike*** • Two cameras (forward facing and rider's head) • Speed sensors • GPS	Safety critical events[f] (n=77)	***Event descriptives*** • 43% of events involved motor vehicles • 57% of events involved other cyclists and pedestrians • Less than 35% of events occurred on-road
(Petzoldt et al., 2016)	Germany	• 31 bicycle riders and 49 e-bike riders • 14,445 km • 1030 hours	***Participant's bike or e-bike*** • Two cameras (forward facing and rider's head) • Speed sensor	Traffic conflicts[f] (n=175) Baseline events (n=350)	***Risk of event increased with:*** • Presence of other road users (both bike and e-bike riders) • Paving stones (bikes and e-bikes) • Cyclist infringements or violations (bikes and e-bikes)

Study	Country	Participants/ Naturalistic data analysed	Instrumentation	Outcome measures	Findings
			• GPS		• Intersections (e-bike riders only) • Bicycle infrastructure (bike path, bike lane not shared with traffic) (bike riders only) ***Risk of event decreased with:*** • Cycling on the carriageway (bike riders only) • Unpaved paths (e-bike riders only)

OR: Odds ratio km: kilometres

[a] ‘*Safety critical event*’ and ‘*critical event*’: anything that made the bicyclist uncomfortable about her/ his own safety while cycling

[b] ‘*Safety problem*’: Conflicting interactions and problems with road/ facility

[c] ‘*Safety-relevant event*’: incident involving one or more of the following characteristics: crash, near crash, cyclist, pedestrian, or motorist errors, or traffic violations

[d] ‘*Events*’: collisions, near collisions or incidents involving motor vehicles

[e] ‘*Cyclist driver events*’: cyclist driver interactions that were potentially unsafe, near-collision or crash related

[f] ‘*Safety critical events*’ and ‘*traffic conflicts*’: Interaction between a bicyclist and another road user such that at least one of the parties has to change speed or direction to avoid a collision

2.4.3 Naturalistic studies of rider traffic violations

In WA, a bicycle is considered to be a legal road vehicle and cyclists are subject to the same road rules as motor vehicles when using a public road ("Western Australia Road Traffic Code," 2000). The most common rules include obeying traffic lights and stop signs, giving way and keeping left. The WA Road Traffic Code 2000 also outlines a set of specific rules for bicycles including that riders must use designated bicycle lanes whenever practicable ("Western Australia Road Traffic Code," 2000). The Traffic Code makes no mention of groups of riders specifically so the rules apply to both individual and group riders. One rule that is particularly targeted to groups is that they must not ride more than two abreast and must be no more than 1.5 metres apart when two abreast ("Western Australia Road Traffic Code," 2000).

Naturalistic study methods can also be useful for examining rider traffic violations. To date, naturalistic data on rider violations comes predominantly from fixed camera or roadside observation studies, as well as a small number of studies using bicycle-mounted technology.

2.4.3.1 Prevalence and consequences of rider traffic violations

The majority of studies examining rider traffic violations have focused specifically on red light violations by individual riders and observational studies from around the world have reported a wide variation in the prevalence of this violation. For example, the prevalence of red light violations ranged from only seven percent in Victoria, Australia (Johnson, Newstead, Charlton, & Oxley, 2011) to 16% in Taiwan (Pai & Jou, 2014), 56% in China (Wu, Yao, & Zhang, 2012) and over 60% in Ireland (Richardson & Caulfield, 2015) and Italy (Fraboni, Marin Puchades, De Angelis, Prati, & Pietrantoni, 2016). In an Australian survey, riders self-reported higher levels of traffic violations with 37% having ridden through a red light (Johnson, Charlton, Oxley, & Newstead, 2013). Another survey of 770 transport cyclists in New South Wales (NSW) examined a wider range of violations with 95% reporting that they ever broke road rules (L. Shaw, Poulos, Hatfield, & Rissel, 2015). The most common violation (65%) was riding on the footpath (legalised in WA in April 2016), followed by riding through red lights, (38%), riding outside of a designated cycle lane (8%), riding the wrong way on a one way street (7%) and treating stop signs as give way signs (5%) (L. Shaw et al., 2015).

There is conflicting evidence on whether rider violations are an important contributor to involvement in a crash. An analysis of bicycle crashes in Queensland found that rider violations were involved in 28% crashes with motor vehicles where the cyclist was at fault, but only eight percent of single bicycle crashes (Schramm, Rakotonirainy, & Haworth, 2010). While another Australian study reported an association between self-reported rider violations and crash risk (Johnson et al. 2013), a similar survey in Brazil found no association (Bacchieri, Barros, Dos Santos, & Gigante, 2010). Johnson et al. describes how rider violations can contribute to negative driver attitudes towards cyclists, as well as negative media portrayal of cyclists as unlawful (Johnson et al., 2013). Therefore, despite the lack of conclusive evidence on a direct link between rider traffic violations and crashes, these violations may have wider repercussions that influence motorist perceptions and indirectly affect safety.

2.4.3.2 Naturalistic studies using fixed cameras or roadside observation

Four published studies utilising video cameras fixed to infrastructure and one using roadside observation to examine risk factors for rider traffic violations, were identified. All of these studies examined only red light violations and are summarised in Table 2.4.

An Australian study used fixed cameras to observe rider red light violations at 10 intersections located on frequently used on-road commuter rider routes in metropolitan Melbourne, Victoria (Johnson et al., 2011). Of 4225 riders, seven percent were non-compliant. It was found that riders turning left had 28 times the odds of infringement compared to travelling straight. There were also lower odds of infringement when there was a vehicle travelling in the same direction, other riders were present or the rider was female. The odds of infringement also significantly decreased with increasing volume of traffic on the road that crossed the one the rider was on (Johnson et al., 2011) (Table 2.4).

A similar study in Beijing, China observed 451 bicycle and e-bike riders at three signalised intersections and reported that 56% rode through the red light (Wu et al., 2012). The authors categorised these violations as *'risk taking'* when riders never stopped at the red light (31%) and *'opportunistic'* when they stopped but crossed before the light turned green (25%). Logistic regression modelling revealed that risk of violation increased with younger age, low cross-traffic volume, smaller number of other riders waiting at the intersection and larger number of other riders violating the red light (Wu et al., 2012) (Table 2.4)

In Taiwan, of 12,447 riders at eight intersections, 16% rode through the red light (7% *'risk taking'*, 9% *'opportunistic'*). The authors reported increased probability of risk taking violations for males, during off peak hours, when the rider was not wearing a helmet, at T or Y-intersection designs, at speed limits of 60 km/h and in low traffic volumes (Pai & Jou, 2014) (Table 2.4).

An analysis of video footage from four intersections in Ireland found that from 3064 riders, 98% of cycle track users (segregated cycling facility with bicycle traffic lights) rode through red lights, with majority occurring during the pedestrian green phase (Richardson & Caulfield, 2015). For cycle lane users (on-road lane adjacent to vehicular traffic), 19% rode through a red light, the majority during a motorist phase. Multinomial logistic regression modelling found that while males were more likely to violate during a motorist red phase, females were more likely to violate during a pedestrian phase (Richardson & Caulfield, 2015) (Table 2.4).

Finally, a study in Bologna, Italy placed roadside observers at four intersections to examine the influence of the presence of other riders on red light violations (Fraboni et al., 2016). Of 1381 riders approaching a red light, 63% rode through the red light (33% *'risk taking'*, 30% *'opportunistic'*). The study found that a larger number of riders waiting at the intersection was associated with less risk-taking violations but did not influence opportunistic violations (Fraboni et al., 2016) (Table 2.4).

These naturalistic studies using fixed cameras or roadside observation have the advantage of allowing a large number of targeted violations to be observed. However, they also have important disadvantages including that only limited information on rider characteristics can be obtained from the observation. Most importantly, these studies are usually only able to observe one type of violation (red light violations in the reviewed studies), at a small number of locations, at selected times, meaning the conclusions drawn may be case specific and not generalisable to other locations, times and situations.

2.4.3.3 Naturalistic studies using bicycle/ helmet instrumentation

To date, only two studies were found which instrumented bicycles or helmets to observe rider traffic violations (Table 2.4). Firstly, a study conducted in the USA instrumented bicycles and e-bikes with GPS to examine the traffic violations of 100 university bike-share users over 2833 short trips (Langford, Chen, & Cherry, 2015). They reported that approximately 70% of all riders rode through red lights, 80% rode through stop signs at speeds less than six km/h and 45% rode the wrong way on roadway segments (Langford et al., 2015) (Table 2.4) Secondly, the study by Hamann et al. described previously, instrumented cyclists' helmets with GPS enabled cameras in the USA in order to observe safety-relevant events. However, they included some rider traffic violations in the definition of events, namely failures to stop or yield when required. Rates of these violations were 9.4 per 100 miles for children aged 11-13 years and 29.4 per 100 miles for adults aged 18+ years (Hamann & Peek-Asa, 2017) (Table 2.4). While is clear that these studies are able to examine a wider range of violations than fixed camera studies, the overall number of each violation captured is much lower. In addition, neither study examined risk factors for violations.

2.4.3.4 Naturalistic studies of group rider violations

To date, only one study has used naturalistic methods to observe group rider traffic violations (Table 2.4). Johnson et al. analysed video footage provided by the Victorian Police of bunch riders on Beach Road and Nepean Highway, which form part of the most popular bunch riding circuit in Melbourne, Victoria (Johnson et al., 2009). Approximately 1.5 hours of footage was filmed over three occasions in 2005 from a dashboard camera on a vehicle which followed bunch riders. This was compared to approximately 50 minutes of footage filmed over two occasions in 2007 from a helicopter following the riders.

The 2005 footage was filmed in summer with each bunch consisting of approximately 100 riders. It was found that riders committed a violation at 46% of red traffic lights, rode more than two abreast 100% of the time and occupied more than a single traffic lane 90% of the time. The authors noted that riders seemed oblivious to other vehicles on the road with cars having to wait an average of two minutes to pass the bunch, even on dual carriageways. They also occupied both traffic lanes at intersections and typically rode four abreast, with this increasing up to 16 abreast at times. Overall, the bunches did not use the painted bike lanes on the roads (Johnson et al., 2009).

The 2007 footage was filmed in winter with bunch sizes of 30-40 riders and presented a very different picture of bunch riding behaviour. Overall, there were no red light violations, the groups rode more than two abreast only five percent of the time and riders occupied more than one lane two percent of the time. It was noted that generally riders spread out and occupied more than one lane only at the end of the rides when they were *'racing'*. Again, the bunches did not use the painted bike lane the majority of the time (Johnson et al., 2009).

The authors acknowledge that it was not possible to determine whether the very different behaviour observed between 2005 and 2007 was due to an actual change in bunch behaviour or whether it was due to effects of the season, differences in bunch size, the presence of the helicopter filming the footage or other unknown factors (Johnson et al., 2009). However, the findings suggest that red light violations, riding more than two abreast and occupying more than one traffic lane may be the predominant traffic violations committed by groups of riders.

While this study provides useful information, there were limitations. First, the presence of a conspicuous car or helicopter for filming may have influenced rider behaviour. Second, only a small amount of footage was available and it was filmed on just one route known for bunch riding in Melbourne. In Perth, there are no such group riding routes and groups as large as 100 are uncommon, meaning it is unlikely that these findings could be generalised to group riders in Perth.

2.4.3.5 Rider violations: gaps in the evidence

Currently, naturalistic evidence on rider traffic violations comes mainly from fixed camera studies at intersections. While these studies have provided useful information on risk factors for violations, they have focused only on red light violations and observed the behaviour of individual, often commuter cyclists. Since groups differ in many ways to individual cyclists, it is unknown if the currently identified risk factors for rider violations, also apply to group riders. Unfortunately, the one study examining group rider violations collected only a small amount of footage filmed from a motor vehicle and helicopter, on only one road in Melbourne, and reported very conflicting observations over a two-year period (Johnson et al. 2009). It is therefore unclear whether the issues identified in this study are also relevant to the Perth group riding context. Currently, there is no information on the prevalence or type of violations committed by group riders in Perth or the group or trip-related risk factors associated with these violations. It would therefore be extremely useful to analyse a large amount of naturalistic group riding footage, filmed from the bicycles of group riders, covering a variety of road locations, seasons, sizes and types of groups, in order to gain an understanding of the issues surrounding traffic violations among group riders in Perth.

Table 2.4 Naturalistic studies of cyclist road rule violations

Study	Country	Methods	Participants/ data	Violations examined	Findings
Fixed camera and roadside observation studies					
(Fraboni et al., 2016)	Italy	Roadside observation	• 4 intersections • 1381 cyclists	• Red light violations	***Prevalence of red light violations*** • 63% of cyclists (33% risk-taking, 30% opportunistic) ***Risk factors for red light violations*** Decreased risk of risk-taking violations with: • Larger number of cyclists waiting at the intersection ($p < 0.001$)
(Johnson et al., 2011)	Victoria Australia	Fixed cameras	• 10 intersections • 4225 cyclists	• Red light violations	***Prevalence of red light violations*** • 7% of cyclists ***Risk factors for red light violations*** Increased odds of violations when: • Turning left (OR: 28.4, 95% CI 17.77-45.39) Decreased odds of violations with: • Female gender (OR: 0.60, 95% CI 0.41-0.87) • When a vehicle was travelling in same direction (OR: 0.39, 95% CI 0.28-0.53) • Other cyclists were present (OR: 0.26, 95% CI 0.19-0.36)
(Pai & Jou, 2014)	Taiwan	Fixed cameras	• 8 intersections • 12,447 cyclists	• Red light violations	***Prevalence of red light violations*** • 16% of cyclists (7% risk-taking, 9% opportunistic)

Study	Country	Methods	Participants/ data	Violations examined	Findings
					Risk factors for red light violations Increased probability of risk-taking violations with: • Male gender (46%) • Off peak hours (19%) • Not wearing a helmet (76%) • T or Y intersections (113%) • Speed limits of 60 km/h (72%) • Low traffic volumes (69%)
(Richardson & Caulfield, 2015)	Ireland	Fixed cameras	• 4 intersections • 3064 cyclists	• Red light violations	***Prevalence of red light violations*** • 98% of cycle track users • 19% of cycle lane users ***Risk factors for red light violations*** Increased odds of risk-taking violations with: • Cycle track use (p<0.001) • Male gender for violating during a motorist red phase (p<0.001) • Female gender for violating during a pedestrian phase (P=0.042)
(Wu et al., 2012)	China	Fixed cameras	• 3 intersections • 451 cyclists	• Red light violations	***Prevalence of red light violations*** • 56% of cyclists (31% risk-taking, 25% opportunistic) ***Risk factors for red light violations*** Increased odds of violations with:

Study	Country	Methods	Participants/ data	Violations examined	Findings
					• Younger age (OR: 7.63, 95% CI 2.54-22.91) • Low cross-traffic volume (OR: 3.65, 95% CI 1.80-7.80) • Larger number of other riders violating the red light (OR: 2.41, 95% CI 1.67-3.49) Decreased odds of violations with: • Larger number of other riders waiting at the intersection OR: 0.72, 95% CI 0.58-0.90)
Bicycle or helmet instrumentation studies					
(Langford et al., 2015)	USA	Bicycles and e-bikes instrumented with GPS	• 100 university bikeshare users • 2833 short trips	• Red light violations • Wrong-way riding • Stop sign violations	***Prevalence of violations*** • Red light violations (70% of cyclists) • Stop sign violations (80% of cyclists) • Wrong way riding (>40% of cyclists)
(Hamann & Peek-Asa, 2017)	USA	GPS enabled helmet cameras	• 10 child cyclists • 10 adult cyclists • 261 trips • 670 miles • 57 hours	• Failure to stop or yield when required	***Prevalence of violations*** • Children: 9.4 violations per 100 miles • Adults: 29.4 violations per 100 miles
Group rider studies					
(Johnson et al., 2009)	Victoria Australia	Video filmed from police	• 1.5 hours of bunch riding footage filmed	• Red light violations	***Prevalence of violations*** 2005 footage: • Red light violations (46% of red lights)

Study	Country	Methods	Participants/ data	Violations examined	Findings
		vehicle and helicopter	from a vehicle in 2005 • 50 minutes of bunch riding footage filmed from a helicopter in 2007	• Riding more than 2 abreast • Occupying more than one lane of traffic • Not using designated bike lane	• Ride more than 2 abreast (100% of the time) • Occupied more than one lane (90% of the time) 2007 footage: • Red light violations (0% of red lights) • Ride more than 2 abreast (5% of the time) • Occupied more than one lane (2% of the time)

2.5 Summary

This literature review found that while there has been extensive research into cycling safety conducted to date, this has focussed almost exclusively on individual, often commuter cyclists. Non-professional group riding is a unique type of cycling that takes place on public roads and is rapidly gaining popularity in Australia. Evidence suggests that group riders may experience quite different safety issues to individual riders, however, this review located only very limited literature examining group rider safety.

Firstly, in terms of crashes, few studies have examined the circumstances surrounding group rider crashes and these have been limited by small sample sizes. The likely under-reporting of group rider crashes to Police, coupled with the lack of recording of whether a cyclist was riding in a group at the time of the crash, makes it difficult to examine group rider crashes using Police or hospitalisation data. In-depth crash investigation methods may overcome these challenges and provide valuable insights into the circumstances and contributing factors surrounding group rider crashes. This review also identified a major gap in the evidence around the long-term impact of crash involvement on return to cycling, cycling cessation and avoidance for different types of cyclists, including group riders.

Finally, naturalistic cycling research using bicycle-mounted video cameras and GPS data is still in its infancy and again, has focused largely on individual cyclists. The one naturalistic study of group riding conducted to date analysed a small amount of video, recorded on only one road in Victoria. A larger naturalistic study of group riding would provide invaluable detail on the types of unsafe events and violations experienced as well as the group and road environment-related risk factors for these.

CHAPTER 3

Phase 1 – In-depth bicycle crash study: Methods

3 PHASE 1 - IN-DEPTH BICYCLE CRASH STUDY: METHODS

This study focused on examining safety issues for group riders in Perth, WA. It formed a separate study within a larger Australian Research Council (ARC)-funded project entitled *'Safer Cycling and the Urban Road Environment'* (Stevenson et al., 2015). The ARC project involved a case-control study that examined the association between road infrastructure and crashes for all types of cyclists in Melbourne and Perth. While the ARC study was used as leverage for data collection, all other aspects of the group riding study were unique. This includes the conception, the follow-up data collection, analysis of factors contributing to crashes and all statistical analyses presented in this thesis. The methodology of the group riding study only is detailed in this thesis. The methodology of Phase 1 only is detailed in this chapter and the Phase 2 methodology is described in Chapter 5.

Phase 1 of the study involved two parts:

1. Part A consisted of an in-depth crash study of riders hospitalised due to an on-road crash in Perth, WA. It compared the characteristics (rider, road-environment, crash-related and contributing factors) of crashes that occurred while group riding (*'group rider crashes'*) to crashes that occurred while riding alone (*'individual rider crashes').*
2. Part B involved a 12-month follow-up of riders hospitalised due to a crash. *'Reduced cycling exposure'* 12 months after the crash was compared for group riders and non-group riders.

3.1 Study design

Phase 1 involved an in-depth longitudinal study of riders hospitalised in Perth, WA. Data collection included:

- Baseline questionnaire administered shortly after the crash;
- Follow-up questionnaire conducted 12 months after the crash;
- Crash data from the Integrated Road Information System (IRIS);
- Injury information from the State Trauma Registry;
- Virtual crash site inspection;
- Analysis of crash types and factors contributing to each crash.

3.2 Group riding definition

The purpose of the in-depth crash study was firstly to compare the characteristics of crashes that occurred while group riding (*'group rider crashes'*) with crashes that occurred while riding alone (*'individual rider crashes').* Different definitions of group riding were used for Parts A and B of Phase 1 in order to meet the different objectives of these Parts. Since certain crash types (rider/ rider) and behaviours (riding two abreast) of interest could involve any group of two or more riders, *'riding with at least one other known rider'* was chosen as the definition for the Part A baseline analysis. For the follow-up assessment however, how rider characteristics were associated with *'reduced cycling exposure'* was of interest. Therefore, *'group riding participation'* was defined as whether a participant rode as part of a group or club of five or more riders in the month before the crash.

3.3 Participant recruitment

Participants included riders hospitalised as a result of an on-road bicycle crash that occurred in Perth, WA between September 2014 and December 2016. Potentially eligible riders were identified through the Royal Perth Hospital (RPH), Sir Charles Gairdner Hospital (SCGH) Fremantle Hospital and Fiona Stanley Hospital (FSH) trauma registries. The trauma registries contain information on all patients who are admitted due to trauma for at least 24 hours. Trauma registry staff at each hospital provided the contact details of potentially eligible riders to the RPH-based research nurse, daily. The research nurse attempted to approach potential participants while in hospital, provided a Participant Information Sheet (PIS) and consent form (Appendix 1) and support services sheet (Appendix 2) and invited them to participate in the study. If they were discharged prior to contact, a letter explaining the study (Appendix 3), the PIS, consent form and support services sheet were posted to their home address. The research nurse then contacted the rider by phone within one week and invited them to participate in the study. Signed consent forms were received from each participant in person, by post or email before any data was collected. Participants were recruited consecutively and it was not intended to include equal numbers of participants from each hospital.

3.4 Inclusion and exclusion criteria

The inclusion criteria applied to the study were:

- Involvement in an on-road crash (paths and off-road trails were not included) as a rider in the Greater Perth area (includes Perth Metropolitan, City of Mandurah, Pinjarra 2 and Shire of Murray areas and accounts for approximately 80% of the WA population) (Australian Bureau of Statistics, 2017) (Figure 3.1);
- Involvement in a bicycle/ motor vehicle, bicycle/ bicycle, bicycle/pedestrian or single bicycle crash.
- Aged 18 years or older.

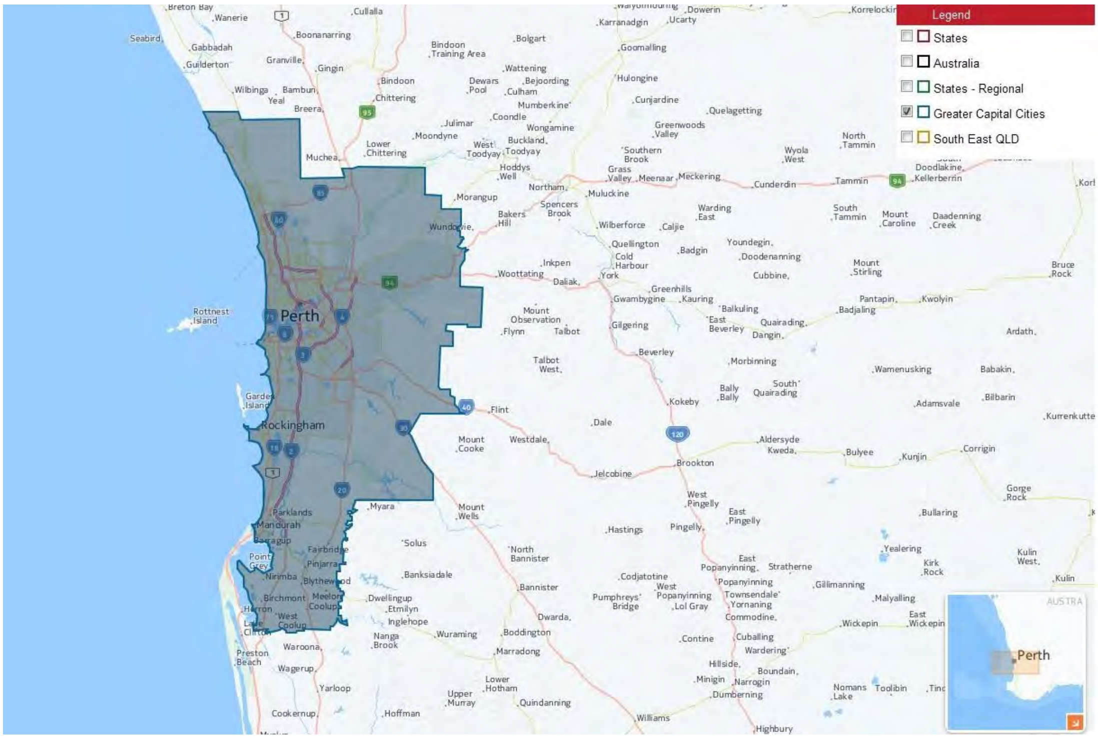
The inclusion criteria resulting from the recruitment process were:

- Admitted to RPH, SCGH, Fremantle Hospital or FSH;
- Admitted to hospital for 24 hours or longer;
- Recorded on the trauma registry of the hospital.

Exclusion criteria applied to the study were:

- Involved in a bicycle race at the time of the crash
- Severely disabled or killed in the crash;
- Unable to recall the events of the crash;
- Non-English speaking.

Figure 3.1 Greater Perth area



(id consulting, 2018)

3.5 Sample size

The intended sample size for Phase 1 of the study was 200 riders but due to issues with hospital and trauma registry closures, the final sample totalled 108 riders. It was anticipated that approximately one-third of the recruited participants would have been group riding (riding with at least one other known rider) at the time of the crash. The decision for the sample size was based on the planned comparison of the individual factors contributing to crashes for group rider compared to individual rider crashes. The reduced final sample size may not have the power to compare the proportions of all of the individual factors contributing to group rider compared to individual rider crashes. However, it is adequate for examining the involvement of broad categories of contributing factors (human/ environmental/ vehicle-related) and selected sub-categories of contributing factors (e.g. road-related factors) using chi-square tests.

Limited previous research suggests that environmental or road-related factors may contribute to approximately 30% of individual rider crashes (Boele-Vos et al., 2017; Vanparijs et al., 2016). If at least 60% of group rider crashes have environmental contributing factors (as indicated by anecdotal reports), a sample size of 31 group rider crashes and 62 individual rider crashes would be adequate to reject the null hypothesis using the chi square test ($\alpha = 0.05$; power = 80%). The sample size was also adequate to detect differences between crashes that occur while group or individual riding for the other variables of interest including crash type (motor vehicle compared to non-motor vehicle), crash location (intersection compared to midblock) and posted speed limit ($\alpha = 0.05$; power = 80%).

The sample size for the follow-up analysis was 83 participants. The outcome of interest was *'reduced cycling exposure'* at follow-up (reduced cycling exposure, no reduction in cycling exposure). It was of interest to determine whether group riding participation before the crash was associated with a lower risk of *'reduced cycling exposure'* at follow-up. It was again estimated that one-third of participants participated in group riding at baseline. While there is no existing research on cycling participation after crash involvement, other research suggests that 62% of motorcyclists do not return to motorcycling after a crash (Mayou & Bryant, 2003). If at least 70% of non-group riders had *'reduced cycling exposure'* and less than 40% of group riders had *'reduced cycling exposure'* at follow-up, a sample size of 31 group riders and 62 non-group riders at follow-up would be adequate to reject the null hypothesis using the chi square test ($\alpha = 0.05$; power = 80%).

3.6 Data collection

Information for Phase 1 was collected at baseline (shortly after the crash) and approximately 12 months after the crash. The baseline data collection included:

- A researcher-administered questionnaire;
- crash information from the IRIS;
- injury information from the State Trauma Registry;
- a virtual crash site inspection examining road characteristics;

The follow-up data collection at 12 months post-crash involved a telephone questionnaire.

3.6.1 Baseline questionnaire

Participants completed a researcher-administered questionnaire in person or by phone, which took 30-40 minutes. The full questionnaire is located in Appendix 4 and contains items with binary, multiple choice and open-ended responses. The majority of participants completed the questionnaire by phone (77.8%). The questionnaire was administered, on average, 18 days (standard deviation (SD): 11.6) after the crash (range: 1 - 52 days). The questionnaire was created, data entered and stored electronically using the Qualtrics Research Suite survey software (Qualtrics, 2015).

Questionnaire items included:

- Demographics, health conditions and medication usage (Appendix 4, Q 4-33);
- Cycling exposure and experience, including group riding (Appendix 4, Q 35-71);
- Previous bicycle crash history (Appendix 4, Q 72-74);
- Risky cycling behaviours (Appendix 4, Q 76-97);
- Crash information (details of bicycle, clothing, helmet, crash location, crash type, nature/ events of the crash, who participant was riding with at the time of the crash, whether they were riding in a bicycle lane, whether they were travelling on the road or between path and road, speed, trip details and contributing factors to the crash) (Appendix 4, Q 99-212).

The questionnaire was based on a structured interview used in a recent Victorian in-depth investigation of bicycle crashes (B. Beck et al., 2016) that formed part of the ARC funded case-control study. Questions about group riding exposure and experience as well as details on who the participant was riding with at the time of the crash were added for the purpose of the group riding study. The questionnaire was piloted with five group riders for face and content validity. Minor amendments were then made to terminology and clarification of questions. Participants also provided a sketch of the crash location and circumstances. They were asked to include the rider (themselves), other road users and to indicate the name of the road(s) at the crash location and their direction of travel (Appendix 5).

3.6.2 Follow-up questionnaire: 12 months

The follow-up questionnaire was conducted by phone approximately 12 months after the crash and took 10-20 minutes to complete (Appendix 6). The follow-up questionnaire was administered, on average 13 months (SD: 0.86) after the crash and this ranged from 12.0 to 15.0 months. No participants were contacted for follow-up earlier than 12 months and participants who could not be contacted by phone, 15 months after the crash were excluded. The questionnaire consisted of several pre-existing measures of pain, function and additional questions on cycling exposure and behaviour.

Pain: Pain level was measured using the Numeric Pain Rating Scale that asks the participant to make three pain ratings, corresponding to current, best and worst pain experienced over the past 24 hours (McCaffery & Beebe, 1989) (Appendix 6, Q 6-11). The scale ranges from 0 - 10 (0: no pain, 1-3: mild pain, 4-6: moderate pain and 8-10: severe pain). This scale provides interval level data and has shown have good sensitivity to detect change in pain (Williamson & Hoggart, 2005).

Level of function: Level of function was measured using the Glasgow Outcome Scale-Extended (GOS-E), a previously developed, widely used and reliable measure (κ=0.85) (Wilson, Pettigrew, & Teasdale, 1998) (Appendix 6, Q 13-34). While originally developed for use among patients with head injury, it is now used widely to assess level of function for both head injured and non-head injured trauma patients (Lewis, Vint, & Pallister, 2013). It contains multiple choice questions relating to the ability to perform a range of activities in six domains including *'independence at home'*, *'independence outside home'*, *'work'*, *'social and leisure'*, *family and friendships'* and *'return to normal life'* (Wilson et al., 1998). The GOS-E scoring system categorises patients into one of eight categories of functional outcome and this is based on the lowest category they obtained in any of the six domains. These categories consist of:

1. Death
2. Vegetative state
3. Lower severe disability
4. Upper severe disability
5. Lower moderate disability
6. Upper moderate disability
7. Lower good recovery
8. Upper good recovery

Cycling exposure, cessation and reduction: The questionnaire also contained items on return to cycling or cessation of cycling since the crash, cycling exposure during the previous month and participation in group riding during the previous month. The same cycling exposure questions were used as in the baseline questionnaire and participants were also asked whether they had ceased, reduced, increased or had no change in cycling exposure (Appendix 6, Q 36-80, Q84-89).

Modifications to bicycle or behaviour: Three questions addressed whether participants had made any modifications to their bicycle, clothing worn when cycling or behaviour while cycling since their crash, for the purpose of safety (Appendix 6, Q 81-83).

3.6.3 Crash information from the Integrated Road Information System

The IRIS database, maintained by Main Roads WA contains information on all crashes in WA which are reported to the Police or through the Online Crash Reporting Facility (Insurance Commission of WA/ WA Police, 2017). All 108 crashes were searched for in the IRIS database by crash date, crash location and date of birth of the participant. Only 43 of the crashes (39.8%) were recorded in the IRIS database. This is likely due to the under-reporting of bicycle crashes in WA.

The IRIS database contains information which includes crash location, intersection/ midblock, intersection type, number of approaches, road gradient, atmospheric conditions, road condition, lighting conditions, speed limit, crash Road Use Movement (RUM) code, rider movement, other road user movement and single or multi-vehicle crash. This information, where available was used in conjunction with the participant questionnaire to determine the exact location and circumstances of the crash in order to conduct the site inspections. The database also contains limited information on contributing factors to the crash including whether speed, inattention and/or fatigue was a factor in the crash. Information on any alcohol readings taken was also available.

3.6.4 Injury information from State Trauma Registry

Detailed information on the participants' injuries was obtained from the WA State Trauma Registry. This registry is based at RPH and collects data about trauma patients from hospitals and health care facilities throughout WA in one single web-based database. It includes all major and minor trauma patients who present to a hospital in WA for treatment and who were hospitalised for more than 24 hours (Department of Health, 2012).

Injury information was not available for seven participants due to issues with data being transferred from the individual hospitals to the State Trauma Registry, which was outside the control of this study. Data collected from the WA State Trauma registry included:

Abbreviated Injury Scale (AIS): The AIS is an anatomically-based scoring system that uses a six point scale to classify each injury by body region, according to its severity (Gennarelli, Wodzin, & Association for the Advancement of Automotive Medicine, 2008). It was first published in 1969 and is the most widely used severity scale for injuries.

Injury Severity Score (ISS): The ISS assesses the combined effects of multiple injuries on patients and is based on the AIS scores (Baker, O'Neill, Haddon, & Long, 1974). The ISS is calculated as the *"sum of the squares of the highest AIS grade in each of the three most severely injured areas"* (Baker et al., 1974) (p.190). These areas are: head or neck, face, chest, abdominal or pelvic contents, extremities or pelvic girdle and external. This scale only allows the consideration of one injury per body region. The ISS ranges from one to 75, with 75 being the most severe score (Baker et al., 1974).

New Injury Severity Score (NISS): The NISS is a variation of the ISS and is the sum of the squares of the three highest severity levels, even if they occur within the same body region (Osler, Baker, & Long, 1997).

Major or minor trauma: This variable categorises trauma in terms of *'major'* or *'minor'*. This is based on the ISS with > 15 indicating *'major'* trauma.

Alcohol consumption: Three alcohol-related variables were recorded. These included: self-reported consumption of alcohol within the 12 hours preceding the trauma event, whether alcohol could be smelt on the breath of the patient and results of blood alcohol tests (if performed).

Illicit drug use: These variables included self-reported use of illicit drugs within the 12 hours preceding the trauma event and results of any toxicology (if performed).

Care in days: Number of days the patient was in hospital as determined by the presentation and discharge dates.

3.6.5 Crash site inspections

A virtual inspection of each bicycle crash site was undertaken by the researcher. The site inspection protocol was developed in consultation with engineers from the Monash University Accident Research Centre in Victoria. The inspections were undertaken electronically using Nearmap, Google Maps, The Department of Planning Metropolitan Region Scheme map, The Main Roads WA Road Information Mapping System and traffic volume data from Main Roads WA. The variables collected for each crash site are presented in Table 3.1 by crashes occurring at any location and those relevant only for intersection crashes and midblock crashes.

3.6.5.1 Nearmap

Nearmap is a provider of high-resolution aerial imagery which can be accessed online by subscription (Nearmap, 2019). There is comprehensive coverage for Perth and imagery is updated on average, every two months. Previous images are also stored online allowing each crash site to be viewed as it was at the time of the crash. The highly detailed visual and topographical content also allows for accurate measurement of distances and road gradients.

3.6.5.2 Google maps

Google Maps is a web mapping service developed by Google offering satellite imagery, street maps and Street View (360-degree panoramic views of streets). The Street View function was used in conjunction with Nearmap to examine the road features at each crash site in detail.

3.6.5.3 Land use

The Department of Planning Metropolitan Region Scheme map was also used to determine the land use classification for each crash site. Land uses were classified as *'parks and recreation', 'state forests', 'central city area', 'industrial', 'special industrial', 'urban', 'civic and cultural', 'port installations'* and *'public purposes'* (Table 3.1) (Department of Planning Lands and Heritage, 2016).

3.6.5.4 Road hierarchy

The Main Roads WA Road Information Mapping System was used to determine the hierarchy of the road (*'primary distributor', 'regional distributor', 'distributor A', 'distributor B', 'local distributor'* or *'access road'*) (Table 3.1) and posted speed limit at the crash site (Main Roads Western Australia, 2016).

3.6.5.5 Traffic volume

Traffic volume information was obtained for each crash site from a Main Roads WA database of annual average daily traffic which is the total volume of vehicle traffic on a road for a year, divided by 365 days. Volumes were obtained for the direction of travel of the rider only and expressed as vehicles per day (vpd). Intersection traffic volumes only are collected by Main Roads WA. Midblock crash site volumes were approximated using surrounding intersection volumes according to the standard methodology used by Main Roads WA. Traffic volume in the direction of travel of the rider was only intended to be an estimate, rather than an exact value and was categorised into three broad groups: *'low-volume'* (<1500 vpd), *'moderate-volume'* (1500-4000 vpd), *'higher-volume'* (>4000 vpd) (Table 3.1)

Table 3.1 Crash site inspection variables

Variable	Categories and definitions	Sources
ALL CRASHES		
Intersection crash	-**Yes:** occurred at intersection defined as: • 20m on the approach to a signalised intersection; or • 10m on the departure side of a signalised intersection; or • 10m on the approach or departure of an un-signalised intersection (roundabout, priority control); or • Within the extent of an auxiliary lane for left or right turning traffic -**No**: occurred at midblock (location between intersections)	-Nearmap -Google Earth
Land use classification	**-Urban** **-Central city** **-Industrial/ special industrial** **-Parks and recreation** **-Rural** **-Private recreation** **-Reservations** **-State forest** **-Civic and cultural** **-Public purposes** **-Port installation**	-Metropolitan Region Scheme (Department of Planning Lands and Heritage, 2016)
Road hierarchy	-**Primary Distributor**: Main Roads responsibility, all of WA, e.g. freeways, highways and Main Roads -**Distributor A**: Local Government road, built up areas only, above 8000 vpd -**Distributor B**: Local Government road, built up areas only, above 6000 vpd -**Regional Distributor**: Local Government road, non-built up areas only, above 100 vpd -**Local Distributor**: Local Government road, maximum 6000 vpd in built up area, maximum 100 vpd in non-built up areas -**Access Road**: Local government road, maximum 3000 vpd in built up area, maximum 75 vpd in non-built up area	-Road hierarchy for Western Australia (Main Roads Western Australia, 2016)
Posted speed limit	Speed limit in km/h	- Main Roads WA Road Information Mapping System

		(Main Roads Western Australia, 2016)
Bicycle lane present	**-No** **-Yes**: bicycle lane present at exact location of crash (continuous bike lane through intersection and formal or unmarked bike at midblock crash)	-Nearmap -Google Earth
Bicycle lane width	Bicycle lane width from line to line (metres)	-Nearmap
Street lighting	**-No** **-Yes**	-Nearmap -Google Earth
Bus route	**-No** **-Yes**	-Google Earth
Intersection of path and road	**-No** **-Yes**: rider was crossing road from path to path, travelling from path to road or from road to path at time of crash	-Nearmap -Google Earth -Participant description
Traffic volume	**- Low volume**: < 1500 vehicles per day (in direction of rider) **- Moderate volume**: 1500-4000 vehicles per day **- Higher volume**: > 4000 vehicles per day	-Main Roads Western Australia
INTERSECTION CRASHES ONLY		
Approaches	-**T-intersection**: 3 approaches -**Cross intersection**: 4 approaches -**Multi-intersection**: more than 4 approaches	-Nearmap -Google Earth
Intersection control type	-**Traffic signals** (traffic lights) -**Roundabout** -**Priority control**: stop sign, give way or no markings	-Nearmap -Google Earth
Number of lanes	Count of total number of lanes in intersection	-Nearmap -Google Earth
Bicycle box	**-No** **-Yes**	-Nearmap -Google Earth
Bicycle lane type (intersection)	**-None** -**Continuous**: bicycle lane continues through intersection in direction of travel -**Not continuous**: Bicycle lane end at or before intersection	-Nearmap -Google Earth
MIDBLOCK CRASHES ONLY		
Direction of travel	**-One-way traffic** **-Two-way traffic**	-Nearmap -Google Earth
Road gradient (longitudinal slope) (%)	-**Flat**: between -5 and 5% -**Upward slope:** ≥ 5% -**Downward slope**: ≤ -5%	-Nearmap
Adjacent parking	**-No** **-Yes**	-Nearmap -Google Earth

Bicycle lane type (midblock)	**-None** **-Formal**: exclusive or advisory cycle lane marked with unbroken or broken white lines **-Unmarked:** informal bike lane formed by the presence of parking leaving a space for riders between the parked cars and the traffic lane	-Nearmap -Google Earth
Median	**-None**: no line or centreline only **-Physical median**: raised concrete kerb, traffic island or vegetation that prohibits movement of traffic across median **-Non-physical median**: Painted median on which vehicle can move if required	-Nearmap -Google Earth
Kerb type	**-None** **-Mountable:** kerbs with sloping faces that enables vehicles to drive over them easily **-Semi-mountable:** has both steep and sloping portions, allows movement of vehicles across the kerb line with low degree of discomfort **-Barrier:** steep-faced kerb designed to prevent vehicle encroachment on roadside	-Google Earth
Street lighting	**-No** **-Yes**	-Nearmap -Google Earth
Traffic calming	**-None** **-Speed hump:** vertical deflection device to slow vehicles -**Slow point:** device intended to reduce vehicle speeds by the creation of a short narrow section of carriageway	-Nearmap -Google Earth
Traffic lanes in direction of travel	Number of lanes for traffic in the direction of travel (count)	-Nearmap -Google Earth
Carriageway width	Width in metres from outer kerb to outer kerb or edges of verges (including traffic in both directions)	-Nearmap
Direction of travel width	Width in metres from left kerb to centreline/ kerb of median or centre of road when no line markings	-Nearmap
Left lane width	Width in metres of the left most traffic lane (not bike lane)	-Nearmap
Nature strip	**-No** **-Yes**	-Nearmap -Google Earth
Footpath (path for pedestrians)	**-No** **-Yes**	-Nearmap -Google Earth

3.6.5.6 Inter-rater reliability

A second experienced researcher also performed independent virtual crash site inspections on 22 randomly selected crashes (20%) in order to evaluate the reliability and objectivity of the researcher's coding. Inter-rater reliability was calculated for all variables using Cohen's kappa co-efficient for categorical variables and intra-class correlation coefficient (ICC) for continuous variables. Overall, 91% of kappa coefficients were 0.8 or above with 66% being 1.0. For continuous variables, 83% of correlation coefficients were 0.8 or above. Left kerb type (κ=0.63), median kerb type (κ=0.62), median type (κ=0.51) and left lane width (ICC=0.7) showed lower inter-rater reliability and these variables were treated with caution.

3.7 Crash classification and contributing factors

3.7.1 Crash type classification

Information from the participants' crash descriptions in the questionnaire, participant sketches and site inspections were used to classify all crashes into categories according to road use movement and mechanism of the crash. The RUM codes developed by Main Roads WA were used as a guide for this classification (Appendix 7), however they are not ideally suited to bicycle crashes. Therefore, a crash type classification system was devised based on the actual crash types observed in the study. Crashes were firstly categorised by those involving a crash with a motor vehicle and those not involving a crash with a motor vehicle.

Crashes involving motor vehicles were classified as:

- Rider crash with motor vehicle travelling in a different direction;
- Rider crash with motor vehicle travelling in the same direction;
- Rider crash with motor vehicle while rider was crossing road to path;
- Rider crash with a car door;
- Rider crash with a parked car;
- Rider crash with a motor vehicle leaving a driveway.

Crashes not involving a collision with a motor vehicle were classified as:

- Rider/ rider crash;
- Rider loss of control on carriageway, no object hit;
- Rider loss of control, hit road infrastructure;
- Rider hit road infrastructure travelling from road to path;
- Rider hit object/ hazard on road carriageway;
- Bicycle malfunction;
- Rider/ pedestrian crash.

Each crash in the study is then described by category, in terms of group rider and individual rider crashes, example diagrams provided for the crash types which involved another road user and RUM codes specified where relevant for each crash. Diagrams were sketched using a free online site (Claim Management Services, 2018).

3.7.2 Human, environmental and vehicle factors contributing to crashes

Finally, a detailed examination of factors contributing to crashes was undertaken for the 108 bicycle crashes. A factor contributing to a crash was defined as any human, environmental or bicycle/ vehicle factor which the investigators considered to have contributed to the overall outcome of the crash (Association of European Motorcycle Manufacturers (ACEM), 2004). Two experienced researchers conducted systematic investigations on each crash using information from the participant interviews (questions on factors contributing to the crash and participant crash descriptions), sketches, virtual crash site inspections and the IRIS database (where available) to identify and list all possible factors contributing to each crash.

Each factor contributing to the crash was coded according to definitions used in the Motorcycle Accidents In Depth Study (MAIDS), a large-scale in-depth investigation of crashes involving powered two wheelers in Europe (Association of European Motorcycle Manufacturers (ACEM), 2004). A recent Victorian in-depth motorcycle crash study which was based on the MAIDS study, was also consulted (Allen et al., 2017). The decision to code factors based on previous motorcycle crash studies was made since investigations revealed that the factors contributing to the bicycle crashes in this study fit very well within this classification scheme, with only minor modifications and additions required. While existing in-depth bicycle crash studies were also consulted, these smaller studies focused specifically on older or adolescent rider crashes and did not classify factors contributing to crashes in a systematic manner (Boele-Vos et al., 2017; Vanparijs et al., 2016).

If an identified factor contributing to a crash did not fall under any of the categories defined by the MAIDS study (Association of European Motorcycle Manufacturers (ACEM), 2004) or Allen et al. (2017), a new factor was created. The three factors added for the purpose of this study were: *'bicycle failure'*, *'view obstruction due to another rider'* and *'vertical alignment of the road'*. Factors contributing to a crash present in the motorcycle crash classification schemes that were not relevant to the cycling or WA context were removed, for example *'tram tracks'*. Table 3.2 lists all specific factors contributing to crashes included in this study and their definitions by category. Each individual factor was categorised as *'human'*, *'environment'* or *'vehicle-related'* based on the MAIDS study (Association of European Motorcycle Manufacturers (ACEM), 2004). Sub-categories of factors contributing to crashes were also created for the purpose of analysis for this study. The broad category of *'human'* factors contributing to crashes contained 13 different specific factors which were subcategorised based on whether the error occurred on the part of the crashed rider, another rider or a motorist. The broad category of *'environment'* factors contributing to crashes contained 10 specific contributing factors which were sub-categorised into *'weather/ lighting factors'*, *'road-related factors'* and *'view obstruction'*. The broad category of *'vehicle'* factors contributing to crashes contained two specific contributing factors and no subcategories were made.

For each crash, a single primary factor contributing to the crash was agreed upon by the two researchers. This was defined as the specific *'human'*, *'environmental'* or *'vehicle'* factor which the research team considered to have made the greatest contribution to the overall outcome of the crash (Association of European Motorcycle Manufacturers (ACEM), 2004). In addition, where required, one or more secondary factors contributing to the crash were determined. In cases where the two researchers disagreed on the primary and secondary factors contributing to crashes, a discussion took place and agreement was reached.

Table 3.2 Definitions of human, environmental and vehicle factors contributing to bicycle crashes

Specific factor contributing to crash	Subcategory	Definition
Human factors		
Alcohol or drug involvement[a]	• Rider error • Other rider error *OR* • Motorist error	Medical or self-reported evidence of excessive alcohol (>0.05 g/dL) or use of illegal drug known to impair riding or driving near the time of crash.
Conflicting behaviours or pre-occupied[a]	• Rider error • Other rider error *OR* • Motorist error	The rider or other road user acted in such a way that was unexpected by other road users, or they were distracted by another activity.
Decision/ reaction failure[a]	• Rider error • Other rider error *OR* • Motorist error	The rider or other road user failed to make the correct decision to avoid the dangerous condition or failed to react, based upon his/ her strategy.
Experience/ exposure to similar situations[a]	• Rider error • Other rider error *OR* • Motorist error	Lack of experience or exposure specific to the bike, vehicle, physical road environment, weather, or traffic conditions present at the time of the incident.
Faulty traffic strategy[a]	• Rider error • Other rider error *OR* • Motorist error	The rider or other road user made a poor decision to perform a manoeuvre or movement.
Misjudgement/ control error[b]	• Rider error • Other rider error *OR* • Motorist error	The rider or other road user misjudged the situation and/ or failed to control the vehicle within its capabilities (including braking and steering actions).
Perception failure[a]	• Rider error • Other rider error *OR* • Motorist error	The rider or other road user failed to detect the dangerous condition based upon the strategy that he was using to detect dangerous conditions.
Physical or physiological failure[a]	• Rider error • Other rider error *OR* • Motorist error	Physical or physiological failure to the rider or other road user, including fatigue, acute or chronic medical condition (e.g. seizure, cardiac failure).
Position of bike/ vehicle unsafe or high risk[b]	• Rider error • Other rider error *OR* • Motorist error	The rider or other road user positioned their vehicle in a way that was deemed as high risk of crash. This includes positioning the vehicle where it was more difficult to be seen by other road users, positioning the vehicle too close to other vehicles, or positioning the vehicle such that negotiating an

		approaching curve was made more difficult.
Speed inappropriate for conditions[b]	• Rider error • Other rider error *OR* • Motorist error	The estimated travel speed of the rider or other road user immediately before the precipitating crash event was judged as not appropriate for the conditions, including the physical road environment, weather, traffic conditions, or the vehicle.
Traffic scan error[a]	• Rider error • Other rider error *OR* • Motorist error	The rider or other road user did not observe or perceive oncoming traffic or traffic that may have been entering the roadway from some other direction.
Unsafe act or high risk behaviour[a]	• Rider error • Other rider error *OR* • Motorist error	The action of a rider or other road user was judged as unsafe or high risk.
3rd or 4th vehicle involvement[a]	• Other rider error *OR* • Motor vehicle error	The presence or actions of a 3rd or 4th vehicle contributed to the cause of the crash.
Environment factors		
Adverse weather[a]	• Weather/ lighting	A weather event, including strong winds, heavy rain, or fog.
Natural light conditions[b]	• Weather/ lighting	The natural light conditions at the time of the crash reduced visibility for the rider or other road user (including dawn, dusk, dark, and sun glare).
Road design issue[a]	• Road-related	A condition which presented a danger to the rider based solely upon the design of the road.
Road maintenance issue[a]	• Road-related	Any road condition that was in poor repair or in need of repair.
Slippery road due to weather[b]	• Road-related	Road surface grip at or near crash site was significantly reduced as a result of recent weather (e.g. rain).
Slippery road due to loose material[b]	• Road-related	Road surface grip at or near crash site was significantly reduced due to presence of loose material, including gravel (fine or coarse) and leaf litter.
Temporary traffic hazard[a]	• Road-related	A danger or risk on a carriage-way (excluding a road design or maintenance defect).
Vertical alignment of road[c]	• Road-related	Upwards or downward slope of road.

View obstruction[a]	• View obstruction	A temporary (mobile) or fixed obstruction that reduced or blocked visibility for rider or other road user (excluding view obstruction due to another rider).
View obstruction due to other rider [c]	• View obstruction	Another rider reduced or blocked visibility for the rider.
Vehicle factors		
Bicycle failure[c]	• Vehicle failure	A pre-existing issue or acute failure of a bicycle affecting its safe operation or ability to avoid a crash.
Motor vehicle failure[a]	• Vehicle failure	A pre-existing issue or acute failure of a motor vehicle affecting its safe operation or ability to avoid a crash

[a] Contributing factor and definition modified from the Association of European Motorcycle Manufacturers (Association of European Motorcycle Manufacturers (ACEM), 2004)
[b] Contributing factor and definition modified from Allen et al. (Allen et al., 2017)
[c] Contributing factor added for purposes of this study

3.8 Part A: Statistical analyses

3.8.1 Part A: Descriptive analyses

All data were coded and analysed using the Statistical Package for the Social Sciences (SPSS), version 22 (SPSS Inc, Chicago, USA). For the baseline data, initially the rider and road environment characteristics of the crashes were described. Injury information, demographic, health, cycling experience and participation, trip characteristics, bicycle and protective wear, temporal conditions and road environment characteristics were compared for group rider and individual rider crashes using:

- Independent samples t-tests for continuous variables;
- chi-square tests for categorical variables;
- Fisher's exact tests for categorical variables when the expected values in any of the cells of the contingency table were below 5;
- Fisher-Freeman-Halton Exact tests for contingency tables larger than 2 x 2 with expected values in any cells less than 5.

Two-sided p-values less than 0.05 were considered statistically significant.

For the exploration of factors contributing to crashes, the decision was made to focus on the involvement of any factor contributing to the crash (primary or secondary factor). Due to there being only one primary factor per crash, numbers were not adequate to compare sub-categories of primary factors. Therefore, only comparisons of the broad categories of primary factors contributing to crashes (human, environmental or vehicle factors) were undertaken using the Fisher-Freeman-Halton Exact test. For any factor contributing to a crash, the presence of each broad category and subcategory of factor were compared for group rider and individual rider crashes using chi-square and Fisher's Exact tests. These comparisons were made for all crashes (n=108), crashes involving a motor vehicle only (n=47) and crashes not involving a motor vehicle only (n=61). P-values < 0.05 were considered statistically significant.

3.8.2 Part A: Outcome of interest

The initial findings highlighted significant differences in the proportion of group rider and individual rider crashes involving the *'environmental factors'* category, and specifically the *'road-related factors'* subcategory. Therefore, *'road-related factors'* was the outcome of interest for the analysis.

3.8.3 Part A: Binary logistic regression

To determine whether group rider crashes were more likely to involve *'road-related factors'* than individual rider crashes, two binary logistic regression models were undertaken. Binary logistic regression is suitable when the dependent variable is categorical and only has two values (Kleinbaum & Klein, 2010). These models provide odds ratios (ORs) which represent *"the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of the exposure"* (Szumilas, 2010) (p.227). They also provide 95% confidence intervals (CIs) which estimate the precision of the odds ratio (Kleinbaum & Klein, 2010).

3.8.3.1 Formula

The formula for binary logistic regression with several independent variables is detailed below.

$$P(Y) = \frac{e^{b_0 + b_1 x_1 + b_2 x_2 + \dots + b_n x_n}}{1 + e^{b_0 + b_1 x_1 + b_2 x_2 + \dots + b_n x_n}}$$

P: probability of *Y* occurring

e: natural logarithm base

b_0: interception at y-axis

b_1: line gradient

b_n: regression coefficient of X_n

X_1: predictor variable

3.8.3.2 Binary logistic regression: all crashes

Initially, a binary logistic regression model was undertaken including all crashes in the study (n=108). *'Road-related factor'* (no, yes) was entered as the dependent variable. *'Group rider crash'* (no, yes) was entered as an independent variable.

Variables considered for inclusion as additional independent variables/ confounding factors were based on findings from the limited literature on factors associated with single bicycle crashes that are more likely to involve infrastructure *or 'road-related factors'* (Schepers & Klein Wolt, 2012). The final model included *'group rider crash'* (no, yes) *'cycling experience in Australia'* (<20 years, ≥20 years), *'cycling exposure'* in the previous month (≤ 3 times per week, > 3 times per week), *'frequency of riding at crash site'* in the previous month (≥ once per week, < once per week) and *'weather conditions'* at the time of the crash (clear, not clear).

3.8.3.3 Binary logistic regression: crashes not involving a motor vehicle

The binary logistic regression model described above was also run only for crashes which did not involve a motor vehicle (n=61). This decision was made because a higher proportion of group rider crashes did not involve a motor vehicle compared to individual rider crashes, and non-motor vehicle crashes may be more vulnerable to road-related contributing factors. Therefore, this may have influenced the findings of the logistic regression model which included all crashes. The models could not be run only for crashes involving motor vehicles due to only six group rider crashes involving motor vehicles.

For the model of crashes which did not involve a motor vehicle, the same dependent and independent variables were included. The final model again included *'group rider* *crash'* (no, yes) *'cycling experience in Australia'* (<20 years, ≥20 years), *'cycling exposure'* in the previous month (≤ 3 times per week, > 3 times per week), *'frequency of riding at crash site'* in the previous month (≥ once per week, < once per week) and *'weather conditions'* at the time of the crash (clear, not clear).

3.9 Part B: Statistical analyses

3.9.1 Part B: Descriptive analyses

The follow-up data were also coded and analysed using SPSS, version 22 (SPSS Inc, Chicago, USA). The main outcome of interest for the follow-up data was *'reduced cycling exposure'* 12 months after the crash. This was determined from participants' self-reported cycling participation in the follow-up interview. Those who had not cycled since the crash or reported cycling less in the month before the follow-up interview, compared to the month before the crash were categorised as experiencing *'reduced cycling exposure'*. Those who reported cycling the same or more than before the crash were categorised as experiencing *'no reduction in cycling exposure'*.

Initially the characteristics of the 83 participants who completed the follow-up interview were described. Participant demographic and health characteristics, cycling experience and crash characteristics, injury characteristics and recovery from injury were compared for participants who had *'reduced cycling exposure'* at follow-up compared to those who had *'no reduction in cycling exposure'*.

Of particular interest was participation in group riding before the crash. For this analysis of factors associated with *'reduced cycling exposure'* at follow-up, whether a participant was a member of a cycling group or club before the crash was a more relevant variable than whether they were riding in a group at the time of the crash. Therefore *'group riding participation'* (no, yes) defined as whether a participant rode as part of a group or club of five or more riders in the month before the crash was examined for the follow-up analysis.

To initially examine the association between different variables and reduced cycling exposure the following tests were used:

- independent samples t-tests for continuous variables;
- chi-square tests for categorical variables;
- Fisher's exact tests for categorical variables when the expected values in any of the cells of the contingency table were below 5;
- Fisher-Freeman-Halton Exact tests for contingency tables larger than 2 x 2 with expected values in any cells less than 5.

3.9.2 Part B: Binary logistic regression

A binary logistic regression model was undertaken for the 83 participants who completed the follow-up interview, to determine factors associated with reduced cycling exposure at follow-up. *'Reduced cycling exposure'* (reduced cycling exposure, no reduction in cycling exposure) was entered as the dependent variable. The main independent variable of interest was *'group riding participation'* in the month before the crash.

Variables considered for inclusion as additional independent variables/ confounding factors were based on findings from the literature on factors associated with poor outcomes after a crash and also the results of the univariate analyses. The final model included the variables: *'group riding participation'* at baseline (no, yes), *'age'* at baseline (years), *'medical condition'* at baseline (no, yes), *'employment status'* at baseline (full time, not full time), *'cycling frequency'* at baseline (≤ 3 days/ week, > 3 days/ week), *'crash involved a motor vehicle'* (no, yes) and *'GOS-E category'* at follow-up (upper good recovery, other).

3.10 Ethical considerations

This research conformed to the principles of the Declaration of Helsinki (World Medical Association, 2013) and the National Statement on Ethical Conduct in Human Research (The National Health and Medical Research Council, Australian Research Council, & Australian Vice-Chancellors' Committee, 2007, updated 2015). Phase 1 of the project was approved by the Curtin University and RPH Human Research Ethics Committees (Appendix 8). RPH provided ethics approval on behalf of the other hospitals involved (Fremantle Hospital, FSH and SCGH) and each of these hospitals' Research Governance Units approved the study. The ethics committees provided approval for the group riding study as a sub-study of the larger ARC-funding cycling study.

Riders who had been involved in a crash were contacted by a research nurse based at RPH in person or by phone and invited to participate in the study. No patient information was provided to Curtin University researchers until they had signed the consent form to participate in the study. These riders provided potentially sensitive medical and crash information. Before approaching potential participants in hospital, the research nurse checked with nurses that the rider was physically and emotionally well enough to be approached. At recruitment, Phase 1 participants received a PIS describing the research, their role, contact details of the researchers, how confidentiality will be protected, that participation is voluntary and that they have the right to withdraw at any time without consequence for their medical treatment (Appendix 1). Informed written consent was obtained from the participants (in person, by email or fax) before any data was collected. A support services sheet was also provided to participants containing details of organisations that they could contact if they were feeling distressed about the crash (Appendix 2). The identity of all participants will be concealed in any publications.

3.11 Data management

Data was stored according to the Curtin University Research Data and Primary Materials Policy. All paper-based data including consent forms were stored in a locked filing cabinet within the Curtin-Monash Accident Research Centre (C-MARC). Questionnaire data from Phase 1 was recorded and stored electronically using the Qualtrics program through Curtin University. All online data was password protected. Final databases were downloaded and saved with only participant IDs and no identifying information. All electronic files including questionnaire databases were stored on the Curtin University Research Drive in a project folder that could only be accessed by nominated researchers on the project. All data will be retained for seven years following the conclusion of the project and then destroyed.

CHAPTER 4

Phase 1 – In-depth bicycle crash study: Results

4 PHASE 1 – IN DEPTH BICYCLE CRASH STUDY: RESULTS

Chapter 4 presents the results of Phase 1, the in-depth crash study of riders hospitalised due to an on-road crash in Perth WA. In the following chapter, *'group rider crashes'* refer to crashes that occurred while riding in a group and *'individual rider crashes'* refer to crashes that occurred while riding alone.

4.1 Part A- Baseline data: Results

Section 4.1 presents the results of the in-depth crash study obtained from the data collected at baseline.

4.1.1 Study participants

Part A of the study consisted of 108 participants with 75 recruited from Royal Perth Hospital (RPH) (69.4%), 21 from Sir Charles Gairdner Hospital (SCGH) (19.4%), seven from Fremantle Hospital (6.5%) and five from Fiona Stanley Hospital (FSH) (4.6%). The larger proportion recruited from RPH was expected as this hospital is the designated provider of major trauma services in WA, treating approximately 80% of the major trauma cases in the State (Department of Health, 2016).

4.1.2 Response rate

During the study period, 624 patients were reviewed for eligibility with 439 excluded from the study for reasons including: involvement in an off-road crash (n= 189), admitted to hospital for less than 24 hours (n=120), crash occurred outside the Greater Perth area (n=56), unable to recall the events of the crash (n=28), aged less than 18 years (n=23), killed or severely disabled in the crash (n=16) and non-English speaking (n=7). An additional 58 patients were unable to be contacted so their eligibility status could not be determined. Of the remaining 127 participants known to meet all eligibility criteria, 108 agreed to participate and completed the baseline questionnaire (response rate: 85.0%). The majority completed the questionnaire by phone (77.8%). Site inspections were also performed for all 108 crash sites and trauma registry data was obtained for 101 of the 108 participants (93.5%).

4.1.3 Group riding status

Of the 108 hospitalised participants, 37 (34.3%) were riding with at least one other known rider at the time of the crash (*'group rider crash'*) while the remaining 71 were riding alone (*'individual rider crash')*. Thirteen of the 37 who were group riding (35.1%) were riding in a group of two riders, three (8.1%) in a group of 3-4, 10 (27.0%) in a group of 5-10, 6 (16.2%) in a group of 11-20 and five (13.5%) were riding with over 20 riders. The maximum group size was 55 riders.

4.1.4 Participant demographics and health

Demographic and health characteristics of the 108 study participants are presented in Table 4.1 by group riding status. These characteristics were obtained from the participant questionnaire. For group rider crashes, age ranged from 22 to 80 years with a mean of 51.6 years (SD: 12.5) and more than half (n=21, 56.8%) were aged over 50 years. The majority were male, had a healthy body mass index (BMI) of <25 (n=25, 67.6%) and were Australian (n=28, 75.7%) (Table 4.1). Over half of group riders (n=22, 59.5%) had a university degree, less than a quarter (n=9, 24.3%) reported a diagnosed medical condition and 35.1% (n=13) reported being on prescription medications at the time of the crash (Table 4.1). Overall, participants involved in group rider and individual rider crashes were very similar in terms of demographic and health characteristics with no significant differences. Only four participants reported that they did not hold an Australian driver's license and all were involved in individual rider crashes.

Table 4.1 Demographic and health characteristics of participants hospitalised due to a bicycle crash, by group riding status

Demographic and health characteristic	Group rider crash (n=37)		Individual rider crash (n=71)		p-value [a]
	N	%	N	%	
Age (years)					
≤ 50	16	43.2	32	45.1	
> 50	21	56.8	39	54.9	0.856
Gender					
Male	32	86.5	59	83.1	
Female	5	13.5	12	16.9	0.646
BMI [b]					
<25	25	67.6	42	60.9	
≥ 25	12	32.4	27	39.1	0.495
Nationality					
Australian	28	75.7	49	69.0	
Other	9	24.3	22	31.0	0.468
University Degree					
No	15	40.5	31	43.7	0.756
Yes	22	59.5	40	56.3	
Medical condition					
No	28	75.7	54	76.1	
Yes	9	24.3	17	23.9	0.965
Prescription medications					
No	24	64.9	47	66.2	
Yes	13	35.1	24	33.8	0.890

[a] p values from chi-square tests [b] missing data

4.1.5 Cycling exposure characteristics

Table 4.2 presents the cycling exposure characteristics obtained from the questionnaire, by group riding status. For those involved in a group rider crash, the number of years of cycling experience in Australia ranged from two to 74 years with a mean of 18.6 years (SD: 18.2). Fourteen group riders (37.8%) had more than 20 years cycling experience in Australia. The majority of group riders were regular riders with 22 (59.5%) riding more than three times per week in the month before the crash. However, a significantly higher proportion of those involved in group rider crashes rode more than 100 km per week in the month before the crash (n=29, 78.4%), compared to individual riders (n=35, 49.3%) (p=0.004). In addition, a higher proportion of individual riders reported that the main purpose of their cycling in the previous month was for commuting/ utilitarian purposes (n=31, 43.7%), than those who were group riding at the time of the crash (n=5, 13.5%) (p=0.002) (Table 4.2).

Table 4.2 Cycling exposure characteristics of participants hospitalised due to a bicycle crash, by group riding status

Cycling exposure characteristic	Group rider crash (n=37)		Individual rider crash (n=71)		p-value [a]
	N	%	N	%	
Cycling experience in Australia					
< 20 years	23	62.2	41	57.7	
20+ years	14	37.8	30	42.3	0.658
Cycling frequency (previous month)					
≤ 3 times/ week	15	40.5	28	39.4	
> 3 times/ week	22	59.5	43	60.6	0.911
Cycling exposure (previous month)					
≤ 100 km/ week	8	21.6	36	50.7	
> 100 km / week	29	78.4	35	49.3	0.004*
Proportion of on-road riding (previous month)					
≤ 50 %	7	18.9	36	50.7	
> 50%	30	81.1	35	49.3	0.001*
Main purpose of cycling (previous month)					
Commuting/ Utilitarian	5	13.5	31	43.7	
Recreation/ Fitness	32	86.5	40	56.3	0.002*
Cycling club/ group member					
No	17	45.9	53	74.6	
Yes	20	54.1	18	25.4	0.003*
Completed rider training [b]					
No	23	62.2	63	90.0	
Yes	14	37.8	7	10.0	0.001*
Crash involvement in previous 3 years [b]					
None	27	73.0	60	85.7	
One or more	10	27.0	10	14.3	0.108

[a] p values from chi-square tests   [b] Missing data   * significant at p<0.05

A significantly higher proportion of those involved in a group rider crash (n=30, 81.1%) reported that more than 50% of their riding took place on roads, compared to individual riders (n=35, 49.3%) (p=0.001). Over half (n=20, 54.1%) of those involved in a group rider crash belonged to a cycling club of five or more riders who they rode with in the previous month, compared to only 25.4% (n=18) of individual riders (p=0.003). More participants who were involved in a group rider crash (n=14, 37.8%) also had completed some formal rider training, than individual riders (n=7, 10.0%)

(p=0.001). Ten group riders (27.0%) had been involved in at least one other crash (any level of severity) in the previous three years (Table 4.2).

4.1.6 Trip characteristics

Table 4.3 presents the characteristics of the trip participants were undertaking when they crashed. The majority of participants involved in a group rider crash (n=36, 97.3%) were riding for recreation or fitness with only one participant riding for commuting/ utilitarian (e.g. shopping, errands) purposes. This was significantly different to individual riders with 45.1% (n=32) commuting or undertaking a utilitarian trip (p<0.001). In terms of the expected trip distance (if the crash had not occurred), a significantly higher proportion of group riders (n=27, 79.4%) were intending to travel more than 20km, compared to individual riders (n=29, 42.0%) (p<0.001). The majority of group riders travelled on the road on which they crashed regularly (n=25, 67.5%) (Table 4.3).

Table 4.3 Trip characteristics of participants hospitalised due to a bicycle crash, by group riding status

Trip characteristic	Group rider crashes (n=37)		Individual rider crashes (n=71)		p-value [a]
	N	%	N	%	
Purpose of trip					
Commuting/ utilitarian	1	2.7	32	45.1	
Recreation/ fitness	36	97.3	39	54.9	<0.001*
Expected trip distance [b]					
≤ 20 km	7	20.6	40	58.0	
> 20km	27	79.4	29	42.0	<0.001*
Frequency ride in crash location					
≥ once per week	25	67.6	54	76.1	
< once per week	12	32.4	17	23.9	0.345

[a] p values from chi-square tests [b] Missing data * significant at p<0.05

4.1.7 Bicycle and protective wear characteristics

The characteristics of the bicycles the participants were riding and protective gear they were wearing at the time of the crash are presented in Table 4.4. A significant difference was evident with the majority of participants involved in a group rider crash riding road bikes (n=34, 94.4%), whereas 19 individual riders (26.8%) were riding other types of bicycles (p=0.009). These included mountain bikes, hybrids (contains features of both road and mountain bikes) and time trial bikes. All bicycles except one were geared, with the other being a fixed wheel bike. Group riders were also riding significantly more expensive bikes, with a higher proportion of group riders' bikes costing over $2000 (n=31, 83.8%) compared to the bikes of individual riders (n=27, 39.1%) (p<0.001) (Table 4.4).

Table 4.4 Bike and protective clothing characteristics of participants hospitalised due to a bicycle crash, by group riding status

Bike and clothing characteristic	Group rider crashes (n=37)		Individual rider crashes (n=71)		p-value
	N	%	N	%	
Type of bike [c]					
Road bike	34	94.4	52	73.2	
Other	2	5.6	19	26.8	0.009 [a]
Cost of bike ($) [c]					
≤ $2000	6	16.2	42	60.9	
> $2000	31	83.8	27	39.1	<0.001 [a] *
Front light					
No	6	16.2	14	19.7	
Yes	31	83.8	57	80.3	0.657 [a]
Rear light					
No	4	10.8	14	19.7	
Yes	33	89.2	57	80.3	0.238 [a]
Any reflective clothing [c]					
No	25	69.4	55	82.1	
Yes	11	30.6	12	17.9	0.142 [a]
Helmet worn [c]					
No	0	0.0	6	8.7	
Yes	37	100.0	63	91.3	0.089 [b]

[a] p values from chi-square tests [b] p values from Fishers Exact test [c] Missing data
* significant at p<0.05

The majority of group riders had front (n=31, 83.8%) and rear (n=33, 89.2%) lights on their bicycles. Only a small proportion of group riders (n=11, 30.6%) were wearing clothing containing any reflective material. All group riders self-reported that they were wearing a helmet at the time of the crash. However, six individual riders (8.7%) reported they were not wearing a helmet but this difference was not significant (p=0.089) (Table 4.4). Reasons given for not wearing a helmet included *'not wanting to mess up hair'*, *'dislike of helmets'*, *'not owning a helmet'* and *'wearing a hat instead'*.

4.1.8 Temporal conditions

Table 4.5 describes the temporal conditions at the time of the crash. The highest proportion of group rider crashes occurred in spring (n=14, 37.8%), in clear weather conditions (n=30, 81.1%) and during daylight hours (n=32, 86.5%). (Table 4.5). The majority of individual rider crashes occurred on weekdays (n=53, 74.6%), whereas the majority of group riding crashes occurred on weekends (n=21, 56.8%) which was significantly different ($p<0.001$) (Table 4.5). A significantly higher proportion of group riding crashes (n=34, 91.9%) occurred in the morning hours (am hours), compared to individual rider crashes (n=46, 64.8%) ($p=0.002$) (Table 4.5).

Table 4.5 Temporal characteristics of bicycle crashes resulting in hospitalisation, by group riding status

Temporal characteristic	Group rider crashes (n=37)		Individual rider crashes (n=71)		p-value
	N	%	N	%	
Season					
Summer	10	27.0	21	29.6	
Autumn	6	16.2	18	25.3	
Winter	7	18.9	10	14.1	
Spring	14	37.8	22	31.0	0.643 [b]
Day of week					
Weekday	16	43.2	53	74.6	
Weekend	21	56.8	18	25.4	0.001 [a] *
Time of day					
AM	34	91.9	46	64.8	
PM	3	8.1	25	35.2	0.002 [a] *
Weather conditions					
Clear	30	81.1	63	88.7	
Other	7	18.9	8	11.3	0.275 [a]
Lighting conditions					
Daylight	32	86.5	56	78.9	
Other	5	13.5	15	21.1	0.334 [a]

[a] p values from chi-square tests   [b] p values from Fisher-Freeman-Halton Exact tests
* significant at $p<0.05$

4.1.9 Injury information from the State Trauma Registry

Table 4.6 and Table 4.7 present the participant injury information, obtained from the State Trauma Registry. This was available for 101 of the 108 participants, 35 (34.7%) were group riding at the time of the crash and 66 (65.3%) were individual riders. For those who were group riding, the ISS ranged from two to 38 with a mean of 9.1 (SD: 6.4) and the mean NISS was 12.1 (SD:7.4). The mean number of AIS regions injured was 4.6 for group riders (SD:2.0). Overall, injury outcomes were very similar for group and individual rider crashes and with few significant differences. However, individual riders had a significantly higher number of mean days in care (hospital or rehabilitation) (5.9 days (SD: 6.2)) compared to group riders (3.5 days (SD:3.2)) (p=0.015) (Table 4.6).

Table 4.6 Injury severity information for participants hospitalised due to a bicycle crash, by group riding status (n=101)

Injury severity characteristic	Group rider crash (n=35)		Individual rider crash (n=66)		p-value [a]
	Mean	SD	Mean	SD	
Injury Severity Score	9.1	6.4	8.5	6.3	0.645
New Injury Severity Score	12.1	7.4	11.5	8.0	0.720
Number of AIS regions	4.6	2.0	4.6	2.3	0.932
Days in care	3.5	3.2	5.9	6.2	0.015 *

[a] p-values from t-tests * significant at p<0.05

Only a small proportion of group rider crashes (n=4, 11.4%) were classified as resulting in major injury (ISS>15) (Table 4.7). The regions of the body where participants were injured are also presented in Table 4.7. The most commonly injured areas for group riders were upper extremities (n=20, 57.1%), lower extremities (n=16, 45.7%), face (n=14, 40.0%) and thorax (n=14, 40.0%). There were no significant differences in the proportion experiencing injury in any area except for the thorax, with a higher proportion of group riders experiencing injuries in this area (n=14, 40.0%), compared to individual riders (n=13, 19.7%) (p=0.028). No group riders and four individual riders (6.1%) self-reported consuming alcohol in the 12 hours prior to the crash (p=0.295) (Table 4.7). Ethanol tests were completed for two of these participants who returned readings of 0.0 and 0.01 percent. No participant self-reported using illicit drugs in the previous 12 hours and no drug tests were performed.

Table 4.7 Injury region and other information for participants hospitalised due to a bicycle crash, by group riding status (n=101)

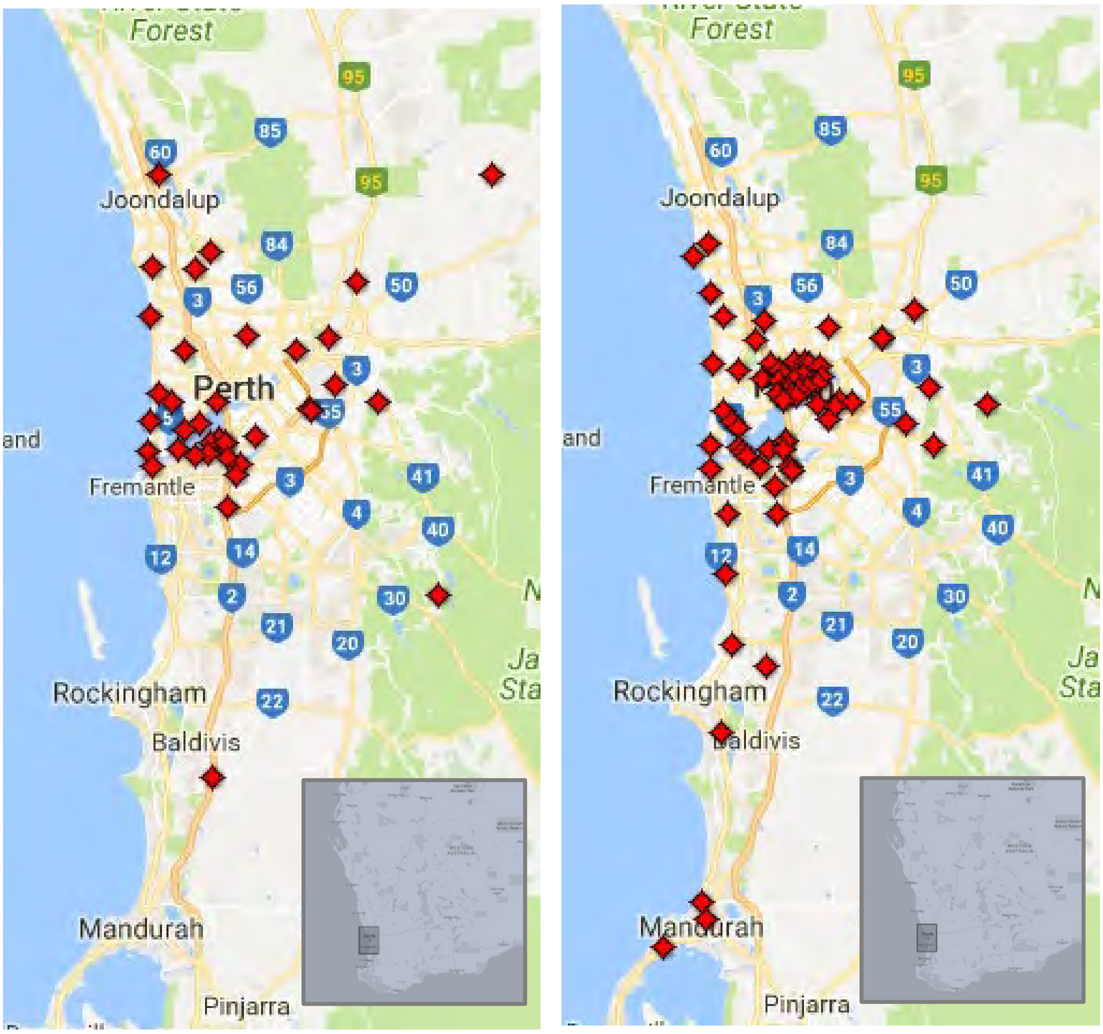
Injury severity and region characteristic	Group rider crash (n=35)		Individual rider crash (n=66)		p-value
	N	%	N	%	
Injury severity					
Minor	31	88.6	57	86.5	
Major [c]	4	11.4	9	13.6	1.00 [b]
Head					
Not injured	25	71.4	51	77.3	
Injured	10	28.6	15	22.7	0.517 [a]
Face					
Not injured	21	60.0	44	66.7	
Injured	14	40.0	22	33.3	0.506 [a]
Neck					
Not injured	35	100.0	63	95.5	
Injured	0	0.0	3	4.5	0.550 [b]
Thorax					
Not injured	21	60.0	53	80.3	
Injured	14	40.0	13	19.7	0.028 [a] *
Abdomen					
Not injured	32	91.4	60	90.9	
Injured	3	8.6	6	9.1	1.00 [b]
Spine					
Not injured	26	74.3	42	63.6	
Injured	9	25.7	24	36.4	0.278 [a]
Upper extremities					
Not injured	15	42.9	29	43.9	
Injured	20	57.1	37	56.1	0.917 [a]
Lower extremities					
Not injured	19	54.3	38	57.6	
Injured	16	45.7	28	42.4	0.751 [a]
Alcohol in last 12 hrs					
No	35	100	62	93.9	
Yes	0	0.0	4	6.1	0.295 [b]

[a] p values from chi-square tests [b] p values from Fishers Exact tests
[c] Major injury defined as an ISS > 15 * significant at p<0.05

4.1.10 Location of crashes

Figure 4.1 presents the location of the 108 crashes for the 37 crashes that occurred while group riding and the 71 individual rider crashes, mapped using GPS Visualizer (GPS Visualizer, 2018). The main difference in the location of crashes was that individual rider crashes were more concentrated around the Perth central business district, whereas few group riding crashes occurred in the Perth city area. Group riding crashes were located in common recreational cycling areas including coastal and riverside routes as well as in the Perth Hills area.

Figure 4.1 Location of group rider and individual rider crashes in the Greater Perth area of WA



Group rider crashes (n=37) *Individual rider crashes (n=71)*
Mapped using GPS Visualizer (GPS Visualizer, 2018)

4.1.11 Road environment characteristics

The following section compares the road environment characteristics for group rider and individual rider crashes. Since the site inspection variables collected varied depending on whether the crash was at an intersection or midblock, road environment characteristics are presented by:

- All crashes;
- Intersection crashes;
- Midblock crashes.

4.1.11.1 Road environment characteristics: All crashes

The location and circumstances of each crash were determined from the participant interview, diagram and where available, the IRIS crash database. Only 43 of the 108 crashes (39.8%) were recorded in the IRIS database. This included seven group rider crashes (18.9% of all group rider crashes) and 36 individual rider crashes (50.7% of all individual rider crashes). Overall, 79% (n=37) of crashes involving a motor vehicle were recorded, compared to 10% (n=6) of crashes not involving a motor vehicle. A total of 27 of these crash records (62.8%) came from the Insurance Commission of WA online reporting system and 16 (37.2%) were reported to WA Police. It should be noted that there was a considerable amount of missing data in the IRIS database for several variables. Once the location and circumstances of each crash were determined, the virtual site inspection was undertaken for each crash site.

Table 4.8 presents the road-related characteristics of the crash sites obtained from the virtual site inspections for all 108 crashes. This table includes the characteristics relevant for both intersection and midblock crashes. A significantly higher proportion of individual rider crashes (n=42, 59.2%) occurred at intersections, compared to group rider crashes (n=13, 35.1%) ($p<0.018$). The most common land use (main purpose of the surrounding area) was *'urban or central city'* for both individual rider (n=61, 85.9%) and group rider crashes (n=23, 62.2%), but a significantly lower proportion of group rider crashes occurred in these land use areas ($p=0.005$). The majority of crashes occurred on the minor road classifications managed by local government, namely *'access roads'* for individual rider crashes (n=20, 28.2%) and *'local distributors'* for group rider crashes (n=14, 37.8%). There were no significant differences for road hierarchy classification. (Table 4.8).

Table 4.8 Road environment characteristics for all bicycle crashes, by group riding status

Road environment characteristic	Group rider crash (n=37)		Individual rider crash (n=71)		p-value
	N	%	N	%	
Intersection					
No	24	64.9	29	40.8	
Yes	13	35.1	42	59.2	0.018 [a] *
Land use: Urban or central city					
No	14	37.8	10	14.1	
Yes	23	62.2	61	85.9	0.005 [a] *
Land use: Parks and recreation					
No	21	56.8	53	74.6	
Yes	16	43.2	18	25.4	0.057 [a]
Road hierarchy					
Access Road	8	21.6	20	28.2	
Local Distributor	14	37.8	15	21.1	
Distributor B	2	5.4	10	14.1	
Distributor A	8	21.6	18	25.4	
Regional Distributor	2	5.4	2	2.8	
Primary Distributor	3	8.1	6	8.5	0.398 [b]
Traffic volume (vehicles per day)[c]					
< 1500	14	37.8	31	43.7	
1500 - 4000	9	24.3	14	19.7	
> 4000	14	37.8	26	36.6	0.798 [a]
Posted speed limit in direction of travel					
≤ 50 km/h	20	54.1	44	62.0	
60 km/h	6	16.2	21	29.6	
≥ 70 km/h	11	29.7	6	8.5	0.014 [b] *
Street lighting					
No	5	13.5	5	7.0	
Yes	32	86.5	66	93.0	0.271 [a]
Bus route					
No	22	59.5	40	56.3	
Yes	15	40.5	31	43.7	0.756 [a]
Bike lane at crash location					
No	25	67.6	56	78.9	
Yes	12	32.4	15	21.1	0.198 [a]
Rider in bike lane at crash location					
No	25	67.6	59	83.1	
Yes	12	32.4	12	16.9	0.065 [a]
Intersection of path and road					
No	35	94.6	55	77.5	
Yes	2	5.4	16	22.5	0.023 [a] *

[a] p-values from chi-square tests [b] p-values from Fisher-Freeman-Halton Exact tests
[c] vehicles per day in the direction of travel of the rider * significant at $p<0.05$

For group rider crashes, the largest proportion occurred on roads with low traffic volumes of less than 1500 vpd in the same direction of travel as the rider (n=14, 37.8%) and on roads with speed limits of 50 km/h or less (n=20, 54.1%), However, a significantly higher proportion of group rider crashes (n=11, 29.7%) occurred on roads with a speed limit of 70 km/h or higher, compared to individual rider crashes (n=6, 8.5%), (p=0.014) (Table 4.8).

All crashes in the study occurred on sealed roads. The majority of group rider crashes were on roads with street lighting (n=32, 86.5%), less than half were on roads that had a bus route (n=15, 40.5%) and on-road bicycle lanes were present at the exact location of the crash for 12 group rider crashes (32.4%). Included in this definition were bicycle lanes that continued through the intersection for intersection crashes and both formal (on-road lane specifically for bicycles) and unmarked bicycle lanes (informal space for bicycles between parked vehicles and the adjacent traffic lane) for midblock crashes. For group rider crashes, eight of the bicycle lanes (66.7%) were 1.2 metres or wider. All group riders reported that at least one rider in the group was in the bicycle lane where available (n=12, 32.4%) (Table 4.8).

Finally, significantly more individual rider crashes (n=16, 22.5%) involved an intersection with the path and road, compared to only two (5.4%) group rider crashes (p=0.023) (Table 4.8). This included when a rider was travelling from path to road, from road to path or when the rider was crossing a road from path to path.

4.1.11.2 Road environment characteristics: intersection crashes.

Table 4.9 presents the road environment characteristics of the 55 crashes (13 group rider and 42 individual rider crashes) that occurred at intersections only, by group riding status. Approximately half of the group rider crashes (n=7, 53.8%) were at priority control intersections (give way sign, stop sign or no signage), approximately a quarter occurred at roundabouts and a quarter at traffic signal intersections. The majority of group rider crashes (n=10, 76.9%) also occurred at T-intersections (three-way intersections). See Figure 4.2 for a diagram of the intersection types. There were no significant differences between group and individual rider crashes for intersection control type or number of intersection approaches.

Table 4.9 Road environment characteristics of bicycle crashes at intersections only, by group riding status

Intersection characteristic	Group rider crash (n=13)		Individual rider crash (n=42)		p-value
	N	%	N	%	
Lanes in direction of travel					
1 lane	8	61.5	25	59.5	
≥ 2 lanes	5	38.5	17	40.5	0.897 [a]
Intersection control type					
Priority control	7	53.8	20	47.6	
Roundabout	3	23.1	11	26.2	
Traffic signals	3	23.1	11	26.2	1.000 [b]
Intersection approaches					
T- intersection	10	76.9	21	50.0	
Cross-intersection	3	23.1	20	47.6	
Multi-intersection	0	0.0	1	2.4	0.268 [b]
Bike lane at intersection					
None	9	69.2	30	71.4	
Continuous (through intersection	3	23.1	5	11.9	
Not continuous (ends at or before intersection)	1	7.7	7	16.7	0.482 [b]

[a] p-values from chi-square tests [b] p-values from Fisher-Freeman-Halton Exact tests

Figure 4.2 Examples of T-intersection, cross intersection and multi-intersection

T-intersection (3-way) *Cross intersection (4-way)* *Multi-intersection (5-way)*
Images from Nearmap (Nearmap, 2019)

The majority group rider crashes at intersections occurred on roads with one lane in the direction of travel (n=8, 61.5%) and none of the intersections had any specific bicycle treatment such as bicycle boxes (a painted space in the intersection that positions bicycles ahead of motor vehicles). Only three group rider crashes at intersections (n=23.1%) and five individual rider crashes (11.9%) had bicycle lanes that continued through the intersection and were present at the exact location of the crash. One group rider crash (7.7%) and seven individual rider crashes (16.7%) had a bicycle lane that ended prior to or at the entry of the intersection. See Figure 4.3 for diagrams of bicycle lane types at intersections. There were no significant differences in terms of lanes in the direction of travel or bicycle lanes (Table 4.9).

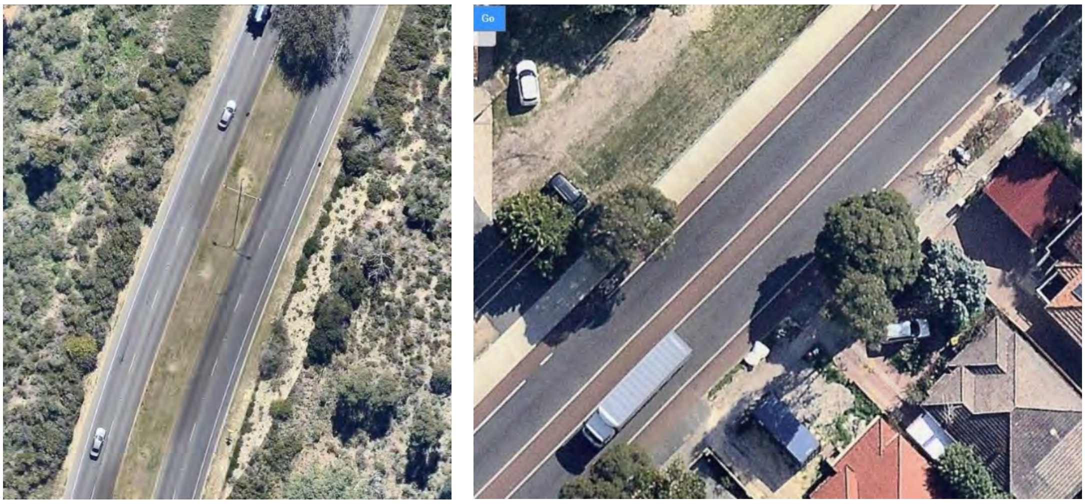
Figure 4.3 Examples of bicycle lane types approaching intersections

Continuous bicycle lane *Lane ends at intersection* *Lane ends before intersection*
Images from Nearmap (Nearmap, 2019)

4.1.11.3 Road environment characteristics: midblock crashes

Table 4.10 presents the characteristics of the 53 crashes that occurred at midblock sites (24 group rider and 29 individual rider crashes), by group riding status. There were no significant differences between group rider and individual rider crashes for any of the midblock characteristics. All midblock crashes occurred on roads that allowed travel in both directions for motor vehicles and bicycles (100%). For group rider crashes, the mean width of the carriageway (kerb to kerb) was 11.7 metres (SD: 6.1). The majority of midblock sites where group rider crashes occurred, had no median (n=15, 62.5%), six (25.0%) had physical medians and three (12.5%) had non-physical medians (Table 4.10). See Figure 4.4 for diagrams of physical and non-physical medians.

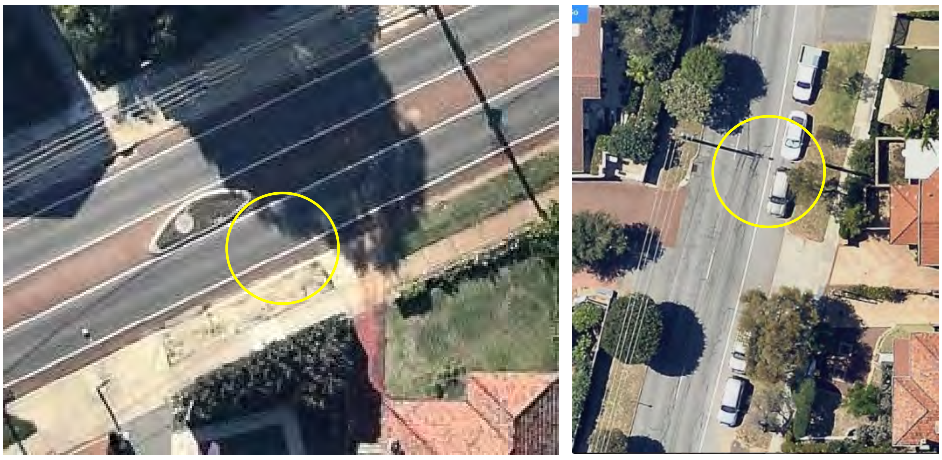
Figure 4.4 Examples of physical and non-physical medians



Physical median *Non-physical median*
Images from Nearmap (Nearmap, 2019)

The majority of group rider crashes at midblocks (n=21, 87.5%) were on roads with only one traffic lane in the direction of travel, a left lane width of 3-3.5m (n=11, 45.8%) or wider than 3.5m (n=11, 45.8%) and no bicycle lane (n=15, 62.5%). Nine group rider (37.5%) and six individual rider crashes (20.7%) were on roads with formal bicycle lanes, while no group rider crashes and four individual rider crashes (13.8%) were on roads with unmarked bicycle lanes (informal bike lanes formed by the presence of on-road parking) ($p=0.097$) (Table 4.10). See Figure 4.5 for diagrams of formal and unmarked bicycle lanes.

Figure 4.5 Examples of formal and unmarked bicycle lanes



Formal bicycle lane *Unmarked bicycle lane formed due to parking*
Images from Nearmap (Nearmap, 2019)

Table 4.10 Road environment characteristics of bicycle crashes at midblocks only, by group riding status

Midblock characteristic	Group rider crash (n=24)		Individual rider crash (n=29)		p-value
	N	%	N	%	
Median type					
None	15	62.5	19	65.5	
Non-physical median	3	12.5	3	10.3	
Physical median	6	25.0	7	24.1	1.000 [c]
Lanes in direction of travel					
1 lane	21	87.5	22	75.9	
≥ 2 lanes	3	12.5	7	24.1	0.318 [b]
Left lane width					
< 3.0 m	2	8.3	5	17.2	
3.0-3.5 m	11	45.8	13	44.8	
> 3.5 m	11	45.8	11	37.9	0.692 [c]
Bicycle lane at midblock					
None	15	62.5	19	65.5	
Formal bicycle lane	9	37.5	6	20.7	
Unmarked bicycle lane	0	0.0	4	13.8	0.097 [c]
Left kerb type					
None	5	20.8	5	17.2	
Mountable or semi-mountable	2	8.3	5	17.2	
Barrier	17	70.8	19	65.5	0.704 [c]
Adjacent parking (not clearway)					
No	21	87.5	19	65.5	
Yes	3	12.5	10	34.5	0.064 [a]
Nature-strip					
No	10	41.7	16	55.2	
Yes	14	58.3	13	44.8	0.328 [a]
Footpath					
No	9	37.5	5	17.2	
Yes	15	62.5	24	82.8	0.096 [a]
Gradient					
Flat (-5 to 5%)	18	75.0	26	89.7	
Sloped (<-5% or >5%)	6	25.0	3	10.3	0.271 [b]

[a] p-values from chi-square tests [b] p-values from Fishers Exact test
[c] p-values from Fisher-Freeman-Halton Exact tests

The left kerb was most commonly a barrier type kerb for group rider crashes (n=17, 70.8%) at midblocks (Table 4.10). Barrier kerbs are steep-faced kerbs designed to prevent vehicle encroachment on the roadside. Adjacent parking was present at the crash site for three group rider crashes (12.5%), a nature-strip for 14 crashes (58.3%) and a footpath for 15 crashes (62.5%). In terms of road gradient (slope), the majority of group rider crashes (n=18, 75%) were on flat sections of road (-5 to 5% longitudinal gradient), as opposed to sloped roads (Table 4.10). There were no significant differences between group and individual rider crashes for any of these characteristics. Three individual rider crashes (5.7%) were at speed humps and one group rider crash (4.2%) occurred at a slow point (a short narrow section of carriageway designed to reduce vehicle speeds).

4.1.12 Crash type descriptions and classification

Information from the participants' crash descriptions in the questionnaire, participant diagrams and site inspections were used to classify all crashes into categories according to road use movement and mechanism of the crash. Crashes are described below by whether they involved a collision with a motor vehicle. As presented in Table 4.11, a significantly higher proportion of individual rider crashes (n=41, 57.7%) involved a collision with a motor vehicle, compared to group rider crashes (n=6, 16.2%) (p<0.001).

Table 4.11 Type of crash by group riding status for all crashes

Type of crash	Group rider crash (n=37)		Individual rider crash (n=71)		p-value
	N	%	N	%	
Type of crash					
Crash involving a motor vehicle	6	16.2	41	57.7	
Crash not involving a motor vehicle	31	83.8	30	42.3	<0.001 [a] *

[a] p-value from chi-square test * significant at p<0.05

4.1.12.1 Crashes involving motor vehicles

This section describes and categorises the six group rider and 41 individual rider crashes, which involved a crash (actual collision) with a motor vehicle. The crashes are classified into the six categories listed in Table 4.12. RUM codes and example diagrams are provided where appropriate (Main Roads Western Australia, 2015)

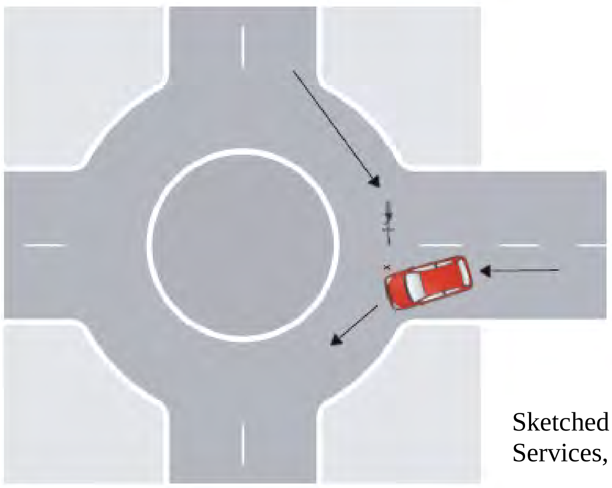
Table 4.12 Crash type classification for crashes involving a motor vehicle, by group riding status (n=47)

Crash type	Group rider crash (n=6)		Individual rider crash (n=41)	
	N	%	N	%
Crash with motor vehicle travelling in a different direction	4	66.7	17	41.5
Crash with motor vehicle travelling in the same direction	2	33.3	15	36.6
Crash with motor vehicle while rider was crossing road to path	0	0.0	4	9.8
Crash with a car door	0	0.0	2	4.9
Crash with a parked car	0	0.0	2	4.9
Crash with a motor vehicle leaving driveway	0	0.0	1	2.4

Crash with motor vehicle travelling in a different direction

Four of the six group rider crashes (66.7%) and 17 of the 41 individual rider crashes (41.5%) involved a crash with a motor vehicle travelling in a different direction to the rider. For the group rider crashes, all involved a group of only two riders and in each case the riders had right of way at the intersection (i.e. the motor vehicle failed to give way to the riders). The first crash occurred at a four-way roundabout where riders were travelling straight. A motor vehicle approaching from the left did not give way resulting in a right-angle crash (RUM 11, Intersection: thru-thru) (Figure 4.6). Five of the individual rider crashes also involved this scenario at a roundabout.

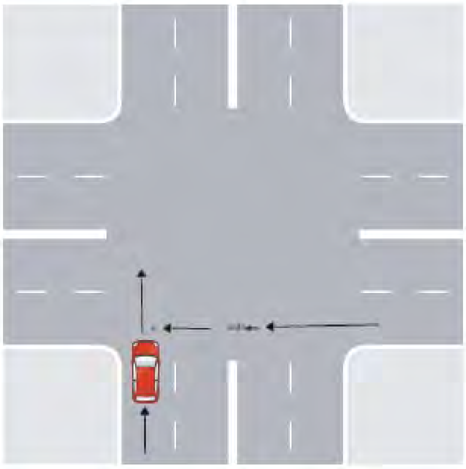
Figure 4.6 Example of an 'Intersection: thru-thru' crash at a roundabout: RUM 11 (n=1 group rider and 5 individual rider crashes)



Sketched using Claim Management Services, 2018

Another individual rider *'Intersection: thru thru'* crash was at a multiple lane priority control cross-intersection where the rider crossing the intersection was hit from the left by a motor vehicle travelling in the designated bus lane (RUM 11) (Figure 4.7).

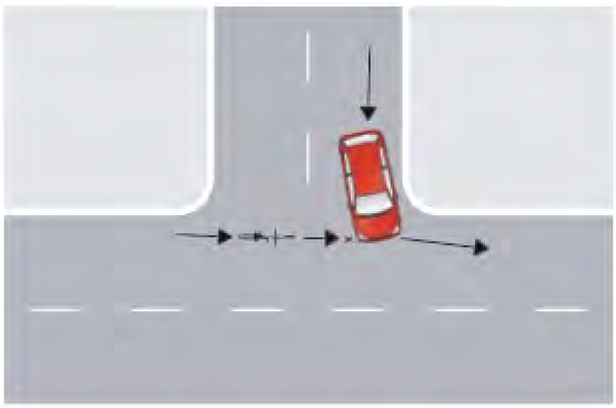
Figure 4.7 Example of an 'Intersection: thru-thru' crash at a priority control cross intersection (RUM 11) (n=1 individual rider crash)



Sketched using Claim Management Services, 2018

Two group rider crashes involved riders travelling straight in the bicycle lane of a main road with two lanes in the direction of travel. While riding past priority control T-intersections (give way), motor vehicles approached from the side streets on their left and failed to give way to the rider before turning left at the intersection. This resulted in right-angle crashes (RUM 17, Intersection: thru-left) (Figure 4.8). Three individual rider crashes also involved this scenario.

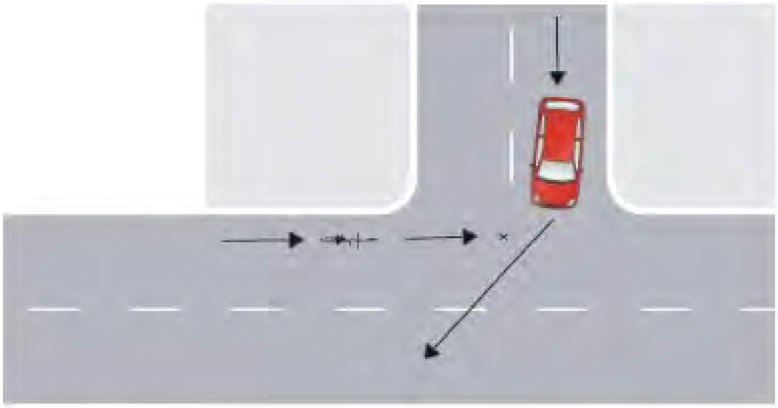
Figure 4.8 Example of an 'Intersection: thru-left' crash at a priority control intersection: RUM 17 (n=2 group rider and 3 individual rider crashes)



Sketched using Claim Management Services, 2018

Another three individual rider crashes involved the same situation but motor vehicles failed to give way to the rider before turning right at the priority control T-intersection, resulting in a crash (RUM 14, Intersection: thru-right) (Figure 4.9).

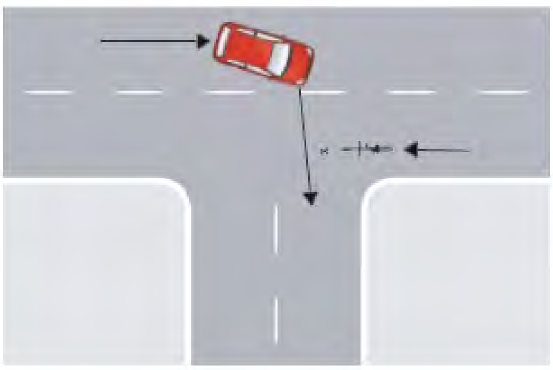
Figure 4.9 Example of an 'Intersection: thru-right' crash at a priority control intersection: RUM 14 (n=3 individual rider crashes)



Sketched using
Claim Management
Services, 2018

The fourth group rider crash occurred when the riders were travelling straight through an unmarked priority control T-intersection. A motor vehicle travelling in the opposite direction turned right resulting in a right-angle crash (RUM 22, Vehicles from opposing directions: thru, right) (Figure 4.10). Four individual rider crashes also involved an oncoming motor vehicle turning right into the path of an oncoming rider. One involved a motor vehicle turning at a T-intersection (Figure 4.10), two at traffic signal cross intersections and one at perpendicular parking (RUM 22).

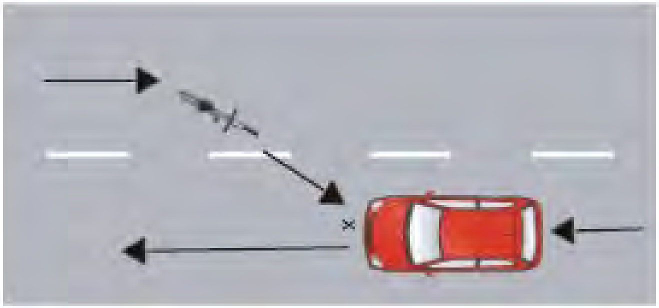
Figure 4.10 Example of a 'Vehicles from opposing directions: thru, right' crash: RUM 22 (n=1 group rider, 4 individual rider crashes)



Sketched using Claim Management
Services, 2018

Finally, one head on crash involving an individual rider happened at a midblock site, when a rider veered into the path of an oncoming motor vehicle (RUM 21, Vehicles from opposing directions: Sideswipe/ head on) (Figure 4.11)

Figure 4.11 Example of a 'Vehicles from opposing directions: Sideswipe/ head on' crash: RUM 21 (n=1 individual rider crash)

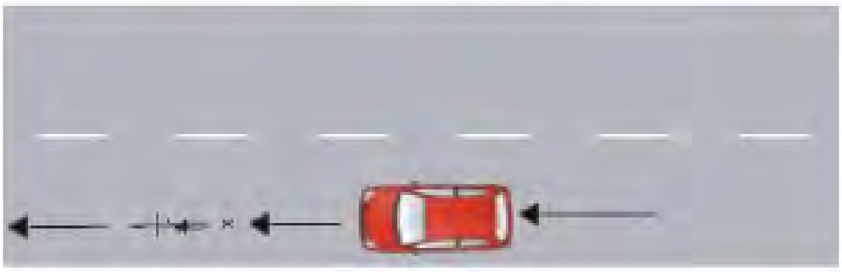


Sketched using Claim Management Services, 2018

Crash with motor vehicle travelling in the same direction

The two remaining group rider crashes (33.3%) and fifteen of the 41 individual rider crashes (36.6%), involved a crash with a motor vehicle travelling in the same direction as the riders. The first group rider crash involved riding on a road with no bicycle lane in a group of five and a motor vehicle hit the rider from behind (RUM 31, Vehicles from one direction: Same lane rear end) (Figure 4.12). Six individual rider crashes also involved motorists rear ending the rider. Three of these occurred when riding in a designated bicycle lane, one in an unmarked bicycle lane and two crash sites had no bicycle lane (RUM 31).

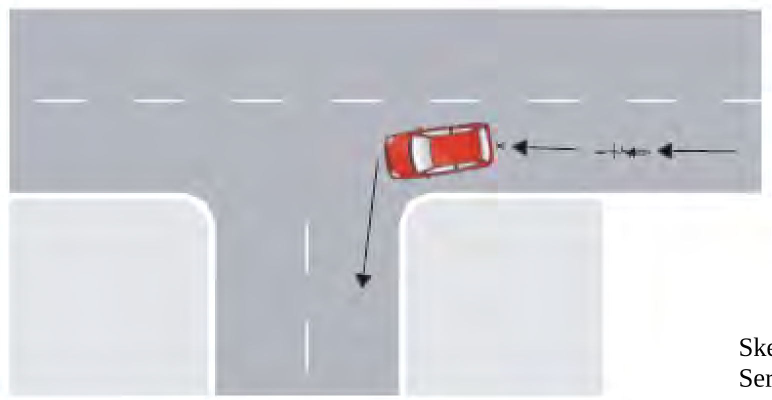
Figure 4.12 Example of a 'Vehicles from one direction: Same lane rear end' crash: RUM 31 (n=1 group rider and 6 individual rider crashes)



Sketched using Claim Management Services, 2018

Two individual rider crashes involved the riders rear ending a motor vehicle when the motor vehicle turned left at a priority control intersection (RUM 32, Vehicles from one direction: same lane, left rear) (Figure 4.13). One individual rider crash also involved rear ending a motor vehicle which stopped in the bicycle lane.

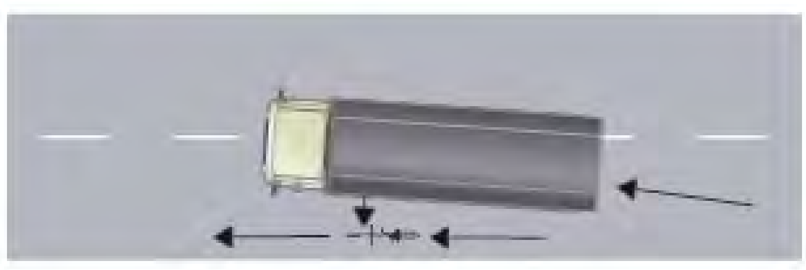
Figure 4.13 Example of a 'Vehicles from one direction: same lane, left rear' crash: RUM 32 (n=2 individual rider crashes)



Sketched using Claim Management Services, 2018

The second group rider crash involved a rider in the bicycle lane who was clipped by a digger on the back of an overtaking truck (RUM 35, Vehicles from one direction: Parallel lanes sideswipe) (Figure 4.14).

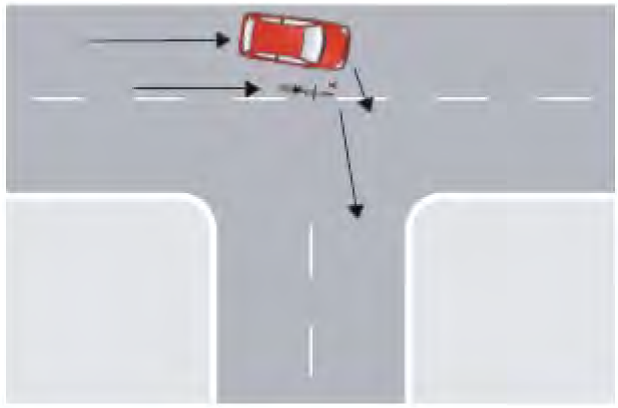
Figure 4.14 Example of 'Vehicles from one direction: Parallel lanes sideswipe': RUM 35 (n=1 group rider crash)



Sketched using Claim Management Services, 2018

One individual rider crash involved a sideswipe between a motor vehicle and a rider travelling in the same direction when they both turned right at a priority control intersection (RUM 38, Vehicles from one direction: parallel lanes, turn right, sideswipe) (Figure 4.15).

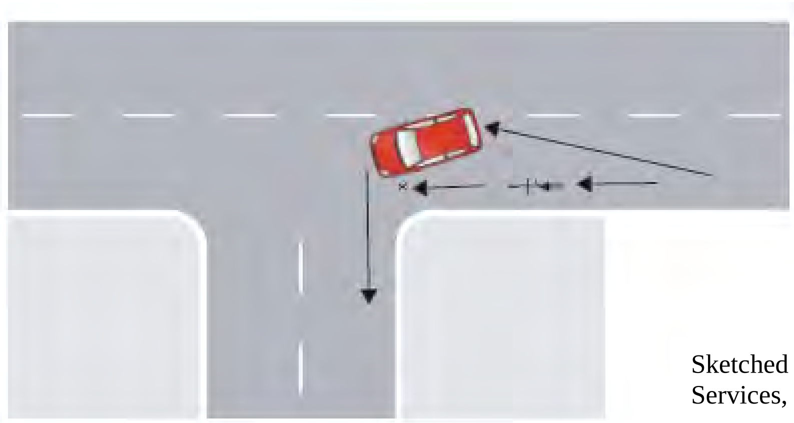
Figure 4.15 Example of a 'Vehicles from one direction: parallel lanes, turn right, sideswipe' crash: RUM 38 (n=1 individual rider crash)



Sketched using Claim Management Services, 2018

Three of the individual rider crashes involved a motor vehicle overtaking the rider who was travelling straight at an intersection, then turning left in front of them, resulting in a crash (RUM 39, Vehicles from one direction: Parallel lanes: turn left, sideswipe). Two of these occurred at priority control intersections and one at traffic signals. One of the riders was travelling in a bicycle lane at the time of the crash (Figure 4.16).

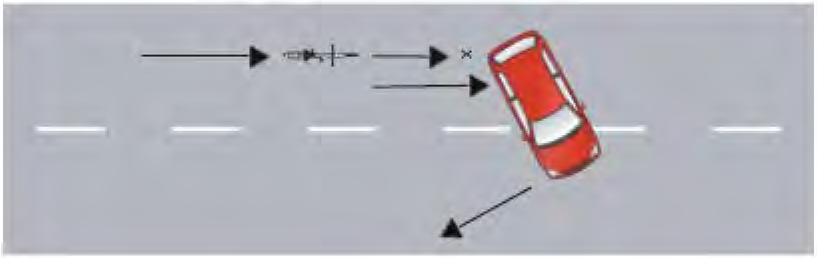
Figure 4.16 Example of a 'Vehicles from one direction: Parallel lanes: turn left, sideswipe' crash: RUM 39 (n=3 individual rider crashes)



Sketched using Claim Management Services, 2018

Finally, two individual rider crashes involved a motor vehicle performing a U-turn in front of a rider (RUM 34, Vehicles from one direction: Same lane, U-turn) (Figure 4.17).

Figure 4.17 Example of a 'Vehicles from one direction: Same lane, U-turn' crash: RUM 34 (n=2 individual rider crashes)



Sketched using
Claim Management
Services, 2018

Crash with motor vehicle while rider was crossing road to path

Four individual riders were involved in crashes with a motor vehicle while the rider was crossing a road at an intersection but travelling to an off-road path. For three of these crashes, the rider was crossing a road from a path to a path. The first occurred when crossing a roundabout at a pedestrian crossing, and they crashed (right angle) with a motor vehicle approaching from the left. The second involved a rider crossing the side street of a four-way priority control intersection from path to path. A motor vehicle travelling in the same direction, turned left into the side street and hit the rider in a right-angle crash. The third involved crossing the road from path to path at the pedestrian crossing of a four-way traffic signal intersection. A motor vehicle travelling in the same direction, turned right at the intersection, hitting the rider in a right-angle crash. The fourth involved a rider who was travelling on the road but was crossing to a path on the opposite side of a priority control T-intersection. This resulted in a right-angle crash with a motor vehicle travelling straight along the main road. There were no suitable RUM codes to assign for these crashes involving the intersection of a path and road.

Collision with a car door

Two individual rider crashes involved hitting a car door. Both involved a motor vehicle in marked on-road parking opening their car door into a passing rider, one who was travelling in the left traffic lane and the other in an unmarked bicycle lane (RUM 64, on path, open car door).

Collision with a parked car

Two further individual rider crashes involved hitting a motor vehicle (rear end crash) which was parked in a bicycle lane (RUM 61, On path, parked).

Collision with a motor vehicle leaving a driveway

Finally, one individual rider was involved a right-angle crash with a motor vehicle which backed out of a driveway (RUM 47, Manoeuvring: leaving driveway).

4.1.12.2 Crashes not involving a motor vehicle

This section describes and categorises the 31 group rider crashes and 30 individual rider crashes, which did not involve any physical contact with a motor vehicle. Crashes are classified into seven categories as listed in Table 4.13. RUM codes are provided where possible (Main Roads Western Australia, 2015) and example diagrams presented for rider/ rider crashes only.

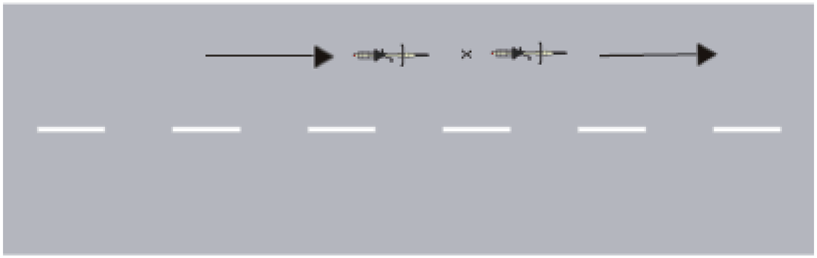
Table 4.13 Crash type classification for crashes not involving a motor vehicle, by group riding status (n=61)

Crash type	Group rider crash (n=31)		Individual rider crash (n=30)	
	N	%	N	%
Rider/ rider	14	45.2	4	13.3
Loss of control on carriageway, no object hit	3	9.7	10	33.3
Loss of control on carriageway, hit road infrastructure	4	12.9	2	6.5
Hit road infrastructure travelling from road to path	1	3.2	3	10.0
Hit object/ hazard on road carriageway	7	22.6	8	26.7
Bicycle malfunction	2	6.5	2	6.7
Pedestrian crash	0	0.0	1	3.3

Rider/ rider crashes

Fourteen group rider crashes involved a rider/ rider crash and all of these were with others riding in the same group as the study participant. Groups ranged in size from two to 55 riders. Ten of these crashes involved actual contact between two of the riders, two crashes involved three riders and one involved a larger number of riders in the group. The majority of group rider crashes were rear end crashes (n=10) where the front wheel of one rider's bike connected with the rear wheel of another rider's bike, resulting in a crash (RUM 31, Vehicles from one direction: Same lane rear end). These were due to rider error, sudden braking or the other rider hitting an object on the road. Eight of these occurred at midblocks, one at traffic signals and one at a merge point (Figure 4.18). One individual rider was also involved a rear end crash with an unknown rider and this occurred at a roundabout.

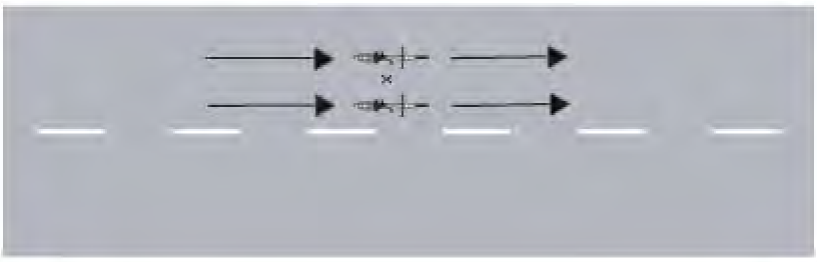
Figure 4.18 Example of a 'Vehicles from one direction: Same lane rear end' crash: RUM 31 (n=10 group rider, 1 individual rider crash)



Sketched using
Claim Management
Services, 2018

Three further group rider crashes involved a crash between two side by side riders (sideswipe) (RUM 35, Vehicles from one direction: parallel lanes, sideswipe). Two of these occurred at midblocks and one at the entry of a roundabout (Figure 4.19).

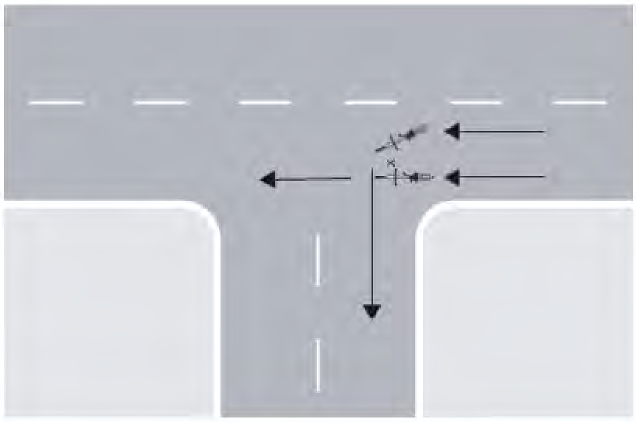
Figure 4.19 Example of a 'Vehicles from one direction: parallel lanes, sideswipe' crash: RUM 35 (n=3 group rider crashes)



Sketched using
Claim Management
Services, 2018

The final group rider crash involved one rider in the group turning left at an intersection, into another rider (RUM 39, Vehicles from one direction: parallel lanes, turn left, sideswipe) (Figure 4.20).

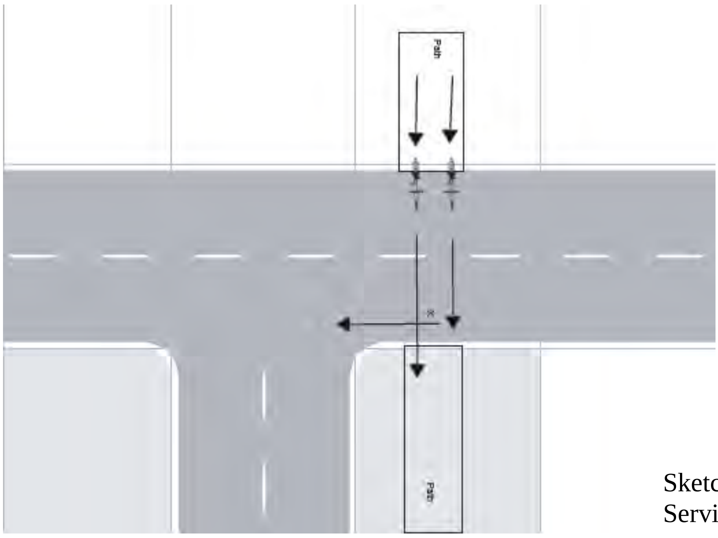
Figure 4.20 Example of a ‘Vehicles from one direction: parallel lanes, turn left, sideswipe’ crash: RUM 39 (n=1 group rider crash)



Sketched using Claim Management Services, 2018

Three individual riders were involved in crashes with another unknown rider and these crashes were quite varied. One involved a crash between a rider crossing a road from path to path and another rider overtaking them and turning right from the path onto the road (RUM 56, overtaking: into right turn) (Figure 4.21).

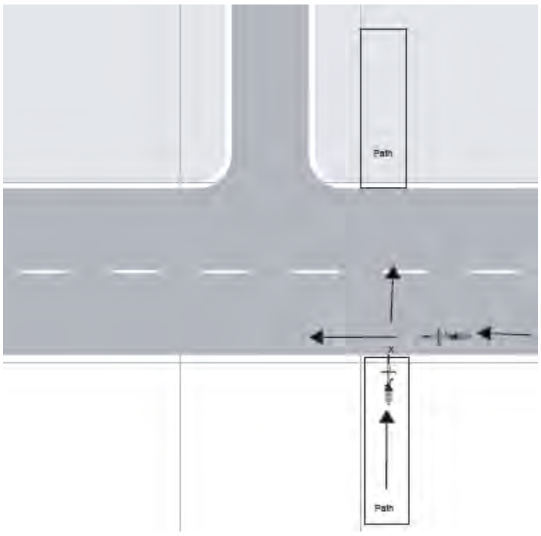
Figure 4.21 Example of an 'Overtaking: into right turn' crash: RUM 56 (n=1 individual rider crash)



Sketched using Claim Management Services, 2018

Another individual rider was crossing the road from path to path at traffic signals when an unknown rider travelled through the traffic signals on the road, resulting in a right-angle crash (RUM 11, Intersection: thru thru) (Figure 4.22).

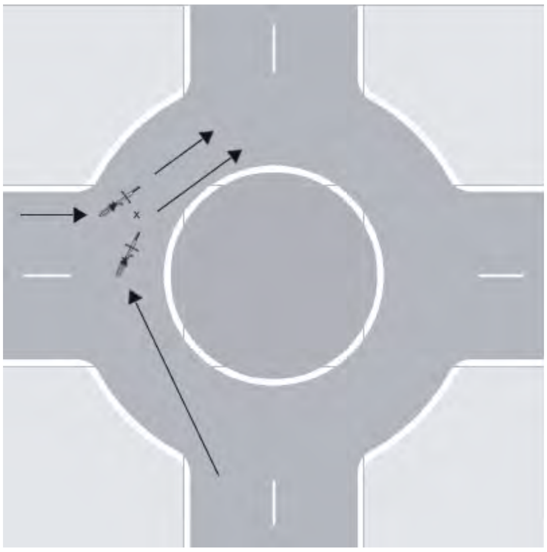
Figure 4.22 Example of an 'Intersection: thru thru' crash (RUM 11) (n=1 individual rider crash)



Sketched using Claim Management Services, 2018

The other individual rider crash involved a side swipe at a roundabout (RUM 38, vehicles from one direction: parallel lanes, turn right sideswipe) (Figure 4.23).

Figure 4.23 Example of a 'Vehicles from one direction: parallel lanes, turn right sideswipe' crash (RUM 38) (n=1 individual rider crash)



Sketched using Claim Management Services, 2018

Loss of control on carriageway: no object hit

Three group rider crashes involved the rider losing control of the bicycle and hitting the ground, without hitting any other object. Two of these involved the rider losing control on a straight road when avoiding a crash with another rider in their group in front of them (RUM 75, Off path on straight: lost control on carriageway). One crash involved losing control when turning a corner on a wet road (RUM 85, Off path on curve: out of control on carriageway). No other riders were involved in these crashes.

Ten individual rider crashes involved a loss of control on the carriageway. For three of these crashes, the rider was travelling from road to path. Seven of these involved the rider losing control on a straight road due to the bicycle or rider's foot slipping (n=5) or losing control avoiding a crash with a motor vehicle (n=2) (RUM 75, Off path on straight: lost control on carriageway). Three of the individual rider crashes involved losing control on a curve or corner with wet roads being a factor for two of these (RUM 85, Off path on curve: out of control on carriageway).

Loss of control on carriageway: hit road infrastructure

Four group rider crashes involved a loss of control on the carriageway that resulted in the rider hitting road infrastructure and crashing. The first involved losing control and hitting the left kerb (RUM 72, Off path on straight: left off carriageway into object/ vehicle) and the second involved losing control and hitting the kerb on the right side of the road (RUM 74, off path on straight: right off carriageway into object/ vehicle). The third crash involved a rider slipping while making a left turn, losing control and hitting a power pole (RUM 76, off path on straight, left turn). The fourth crash involved a rider losing control on a curve and hitting a traffic island (RUM 82, Off path on curve: off right bend into object). No other riders were involved in these crashes.

Two individual rider crashes also involved losing control and hitting road infrastructure. One lost control on a straight road and hit the left kerb (RUM 72, Off path on straight: left off carriageway into object/ vehicle) and the other lost control on a straight road and hit a pole on the left side of the road (RUM 72, Off path on straight: left off carriageway into object/ vehicle).

Hit road infrastructure travelling from road to path

One group rider crash and three individual rider crashes involved a rider crashing while negotiating a kerb travelling from road to path. There are no RUM codes for this crash type.

Hit object/ hazard on road carriageway

Seven group rider crashes involved the participant hitting a hazard on the road, resulting in a crash. These objects included a stick, wood, raised or loose concrete (RUM 67, On path: temporary object on carriageway), a pedestrian plate (RUM 65, On path: Permanent obstruction) and two crashed as a result of riding over angled railway tracks (RUM 94, Passengers and miscellaneous: struck railway object).

Eight individual rider crashes also involved hitting hazards and these included a metal grate, metal socket, sand, gravel (RUM 67, On path: temporary object on carriageway), roadwork materials (RUM 66, On path: Temporary roadworks) and a steep speed hump (RUM 65, On path: Permanent obstruction). For three of these crashes, the rider was travelling from road to path.

Bicycle malfunction

Two group rider and two individual rider crashes involved a bicycle malfunction that resulted in a loss of control crash (RUM 75, Off path on straight: lost control on carriageway). Two crashes involved the bicycle wheel coming off, another a popped tyre and the final a snapped chain. For one of the crashes, the rider was travelling from path to road.

Pedestrian crash

One individual rider crash involved a collision with a pedestrian. The participant clipped a pedestrian on the footpath as they passed on the road, resulting in the rider falling off the bicycle (RUM 5, Pedestrian: walking with traffic).

4.1.13 Human, environmental and vehicle factors contributing to crashes

An examination of the human, environmental and vehicle factors contributing to crashes was undertaken for the 108 crashes using the information obtained from the participant questionnaires, diagrams and site inspections. The IRIS database was also checked to determine if speed, inattention, fatigue or alcohol were listed as factors contributing to the crash for any available crashes, however, no incidents of these factors were recorded. A decision was made for each crash on the primary and secondary factors contributing to the crash using all available data. Each individual factor contributing to the crash was broadly categorised as human, environmental or vehicle-related factors and also sub-categorised as below (see Table 3.2 for a detailed description of factors contributing to the crash).

-Human factors

- Rider error;
- Other rider error;
- Motorist error.

-Environmental factors

- Weather/ lighting;
- Road-related;
- View obstruction.

-Vehicle factors

4.1.14 Primary factor contributing to the crash

Table 4.14 presents the categories of primary factors contributing to the crash for group rider compared to individual rider crashes. Primary factors contributing to the crash were only tabulated by broad category (human/ environment/ vehicle factors) due to the small numbers in several subcategories. There was a significant difference in the primary factors between group rider and individual rider crashes (p=0.027). A higher proportion of individual rider crashes had a human-related primary factor (n=63, 88.7%), compared to group rider crashes (n=25, 67.6%). Also, a higher proportion of group rider crashes had an environment-related primary factor (n=10, 27.0%) compared to individual rider crashes (n=6, 8.5%).

Table 4.14 Categories of primary factors contributing to crashes, by group riding status (n=108)

Factor category	Group rider crash (n=37)		Individual rider crash (n=71)		p-value [a]
	N	%	N	%	
Human	25	67.6	63	88.7	
Environmental	10	27.0	6	8.5	
Vehicle	2	5.4	2	2.8	0.027 *

[a] p-value from Fisher-Freeman-Halton test * significant at $p<0.05$

All following descriptions of the factors contributing to the crash are based on the definitions used in the MAIDS study and Allen et al. (Allen et al., 2017; Association of European Motorcycle Manufacturers (ACEM), 2004).

For individual primary factors contributing to the crash, the most common for group rider crashes were:

- *'road maintenance issues'* (any road condition that was in poor repair or in need of repair) (n=5, 13.5%);
- *'conflicting behaviours/ preoccupied'* on the part of the rider who crashed (the rider acted in a way that was unexpected by other road users, or they were distracted by another activity) (n=5, 13.5%).

For individual rider crashes, the most common individual primary factors contributing to the crash were:

- *'traffic scan errors'* on the part of a motorist (the road user did not observe or perceive oncoming traffic or traffic that may have been entering the roadway from some other direction) (n=18, 25.4%);
- *'perception failure'* on the part of a motorist (the road user failed to detect the dangerous condition based upon the strategy they were using) (n=14, 18.3%);
- *'misjudgement control'* on the part of the rider (the rider misjudged the situation and/ or failed to control the bicycle within its capabilities) (n=10, 14.1%).

4.1.15 All factors contributing to crashes

All factors contributing to crashes (including both primary *and* secondary factors) were analysed in detail. Each crash could have several individual factors, subcategories of factors and broad categories of factors. The following tables present all factors contributing to the crash by overall category and subcategory, for group rider compared to individual rider crashes. Table 4.15 presents these results for all crashes (n=108), Table 4.16 presents crashes that involved a motor vehicle only (n=47) and Table 4.17 presents crashes that did not involve a motor vehicle only (n=61).

Table 4.15 All factors contributing to a crash (primary and secondary) by group riding status for all crashes (n=108)

Factor category and sub-category	Group rider crash (n=37)		Individual rider crash (n=71)		p-value
	N	%	N	%	
Human factors					
No	**2**	**5.4**	**3**	**4.2**	
Yes	**35**	**94.6**	**68**	**95.8**	**1.000[b]**
Rider error					
No	13	35.1	33	46.5	
Yes	24	64.9	38	53.5	0.258 [a]
Other rider error					
No	26	70.3	67	94.4	
Yes	11	29.7	4	5.6	0.001 [a]*
Motorist error					
No	30	81.1	34	47.9	
Yes	7	18.9	37	52.1	0.001 [a]*
Environmental factors					
No	**10**	**27.0**	**37**	**43.7**	
Yes	**27**	**73.0**	**34**	**56.3**	**0.015** [a]*
Weather/ lighting					
No	29	78.4	58	81.7	
Yes	8	21.6	13	18.3	0.680 [a]
Road-related					
No	17	45.9	52	73.2	
Yes	20	54.1	19	26.8	0.005 [a]*
View obstruction					
No	27	73.0	62	87.3	
Yes	10	27.0	9	12.7	0.063 [a]
Vehicle factor					
No	**34**	**91.9**	**68**	**95.8**	
Yes	**3**	**8.1**	**3**	**4.2**	**0.410[b]**

[a] p-values from chi-square tests   [b] p-values from Fishers Exact test   * significant at p<0.05

Table 4.16 All factors contributing to a crash (primary and secondary) by group riding status for crashes involving a motor vehicle (n=47)

Factor category and sub-category	Group rider crash (n=6) N	Group rider crash (n=6) %	Individual rider crash (n=41) N	Individual rider crash (n=41) %	p-value [a]
Human factors					
No	**0**	**0.0**	**0**	**0.0**	
Yes	**6**	**100.0**	**41**	**100.0**	**N/A**
Rider error					
No	6	100.0	27	65.9	
Yes	0	0.0	14	34.1	0.159
Other rider error					
No	6	100.0	40	97.6	
Yes	0	0.0	1	2.4	1.000
Motorist error					
No	0	0.0	5	12.2	
Yes	6	100.0	36	87.8	1.000
Environmental factors					
No	**5**	**83.3**	**20**	**48.8**	
Yes	**1**	**16.7**	**21**	**51.2**	**0.125**
Weather/ lighting					
No	5	83.3	29	70.7	
Yes	1	16.7	12	29.3	1.000
Road-related					
No	6	100.0	33	80.5	
Yes	0	0.0	8	19.5	0.571
View obstruction					
No	6	100.0	36	87.8	
Yes	0	0.0	5	12.2	1.000
Vehicle factor					
No	**5**	**83.3**	**40**	**97.6**	
Yes	**1**	**16.7**	**1**	**2.4**	**0.241**

[a] p-values from Fishers Exact test

Table 4.17 All factors contributing to a crash (primary and secondary) by group riding status for crashes not involving a motor vehicle (n=61)

Factor category and sub-category	Group rider crash (n=31)		Individual rider crash (n=30)		p-value
	N	%	N	%	
Human factors					
No	**2**	**6.5**	**3**	**10.0**	
Yes	**29**	**93.5**	**27**	**90.0**	**0.671[b]**
Rider error					
No	7	22.6	6	20.0	
Yes	24	77.4	24	80.0	0.806[a]
Other rider error					
No	20	64.5	27	90.0	
Yes	11	35.5	3	10.0	0.018 [a] *
Motorist error					
No	30	96.8	29	96.7	
Yes	1	3.2	1	3.3	1.000[b]
Environmental factors					
No	**5**	**16.1**	**17**	**56.7**	
Yes	**26**	**83.9**	**13**	**43.4**	**0.001 [a]***
Weather/ lighting					
No	24	77.4	29	96.7	
Yes	7	22.6	1	3.3	0.053[b]
Road-related					
No	11	35.5	19	63.3	
Yes	20	64.5	11	36.7	0.030 [a]*
View obstruction					
No	21	67.7	26	86.7	
Yes	10	32.3	4	13.3	0.079 [a]
Vehicle factor					
No	**29**	**93.5**	**28**	**93.3**	
Yes	**2**	**6.5**	**2**	**6.7**	**1.000 [b]**

[a] p-values from chi-square tests   [b] p-values from Fishers Exact test   * significant at p<0.05

4.1.15.1 Human factors

At least one *'human factor'* contributing to a crash (primary or secondary) was present in the majority of both group rider (n=35, 95.6%) and individual rider crashes (n=68, 95.8%) and there was no significant difference (p=1.000) (Table 4.15). *'Human factors'* were present in all group rider crashes (n=6) and individual rider crashes (n=41), which involved a motor vehicle (Table 4.16). For crashes not involving a motor vehicle, there was no significant difference between the presence of *'human factors'* in group rider crashes (n=29, 93.5%), compared to individual rider crashes (n=27, 90.0%) (p=0.671) (Table 4.17).

Rider error

An examination of the subcategories within *'human factors'* revealed that *'rider error'* (on the part of the rider who crashed) was present in more than half of all group rider (n=24, 64.9%) and individual rider crashes (n=38, 53.5%) and there was no significant difference (p=0.258) (Table 4.15). When examining by crash type, there was no significant difference between the presence of *'rider error'* in crashes that occurred while group riding or individually for either crashes involving a motor vehicle (p=0.159) (Table 4.16), or crashes which did not involve a motor vehicle (p=0.806) (Table 4.17).

Overall, the most common types of specific *'rider error'* on the part of the rider who crashed for group riders were:

- *'misjudgement/ control'* (rider misjudged the situation and/or failed to control the bicycle within its capabilities) (n=16, 43.2%);
- *'perception failure'* (rider failed to detect the dangerous condition based upon the strategy that they were using) (n=9, 24.3%);
- *'Conflicting behaviours/ pre-occupied'* (rider acted in a way that was unexpected by other road users or were distracted by another activity) (n=7, 18.9%);
- *'speed inappropriate for conditions'* (the estimated travel speed of the rider was judged as not appropriate for the conditions) (n=4, 10.8%).

The most common *'rider errors'* for individual rider crashes were:

- *'misjudgement/ control'* (n=18, 25.4%);
- *'perception failure'* (n=10, 14.1%);
- *'Conflicting behaviours/ pre-occupied'* (n=8, 11.3%);
- *'speed inappropriate for conditions'* (n=7, 9.9%).

Other less common *'rider errors'* included *'decision/ reaction failure', 'physical or physiological failure', 'experience/ exposure to similar situations', 'faulty traffic strategy', 'traffic scan errors'* and *'position of bike unsafe or high risk'* (see Table 3.2 for error definitions).

Other rider error

Overall, *'other rider error'* (error by a rider who was not the participant in the study) was significantly more common among group rider crashes (n=11, 29.7%), compared to individual rider crashes (n=4, 5.6%) (p=0.001) (Table 4.15). There was no significant difference in the presence of *'other rider errors'* among crashes that occurred while riding in a group or individually which involved a motor vehicle (p=1.000) (Table 4.16). However, for crashes which did not involve a motor vehicle, *'other rider errors'* were present for significantly more group rider crashes (n=11, 36.5%), than individual rider crashes (n=3, 10.0%) (p=0.018) (Table 4.17).

Overall, the most common *'other rider errors'* for group rider crashes were:

- *'perception failure'* (the other rider failed to detect the dangerous condition based upon the strategy that they were using) (n=4, 10.8%);
- *'misjudgement/ control'* (the other rider misjudged the situation and/ or failed to control the vehicle within its capabilities) (n=2, 5.4%);
- *'experience/ exposure to similar situations'* (lack of experience or exposure specific to the bike, vehicle, road environment, weather or traffic conditions) (n=2, 5.4%).

The most common *'other rider error'* for individual rider crashes was:

- *'faulty traffic strategy'* (the other rider made a poor decision to perform a manoeuvre or movement) (n=3, 4.2%).

Less common *'other rider errors'* included *'decision/ reaction failure', 'conflicting behaviours/ pre-occupied'* and *'unsafe act or high-risk behaviour'* (see Table 3.2 for error definitions)

Motorist error

'Motorist error' was a significantly more common contributing factor among individual rider crashes (n=37, 52.1%), than group rider crashes (n=7, 18.9%) (p=0.001) overall (Table 4.15). However, it should be noted that this would be due to only a very small number of group rider crashes involving motor vehicles. For crashes involving motor vehicles only, there was no significant difference in *'motorist error'* between group rider (n=6, 100.0%) and individual rider crashes (n=36, 87.8%) (p=1.000) (Table 4.16). For crashes that did not involve a collision with a motor vehicle, *'motorist error'* only contributed to one group rider and one individual rider crash (Table 4.17).

The most common type of *'motorist error'* for group rider crashes was:

- *'traffic scan'* error (motorist did not observe or perceive oncoming traffic or traffic that may have been entering the roadway from some other direction) (n=5, 13.5%).

The most common types of *'motorist error'* for individual rider crashes were:

- *'traffic scan'* error (n=18, 25.4%);
- *'perception failure'* (motorist failed to detect the dangerous condition based upon the strategy that they were using) (n=12, 16.9%);
- *'faulty traffic strategy'* (the motorist made a poor decision to perform a manoeuvre or movement (n=10, 14.1%).

Less common *'motorist errors'* were *'alcohol or drug involvement'*, *'conflicting behaviours or pre-occupied'*, *'3rd or 4th vehicle involvement'*, *'decision/ reaction* *failure' 'misjudgement/ control error'* and *'position of vehicle unsafe or high risk'* (see Table 3.2 for error definitions).

4.1.15.2 Environmental factors

The broad category of *'environmental factors'* contributed to a significantly higher proportion of group rider crashes (n=27, 73.0%) than individual rider crashes (n=34, 56.3%) (p=0.013) (Table 4.15). For crashes involving a motor vehicle, there was no significant difference between group rider (n=1, 16.7%) and individual rider crashes (n=21, 51.1%) for *'environmental factors'* (p=0.125) (Table 4.16). However, for crashes not involving a motor vehicle, *'environmental factors'* were present in a significantly higher proportion of group rider (n=26, 83.9%) than individual rider crashes (n=13, 43.4%) (p=0.001) (Table 4.17).

Weather/ lighting factors

Overall, there was no significant difference in the proportion of group rider crashes (n=8, 21.6%) and individual rider crashes (n=13, 18.3%) which were affected by *'weather/ lighting'* factors (p=0.680) (Table 4.15). There were also no significant differences in the proportion of crashes that occurred while riding in a group or individually involving *'weather/ lighting'* factors for crashes involving a motor vehicle (p=1.000) (Table 4.16), or crashes which did not involve a motor vehicle (p=0.053) (Table 4.17).

The most common specific *'weather/ lighting factors'* for group rider crashes were:

- *'natural light conditions'* (natural light conditions reduced visibility for the rider: dawn, dusk, dark, sun glare) (n=5, 13.5%);
- *'Adverse weather conditions'* (a weather event including strong winds, heavy rain or fog) (n=2, 5.4%).

The most common specific *'weather/ lighting factors'* for individual rider crashes were also:

- *'natural light conditions'* (n=11, 15.5%);
- *'Adverse weather conditions'* (n=1, 1.4%).

Road-related factors

Overall, *'road-related factors'* contributed to a higher proportion of group rider crashes (n=20, 54.1%), than individual rider crashes (n=19, 26.8%) (p=0.005) (Table 4.15). For crashes involving a motor vehicle only, there was no significant difference in the proportion involving *'road-related factors'* for group rider (n=0, 0.0%) or individual rider crashes (n=8, 19.5%) (p=0.571) (Table 4.16). However, for crashes which did not involve a motor vehicle, *'road-related factors'* were present in a significantly higher proportion of group rider crashes (n=20, 64.5%) than individual rider crashes (n=11, 36.7%) (p=0.030) (Table 4.17).

The most common specific *'road-related factors'* among group rider crashes were:

- *'road maintenance issue'* (any road condition that was in poor repair or in need of repair) including uneven bitumen, raised cement and a raised manhole cover (n=7, 18.9%);
- *'slippery road due to weather'* (road surface grip was significantly reduced as a result of recent weather, e.g. rain) (n=7, 18.9%);
- *'temporary traffic hazard'* (a danger or risk on carriageway) such as concrete or wood (n=3, 8.1%);
- *'road design issue'* (condition which presented a danger to the rider based solely upon the design of the road) (n=3, 8.1%) such as angled railway tracks and kerb design at the start of bicycle paths;
- *'vertical alignment of road'* (upwards or downwards slope of road) (n=3, 8.1%);
- *'slippery road due to loose material'* (road surface grip was significantly reduced due to loose material) including sticks and dirt (n=3, 8.1%).

For individual rider crashes the most common specific 'road-related factors' were:

- *'road design issue'* (n=5, 7.0%) including speed hump design and roadside parking position;
- *'vertical alignment of road'* (n=5, 7.0%);
- *'temporary traffic hazard'* including parked cars, loose metal and a metal grate (n=4, 5.6%);
- *'slippery road due to weather'* (n=3, 4.2%);

- *'slippery road due to loose material'* including sand and gravel (n=3, 4.2%).

View-obstruction factors

Overall, there was no significant difference in the proportion of group rider crashes (n=10, 27.0%) and individual rider crashes (n=9, 12.7%) affected by *'view obstruction factors'* (p=0.063) (Table 4.15). There was also no significant difference in the proportion of crashes that occurred while riding in a group or individually affected by *'view-obstruction factors'* for crashes involving a motor vehicle (p=1.000) (Table 4.16), or crashes not involving a motor vehicle (p=0.079) (Table 4.17).

For all group rider crashes involving a *'view-obstruction factor'*, the obstruction was caused by other riders (another rider reduced or blocked visibility for the rider) (n=10, 27.0%), compared to only one individual rider crash (1.4%). Eight (11.3%) individual rider crashes involved other view obstructions (a temporary or fixed obstruction that reduced or blocked visibility for rider) including roadworks, parked cars or motor vehicle traffic on the road.

4.1.15.3 Vehicle-related factors

Finally, *'vehicle-related factors'* only contributed to a small proportion of both group rider crashes (n=3, 8.1%) and individual rider crashes (n=3, 4.2%) (p=0.410) (Table 4.15). Two group rider crashes (5.4%) and three individual rider crashes (4.2%) involved a *'bicycle failure'* (a pre-existing or acute failure of a bicycle affecting its safe operation or ability to avoid a crash) and one group rider crash (2.7%) involved a *'motor vehicle failure'* (a pre-existing or acute failure of a motor vehicle affecting its safe operation or ability to avoid a crash).

4.1.16 Binary logistic regression: association between group riding and crashes involving road-related factors

The previous examination of factors contributing to crashes highlighted significant differences in the proportion of group rider and individual rider crashes which involved an *'environmental factor'* and specifically a *'road-related factor'*. In order to determine whether a *'road-related factor'* was more likely to be present in a group rider than individual rider crash, after controlling for potential confounding factors, two binary logistic regression models were undertaken.

4.1.16.1 Binary logistic regression: road-related factors for all crashes

Initially, a binary logistic regression model was undertaken including all crashes in the study (n=108). *'Road-related factor'* (no, yes) was entered as the dependent variable. *'Group rider crash'* (no, yes) was entered as an independent variable.

From the literature, variables considered for inclusion in the model were: *'gender'*, *'age'*, *'cycling experience in Australia'*, *'cycling frequency'*, *'cycling exposure'* *'frequency of riding at crash site'*, *'weather conditions'*, *'daylight conditions'*, *'intersection crash'*, *'land use at crash location'* and *'bicycle lane present'* (Fabriek, De Waard, & Schepers, 2012; Heesch, Garrard, et al., 2011; Horrey, Wickens, & Consalus, 2006; Schepers & den Brinker, 2011; Schepers & Klein Wolt, 2012).

Univariate associations between each of these variables and whether the crash involved a *'road-related factor'* were then examined using t-tests, chi-square tests, Fisher's exact tests and Fisher-Freeman-Halton Exact tests where appropriate. Variables with p-values less an 0.25 in the univariate analyses (Bursac, Gauss, Williams, & Hosmer, 2008) were initially entered into the model and this consisted of: *'group rider crash'*, *'cycling experience in Australia'*, *'cycling exposure'*, *'cycling exposure'*, *'frequency of riding at crash site'* in the previous month, and *'weather conditions'* at the time of the crash.

Chi-square tests for multicollinearity between these independent variables revealed that *'group rider crash'* and *'cycling exposure'* were significantly associated (p=0.004). This was expected due to group rides usually being of a longer distance than other cycling trips. *'Cycling exposure'* (≤100km/week, >100 km/week) was therefore removed from the model.

Each variable listed above which was not significant at the univariate level was then separately added to the model and whether it significantly improved the fit of the model was examined. This was determined using chi-square tests to determine if there was a significant difference between the Log-likelihoods of the previous model (-2LL=116.648) and the new model with the variable added. None of the other variables significantly improved the fit of the model ($p<0.05$) so no further variables were added.

Therefore, the final model included *'group rider crash'* (no, yes) *'cycling experience in Australia'* (<20 years, ≥20 years), *'cycling exposure'* in the previous month (≤ 3 times per week, > 3 times per week), *'frequency of riding at crash site'* in the previous month (≥ once per week, < once per week) and *'weather conditions'* at the time of the crash (clear, not clear).

Interactions between the main effects in the binary logistic regression models were investigated. Two-way interaction terms were tested in the model for each different combination of the significant main effects. None of the interaction terms were significant.

Table 4.18 presents the multivariate logistic regression model examining the association between group rider crashes and road-related factors, for all 108 crashes. After controlling for potential confounding factors, group rider crashes had over three times the odds of road-related contributing factors (OR: 3.19, 95% CI: 1.26-8.04, p=0.014), compared to individual rider crashes.

In addition, participants who were less familiar with the road they crashed on (cycled at the location less than once per week) had over four times the odds of a crash involving road-related factors (OR: 4.53, 95% CI: 1.63-12.61, p=0.004), compared to those who rode at the location at least once per week. Finally, crashes that occurred when weather conditions were not clear had over four times the odds of involving road-related factors (OR: 4.59, 95% CI: 1.22-17.19, p=0.024), compared to those which occurred in clear weather. The model correctly classified the outcome for 76.9% of all cases (Table 4.18).

Table 4.18 Binary logistic regression model of the association between group riding and crashes involving 'road-related factors' (all crashes, n=108)

Variable	Adjusted OR	Standard Error	95% CI	p-value
Constant	0.25	0.52		0.008
Group rider crash: yes	3.19	0.47	1.26-8.04	0.014*
Cycling experience in Australia: ≥ 20 years	0.74	0.45	0.30-1.80	0.504
Cycling exposure: >3 times per week	0.81	0.48	0.32-2.07	0.662
Frequency of riding at crash site: < once per week	4.53	0.52	1.63-12.61	0.004*
Weather conditions: not clear	4.59	0.67	1.22-17.19	0.024*

Model statistics: χ^2 = 24.628, 5 df, p<0.001 * significant at p<0.05

4.1.16.2 Binary logistic regression: road-related factors for non-motor vehicle crashes

The findings of the regression model above for all crashes may have been influenced by the fact that a higher proportion of group rider crashes did not involve a motor vehicle. Non-motor vehicle crashes are likely to be more vulnerable to road-related factors. Therefore, the binary logistic regression model described above was also run only for crashes which did not involve a motor vehicle (n=61). The same dependent and independent variables were included. Each variable listed in the previous section which was not significant at the univariate level was then separately added to the model to examine whether it significantly improved the fit of the model based on the Log-likelihood values. None of the other variables significantly improved the fit of the model (p<0.05) so no further variables were added.

A separate model could not be run for crashes involving motor vehicles due to only six group rider crashes involving motor vehicles. However, none of the six group rider crashes and only a small proportion of individual rider crashes (19.5%) involving motor vehicles included road-related factors.

The results of the model examining the association between group rider crashes and road-related factors for crashes that did not involve a motor vehicle only (n=61) are presented in Table 4.19. Again, group rider crashes had over three times the odds of road-related factors being present (OR: 3.31, 95% CI: 1.05-10.49, p=0.042). In addition, those who rode in the location of the crash less than once per week had over four times the odds of a crash involving road-related factors (OR: 4.58, 95% CI: 1.25-16.77, p=0.022). Weather conditions were not significantly associated with crashes involving road-related factors in this model (p=0.496). The model correctly classified the outcome for 72.1% of all cases.

Table 4.19 Binary logistic regression model of the association between group riding and crashes involving road-related factors (non-motor vehicle crashes, n=61)

Variable	Adjusted OR	Standard Error	95% CI	p-value
Constant	0.40	0.66		0.163
Group rider crash: yes	3.31	0.59	1.05-10.49	0.042*
Cycling experience in Australia: ≥ 20 years	0.50	0.60	0.16-1.63	0.253
Cycling exposure: >3 times per week	1.16	0.61	0.35-3.79	0.809
Frequency of riding at crash site: < once per week	4.58	0.66	1.25-16.77	0.022*
Weather conditions: not clear	1.84	0.90	0.32-10.76	0.496

Model statistics: χ^2 = 13.085, 5 df, p<0.023 * significant at p<0.05

4.2 Part B – 12-month follow up: Results

Section 4.2 presents the results of the follow-up component of the in-depth crash study of hospitalised riders, completed approximately 12 months after the crash.

4.2.1 Study participants

A total of 83 out of the 108 participants (76.9%) completed the follow-up telephone interview approximately 12 months after their bicycle crash. Researcher administered interviews were conducted an average of 13.0 months (SD: 0.86) after the crash. Interviews were purposely not conducted earlier than 12 months or later than 15 months after the crash since it was important that all participants were interviewed at a similar time into their recovery. There were no significant differences between those who completed and did not complete the follow-up interview in terms of gender (p=0.757), age (p=0.587), education level (p=0.871), nationality (p=0.929), cycling exposure in the month before the crash (p=0.705), main purpose of cycling (p=0.519), years riding a bike in Australia (p=0.286), member of cycling club or group (p=0.922), crash involving a motor vehicle (p=0.686), major or minor injury (p=0.728), ISS (p=0.076), NISS (p=0.112) or total care in days due to injury (p=0.815).

4.2.2 Cycling cessation and reduced cycling exposure

The main outcome of interest from the follow-up assessment was cycling cessation or reduced cycling exposure at follow-up. This was determined from participants' self-reported cycling participation in the follow-up interview. Those who had not cycled since the crash or reported cycling less in the month before the follow-up interview, compared to the month before the crash were defined as experiencing '*reduced cycling exposure*' and those who reported cycling the same or more than before the crash were defined as experiencing '*no reduction in cycling exposure*'.

At follow-up, 65 participants (78.3%) had cycled since their crash. On average, they resumed cycling 19.2 weeks (SD: 15.2) after the crash, equivalent to approximately 4.5 months, with a range of one week to one year. Among those who had resumed cycling, 32 (49.2%) reported cycling less in the month before the follow-up interview than in the month before the crash, 31 (47.7%) reported cycling the same amount and two reported cycling more than before the crash (3.1%).

A total of 18 participants overall (21.7%) had not returned to cycling since the crash. Eight of these 18 participants stated that they still intended to return to cycling (44.4%), six did not intend to return to cycling (33.3%) and four were undecided (22.2%).

Participants who had not returned to cycling or rode less than before the crash (n=50) were asked the reasons for their cessation/ reduced cycling exposure. Overall, 42 (84.0%) of these 50 participants stated that they had stopped or reduced cycling due to the crash they experienced. Specifically, 25 (50.0%) cited physical injury, 23 (46.0%) cited fear of crashing/ lack of confidence, six (12.0%) due to family or General Practitioner (GP) discouraging cycling and four (8.0%) due to damage to their bicycle as a result of the crash. Eight participants (16.0%) stated that their cessation/ reduced cycling exposure was not due to the crash. Overall, 31 of the 50 participants (62.0%) who had stopped or reduced cycling reported that they had replaced some or all of their previous cycling activity with another form of exercise.

In terms of group riding specifically, at baseline 35 of the 83 participants (42.2%) reported that they rode as part of a club or group of five or more riders in the month before the crash. At follow up, 15 of the 35 group riders (42.9%) had reduced cycling exposure, compared to 35 of the 48 non-group riders (72.9%). At follow-up, 22 (62.9%) of the 35 group riders reported that they had resumed group riding specifically, seven had resumed riding but not with a group (20.0%) and six had not resumed riding at all (17.1%).

For the remainder of the results, the 83 participants who completed the follow-up interview are described in terms of whether they experienced *‘reduced cycling exposure’* or *‘no reduction in cycling exposure’* at follow-up. Overall 50 participants (60.2%) experienced *‘reduced cycling exposure’* and 33 (39.8%) had *‘no reduction in cycling exposure’* at follow-up. Those who experienced *‘reduced cycling exposure’* and *‘no reduction in cycling exposure’* were both followed up an average of 13.0 months (SD: 0.86) after their crash (p=0.788).

4.2.3 Participant demographic and health characteristics

Table 4.20 compares the demographic and health characteristics (at baseline) of the 83 participants who completed the follow-up interview, by reduced cycling exposure 12 months after the crash.

Table 4.20 Demographic and health characteristics of participants who completed the follow-up interview, by reduced cycling exposure

Demographic and health characteristic [b]	No reduction in cycling exposure (n=33)		Reduced cycling exposure (n=50)		p-value [a]
	N	%	N	%	
Gender					
Male	31	93.9	38	76.0	
Female	2	6.1	12	24.0	0.033*
Employment status					
Full time	25	75.8	27	54.0	
Other	8	24.2	23	46.0	0.045*
Age (years)					
≤ 50	18	54.5	20	40.0	
> 50	15	45.5	30	60.0	0.193
BMI					
<25	23	69.7	29	58.0	
≥ 25	10	30.3	21	42.0	0.281
University Degree					
No	13	39.4	22	44.0	
Yes	20	60.6	28	56.0	0.687
Nationality					
Australian	24	72.7	35	70.0	
Other	9	27.3	15	30.0	0.789
Medical condition					
No	25	75.8	39	78.0	
Yes	8	24.2	11	22.0	0.812
Prescription medications					
No	21	63.6	32	64.0	
Yes	12	36.4	18	36.0	0.973

[a] p-values from chi-square tests [b] all variables collected at baseline * significant at p<0.05

A significantly higher proportion of participants who had reduced cycling exposure were female (n=12, 24.0%), compared to those who had no reduction in cycling exposure (n=2, 6.1%) (p=0.033) (Table 4.20). A significantly higher proportion of those who had no reduction in cycling exposure were also employed full time at baseline (n=25, 75.8%), compared to those who had reduced cycling exposure (n=27, 54.0%) (p=0.045). There were no other significant differences in demographic and health characteristics of participants who had reduced cycling exposure, compared to those who had no reduction in cycling exposure (Table 4.20).

4.2.4 Cycling exposure and crash characteristics

Table 4.21 presents the cycling exposure and crash characteristics of the 83 participants who completed the follow-up interview. In terms of cycling frequency before the crash, 72.7% of participants (n=24) who had no reduction in cycling exposure, rode more than three times per week, compared to 54.0% (n=27) of those who had reduced cycling exposure. This difference was not significant (p=0.086). The main purpose of cycling before the crash was predominantly recreation/ fitness for both those who had no reduction in cycling exposure (n=20, 66.7%) and those who had reduced cycling exposure (n=32, 64.0%) and there was no significant difference (p=0.803). However, a significantly higher proportion of those who had no reduction in cycling exposure (n=20, 60.6%) rode as part of a group/ club of five or more riders in the month before the crash, compared to those who had reduced cycling exposure (n=15, 30.0%) (p=0.006). Twenty-six participants who had reduced cycling exposure (52.0%) experienced a crash involving a motor vehicle, compared to 11 (33.3%) participants who had no reduction in cycling exposure, however this difference was not significant (p=0.094). Finally, four participants (12.1%) who had no reduction in cycling exposure were involved in a subsequent crash in the year following their initial crash (the most severe of these required an ED visit only), compared to no participants who had reduced cycling exposure. This difference was not significant (p=0.114).

Table 4.21 Cycling exposure and crash characteristics of participants who completed the follow-up interview, by reduced cycling exposure

Cycling exposure and crash characteristic	No reduction in cycling exposure (n=33)		Reduced cycling exposure (n=50)		p-value
	N	%	N	%	
Cycling frequency (previous month) [c]					
≤ 3 times/ week	9	27.3	23	46.0	
> 3 times/ week	24	72.7	27	54.0	0.086 [a]
Main purpose of cycling (previous month) [c]					
Commuting/ Utilitarian	11	33.3	18	36.0	
Recreation/ Fitness	22	66.7	32	64.0	0.803 [a]
Group riding participation [c]					
No	13	39.4	35	70.0	
Yes	20	60.6	15	30.0	0.006 [a] *
Crash involve motor vehicle [c]					
No	22	66.7	24	48.0	
Yes	11	33.3	26	52.0	0.094 [a]
Involvement in subsequent crash					
None	29	87.9	50	100	
One or more	4	12.1	0	0.0	0.114 [b]

[a] p-values from chi-square tests
[b] p-values from Fishers Exact test
[c] variables collected at baseline
* significant at p<0.05

4.2.5 Injury characteristics from the State Trauma Registry

Table 4.22 presents the baseline injury severity characteristics for the 77 participants who completed the follow up interview and for whom injury information was available, from the State Trauma Registry. There were no significant differences between those who had reduced cycling exposure at follow-up and those who had no reduction in cycling exposure in terms of ISS (p=0.434), major injury (ISS>15) (p=0.520), NISS (p=0.144), the number of AIS regions injured (p=0.367) and days in hospital care (p=0.449).

Table 4.22 Injury severity information for participants who completed the follow-up interview, by reduced cycling exposure post-crash

Injury severity characteristic [c]	No reduction in cycling exposure (n=29)		Reduced cycling exposure (n=48)		p-value
	Mean	SD	Mean	SD	
Injury Severity Score	8.6	4.6	9.8	7.8	0.434 [a]
New Injury Severity Score	10.9	4.9	13.3	9.6	0.144 [a]
Number of AIS regions	4.3	1.8	4.8	2.5	0.367 [a]
Days in care	4.7	7.1	5.8	5.1	0.449 [a]
Injury severity (N,%)					
Minor	26	89.7	40	83.3	
Major [d]	3	10.3	8	16.7	0.520 [b]

[a] p-values from t-tests
[b] p values from Fishers Exact test
[c] variables collected at baseline
[d] Major injury defined as ISS > 15

4.2.6 Recovery from injury

Table 4.23 presents the injury recovery characteristics collected at the follow-up interview for the 83 participants. Approximately two-thirds of participants who had reduced cycling exposure (n=33) and those who had no reduction in cycling exposure (n=20) reported that they still experienced physical effects from injuries resulting from the crash, at the follow-up interview. There was no significant difference between groups (p=0.617). These effects ranged from pain, weakness, stiffness, tightness, headaches, slowed movements, grip problems, muscle wastage, loss of flexibility, nerve damage, numbness, reduced mobility in joints and poor balance. In addition, 21 participants who had reduced cycling exposure (42.0%) and 10 who had no reduction in cycling exposure (30.3%), reported that they had experienced pain from their injuries in the last 24 hours. This difference was not significant (p=0.281). Three participants who had reduced cycling exposure (6.0%) and no participants who had no reduction in cycling exposure reported that they had been diagnosed with PTSD as a result of the crash. In addition, six participants who had reduced cycling exposure (12.0%) reported they underwent counselling as a result of the crash, compared to no participants who had no reduction in cycling exposure. The types of counselling included psychologist, psychiatrist and the Road Trauma Unit counselling services.

Table 4.23 Injury recovery information for participants who completed the follow-up interview, by reduced cycling exposure

Injury recovery characteristic [c]	No reduction in cycling exposure (n=33)		Reduced cycling exposure (n=50)		p-value
	N	%	N	%	
Physical effects					
No	13	39.4	17	34.0	
Yes	20	60.6	33	66.0	0.617 [a]
Pain from injuries					
No	23	69.7	29	58.0	
Yes	10	30.3	21	42.0	0.281 [a]
PTSD diagnosis					
No	33	100.0	47	94.0	
Yes	0	0.0	3	6.0	0.273 [b]
Counselling					
No	33	100.0	44	88.0	
Yes	0	0.0	6	12.0	0.076 [b]

[a] p-values from chi-square tests [b] p-values from Fishers Exact tests [c] variables collected at follow-up

Table 4.24 presents the results of the GOS-E administered at the follow-up interview. The GOS-E scoring system categorises participants into one of eight categories according to their reported overall level of function on six domains after an injury. The majority of participants who had no reduction in cycling exposure (n=30, 90.9%) and those who had reduced cycling exposure (n=33, 66.0%) had the highest level of recovery, '*category 8: upper good recovery*'. Therefore, a binary variable was created categorising participants who had the highest level of *recovery* '*category 8: upper good recovery*' and '*other*'. A significantly higher proportion of those who had no reduction in cycling exposure (n=30, 90.9%) had '*upper good recovery*', compared to those who had reduced cycling exposure (n=33, 66.0%) (p=0.009). Table 4.24 also presents participants' recovery on each of the six GOS-E domains. Overall, only three participants (9.1%) who had no reduction in cycling exposure reported problems in any of the domains, compared to 17 (34.0%) who had reduced cycling exposure. For the '*work*' domain, all participants who had no reduction in cycling exposure reported they were able to work to their previous capacity, but eight participants (16.0%) who had reduced cycling exposure reported they were not able to. For the '*social and leisure activities*' domain, all those who had no reduction in cycling exposure reported they were able to resume regular social and leisure activities outside the home but six (12.0%) who had reduced cycling exposure were not able to. For the '*family and* *friendships'* domain, one participant (3.0%) who had no reduction in cycling exposure and eight (16.0%) who had reduced cycling exposure stated that they had experienced family or friendship disruption due to psychological problems after the crash. One participant (3.0%) who had no reduction in cycling exposure and seven (14.0%) who had reduced cycling exposure stated that there were problems affecting their *'return to normal life'*

Table 4.24 Glasgow Outcome Scale – Extended (GOS-E) results for participants who completed the follow-up interview, by cycling reduction

GOS-E scale and domains [c]	No cycling reduction (n=33)		Cycling reduction (n=50)		p-value
	N	%	N	%	
GOS-E OVERALL SCALE					
GOS-E (categories) [b]					
Upper good recovery	30	90.9	33	66.0	
Lower good recovery	1	3.0	5	10.0	
Upper moderate disability	1	3.0	10	20.0	
Upper severe disability	1	3.0	2	4.0	N/A
GOS-E (binary categories)					
Upper good recovery	30	90.9	33	66.0	
Other recovery	3	9.1	17	34.0	0.009 [a] *
GOS-E INDIVIDUAL DOMAINS					
Independence at home					
No	0	0.0	1	2.0	
Yes	33	100.0	49	98.0	N/A
Independence outside home					
No	1	3.0	1	2.0	
Yes	32	97.0	49	98.0	N/A
Work to previous capacity					
No	0	0.0	8	16.0	
Yes	33	100.0	42	84.0	N/A
Social and leisure activities					
No	0	0.0	6	12.0	
Yes	33	100.0	44	88.0	N/A
Family and friendship disruption					
No	32	97.0	42	84.0	
Yes	1	3.0	8	16.0	N/A
Problems affecting return to normal life					
No	32	97.0	43	86.0	
Yes	1	3.0	7	14.0	N/A

[a] p-values from chi-square test [b] only 4 of the 8 GOS-E categories are presented as participants only fell under these categories [c] variables collected at follow-up * significant at p<0.05

4.2.7 Modifications since the crash

For participants who had returned to cycling (n=65), only seven (10.8%) stated they had made any modifications to their bicycle and five (7.7%) had made modifications to the clothing/ gear they wear while riding for the purpose of safety. All five of these participants started wearing high visibility or brighter clothing. Nineteen participants (29.2%) stated that they had made modifications to their behaviour since the crash for the purpose of safety. The majority stated they rode with more awareness/ caution since the crash (n=14), others reported they kept more distance from the wheel of the next rider in their group (n=2), cycled at slower speeds (n=2) avoided heavy traffic (n=1), rode with bicycle lights on (n=1), obeyed more road rules (n=1), no longer participated in racing (n=1), cornered more carefully (n=1), cycled closer to edge of the road (n=1) and cycled on the inside of their group (n=1).

4.2.8 Binary logistic regression model of reduced cycling exposure

A binary logistic regression model was undertaken for the 83 participants who completed the follow-up interview examining the association between *'group riding participation'* at baseline and *'reduced cycling exposure'* at follow-up. *'Reduced cycling exposure'* at follow-up (no reduction in cycling exposure, reduced cycling exposure) was entered as the dependent variable. *'Group riding participation'* in the month before the crash was entered as an independent variable. From the literature, *'age', 'medical condition', 'crash involved a motor vehicle'* and *'cycling frequency'* were entered in the model (Tournier 2014; Heron-Delaney 2013). Variables with p-values less than 0.25 in the univariate analyses were also considered including *'gender', 'employment status', 'involvement in a subsequent crash', 'New Injury Severity Score', 'counselling',* and *'GOS-E category'*. The variables *'gender', 'involvement in a subsequent crash'* and *'counselling'* were unable to be included due to very low numbers in some cells (n= 0 to 2). The *'New Injury Severity Score'* was excluded due to missing information for eight participants. All remaining independent variables were checked for the assumption of multicollinearity with no evidence of this.

The addition of *'GOS-E category'* and *'employment status'* significantly improved the fit of the model (p=0.010). This was examined using chi-square tests to determine if there was a significant difference between the Log-likelihoods of the previous model (-2LL=97.746) and the new model with the two variables added (-2LL=88.531). The addition of these two variables also improved the ability of the model to correctly classify the outcome from 71.1% to 74.7%.

Therefore, the final model included the variables: ‘*group riding participation*’ at baseline (no, yes), ‘*age*’ at baseline (years), ‘*medical condition*’ at baseline (no, yes), ‘*employment status*’ at baseline (full time, not full time), ‘*cycling frequency*’ at baseline (≤ 3 days/ week, > 3 days/ week), ‘*crash involved a motor vehicle*’ (no, yes) and ‘*GOS-E category*’ at follow-up (upper good recovery, other).

Interactions between the main effects on ‘*reduced cycling exposure*’ in the binary logistic regression models were investigated. Two-way interaction terms were tested in the model for each different combination of the significant main effects. None of the interaction terms were significant.

Table 4.25 presents the multivariate logistic regression model examining the association between ‘*group riding participation*’ at baseline and ‘*reduced cycling exposure*’ at follow-up, adjusting for confounding factors, for 83 participants. After controlling for potential confounding factors, those who did not participate in group riding before the crash had nearly four times the odds of reduced cycling exposure at follow-up (OR: 3.8, 95% CI: 1.23-11.78, p=0.021), compared to group riders. In addition, participants categorised as having the highest level of recovery, ‘*upper good recovery*’ on the GOS-E were at significantly lower odds of reduced cycling exposure at follow up (OR: 0.15, 95% CI: 0.03-0.70, p=0.016). No other variables in the model were significantly associated with reduced cycling exposure (p>0.05). The model correctly classified the outcome for 74.7% of cases.

Table 4.25 Binary logistic regression model of reduced cycling exposure at 12-month follow-up (n=83)

Variable	Adjusted OR	Standard Error	95% CI	p-value
Constant	1.55	1.33		0.742
Group riding participation: no[a]	3.80	0.58	1.23-11.78	0.021*
Age (years)[a]	1.01	0.02	0.97-1.06	0.467
Medical condition: yes[a]	0.47	0.70	0.12-1.87	0.284
Employment: not full time[a]	3.19	0.66	0.88-11.58	0.078
Cycling frequency: > 3 times/ week[a]	0.58	0.56	0.19-1.75	0.333
Crash involve motor vehicle: yes[a]	1.14	0.59	0.36-3.65	0.820
GOS-E: upper good recovery[b]	0.15	0.80	0.03-0.70	0.016*

Model statistics: $\chi^2 = 23.025$, *7 df, p=0.002*

[a] *Recorded at baseline assessment.* [b] *Recorded at follow-up assessment* * significant at p<0.05

CHAPTER 5

Phase 2- Naturalistic group riding study: Methods

5 PHASE 2 - NATURALISTIC GROUP RIDING STUDY: METHODS

Chapter 5 presents the methods of Phase 2, a naturalistic study of unsafe events and traffic violations observed among group riders in Perth, WA. Naturalistic road safety research involves the unobtrusive observation of road users in their natural environment (Dingus et al., 2006). The naturalistic group riding study utilised some of the video data collected as part of the larger ARC-funded study. In addition, participants were recruited and group riding footage collected specifically for the group riding study. The ARC study however, only used the video footage and GPS data to randomly select control sites for a case-control study. The design of the naturalistic group riding study, all data reduction and coding, as well as all analyses were conducted by the student and were completely unique and separate from the larger ARC-funded study.

The analysis of the naturalistic study was completed in three separate parts:

- Part A consisted of a case-crossover study examining road environment and group position-related risk factors for unsafe events involving a motor vehicle, that occurred while group riding in Perth, WA;
- Part B was a case-crossover study examining road environment and group position-related risk factors for unsafe events that did not involve a motor vehicle, in Perth;
- Part C consisted of a cross-sectional study examining group and trip-related factors associated with traffic violations that occurred while group riding in Perth.

5.1 Part A: Unsafe events involving a motor vehicle

Part A consisted of a case-crossover study examining road environment and group position-related risk factors for unsafe events involving a motor vehicle that occurred while group riding in Perth, WA.

5.1.1 Part A: Participant recruitment

Participants consisted of a convenience sample of 52 group riders in Perth, WA recruited between March 2015 and April 2017. Several recruitment strategies were utilised including emails to Government Departments in Perth, university newsletters, posts on online cycling forums, flyers at bicycle shops/ cafes and word of mouth. In addition, riders were recruited on the road when stopped at traffic lights around Perth. When riders stopped at a red light, they were greeted and invited to take a slap band for their wrist which had the name of the study and website printed on it (Curtin-Monash Accident Research Centre (C-MARC), 2015). All riders were directed to the website which contained a description of the study and a link to an online survey (Appendix 9).

Within the online survey, riders were asked to indicate whether they participated in group riding, if they were interested in participating in the naturalistic study and if so, to leave their contact details. The Curtin University researcher then contacted potential participants by phone, explained the study in more detail and sent a PIS and consent form (Appendix 10) to the group rider by email. If the group rider agreed to participate, an appointment was made to attach the video cameras to their bicycle. Participants were recruited consecutively.

A total of 198 group riders completed the online survey with 114 (57.6%) obtained through roadside recruitment and 84 (42.4%) through the other methods. From the 198 group riders, 147 (74.2%) agreed to be contacted regarding participation in the naturalistic study. Potential participants were contacted consecutively to a maximum of five riders who rode with the same riding group, until the desired sample size was reached. Researchers attempted to contact 74 of the group riders, nine (12.2%) were unable to be contacted and five (6.8%) contacted were ineligible. Of the 60 group riders invited to participate in the study, 52 agreed (86.7%).

5.1.2 Part A: Inclusion and exclusion criteria

Participant eligibility was determined from the responses to the online survey and confirmed during the initial phone call. Within the survey, participants were asked details of their participation in group riding. The inclusion criteria were:

- Aged 18 years or older;
- Participated in group riding (also called bunch/ peloton/ club riding) at least once a month in Perth, WA.

The exclusion criteria were:

- Rode with a group of less than five riders (including the participant).
- Rode with a group only for formal racing purposes

Group riders from both formal and informal groups were included and all levels of experience were eligible. The researcher requested that video footage was only recorded by one rider per trip. Only groups of five or more riders were eligible for the study because it was intended to include *'serious leisure'* and *'club'* group riders as described by O'Connor and Brown. These were riders who were part of an organised or semi-organised, regular group with shared perspectives and rituals (O'Connor & Brown, 2007). Those who only rode with a very small group of friends or family (2-4 riders) on an irregular basis, were not included.

5.1.3 Part A: Data collection

Data collection for the naturalistic study consisted of:

- An online survey (Appendix 9);
- Naturalistic video footage and GPS data;
- A researcher-administered questionnaire (Appendix 11).

5.1.3.1 Online survey

Potential participants completed an online survey which provided background information on their cycling and group riding participation and determined their eligibility for the naturalistic study. The survey was created, data entered and stored electronically using the web-based Google Docs program. The survey was pilot tested with five group riders before commencement for face and content validity and minor modifications were made.

Online survey items consisted of:

- Demographics (Appendix 9, Q 12-22);
- Cycling and group riding participation and experience (Appendix 9, Q 23-46);
- Risky cycling behaviours (Appendix 9, Q 47-74);
- Crash history and use of road infrastructure (Appendix 9, Q 75-86).

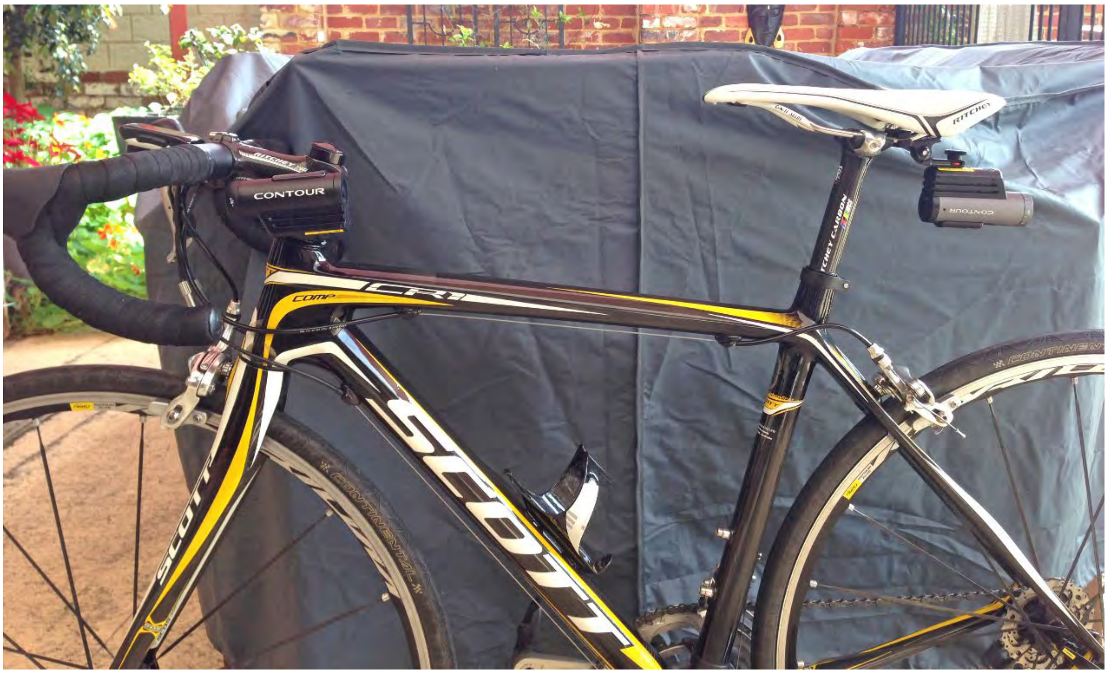
5.1.3.2 Naturalistic video footage and GPS data

Initially, the video cameras were piloted with five group riders to determine the optimal camera attachment and positioning for capturing group riding footage. Contour brand video cameras were attached to participants' bicycles using flexible straps or mounts (Figure 5.1). These cameras provided high quality high definition video, filmed at 720 pixels, at 60 frames per second, with a field of view of 170 degrees. They also recorded sound. The dimensions of the cameras were 100 x 55 x 34 mm. The cameras had lithium ion rechargeable batteries that lasted approximately two hours and could be recharged using a universal serial bus (USB) cable. The camera sim cards held approximately six hours of video data.

Figure 5.1 Contour+2 video camera - top view

The researcher attached two Contour cameras to each bicycle where possible. The Contour ROAM2 camera was mounted under the handlebars for forward footage and the Contour+2 camera was mounted under the seat to provide rear footage (Figure 5.2). Where the design of the bicycle made it impossible to attach two cameras, the Contour+2 camera was attached to the front of the bicycle only (n=5 participants, 9.6%). A waterproof case was also provided for the Contour+2 camera in case of wet weather. The Contour ROAM2 camera was waterproof.

Figure 5.2 Contour cameras fitted to a bicycle



The Contour+2 camera also had an inbuilt GPS receiver which captured and recorded the following data every second:

- Date;
- Time;
- Location (latitude and longitude);
- Travel speed (km/h);
- Direction of travel (bearing);
- Corresponding video image frame.

The GPS started automatically when the camera was switched on. GPS data was extracted and saved as gpx and csv files using the Contour Storyteller software, version 3.6.2.

All participants received a PIS and signed a consent form (Appendix 10) before video cameras were attached to their bicycles. Each participant attended an induction with the researcher at a convenient time and location. The cameras were then fitted to their bicycle and the participant was instructed on the mounting of the cameras on their bicycles, starting and stopping camera recording, interpreting the indicator lights on the cameras, recharging the camera batteries and use of the wet weather case. An instruction sheet was also provided (Appendix 12). The straps and mounts remained on the participants' bicycles for the duration of time they had the cameras, however the cameras were removed from the mounts for charging, when participating in non-group riding and when the bicycle was left unattended. Participants were asked to record any group riding (five or more riders including themselves) they participated in until the cameras' sim cards were full.

It should be noted that although the GPS was supposed to start automatically when the camera was switched on, due to camera error, GPS data was missing from 40% of the video collected. In addition, the short battery life of the cameras as well as user error resulted in substantial missing video footage. Future studies should consider using synchronised recording equipment that starts automatically when the bicycle is in motion.

5.1.3.3 Researcher-administered questionnaire

A questionnaire was administered to each participant by phone, following the collection of the video data (Appendix 11). Questionnaires consisted of closed and open-ended questions, were audio recorded and notes were also made using the AudioNote app for iPad, with the permission of the participant. Responses were then entered into a SPSS database.

The questionnaire included items on:

- Group riding participation and experience (Appendix 11, Q1.1-1.5);
- Group characteristics for each trip recorded (size, distance travelled, average speed, cost to ride, uniform, written code of conduct, designated ride leader, organisational structure, open/closed membership, drop riders and sprint points) (Appendix 11, Q 2.1-2.18);
- Opinions on safety issues for group riders (Appendix 11, Q 3.1-3.5).

5.1.4 Part A: Video and GPS processing

Initially, the separate video files for the front and rear camera footage were matched using the PluralEyes 4 software (Red Giant, 2015). This automatically analyses the audio tracks from the footage and matches them on distinctive audio patterns common to both front and rear footage. These matchings were then manually checked for accuracy. For each trip, front and rear footage was then synchronised together into a single video file using the Adobe Premiere Pro CC software (Adobe, 2015), so that footage from both cameras could be viewed simultaneously.

Using the GPS data in the extracted csv file, a subtitles add-on file was then generated for each synchronised video file. These subtitles were displayed and updated every second (see Figure 5.3). These subtitles contained information on:

- Time of day;
- Day of the week;
- Date;
- Travel speed of participant;
- Direction of travel;
- Latitude and longitude.

For trips and portions of trips where GPS data was not available, subtitles displayed the time of day, day of the week and date only.

Figure 5.3 Example of a synchronised group riding video file with subtitles

Synchronised using Adobe Premiere Pro CC software (Adobe, 2015)

5.1.5 Part A: Group riding route mapping

Every trip recorded on the cameras (n=126 trips) was manually mapped using ArcMap 10.2 (Environmental Systems Research Institute (ESRI), 2010) based on the extracted

GPS data and video footage. Each section of the mapped route was coded using ArcMap attribute tables to indicate whether the group was riding on a road or off-road and which bicycle cameras (front, rear or both) were in operation. Sections of the route excluded due to off-road riding, darkness or less than five riders were also coded in the attribute tables. The number of eligible kilometres of road riding completed for each trip was then extracted from the tables. Figure 5.4 shows the routes of all 126 group riding trips mapped in ArcMap 10.2.

Figure 5.4 Routes of the 126 group riding trips

Image created using ArcMap 10.2

5.1.6 Part A: Case-crossover study

A case-crossover study design was undertaken for Part A. This is a method in which a case serves as their own control (Maclure, 1991). This design is effective for investigating the effects of a transient exposure on an acute outcome (Lombardi, 2010). This design was implemented to examine the effect of road environment and group position-related factors (transient exposures) on unsafe events involving a motor vehicle (acute outcome). Cases were the sites where unsafe events occurred and the controls (sites where no unsafe event occurred) were selected from within the same group-riding trip as the cases. Thereby, group characteristics which remained constant for the duration of the trip and may be associated with the risk of an unsafe event (potential confounders), were controlled for. These included the personal characteristics of the group riders, group riding experience, purpose of the ride, organisational structure of the group and safety culture of the group. In addition, trip characteristics such as group members present for the specific trip, the season and weather conditions, were controlled for in the case-crossover methodology. Only trips which included at least one unsafe event involving a motor vehicle (n=60 trips) were included in the analysis for Part A.

5.1.7 Part A: Sample size

The sample size was based on the estimated hours of eligible road riding footage required to observe an adequate number of unsafe events involving motor vehicles. For Part A, the road environment and group position characteristics of unsafe event (case) sites were compared to two matched control sites (where no unsafe event occurred), per event. Independent variables of interest included for example, type of traffic control, whether raised traffic islands were present, speed limits and group position on the road. It was assumed the correlation coefficient for exposure between matched unsafe event and control sites was 0.1. From the limited Australian literature on the prevalence of different road infrastructure at the site of bicycle crashes involving motor vehicles, it was estimated that speed limits ≥ 60 km/h would be present at 40% of control sites, traffic islands at 20% of control sites, the group would be positioned in a bicycle lane at 10% of control sites and a roundabout would be present at 5% of control sites (B. Beck et al., 2016; Haworth & Debnath, 2013).

From these estimations, a sample size of 100 unsafe event (case) sites and 200 control sites would allow the detection of ORs between 1.8 and 2.3 for these variables (α=0.05, power=80%). Calculations were performed using the PS: Power computer program(Dupont & Plummer, 2014). Based on limited information from studies of individual riders (Dozza & Werneke, 2014; Johnson et al., 2010), it was estimated that one event involving a motor vehicle would occur for every 90 minutes of footage. Therefore, this study aimed to collect 150 hours of eligible footage in order to obtain 100 unsafe event (case) sites, matched to 200 control sites (Dupont & Plummer, 2014). The final data resulted in 108 unsafe event (case) sites involving a motor vehicle and 216 matched control sites, obtained from 135 hours of eligible footage.

5.1.8 Part A: Data reduction

For naturalistic studies, data reduction refers to the process of going through the raw data in order to identify events and information of interest (Hallmark et al., 2015). First, all video footage was manually watched by the researcher. Time periods where only the rear camera was recording, the group rode off-road, footage was too dark to analyse, groups were stopped on the side of the road or there were less than five riders, were excluded. In addition, potential unsafe events (cases) involving a motor vehicle were identified based on definitions used in the Strategic Highway Research Program 2 (SHRP 2) Naturalistic Driving Study (Virginia Tech Transportation Institute, 2015). At the initial stage, only the time point and GPS co-ordinates of each potential unsafe event (case) were recorded and a descriptive note made.

A second researcher then also watched 10% of the video footage equivalent to 12 randomly selected trips and completed the same process. The level of agreement between researchers for the number of potential unsafe events involving a motor vehicle per trip, was calculated using ICCs. The average measure ICC was 0.85 (95% CI: 0.47-0.96, $p=0.002$), indicating strong agreement.

5.1.9 Part A: Unsafe event (case) sites involving a motor vehicle

The two researchers examined each potentially unsafe event (case) involving a motor vehicle. The potential event was watched from 12 seconds before the beginning of the event to five seconds after the end of the event, consistent with the procedures used in the SHRP 2 Naturalistic Driving Study (Victor et al., 2015).

The researchers determined whether the potential event met the criteria for inclusion as an unsafe event involving a motor vehicle. These criteria were based on definitions used in the SHRP 2 Naturalistic Driving Study (Virginia Tech Transportation Institute, 2015), with language modified to fit the group riding context. Unsafe events (cases) included *'crashes'*, *'near crashes'* and *'crash-relevant events'* as defined in the SHRP 2 Study and *'unsafe close passing only'* events were added specifically for this study.

From 205 potentially unsafe events identified, 108 (53%) met the criteria for inclusion. The unsafe event (case) site was defined as the crash point for *'crashes'*, the point of minimum time to collision for *'near crashes'* and *'crash relevant events'* and the point of closest passing for *'unsafe close passing only'* events (Victor et al., 2015). The GPS co-ordinates for each unsafe event (case) site were then obtained.

5.1.9.1 Definitions of unsafe events (cases) involving motor vehicles

Table 5.1 presents the definitions for unsafe events involving motor vehicles (cases). Unsafe events were defined by severity with *'crashes'* being the most severe, followed by *'near crashes'*, *'crash-relevant events'* and *'unsafe close passing only'*. It should be noted that there were no actual *'crashes'* with motor vehicles observed in the video footage.

Table 5.1 Definitions for inclusion as an unsafe event (case) in the study

Unsafe event	Definition
Crash [a]	Any contact that the subject rider/s has with an object, either moving or fixed, at any speed. This also includes any contact between the ground and the bike (other than tyres) or ground and rider (other than foot).
Near crash [a]	Any circumstance that requires a rapid evasive manoeuvre by the subject rider/s or any other vehicle, pedestrian, bicyclist, or animal to avoid a crash. Near crashes must: 1. Not involve a crash 2. Not be pre-meditated by the subject 3. Require an evasive manoeuvre (steering, braking, accelerating or combination) 4. Require rapidity or swiftness of response
Crash relevant [a]	Any circumstance that requires an evasive manoeuvre on the part of the subject rider/s or any other vehicle, pedestrian, bicyclist, or animal that is less urgent than a rapid evasive manoeuvre, but greater in urgency than a normal manoeuvre to avoid a crash. Crash relevant events must: 1. Not involve a crash 2. Not be pre-meditated by the subject 3. Require an evasive manoeuvre (steering, braking, accelerating or combination) 4. Rapidity or swiftness of response is not required
Unsafe close passing only [b]	An incident where a motor vehicle passes at least one group rider at an unsafe distance. An unsafe close passing event must: 1. Involve a motor vehicle passing at least one group rider at a lateral distance of less than one metre if the posted speed limit is ≤ 60 km/h; or at less than 1.5 metres if the speed limit is > 60 km/h. 2. Not meet the criteria for a crash, near crash or crash relevant event. If it does, the event should be included as one of these three events instead.

[a] Definition modified from the SHRP 2 Naturalistic Driving Study (Virginia Tech Transportation Institute, 2015) [b] Definition added for this study based on the WA Road Traffic Code ("Western Australia Road Traffic Code," 2000)

5.1.9.2 Unsafe close passing only by a motor vehicle

Potential unsafe close passing only events (cases) involving a motor vehicle were identified manually by the researchers based on the safe distance laws that were in place in WA at the time of data collection ("Western Australia Road Traffic Code," 2000). Since the law at the time was ambiguous and did not specify measurements for safe distances, only incidents of unsafe close passing on the footage that were obvious to the researchers were flagged.

In November 2017 (after data collection for this study was completed), safe passing laws were introduced in WA which specified safe distances for motor vehicles when passing bicycles. Under the new laws, a driver of a motor vehicle must pass a bicycle travelling in the same direction at a safe distance being: one metre if the speed limit of the road is 60km/h or less and 1.5 metres if the speed limit is more than 60 km/h ("Road Traffic Code Amendment Regulations," 2017).

To check and verify the potential unsafe close passing events identified, estimates of passing distance were also made using the video footage. For each potential unsafe close passing event, first lens distortion (fish-eye effect of the camera) was corrected for (straightened) in the video footage. Then, using the most relevant video frame, the road carriageway width was determined using Nearmap measurement tools. The distance between the right handlebar of the bicycle and left side mirror of the motor vehicle were then estimated using on-screen measurements. The measurements of passing distance were only approximations and were expressed as categories based on safe passing distance laws (≤ 1m, 1<1.5m, ≥ 1.5m), not as precise distances ("Western Australia Road Traffic Code," 2000). The posted speed limit of the road was also determined (≤ 60 km/h, > 60 km/h).

Potential unsafe close passing events which met the criteria under the November 2017 laws were included as unsafe close passing events in the study. A total of 23 out of the 25 potential close passing events identified (92%) were included.

5.1.10 Part A: Selection of control sites

For each unsafe event involving a motor vehicle (case), two control time points (where no unsafe event occurred) were obtained. These were randomly selected from the eligible video footage from the same trip in which the unsafe event (case) occurred. The random selections were made using a standard random number generator to generate hundreds of independent random numbers for each trip. These were then converted to time points within the eligible footage of each trip. All time points which occurred within 60 seconds of an unsafe event (case) were removed, then time points which occurred within 60 seconds of each other were consecutively removed. The remaining time points were shuffled and two time points matched to each unsafe event, consecutively. The footage was watched and analysed by the two researchers from 12 seconds before the control time point to five seconds after the time point. The GPS co-ordinates for each randomly selected time point were then determined and the 216 control sites (locations) obtained.

Matching on group and trip characteristics was determined to be the priority for minimising bias in the study. Matching unsafe event (case) and control sites on some road characteristics (divided/ undivided road, intersection/ non-intersection, speed limit, traffic volume etc) was also considered. However, this severely limited the available control sites to select from within each trip and often resulted in matched sites not being available. Instead of matching, these road characteristics were tested and controlled for in the subsequent multivariate modelling.

5.1.11 Part A: Data collection for unsafe event (case) and control sites

Data collection for each of the unsafe event (case) sites involving a motor vehicle and control sites for Part A included:

- Temporal, unsafe event (cases only), group rider behaviour and motorist behaviour characteristics obtained from the video footage;
- Road environment characteristics of each site obtained through virtual site inspections.

5.1.11.1 Temporal, unsafe event, group rider and motorist behaviour characteristics

Temporal information was determined from the video footage and GPS data for each unsafe event (case) including: *'day of week'*, *'season'*, *'time of day'*, *'peak traffic'*, *'light conditions'* and *'weather'*. Details of the unsafe event (case) involving a motor vehicle and the behaviour of the group rider/s and motorist involved were coded based on selected variables from the SHRP 2 Naturalistic Driving Study data dictionary (Virginia Tech Transportation Institute, 2015). A total of 19 of the 95 variables used in the SHRP 2 study were relevant and utilised for this study. The two researchers together coded each unsafe event (case) according to the characteristics listed in Table 5.2. These variables were then modified where required to fit the group riding context and 11 variables were added (8 group rider-related and 3 motorist-related variables). The riding group was analysed as a whole, meaning if an unsafe event (case) involved one, several or all of the riders in the group, it was treated as one unsafe event (case).

Table 5.2 Event, group rider and motorist-related variables for unsafe events involving a motor vehicle (cases) and controls

Event-related	Group rider-related	Motorist-related
• Conflict begin[a]	• Trip number[a]	• Motorist type[a]
• Conflict end[a]	• Rider reaction start[a]	• Motorist location[a]
• Precipitating event[a]	• Rider pre-incident manoeuvre[a]	• Motorist pre-incident manoeuvre[a]
• Event nature[a]	• Rider evasive manoeuvre[a]	• Motorist evasive manoeuvre[a]
• Event severity[a]	• Rider post-manoeuvre control[a]	• Motorist behaviour[a]
• Traffic density[a]	• Rider behaviour[a]	• Motorist violation[b]
• Fault[a]	• Rider tasks[a]	• Motorist aggression[b]
	• Rider count[b]	• Motorist reckless behaviour[b]
	• Rider speed[b]	
	• Rider proximity[b]	
	• Rolling manoeuvre[b]	
	• Group/s position on road[b]	
	• Rider violation[b]	
	• Rider aggression[b]	
	• Rider reckless behaviour[b]	

[a] Variable from SHRP 2 Naturalistic Driving Study (Virginia Tech Transportation Institute, 2015)
[b] Variable added for this study

Table 5.2 lists the unsafe event, group rider and motorist-related variables included from the SHRP 2 study as well as the added variables. *'Group rider-related'* variables have been adapted from *'Vehicle 1'* related variables in the SHRP 2 study. Appendix 13 details each variable used in the entire naturalistic study (Parts A, B & C), including those listed in Table 5.2, the definition of each and categories included.

Information was obtained on all listed variables for each unsafe event (case) involving a motor vehicle. For controls, information was obtained for relevant variables only, these being: *'conflict begin'* (beginning of control time period), *'conflict end'* (end of control time period), *'traffic density'*, *'trip number'*, *'rider pre-incident manoeuvre'* (manoeuvre riders were engaged in immediately (up to 5 seconds before) the control time point), *'rider behaviour'*, *'riding tasks'*, *'rider count'*, *'rider speed'*, *'rider proximity'*, *'rolling manoeuvre'*, *'group position on road'*, *'rider violation'* and *'rider reckless behaviour'* (Table 5.2, Appendix 13) (Virginia Tech Transportation Institute, 2015).

5.1.11.2 Road environment characteristics

A virtual site inspection of each unsafe event (case) and control site was undertaken by the two researchers. The site inspections largely followed the protocol for the crash site inspections undertaken in Phase 1 of the study (Section 3.6.5). However, a smaller selection of the variables was used. In addition, since the exact location of each unsafe event (case) and control site was known from the video footage, the same road environment characteristics could be obtained for both intersection and midblock sites. The inspections were undertaken electronically using Nearmap, Google Maps, The Department of Planning Metropolitan Region Scheme map (Department of Planning Lands and Heritage, 2016), The Main Roads WA Road Information Mapping System (Main Roads Western Australia, 2016) and the video footage. A list of road environment characteristics obtained as part of the site inspections is provided in Table 5.3. For categories and definitions for each variable see Table 3.1 in Section 3.6.5.

Table 5.3 Site inspection variables for all unsafe event (case) and control sites

Variable	
• Intersection site	• Roadway alignment
• Land use classification	• One/ two-way travel
• Road hierarchy	• Divided road
• Posted speed limit	• Median
• Bicycle lane present	• Traffic islands (raised)
• Bicycle lane width	• Kerb type
• Intersection control type	• Traffic calming
• Road gradient	• Traffic lanes in direction of travel
• Adjacent parking	• Carriageway width
• Surface type	• Direction of travel width
• Surface condition	• Left lane width
• Construction zone	

5.1.12 Part A: Statistical analysis

5.1.12.1 Description of unsafe events involving motor vehicles (cases)

All data were coded and analysed using SPSS, version 22 (SPSS Inc, Chicago, USA). Initially, the 108 unsafe events involving motor vehicles (cases) were described using percentages in terms of temporal conditions, event severity, motor vehicle type involved, unsafe event fault, violations, road user behaviour and road user aggression. Then the nature of the unsafe events (cases) were categorised into *'conflict with a vehicle originally travelling in the same direction'* as the group or *'conflict with a vehicle originally travelling in a different direction'* to the group. These were further sub-categorised and the characteristics of unsafe events (cases) described in detail.

5.1.12.2 Case-crossover study: dependent and independent variables

The case-crossover study examined road environment and group position-related factors associated with unsafe events involving a motor vehicle. The location of the 108 unsafe event (case) sites involving a motor vehicle and 216 control sites were mapped using the online GPS Visualizer (GPS Visualizer, 2018). The outcome of interest (dependent variable) was *'unsafe event site'* (no: control site, yes: case site). The road environment and group position-related factors at each site were the independent variables.

5.1.12.3 Clustering of unsafe event (case) and control sites

Ordinary logistic regression used to examine binary outcomes assumes that all observations are independent of each other. In this study, there were multiple unsafe event (case) and control sites within each trip meaning the data was clustered. Clustered data is data which can be classified into a number of distinct groups within the study (Jones & McLachlan, 1992). It was possible that the multiple sites drawn from within each cluster (trip) in this study were correlated in terms of exposure to the road environment and group position-related factors, so the assumption of independence was violated.

5.1.12.4 Statistical models for clustered data

Several statistical models that can account for clustering within data were considered for the analysis including Generalised Linear Mixed Models (GLMM), conditional logistic regression and Generalised Estimating Equations (GEE) logistic regression. In GLMM, the differences between clusters are modelled as random effects, in addition to the usual fixed effects and can provide information on what the specific differences are between clusters (Hubbard et al., 2010; Laird & Ware, 1982). However, modelling of random effects requires large sample sizes (Kain, Bolker, & McCoy, 2015) and the current study was not investigating the specific differences between clusters. Therefore, GLMM was unsuitable for this study. Conditional logistic regression is a variation of logistic regression which controls for matching of cases and controls, using the conditional likelihood approach (Breslow & Day, 1980). However, in this method, clusters which have missing values or identical values of the covariates are removed from the model (Lin, Lai, & Chuang, 2007). It has been reported that conditional logistic regression and GEE produce consistent estimates, however GEE obtains more efficient estimates, especially for small sample sizes (Lin et al., 2007). Therefore, the GEE method was chosen for this study.

5.1.12.5 Generalised Estimating Equations (GEE)

GEE was introduced by Liang and Zeger originally for modelling correlated longitudinal data and it has since been extended to other clustered data (Liang & Zeger, 1986). GEE assumes the observations are marginally correlated and takes into account the dependency of observations within a cluster by specifying a working correlation structure (Liang & Zeger, 1986). This adjustment reduces bias in the estimation of the parameters. It uses a quasi-likelihood-based approach and is considered an estimation method. In GEE, the same correlation structure is assumed for all clusters. The GEE method does not require an equal number of observations per cluster (Hubbard et al., 2010; Liang & Zeger, 1986).

Since the dependent variable was binary, a GEE binary logistic model was chosen. Similar to standard logistic regression, these models provide odds ratios and 95% CIs which estimate the precision of the odds ratio, but the GEE model also accounts for the dependence within clusters.

5.1.12.6 Univariate analyses

Due to the clustered data, initial univariate analyses were conducted using GEE logistic regression in SPSS version 22. *'Unsafe event site'* (no: control site, yes: case site) was entered as the dependent variable. Then, the univariate associations with road environment and group position-related factors (independent variables) were each examined using unadjusted odds ratios and 95% CIs, with only one independent variable entered in the model. This method was used so that the univariate associations could be examined while still accounting for the clustering of sites within trips.

Each trip was treated as a different *'subject'* for the purpose of model building in SPSS and the different sites within each trip were entered as the *'within subject'* variable in the GEE model. An exchangeable working correlation matrix was chosen since this is suitable when there is no chronological ordering of the observations from within the same cluster (N. J. Horton & Lipsitz, 1999) and has been used in previous naturalistic driving research (Guo & Hankey, 2009). However, it should be noted that GEE is not sensitive to the choice of correlation structures and will converge to a true value, even when the correlation function is incorrectly specified (Liang & Zeger, 1986).

From the GEE modelling, correlations among observations from within the same cluster (trip) were estimated to be -0.055. The small value indicates a rather weak marginal correlation (Cohen, 1988) but this is similar to the within-driver correlations reported from GEE analyses of the 100-Car Naturalistic Driving Study (correlations of 0.003 for crashes and 0.035 for near crashes) (Guo & Hankey, 2009).

5.1.12.7 Multivariate GEE logistic regression model

A multivariate GEE logistic regression model was undertaken using the same methodology in order to examine the association between multiple road environment and group position-related factors and the risk of an unsafe event (case). Again, *'unsafe event site'* (no: control site, yes: case site) was entered as the dependent variable. Variables considered for inclusion as independent variables/ confounding factors were based on findings from the limited literature on factors associated with group riding crashes as well as bicycle crashes in general. The final multivariate GEE model included the following independent variables: *'traffic control'* (midblock, priority control intersection, roundabout, traffic signals), *'traffic islands'* (no, yes), *'posted speed limit'* (≤ 50 km/h, ≥ 60 km/h), *'group position'* (single file in traffic lane, 2 abreast in traffic lane, 2 abreast in bike and traffic lane, all riders in bike lane), *'rider violation'* (no, yes), *'traffic density'* (free flow – no leading traffic, leading traffic or restricted flow) and *'number of riders'* (count).

5.2 Part B - Unsafe events not involving a motor vehicle

Part B involved a case-crossover study examining road environment and group position-related risk factors for unsafe events that did not involve a motor vehicle that occurred while group riding in Perth. Part B used the same participants and naturalistic data that was described in Part A.

5.2.1 Part B: Case-crossover study

For the case-crossover study, cases were the sites where unsafe events not involving a motor vehicle occurred and the controls (sites where no unsafe event occurred) were again selected from within the same group-riding trip as the cases. Only trips which included at least one unsafe event not involving a motor vehicle (n=40 trips) were included in the analysis for Part B.

5.2.2 Part B: Sample size

It was estimated that unsafe events not involving a motor vehicle would occur every 90 minutes. However, these events only occurred every 137 minutes, resulting in 59 unsafe event (case) sites and 118 matched control sites from the 135 hours of eligible footage. Independent variables of interest included *'roadway alignment'*, *'road gradient'* and group *'rolling'* manoeuvres where two columns of riders take turns at the front in an orderly rotation. It was again assumed a correlation co-efficient of 0.1. From the limited literature, it was estimated that the prevalence of curved roads, sloped roads and rolling behaviour at control sites was approximately 10% (B. Beck et al., 2016; Haworth & Debnath, 2013). From this estimation, the smaller sample size of 59 unsafe event (case) sites which did not involve a motor vehicle and 118 control sites would allow the detection of ORs of at least 2.3 for these variables (α=0.05, power=80%) (Dupont & Plummer, 2014).

5.2.3 Part B: Data reduction

During the watching of the video footage by the researcher, potential unsafe events (cases) not involving a motor vehicle were identified. Potential unsafe events were based on definitions used in the SHRP 2 Naturalistic Driving Study (Virginia Tech Transportation Institute, 2015). At the initial stage, only the time point and GPS co-ordinates of each potential unsafe event (case) was recorded and a descriptive note made.

The second researcher then identified potential unsafe events not involving a motor vehicle from 10% of the footage (12 trips). The ICC was used to examine the level of agreement between researchers for the number of unsafe events not involving a motor vehicle, per trip. The average measure ICC was 0.89 (95% CI: 0.60-0.97, p=0.001), indicating strong agreement.

5.2.4 Part B: Unsafe event (case) sites not involving a motor vehicle

The two researchers returned to each potential unsafe event (case) and determined whether it met the criteria for inclusion in the study. These criteria were again based on the definitions of unsafe events used in the SHRP 2 Naturalistic Driving Study (Virginia Tech Transportation Institute, 2015), with language modified to fit the group riding context (see Table 5.1). Unsafe events (cases) not involving a motor vehicle included conflicts between riders within the group, conflicts with riders outside of the group, conflicts with obstacles/ objects and single rider loss of control conflicts. *‘Crashes’*, *‘near crashes’* and *crash-relevant events’* of this nature were included from the SHRP 2 Study but *‘unsafe close passing only’* by a motor vehicle was not relevant for Part B of the study. From 98 potentially unsafe events (cases) not involving a motor vehicle identified, 59 (60.2%) met the criteria for inclusion in Part B of the study. The GPS co-ordinates for each unsafe event (case) sites were also obtained.

5.2.5 Part B: Selection of control sites

For each unsafe event (case) which did not involve a motor vehicle (n=59), two control time points where no unsafe event occurred were obtained. These were randomly selected from the eligible video footage from the same trip in which the unsafe event occurred, using the same process as described in Part A. Different control sites were chosen from those used in Part A. The footage was watched and analysed by the two researchers and the GPS co-ordinates obtained for each of the 118 control sites.

5.2.6 Part B: Data collection for unsafe event (case) and control sites

Data collection for the unsafe event (case) sites not involving a motor vehicle and control sites for Part B of the naturalistic study included:

- Temporal, unsafe event, group rider and other rider behaviour characteristics obtained from the video footage;
- Road environment characteristics of each site obtained through virtual site inspections.

5.2.6.1 Temporal, unsafe event, group rider and other rider behaviour characteristics

Temporal information was determined from the video footage and GPS data for each unsafe event (case) including: *'day of week', 'season', 'time of day', 'peak traffic', 'light conditions'* and *'weather'*.

Details of the unsafe event (case) not involving a motor vehicle and the behaviour of the group rider/s and riders who were not part of the group were coded based on selected variables from the SHRP 2 Naturalistic Driving Study (Virginia Tech Transportation Institute, 2015). A total of 17 of the 95 variables used in the SHRP 2 study were relevant and utilised for Part B of this study. The two researchers coded each unsafe event (case) according to the characteristics listed below in Table 5.4. These variables were modified where required to fit the group riding context and seven rider-related variables were added (Table 5.4). The variables *'fault'* and *'rider aggression'* were not included for Part B as these were not relevant for the majority of the events which did not involve a motor vehicle. Appendix 13 details each variable used in the entire naturalistic study, including those listed in Table 5.4, the definition of each variable and categories included. Information was obtained on all listed variables for each unsafe event (case) not involving a motor vehicle. For controls, information was obtained for relevant variables only.

Table 5.4 Event, group-rider and other rider-related variables for unsafe events not involving a motor vehicle and controls

Event-related	Group rider-related	Other rider-related
• Conflict begin[a]	• Trip number[a]	• Other rider location[a]
• Conflict end[a]	• Rider reaction start[a]	• Other rider pre-incident manoeuvre[a]
• Precipitating event[a]	• Rider pre-incident manoeuvre[a]	• Other rider evasive manoeuvre[a]
• Event nature[a]	• Rider evasive manoeuvre[a]	• Other rider behaviour[a]
• Event severity[a]	• Rider post-manoeuvre control[a]	
• Traffic density[a]	• Rider behaviour[a]	
	• Riding tasks[a]	
	• Rider count[b]	
	• Rider speed[b]	
	• Rider proximity[b]	
	• Rolling manoeuvre[b]	
	• Group position on road[b]	
	• Rider violation[b]	
	• Rider reckless behaviour[b]	

[a] Variable from SHRP 2 Naturalistic Driving Study (Virginia Tech Transportation Institute, 2015)
[b] Variable added for this study

5.2.6.2 Road environment characteristics

A virtual site inspection of each unsafe event (case) and the two matched control sites examining road environment characteristics, was undertaken by both researchers, following the protocol detailed in Part A, Section 3.6.5.

5.2.7 Part B: Statistical analysis

5.2.7.1 Description of unsafe events not involving motor vehicles (cases)

Initially, the 59 unsafe events (cases) which did not involve motor vehicles were described using percentages in terms of temporal conditions, unsafe event severity, involvement of riders outside the group, group rider violations and rider behaviour. Then, the nature of the unsafe events (cases) were categorised into *'conflict between riders within the group'*, *'conflict with rider outside of the group'*, *'conflict with obstacle/ object on roadway'* or *'single rider loss of control conflict'* and described.

5.2.7.2 Case-crossover study: dependent and independent variables

The case-crossover study examined road environment and group position-related factors associated with unsafe events not involving a motor vehicle. The location of the 59 unsafe event (case) sites not involving a motor vehicle and 118 control sites were mapped using the online GPS Visualizer (GPS Visualizer, 2018). The outcome of interest (dependent variable) was *'unsafe event site'* (no: control site, yes: case site). The road environment and group-position-related factors at each site were the independent variables. Again, GEE logistic regression was used for all analyses.

5.2.7.3 Univariate analyses

Initial univariate analyses were conducted using GEE logistic regression in SPSS version 22, accounting for the clustering of observations within trips. *'Unsafe event site'* (no: control site, yes: case site) was entered as the dependent variable. Then, the univariate associations with road environment and group position-related factors (independent variables) were each examined using unadjusted odds ratios and 95% CIs, with only one independent variable entered in the model. An exchangeable working correlation matrix was again used. From the GEE modelling, correlations among observations from within the same cluster (trip) were estimated to be -0.058, indicating a weak marginal correlation (Cohen, 1988).

5.2.7.4 Multivariate GEE logistic regression model

A multivariate GEE logistic regression model was then undertaken using the same methodology in order to examine the association between multiple road environment and group position-related factors and the risk of an unsafe event which did not involve a motor vehicle. Again, *'unsafe event site'* (no: control site, yes: case site) was entered as the dependent variable. Variables considered for inclusion as independent variables/ confounding factors were based on findings from the limited literature on factors associated with individual rider and rider/ rider crashes. The final multivariate GEE model included the following independent variables: *'rider proximity'* (close proximity, staggered), *'roadway alignment'* (straight, curved), *'construction zone'* (no, yes) and *'traffic density'* (free flow no lead traffic, leading traffic or restricted flow).

5.3 Part C: Group rider violations

Part C consisted of a cross-sectional study examining group and trip-related factors associated with traffic violations that occurred while group riding. Part C used the same participants and data described in Part A and B.

5.3.1 Part C: Cross-sectional study

The cross-sectional study consisted only of trips which included at least 20 minutes of video footage recorded simultaneously on both front and rear cameras (n=91 trips). Any footage within these 91 trips where only one camera was recording was excluded. This was to ensure that the researchers had same opportunity to detect traffic violations committed by group riders across all the included footage.

5.3.2 Part C: Sample size

Part C involved an examination of group-related characteristics associated with the number of group rider traffic violations per trip. Independent variables of interest included the group's *'organisational structure'*, whether the group had a *'cost'*, *'uniform', 'written code of conduct', 'designated ride leader', 'committee/ incorporated business', 'open/ closed membership', 'sprint points'*, whether they *'drop riders'* and the *'group purpose'*. Very limited information exists on the rate of violations for group riders or riders in general. The study by Johnson et al.'s found that groups rode more than two abreast approximately five percent of the time or three minutes per hour (Johnson et al., 2009). It was assumed this comprised at least three separate incidents. In addition, a rate of 29 failure to stop/ yield violations per 100 miles (160 km) has been reported for individual riders (Hamann & Peek-Asa, 2017). If a travel speed of 30 km/h is assumed, this equates to five violations per hour. Due to uncertainty, a range of 2-5 violations per hour and an average trip duration of one hour was assumed for the sample size calculation. Zhu & Lakkis presented three different methods of sample size calculation for analysing count data using negative binomial regression (Zhu & Lakkis, 2014).

Using these methods, if two violations per hour were observed under the riskier category of each of the binary independent variables, 36-41 trips per category (72-82 trips in total) would be required to detect an incidence rate ratio (IRR) of 0.5 (α=0.05, power=80%). If five violations per hour were observed under the riskier category of each of the independent variables, 24-27 trips per category (48-54 trips in total) would be required to detect an IRR of 0.5 (α=0.05, power=80%). Therefore, this study aimed to achieve a minimum of 85 eligible trips (Zhu & Lakkis, 2014).

5.3.3 Part C: Data reduction

As the researcher watched the video footage, potential traffic violations committed by riders in the group were identified, based on the WA Road Traffic Code 2000 ("Western Australia Road Traffic Code," 2000). At the initial stage, only the time point and GPS co-ordinates of each potential violation were recorded and a descriptive note made. The time points and location of each stop sign and red traffic light, even when a violation did not occur, were also noted for exposure purposes.

A second researcher also identified group rider violations from 10% of the footage. Cohen's kappa coefficients were used to determine the level of agreement between researchers on whether each red traffic light and stop sign involved a violation or no violation. There was strong agreement for *'red light violations'* (κ=0.86, $p<0.001$) and *'stop sign violations'* (κ=0.91, $p<0.001$). The ICC was used to examine the level of agreement for number of *'other violations'* identified per trip. The average measure ICC was 0.96 (95% CI: 0.87-0.99, $p<0.001$), showing strong agreement.

Both researchers then examined each potential violation and reached agreement on whether each fit the criteria for a violation and should be included in the study. Both researchers then analysed and coded each violation in detail.

5.3.4 Part C: Definitions of group rider violations

The identification of group rider violations was based on the WA Road Traffic Code ("Western Australia Road Traffic Code," 2000). Initially, researchers familiarised themselves with the Code in terms of regulations relating to bicyclists. In general, regulations that apply to drivers of motor vehicles also apply to riders using the roads (with some exceptions) and there are additional regulations specifically relating to riders ("Western Australia Road Traffic Code," 2000). Only violations committed by one or more rider within the study group were included and not those committed by other riders or motorists on the road.

Following the initial viewing, the two researchers narrowed the inclusion criteria for group rider violations to six types of violations which could be clearly and unambiguously determined from the footage. These were: '*red light violations', 'stop sign violations', 'one-way sign violations', 'right of way violations', 'wrong side of road violations', and 'riding more than two-abreast violations'*. From the 408 identifiable violations in the eligible footage, 399 violations (97.8%) were included. The six types of violations included in Part C are described in detail below and the relevant regulations from the WA Road Traffic Code are listed in Table 5.5 and detailed in Appendix 14.

Other violations were excluded due to certain regulations in the WA Road Traffic Code (2000) being subjective, ambiguous or impossible to accurately determine from the video footage. For example, the Code stipulates that when riding two abreast, riders must not be more than 1.5m apart ("Western Australia Road Traffic Code," 2000). This precise measurement was impossible to determine so this specific regulation was excluded. In addition, the Code states that when an on-road bicycle lane is provided and it is in reasonable condition, a rider must use only the bicycle lane and no other part of the carriageway ("Western Australia Road Traffic Code," 2000). Since *'reasonable condition'* is subjective and difficult to determine from the footage, this violation was also excluded.

5.3.4.1 Red light violations

A *'red light violation'* was recorded if any rider in the group proceeded beyond the stop line at a set of traffic lights, when the traffic control signal was displaying a red light or arrow. Entering the intersection on an orange light was not included as a violation, even if it turned red before the rider/s exited the intersection ("Western Australia Road Traffic Code," 2000). If more than one rider in the group committed a violation at the same red traffic light, this was counted as a single violation (Table 5.5, Appendix 14).

Table 5.5 Relevant regulations from the WA Road Traffic Code 2000

Type of violation	Regulations from WA Road Traffic Code 2000
Red light violation	Part 6, Division 1, Regulation 40: Stopping for a circular red signal or red arrow
Stop sign violation	Part 7, Division 1, Regulation 50: Stopping and giving way at a stop sign or stop line at an intersection without traffic-control signals
One-way sign violation	Part 8, Division 2, Regulation 80: One-way signs
Right of way violation	Part 7, Division 1, Regulation 50: Stopping and giving way at a stop sign or stop line at an intersection without traffic-control signals
	Part 7, Division 1, Regulation 52: Giving way at a give way sign or give way line at an intersection
	Part 7, Division 2, Regulation 55: Giving way at an intersection (except a T-intersection or roundabout)
	Part 7, Division 2, Regulation 56: Giving way at a T-intersection
	Part 7, Division 3, Regulation 57: Giving way when entering a carriageway from land abutting a carriageway or road
	Part 7, Division 3, Regulation 58: Giving way when entering land abutting a carriageway or road from a carriageway
	Part 9, Division N/A, Regulation 95: Right of way in a roundabout
Wrong side of road violation	Part 9, Division N/A, Regulation 96: Driving through a roundabout
	Part 11, Division 2, Regulation 115: Keeping to the left of marked or unmarked two-way carriageway
	Part 11, Division 2, Regulation 116: Keeping left of continuous dividing lines
	Part 11, Division 2, Regulation 117: Keeping to the left of a median strip
	Part 11, Division 2, Regulation 120: Avoiding obstructions on a carriageway
Riding more than two abreast violation	Part 11, Division 4, Regulation 130: Riding a 2-wheeled vehicle alongside more than one other rider

("Western Australia Road Traffic Code," 2000). See Appendix 14 for full regulations

5.3.4.2 Stop sign violations

A *'stop sign violation'* was recorded if any rider in the group did not come to a complete stop at or as near as practicable to the stop line associated with a stop sign ("Western Australia Road Traffic Code," 2000). Since *'near as practicable'* is subjective, if all riders came to a complete stop at any distance within visibility of the stop sign, as a result of the stop sign, this was not counted as a violation. If more than one rider in the group committed a violation at the same stop sign, this was counted as a single violation (Table 5.5, Appendix 14).

5.3.4.3 One-way sign violations

A *'one-way sign violation'* was recorded if any rider in the group rode the wrong way on a carriageway where a one-way sign applied ("Western Australia Road Traffic Code," 2000). If more than one rider in the group committed a violation at the same one-way sign, this was counted as a single violation (Table 5.5, Appendix 14).

5.3.4.4 Right of way violations

A *'right of way violation'* was recorded if any rider in the group entered traffic and did not give way to other vehicles as prescribed by the Code. This included right of way violations at stop signs or lines, give way signs or lines, uncontrolled intersections, T-intersections, roundabouts or land abutting the carriageway (e.g. driveway) ("Western Australia Road Traffic Code," 2000). If more than one rider in the group committed the same *'right of way violation'*, this was counted as a single violation (Table 5.5, Appendix 14).

5.3.4.5 Wrong side of road violations

A *'wrong side of road violation'* was recorded when any rider in the group rode on the wrong side of the road at a roundabout, on a road divided by a median strip or traffic islands or on a road marked with continuous white dividing lines only ("Western Australia Road Traffic Code," 2000). Riding on the wrong side of an unmarked road or a road with broken white lines were not included as a violation in this study. The Code stipulates that drivers (or riders) can travel on the wrong side of these roads if they can see ahead for a distance sufficient to enable them to do so safely ("Western Australia Road Traffic Code," 2000). Since this is subjective and difficult to determine from the footage, riding on the wrong side of these particular roads were not included. In accordance with the Code, riding on the wrong side of the road in order to avoid an obstruction on the carriageway (e.g. a parked car or hazard) was also not counted as a violation ("Western Australia Road Traffic Code," 2000). If more than one rider in the group rode on the wrong side of the road at the one time, this was counted as a single violation (Table 5.5, Appendix 14).

5.3.4.6 Riding more than two abreast violations

A *'riding more than two abreast violation'* was recorded when any riders in the group rode three or more abreast for at least 10 seconds. In accordance with the Code, riding more than two abreast due to overtaking other riders was not counted as a violation ("Western Australia Road Traffic Code," 2000). In addition, riding three abreast in order to travel from the front to the back or back to the front of the group was not counted as a violation. If several riders in the group rode more than two abreast at the one time, this was counted as a single violation (Table 5.5, Appendix 14).

5.3.5 Part C: Data collection for group-rider violations

Data collection for the group rider violations consisted of group rider behaviour, situational and road environment characteristics observed in the video footage. Different characteristics were collected for '*red light violations*', '*stop sign violations*' and '*other violations*' ('*one-way sign*', '*right of way*', '*wrong side of road*' and '*riding more than two abreast*'), as appropriate.

5.3.5.1 Red light violations

The two researchers returned to every red light in the eligible footage (n=537). For '*red light violations*' (n=64) and red lights where no violation occurred (n=473), the '*day of week*' (weekday, weekend), '*direction of travel*' of the group (straight, turning left, turning right) and the '*number of riders*' present (count) were recorded. In addition, the situation surrounding the violation was recorded including the position of rider/s in the group who committed the '*red light violation*' (leading, following or all riders), traffic light phase on approach (red, orange, green) and whether there was a short green light phase in the direction of travel of the group (no, yes). Finally, for each of the *'red light violations'*, it was recorded whether an unsafe event was associated with the violation (no, yes).

5.3.5.2 Stop sign violations

The two researchers returned to every stop sign in the eligible footage (n=129). For *'stop sign violations'* (n=103) and stop signs with no violation (n=26), again the *'day of week'* (weekday, weekend), *'direction of travel'* of the group (straight, turning left, turning right) and the *'number of riders'* present (count) were recorded. In addition, the situation surrounding the violation was recorded including position of rider/s in the group who committed the *'stop sign violation'* (leading, following or all riders) and whether there was approaching traffic from another direction as the group approached the stop sign (no, yes). Finally, for each of the *'stop sign violations'*, it was recorded whether an unsafe event was associated with the violation (no, yes).

5.3.5.3 Other violations

The two researchers also returned to every *'other violation'* (*'one-way sign', 'right of way', 'wrong side of road' and 'riding more than two abreast'*) (n=232). For these violations, *'day of week'* (weekday, weekend) and the *'number of riders'* present (count) were recorded. Situational variables collected included: *'duration of violation'* (seconds), *'type of intersection'* (where relevant) (roundabout, give way, stop sign, priority control), *'roadway alignment'* (straight, curved) and *'travel to or from an off-road path'* (no, yes). Again, whether the violation was associated with an unsafe event was recorded (no, yes).

5.3.6 Part C: Data collection for group and trip characteristics

5.3.6.1 Characteristics of the riding groups

Characteristics of the riding group were those which remained constant across each trip recorded by that group. These were self-reported by the study participants through the researcher-administered questionnaire (Appendix 11) and confirmed through the group's website, where available. Since there is little published information on the characteristics of riding groups, several of the group characteristic questions were left open-ended. These items collected only brief responses and after data collection was complete, they were coded using content analysis (Krippendorff, 2013). The variables were then combined and categorised appropriately in SPSS, resulting in quantitative variables.

Several group characteristics were extracted and these were expressed as binary variables. These characteristics included whether:

- It costs to ride with the group (no, yes);
- There was a uniform available (no, yes);
- The group had a written code of conduct for rider behaviour (no, yes);
- There was a designated ride leader on each ride (no, yes);
- The group had a committee or was an incorporated business (no, yes);
- Group membership was closed or open (closed, open);
- The group would drop riders (leave them behind) on rides (no, yes);
- The group had sprint points (informal race points) on rides (no, yes);
- The group's purpose/s (social and training, social only).

Among the 33 riding groups included in Part C, many of the above characteristics were highly associated. In particular, five of the items consistently resulted in the same yes/ no responses within groups and these were: *'cost'*, *'uniform'*, *'written code of conduct'*, *'designated ride leader'* and *'committee/ business'*. Six groups responded *'yes'* on all these items, 10 groups responded *'no'* on all these items and 17 groups gave a mixture of responses on the five items. These five items related to the organisational structure of the group so were replaced with a single variable *'organisational structure'* which had three categories:

- Formal: Six groups (42 trips) consisting of formal cycling clubs, charity training rides and paid training groups run through incorporated businesses;
- Semi-formal: 17 groups (30 trips) consisting of groups run through bike shops, cafes, Facebook and groups which had evolved out of former charity rides;
- Informal: 10 groups (19 trips) consisting of informal groups of friends.

The other four group characteristics *'open/ closed membership'*, *'drop riders'*, *'sprint points'* and *'group purpose'*, were retained as separate variables.

5.3.6.2 Trip characteristics

Trip characteristics were those which could vary from trip to trip, even within the same group. These included *'day of the week'* (weekday, weekend) and *'average number of riders'* per trip (count) which were both obtained from the video footage. In addition, two self-reported trip characteristics were obtained from the questionnaire and included *'usual distance travelled'* (km) and *'average speed'* (km/h). These varied between trips recorded by the same group as different routes and rides of various paces are undertaken on different days of the week.

5.3.7 Part C: Statistical analysis

5.3.7.1 Description of violations

Initially, the 64 *'red light violations'* were described using percentages in terms of rider behaviour and situational characteristics. The exposure measure for *'red light violations'* was the total number of red traffic lights. Therefore, the characteristics of the 64 violations were compared to the 473 red lights where no violation occurred in terms of *'day of week', 'direction of travel'* of the group and *'number of riders'* using chi-square tests for categorical variables and t-tests for continuous variables. Due to the low number of *'red light violations'* and small number of violations per group, no further analyses were undertaken for *'red light violations'*.

Secondly, the 103 *'stop sign violations'* were described using percentages in terms of situational characteristics. The exposure measure for *'stop sign violations'* was the total number of stop signs. Therefore, the characteristics of the 103 violations were compared to the 26 stop signs where no violation occurred in terms of *'day of week', 'direction of travel'* of the group and *'number of riders'* using chi-square and t-tests. Since *'stop sign violations'* were determined to be based completely on traffic circumstances and not group characteristics, no further analyses were undertaken for *'stop sign violations'*.

Finally, the 232 *'other violations'* were described in terms of violation type (*'one-way sign', 'right of way', 'wrong side of road'* and *'riding more than two abreast'*) using percentages. Then, the total number of *'other violations'* (combined) were described in terms of group characteristics, using percentages.

5.3.7.2 Univariate analyses for other violations

Further analyses examining the number of *'other violations'* (combined) were undertaken. The exposure measure for *'other violations'* was hours of eligible footage, since these violation types could generally occur at any time. First, outlier values for the rate of *'other violations'* (number per hour) were identified using boxplots. Then, using the value modification method, each outlier was replaced with the largest observed value that was not an outlier (Kwak & Kim, 2017). The rate of *'other violations'* was calculated for the 91 eligible trips and presented by group characteristics, in terms of means and SDs.

The data was clustered. However, for this examination of group characteristics associated with the rate of violations per trip, it was the clustering of trips within riding groups that needed to be accounted for. Ordinary Poisson or Negative Binomial Regression used to examine count outcomes, assumes that all observations are independent of each other. Since this assumption was violated, GEE modelling was again chosen. GEE negative binomial regression was used since the dependent variable, *'number of other violations'* was count data and it was over-dispersed (conditional variance exceeds the conditional mean) (Coxe, West, & Aiken, 2009). Negative binomial regression has an extra parameter to model the over-dispersion (Coxe et al., 2009). As for standard negative binomial regression, the GEE model provides an IRR and 95% CI, but the model also accounts for the dependence within clusters. IRRs are the ratio of two incidence rates with the incidence rate being the number of events (*'number of other violations per trip'*) divided by the person-time at risk (*'hours of eligible footage per trip'*) (Hilbe, 2011).

Due to the clustered data and the *'number of other violations per trip'* being related to exposure (*'hours of eligible footage per trip'*), univariate analyses were conducted using GEE negative binomial regression in SPSS version 22. The *'number of other violations per trip'* (count) was entered as the dependent variable. Then the univariate associations with group characteristics (independent variables) were each examined using unadjusted IRRs and 95% CIs with only one variable entered in the model. This method was used so that the univariate associations could be examined while still accounting for the clustering of trips within groups and also for exposure.

Each riding group was treated as a different *'subject'* in SPSS and the different trips within each group were entered as the *'within subject'* variable in the GEE model. The natural log *'ln (hours of eligible footage per trip)'* was entered as the offset variable to control for exposure, as required for negative binomial regression which uses a log link (Coxe et al., 2009). An exchangeable working correlation matrix was again chosen. From the GEE modelling, correlations among observations from within the same cluster (riding group) were estimated to range from 0.105 to 0.368 for the independent variables, indicating weak to moderate marginal correlations (Cohen, 1988).

5.3.7.3 Multivariate GEE negative binomial regression model

A multivariate GEE negative binomial regression model was undertaken in order to examine the association between multiple group and trip-related factors and the rate of *'other violations.'* Again, *'number of other violations per trip'* was entered as the dependent variable and *'ln (hours of eligible footage per trip)'* entered as the offset variable. Group-level variables considered for inclusion as independent variables in the model were those with p-values of less than 0.25 in the univariate analyses. Trip-level variables considered for inclusion in the model were based on findings from the limited literature on factors associated with rider violations.

The final multivariate GEE model included the following independent variables: *'organisational structure'* (semi-formal, informal, formal), *'sprint points'* (no, yes) and *'average number of riders'* (count). Since the *'organisational structure'* variable was based on five specific group characteristics, *'organisational structure'* was then removed and the multivariate model run with each of the five specific characteristics entered separately *('cost', 'committee/ incorporated business', 'written code of conduct', 'designated ride leader'* and *'uniform'*). This was to determine which of these specific characteristics were associated with the rate of other violations per trip. QIC and QICC values were also determined for each of the five models.

5.4 Ethical considerations

Phase 2 was approved by the Curtin University Human Research Ethics Committee as a *'sub-study'* of the larger ARC-funded cycling study. Group riders who participated in Phase 2 of the study received a PIS and signed a consent form (Appendix 10) before cameras were attached to their bicycles. A waiver of consent was granted by the Curtin University Human Research Ethics Committee concerning group riders other than the study participant who appeared in the group riding footage. This was on the grounds of there being negligible risk from being filmed, the potential road safety benefits, being impracticable to obtain consent from all riders who appear in the footage and sufficient protection of privacy. Participants were asked to ride as they usually would while cameras were attached, so participation did not increase their risk of crash involvement. Participants were informed that in the event of a crash, video footage could be subpoenaed in a court of law. Otherwise, all footage and data collected was kept completely confidential and only viewed by the Curtin University researchers. All participants gave verbal permission for the researcher-administered questionnaire to be audio recorded. The identity of all participants and groups will be concealed in any publications.

5.5 Data management

Phase 2 data was stored according to the Curtin University Research Data and Primary Materials Policy. All paper-based data including consent forms from Phase 2 were stored in a locked filing cabinet at C-MARC. Online survey data from Phase 2 was recorded and stored electronically using the Google Docs program and was password protected. Final databases were downloaded and saved with only participant IDs and no identifying information. All electronic files including questionnaire databases, video footage, GPS data, maps and audio files were stored on the Curtin Research drive in a project folder that could only be accessed by nominated researchers on the project. All data and files will be retained for a period of seven years following the conclusion of the project and then destroyed.

CHAPTER 6

Phase 2- Naturalistic group riding study: Results

6 PHASE 2 – NATURALISTIC GROUP RIDING STUDY: RESULTS

Chapter 6 presents the results of Phase 2, a naturalistic study of unsafe events and traffic violations observed among group riders in Perth, WA. The results are presented in three parts.

- Part A: case-crossover study examining road environment and group position-related risk factors for unsafe events involving a motor vehicle that occurred while group riding in Perth, WA;
- Part B: case-crossover study examining road environment and group position-related risk factors for unsafe events that did not involve a motor vehicle, in Perth;
- Part C: cross-sectional study examining group and trip-related factors associated with traffic violations that occurred while group riding in Perth.

6.1 Total participants and naturalistic footage collected

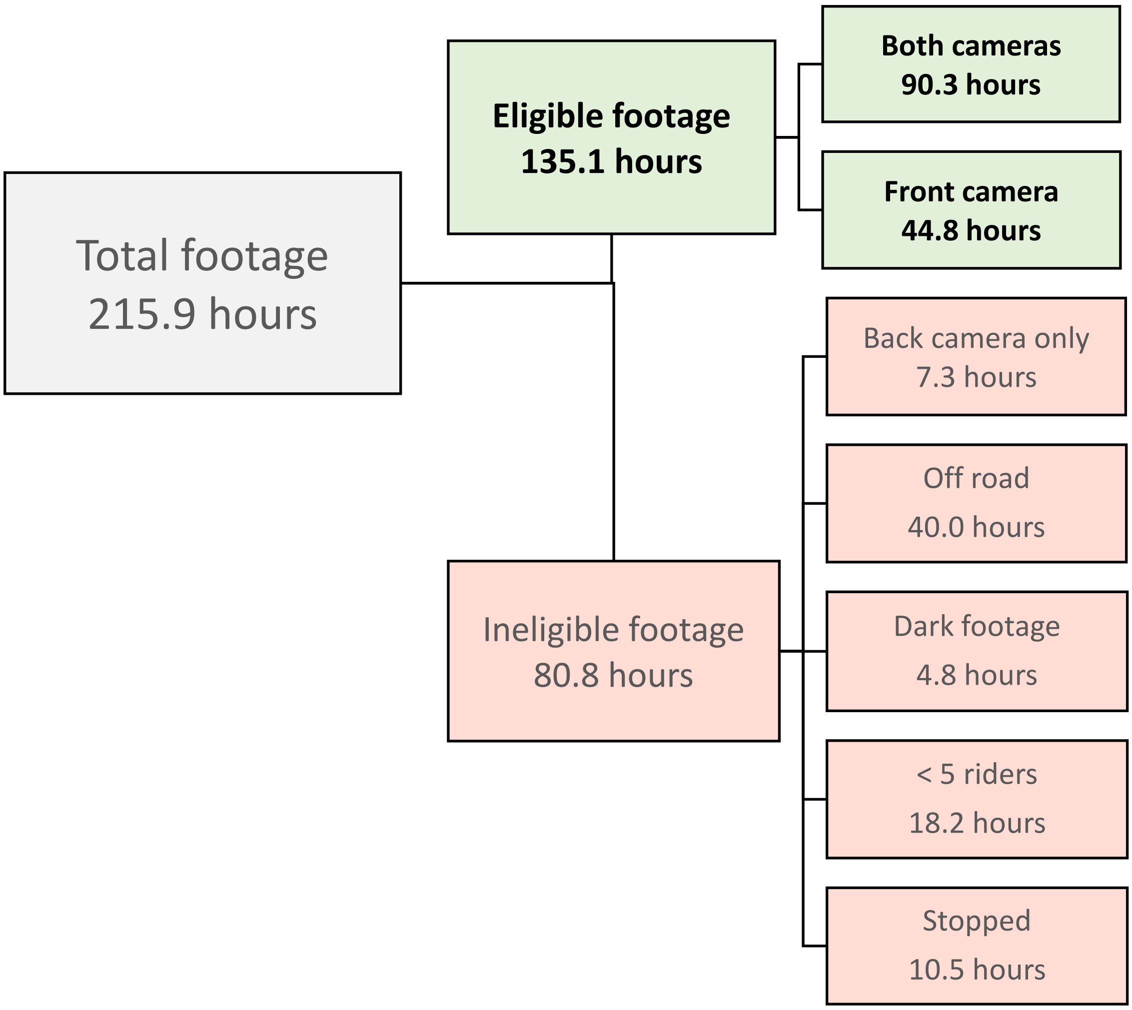
The total sample for the naturalistic study consisted of 126 group riding trips, recorded by 52 participants (individual group riders), who represented 40 different riding groups. Individual participants recorded between one and seven trips with a mean of 2.4 trips (SD: 1.4) and there was a range of one to 23 trips per riding group with a mean of 3.2 trips (SD:4.7). Individual participants consisted of 43 males (82.7%), with ages ranging from 19 to 78 years and a mean age of 47.0 years (SD: 11.9).

Figure 6.1 presents the breakdown of hours of total footage, eligible footage and ineligible footage for the overall naturalistic study. There was a total of 215.9 hours of video recorded for the study. Each trip ranged in duration from 15 to 192 minutes with a mean length of 102.8 minutes (SD: 42.8). A total of 131.3 hours (60.8%) of footage had video from both cameras, 77.3 hours (35.8%) had front camera only and 7.3 hours (3.4%) had rear camera footage only.

A total of 80.8 hours of video were excluded (37.4%). This consisted of: rear camera only footage (7.3 hours), off-road riding (40.0 hours), darkness (4.8 hours), less than five riders (18.2 hours) and stopped off-road or on the side of the road (10.5 hours).

This resulted in 135.1 hours of remaining eligible footage, 90.3 hours (66.8%) from both cameras and 44.8 hours (33.2%) from the front camera only. This consisted of 3757 kilometres travelled with an average of 29.8 kilometres per trip (SD: 16.8). Of the 135.1 hours of footage, there were 80.5 hours of GPS data available (60.0%). Video data was included in the study whether GPS data was available or not.

Figure 6.1 Total video footage collected for the naturalistic study



6.2 Part A: Unsafe events involving motor vehicles

Section 6.2 describes the results of a case-crossover study examining road environment and group position-related risk factors for unsafe events involving a motor vehicle that occurred while group riding.

6.2.1 Naturalistic video footage for unsafe events involving motor vehicles

The case-crossover study of unsafe events involving motor vehicles included only the trips with eligible footage which contained at least one unsafe event (case) involving a motor vehicle. There was a total of 108 unsafe events (cases) involving a motor vehicle observed and these occurred in 60 trips, recorded by 31 different riding groups. The duration of these 60 trips ranged from 61 to 192 minutes with an average of 119.0 minutes (SD: 40.3). From the 60 trips, there was a total of 83.5 hours of eligible video footage, 59.1 hours with footage from both cameras (70.8%) and 24.4 hours with front camera only (29.2%). This equated to 2218 eligible kilometres travelled with an average of 37.0 eligible kilometres per trip (SD: 16.4). Each trip had between one and five unsafe events (cases) involving a motor vehicle, with an average of 1.8 events (SD: 1.0). There was a total of 52.2 hours of available GPS data (62.5%) but all eligible footage was included whether or not GPS data was available. Table 6.1 presents the naturalistic data included for Part A of the Phase 2.

Table 6.1 Naturalistic data included for Part A – unsafe events involving a motor vehicle

Data collected	
Unsafe events involving a motor vehicle (n)	108
Group riding trips (n)	60
Riding groups (n)	31
Eligible video footage (hours)	83.5
GPS data (hours)	52.2
Distance travelled (km)	2218

6.2.2 Temporal conditions for unsafe events involving motor vehicles

Table 6.2 describes the temporal conditions for each of the 108 unsafe events (cases) involving a motor vehicle. The majority of the events occurred on weekends (n=77, 71.3%), in spring (n=45, 41.7%) or summer (n=25, 23.1%) and between 7am and 9am (n=69, 63.9%). Overall, only 11 events (10.2%) occurred during peak hour traffic times defined as 7-9am on weekdays. There were no events during afternoon peak times. The majority of unsafe events (cases) also occurred during daylight conditions (n=104, 96.3%), compared to dawn (dark footage was excluded) and in clear or overcast weather (n=103, 95.4%).

Table 6.2 Temporal conditions for unsafe events (cases) involving motor vehicles

Temporal condition	N=108	%
Day of week		
Weekend	77	71.3
Weekday	31	28.7
Season		
Summer	25	23.1
Autumn	12	11.1
Winter	26	24.1
Spring	45	41.7
Time of day		
Before 7am	23	21.3
7-9am	69	63.9
After 9am	16	14.8
Peak traffic		
Off peak	97	89.8
Peak	11	10.2
Light conditions		
Daylight	104	96.3
Dawn	4	3.7
Weather		
Clear/ overcast	103	95.4
Rain	5	4.6

6.2.3 Characteristics of unsafe events involving motor vehicles

Table 6.3 summarises the overall characteristics of the 108 unsafe events involving motor vehicles.

6.2.3.1 Unsafe event (case) severity and motor vehicle type

In terms of unsafe event (case) severity, there were no actual *'crashes'* involving motor vehicles observed in the footage but there were seven *'near crashes'* (6.5%) (Table 6.3). *'Near crashes'* required a rapid evasive manoeuvre by the group rider/s or motorist to avoid a crash (Virginia Tech Transportation Institute, 2015). The majority of events were *'crash-relevant events'* (n=78, 72.2%) which required a less urgent evasive manoeuvre to avoid a crash (Virginia Tech Transportation Institute, 2015). Finally, 23 events (21.3%) involved *'unsafe close passing only'* of group riders by motorists and no evasive manoeuvre was performed. It should be noted that in addition to these 23 events, eight of the *'near crashes'* or *'crash-relevant events'* also involved unsafe close passing but these events required evasive manoeuvres, so were classified as higher severity events. Overall, 31 events (28.7%) involved unsafe close passing by a motor vehicle. Types of motor vehicles involved in the event (first motor vehicle involved only) were predominantly automobiles (light passenger vehicles) (n=73, 67.6%), followed by utility vehicles (tray-back vehicles) (n=15, 13.9%). (Table 6.3).

6.2.3.2 Unsafe event (case) fault, violations and road user behaviour

Unsafe event (case) fault was determined based on whether the group rider/s or motorist committed the error that led to the event (Virginia Tech Transportation Institute, 2015). Motorists were at fault for 89 unsafe events (82.4%), group rider/s for 18 events (16.7%) and one event was shared motorist/ rider fault (0.9%) (Table 6.3). A total of 47 unsafe events (43.5%) involved at least one motorist violation, the most common being *'unsafe close passing'* (n=31, 28.7%), followed by *'right of way'* violations (n=10, 9.3%). Motorist violations totalled more than 47 due to some unsafe events involving more than one violation. Nine unsafe events (8.3%) involved at least one group rider violation and these included *'right of way'* violations (n=5), *'riding more than two abreast'* (n=2), *'wrong side of road'* (n=3), *'red traffic light'* violations (n=1) (Table 6.3).

Table 6.3 Characteristics of unsafe events involving motor vehicles

Unsafe event characteristic	N=108	%
Severity		
Near crash	7	6.5
Crash relevant	78	72.2
Close passing only	23	21.3
Close passing involved in unsafe event		
No	77	71.3
Yes	31	28.7
Type of motor vehicle [a]		
Automobile	73	67.6
Utility	15	13.9
Truck	10	9.3
Light vehicle pulling trailer	5	4.6
Van	4	3.7
Bus	1	0.9
Fault		
Motorist	89	82.4
Rider/s in group	18	16.7
Shared fault	1	0.9
Motorist violation [b]		
No	61	56.5
Yes	47	43.5
Group rider violation [b]		
No	99	91.7
Yes	9	8.3
Motorist reckless behaviour		
No	96	88.9
Yes	12	11.1
Group rider reckless behaviour		
No	98	90.7
Yes	10	9.3
Aggression present		
None	92	85.2
Motorist to rider/s	10	9.3
Rider/s to motorist	5	4.6
Both motorist and rider/s	1	0.9

[a] First motor vehicle involved in unsafe event only [b] One or more violations per unsafe event

The road user behaviour variables were used to determine whether the group rider/s or motorist behaviour was *'reckless'* (deliberate, careless or aggressive), irrespective of fault or violations. Overall, 12 unsafe events (cases) involved reckless behaviour on the part of the motorists (11.1%) and 10 on the part of the group rider/s (9.3%). Examples of motorist behaviour included *'aggressive/ deliberate close passing'*, *'overtaking on curves'*, *'driving on the wrong side of traffic islands'*, *'passing on the* *left on a single lane road'* and *'turning right from the straight travel lane'* at traffic lights. Group rider behaviour included *'approaching intersections too fast', 'red light violation', 'riding on the wrong side of the road', 'following a motor vehicle too closely'* and *'overtaking a truck on the left on a curve'*. Overall, while group riders were at fault for a much lower number of unsafe events (18 and one shared fault), compared to motorists, their behaviour was deemed reckless in 10 of these events (52.6%). While motorists were at fault for a higher number of unsafe events (89 and one shared fault), their behaviour was deemed reckless in only 12 of these (13.3%) (Table 6.3). Overall, the majority of unsafe events were the fault of the motorist, but these were predominantly the result of errors and misjudgements.

6.2.3.3 Motorist and group rider aggression

Finally, obvious aggressive behaviour was present for 16 of the events (14.8%). Aggressive behaviour from motorists towards group riders (n=10, 9.3%) included repeated beeping, passing closer than necessary while beeping, yelling and revving the engine. Aggressive behaviour from group riders towards the motorist (n=5, 4.6%) included yelling, swearing, hand gestures and knocking on a car window. There was also one incident (0.9%) where both riders and the motorist displayed aggressive behaviour (Table 6.3).

6.2.4 Nature of unsafe events involving motor vehicles

Table 6.4 describes the nature of the 108 unsafe events (cases) involving motor vehicles. A total of 88 unsafe events (81.5%) involved a conflict with a motor vehicle originally travelling in the same direction as the group and the large majority involved a passing manoeuvre (n=71, 65.7%). Twenty unsafe events (18.5%) involved a conflict with a motor vehicle originally travelling in a different direction to the group. The next sections describe the unsafe events (cases) involving a motor vehicle, by category.

Table 6.4 Nature of unsafe events (cases) involving motor vehicles

Unsafe event nature	N=108	%
Conflict with vehicle originally travelling in same direction	**88**	**81.5**
Conflict with adjacent motor vehicle: passing	71	65.7
• Motor vehicle attempted to pass group but faced infrastructure/ merge	28	25.9
• Close passing only by motor vehicle	23	21.3
• Motor vehicle passing group resulted in a conflict with another motor vehicle	16	14.8
• Other unsafe passing	4	3.7
Conflict with adjacent motor vehicle: lane change	10	9.3
Conflict with a lead motor vehicle	6	5.6
Conflict with parked motor vehicle	1	0.9
Conflict with vehicle originally travelling in different direction	**20**	**18.5**
Conflict between vehicles turning across, into or moving across paths	16	14.8
Conflict with oncoming motor vehicle	4	3.7

6.2.4.1 Conflict with adjacent motor vehicle: passing

Motor vehicle attempted to pass group rider/s but faced infrastructure/ merge

A total of 28 unsafe events (cases) involved a conflict with an adjacent motor vehicle where the vehicle attempted to pass or overtake the rider/s but the presence of road infrastructure ahead led to an unsafe event. These were all '*crash-relevant*' severity events. For 15 unsafe events (53.6%), after starting the passing manoeuvre, the motorist realised they could not pass due to the infrastructure ahead and braked and/or steered to the right to avoid a crash and allowed the rider/s to continue in front. For 13 (46.4%) of the unsafe events, the motorist continued to overtake and the rider/s had to brake or steer left to avoid a crash.

Twelve (42.9%) of these unsafe events occurred at roundabouts, eight (28.6%) at traffic islands, six (21.4%) at slow points and two (7.1%) at merge points. Groups ranged in size from six to 29 riders and 22 groups were riding single file with six groups riding two-abreast. The majority of sites had only one lane in the direction of travel (n=26, 92.9%)) and two sites (7.1%) had two lanes. Traffic islands were present in the vicinity of 20 events (71.4%) and bicycle lanes were present on approach to the infrastructure for eight events (28.6%). All 12 roundabout sites had a single lane on approach, seven had bicycle lanes which ended prior to the roundabout (58.3%) and 11 of the 12 groups were riding single file at the time of the event (91.7%). The motorist was determined to be at fault in all 28 cases and there were eight motorist violations for close passing (28.6%).

Unsafe close passing by motor vehicle only

A total of 23 unsafe events (cases) involved *'unsafe close passing only'* with no evasive manoeuvre. Eight of the groups (34.8%) were riding single file, 14 (60.9%) were riding two-abreast and one (4.3%) was riding three abreast at the time of the event. Twenty (87.0%) unsafe events occurred at midblock sites and three (13.0%) at intersections. Twelve (52.2%) unsafe events occurred on roads with a single lane in the direction of travel, 10 (43.5%) occurred on roads with two lanes and one (4.3%) occurred on a road with three lanes in the direction of travel. Seven (30.4%) unsafe event (case) sites had traffic islands in the vicinity and eight (34.8%) had bicycle lanes present. Group sizes ranged from five to 32 riders. The events were determined to be the fault of the motorist in 22 cases (95.7%) and shared fault in one case (4.3%) (where the group was riding three abreast and occupying more than one lane). This was the only group rider violation observed for this category of event. All 23 events involved a motorist violation for unsafe passing and one motorist also crossed a solid white line in order to overtake.

Motor vehicle passing group resulted in a conflict with another motor vehicle

There were 16 unsafe events (cases) where the motorist passing the group resulted in a conflict with another motor vehicle. Two (12.5%) of these unsafe events were *'near crashes'* and 14 (87.5%) were *'crash-relevant'* events. Thirteen (81.3%) unsafe events involved a motor vehicle overtaking or attempting to overtake the group but facing an oncoming motor vehicle and three (18.8%) involved another motor vehicle travelling in the same direction. In all events, the passing motor vehicle braked and steered left towards the rider/s or only steered left to avoid a crash with the other vehicle. In addition, the majority of oncoming motor vehicles also braked to avoid a crash. Group sizes ranged from six to 28 riders. Nine (56.3%) of the groups were riding single file at the time and seven (43.8%) were riding two abreast. All but one unsafe event

(93.8%) occurred at midblock sites, 14 (87.5%) had a single lane in the direction of travel, three (18.8%) had traffic islands in the vicinity and only one site (6.3%) had a bicycle lane. The passing motorist was determined to be at fault in all unsafe events and seven (43.8%) involved motorist violations.

Other unsafe passing

Four '*crash-relevant'* events involved other incidents of unsafe passing. Three (75.0%) involved motor vehicles passing the riders and one (25.0%) involved group riders passing a motor vehicle. The first unsafe event involved the motorist passing the group on their left. The second involved another involved a motor vehicle coming close to the rear of the group when overtaking. The third involved a motor vehicle turning right from a straight travel lane and attempting to overtake the group at traffic lights. The fourth involved a group rider attempting to pass a large truck on the left as it was negotiating a curve. Group sizes ranged from 12 to 16 riders. Groups were riding two abreast in a traffic lane for all of these unsafe events. Three (75.0%) unsafe events occurred at midblocks and one (25.0%) at a traffic signal intersection. For three unsafe events (75.0%), the motorist was determined to be at fault and for one (25.0%), the group riders. There was one motorist violation identified.

6.2.4.2 Conflict with adjacent vehicle: lane change

Ten *'crash-relevant'* events involved a conflict with an adjacent motor vehicle and related to a lane change manoeuvre. Five (50.0%) unsafe events (cases) involved the motor vehicle changing from the right traffic lane to the left lane in close proximity to the front of the group. Three (60.0%) of these unsafe events involved the motor vehicle changing lanes then immediately slowing to turn left. Five (50.0%) unsafe events involved the rider/s changing lanes in front of a motor vehicle. Three (60.0%) of these events involved the rider/s changing to the right traffic lane with the intention of turning right at an upcoming intersection. Group sizes for the 10 unsafe events ranged from eight to 28 riders with six groups (60.0%) riding two abreast and four (40%) riding single file. All unsafe events occurred at sites with two or more lanes in the direction of travel, with eight (80.0%) occurring on the approach to intersections and two (20.0%) at midblock sites. Motorists were determined to be at fault for five

(50.0%) unsafe events and group riders were also at fault for five (50.0%) events. There were no violations observed.

6.2.4.3 Conflict with a lead motor vehicle

Six unsafe events (cases) involved conflicts with a lead motor vehicle, with three (50.0%) being classified as *'near crashes'* and three (50.0%) as *'crash relevant'* events. All unsafe events involved the leading motor vehicle braking. Group size ranged from five to 40 riders and all groups were riding two abreast in a traffic lane. Three (50.0%) of the unsafe events occurred at midblock locations and three (50.0%) at priority control intersections. No bicycle lanes were present. No violations were identified but fault was assigned to the motorist for three (50.0%) unsafe events and group riders for three (50.0%) events.

6.2.4.4 Conflict with a parked motor vehicle

One unsafe event involved a conflict with a parked motor vehicle and involved a door being opened in close proximity to the group. The leading riders steered right to avoid a crash. This was a *'crash-relevant'* event involving a group of 10 riders, riding single file on a single lane road with marked adjacent parallel parking. The motorist was determined to be at fault for this unsafe event.

6.2.4.5 Conflict between motor vehicle and group riders crossing paths

There were 16 unsafe events (cases) involving a conflict with a motor vehicle and group riders crossing paths. One (6.3%) was a *'near crash'* and 15 (93.7%) were *'crash relevant'* events. These all involved right of way errors on the part of the motorist or rider/s. Group sizes ranged from five to 40 riders with eight groups (50.0%) riding single file and eight (50.0%) riding two abreast. Twelve (75.0%) unsafe events occurred at intersections, two (12.5%) at driveways, one (6.3%) at roadside parking and one (6.3%) at the intersection of a road and path. Nine (56.3%) unsafe events were determined to be the fault of the motorist due to failure to give way to the group. These all involved a motor vehicle pulling out from a perpendicular road, driveway or parking, aiming to travel in the same direction as the riders. Seven (43.7%) unsafe events were determined to be the fault of the group rider/s due to failure to give way to the motor vehicle. Four (57.1%) of these involved riders approaching an intersection at high speed and being unable to stop, two (28.6%) involved failing to give way when turning right at traffic signals and one (14.3%) involved failing to give way when turning right from an off-road path onto the road.

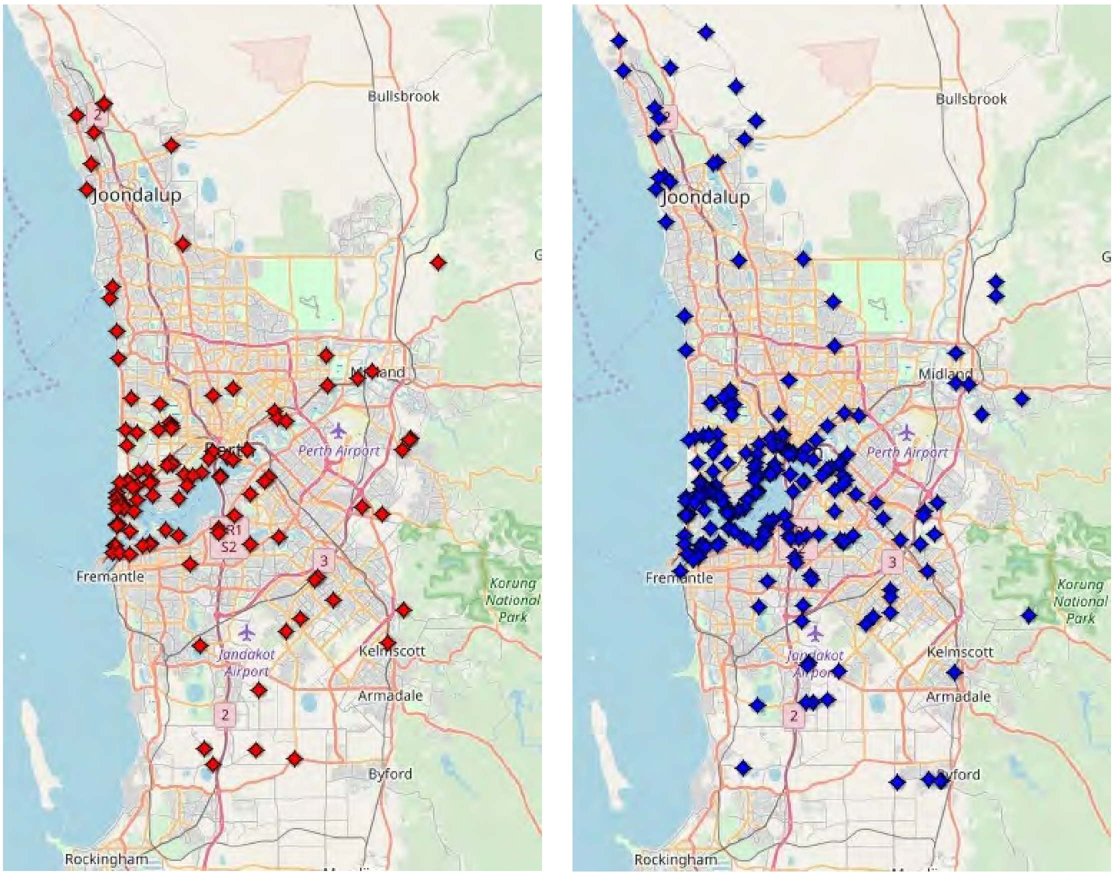
6.2.4.6 Conflict with oncoming motor vehicle

Four unsafe events (cases) involved a conflict with an oncoming motor vehicle. These events consisted of one (25.0%) *'near crash'* and three (75.0%) *'crash-relevant'* events and involved groups of 10 to 29 riders. All occurred at midblock locations on undivided roads with one lane in the direction of travel. Two (50.0%) occurred on straight roads and two (50.0%) on curved roads. All groups were riding in the traffic lane at the time of the event. The unsafe events involved one (25.0%) motorist violation and one (25.0%) group rider violation, both for travelling on the wrong side of the road. Two (50.0%) unsafe events were determined to be the fault of the group riders and two (50.0%) were the fault of the oncoming motor vehicle.

6.2.5 Case-crossover study: unsafe events involving a motor vehicle

The following sections describe the results of the case-crossover study examining the road environment and group position-related risk factors for unsafe events involving a motor vehicle. This study compared the characteristics of the 108 unsafe event (case) sites involving a motor vehicle to 216 control sites where no unsafe event occurred. Figure 6.2 shows the location of the 108 unsafe event (case) sites involving a motor vehicle and 216 control sites, mapped using the online site, GPS Visualizer (GPS Visualizer, 2018).

Figure 6.2 Location of 108 unsafe event sites involving a motor vehicle and 216 control sites in the Greater Perth area



Unsafe event (case) site locations *Control site locations*

Mapped using GPS Visualizer, 2018

6.2.5.1 Group position and behavioural characteristics: unsafe events involving a motor vehicle

Table 6.5 presents the group position and behavioural characteristics for the 108 unsafe event (case) sites involving a motor vehicle and 216 control sites. Also presented are the unadjusted odds ratios and 95% CIs from GEE logistic regression. These were initially calculated individually for each variable, not controlling for other variables.

In terms of group position on the road, for control sites, the majority were riding two abreast in the traffic lane (n=125, 57.9%). For unsafe event (case) sites, the highest proportion of groups were riding single file in the traffic lane (n=51, 47.2%). Compared to riding single file in the traffic lane, riding two abreast in the traffic lane significantly reduced the risk of an unsafe event (OR: 0.45, 95% CI: 0.32-0.64, p<0.001) and riding with all riders in the bicycle lane also significantly reduced the risk (OR: 0.18, 95% CI:0.06-0.54, p=0.002) (Table 6.5). For the unsafe events (cases) where the group were riding single file in the traffic lane, 74.5% involved a passing motor vehicle. For unsafe events where the group was riding two abreast in the traffic lane, 53.3% involved a passing motor vehicle. While the majority of groups were travelling straight at both control sites (n=181, 83.8%) and unsafe event (case) sites (n=75, 69.4%), performing another manoeuvre (turning, negotiating a curve, changing lanes or merging) significantly increased the risk of an unsafe event (OR: 2.11, 95% CI: 1.31-3.41, p=0.002) (Table 6.5).

Table 6.5 Group position and behavioural characteristics for unsafe event (case) sites involving a motor vehicle and control sites

Group position/ behavioural characteristic	Control sites (n=216)		Unsafe event (case) sites (n=108)		OR[a]	95% CI		p-value
	N	%	N	%				
Group position								
Single file in traffic lane	53	24.5	51	47.2	1.00			
2 abreast in traffic lane	125	57.9	45	41.7	0.45	0.32	0.64	<0.001*
2 abreast in bike and traffic lane	17	7.9	9	8.3	0.71	0.41	1.24	0.223
All riders in bike lane	21	9.7	3	2.8	0.18	0.06	0.54	0.002*
Rider manoeuvre								
Straight	181	83.8	75	69.4	1.00			
Other	35	16.2	33	30.6	2.11	1.31	3.41	0.002*
Rider proximity								
Close proximity (<3m)	174	80.6	92	85.2	1.00			
Staggered (≥3m)	42	19.4	16	14.8	0.75	0.43	1.31	0.312
Rolling								
No	205	94.9	106	98.1	1.00			
Yes	11	5.1	2	1.9	0.41	0.15	1.11	0.080
Rider violation								
No	206	95.4	99	91.7	1.00			
Yes	10	4.6	9	8.3	1.77	0.81	3.85	0.150

[a] Unadjusted OR (odds ratios) from GEE logistic regression accounting for clustering of sites within trips. Not controlling for any other variables * significant at p<0.05

For the majority of control and unsafe event (case) sites, the group were riding in close proximity to each other (< 3 metres distance from the rider in front). Only a small proportion of groups were *'rolling'* (section 2.1.2) at control or unsafe event (case) sites and no groups were sprinting or racing at the location. Group rider violations were observed at nine unsafe event (case) sites (8.3%) and 10 (4.6%) control sites. There were no significant differences for these characteristics (Table 6.5).

6.2.5.2 Number of riders, speed and location characteristics: unsafe event sites involving a motor vehicle

Table 6.6 presents the group rider characteristics for the 108 unsafe event (case) sites and 216 control sites. Unadjusted ORs and 95% CIs from GEE logistic regression have been calculated individually for each variable. The number of riders (rider count at exact location) occasionally changed at different time points within a trip. As expected however, the number of riders was very similar with an average of 13.4 riders (SD 6.6) at control sites and 13.2 riders (SD: 7.2) at unsafe event (case) sites (p=0.351). Group rider speed data was only available for 125 control (57.9%) and 60 unsafe event sites (55.6%) due to missing GPS data. Average speed was 26.9 km/h (SD: 9.7) for control sites and 28.2 km/h (SD: 9.5) for unsafe event sites (p=0.447). Control sites were located, on average 67.2 minutes (SD: 35.3) into the trip, compared to 59.6 minutes (SD: 39.2) for unsafe event sites (p=0.100).

Table 6.6 Number of riders, speed and location characteristics for unsafe event (case) sites involving a motor vehicle and control sites

Group rider characteristic	Control sites (n=216)		Unsafe event (case) sites (n=108)		OR [a]	95% CI		p-value
	Mean	SD	Mean	SD				
Number of riders (count)	13.4	6.6	13.2	7.2	1.01	0.99	1.03	0.351
Rider speed (km/h) [b]	26.9	9.7	28.2	9.5	1.01	0.98	1.04	0.447
Time into trip (minutes)	67.2	35.3	59.6	39.2	1.01	1.00	1.02	0.100

[a] Unadjusted OR (odds ratios) from GEE logistic regression accounting for clustering of sites within trips. Not controlling for any other variables
[b] Missing data: rider speed data available for 125 control and 60 unsafe event sites)

6.2.5.3 General road characteristics: unsafe events involving a motor vehicle

Table 6.7 presents the general road characteristics for the 108 unsafe event (case) sites involving a motor vehicle and the 216 control sites. The majority of control sites were located on low-volume roads (access roads, local distributors and regional distributors) (n=100, 46.3%), followed by medium-volume roads (Distributor A and Distributor B roads) (n=92, 42.6%) (see Table 3.1 for definitions). The majority of unsafe event (case) sites were located on medium-volume roads (n=63, 58.3%). Medium-volume roads significantly increased the risk of an unsafe event involving a motor vehicle compared to low-volume roads (OR: 1.90, 95% CI: 1.20- 3.00, p=0.006).

The majority of control sites (n=120, 55.6%) were located on roads with speed limits of 50 km/h or less while the majority of unsafe event (case) sites were located on roads with speed limits of 60 km/h or more (n=64, 59.3%). Speed limits of 60 km/h or more significantly increased the risk of an unsafe event (OR: 1.60, 95% CI: 1.17-2.20, p=0.003) (Table 6.7). For the 64 unsafe event sites with speed limits of 60km/h or more, the majority (84.4%) involved a motor vehicle travelling in the same direction passing the group. For the 44 unsafe events sites with speed limits ≤ 50 km/h, 59.1% involved a passing motor vehicle.

Table 6.7 General road characteristics for unsafe event (case) sites involving a motor vehicle and control sites

General road characteristic	Control sites (n=216)		Unsafe event (case) sites (n=108)		OR[a]	95% CI		p-value
	N	%	N	%				
Road classification								
Low-volume	100	46.3	31	28.7	1.00			
Medium-volume	92	42.6	63	58.3	1.90	1.20	3.00	0.006*
High-volume	24	11.1	14	13.0	1.67	0.81	3.45	0.168
State or Local Road								
Local	192	88.9	94	87.0	1.00			
State	24	11.1	14	13.0	1.16	0.62	2.19	0.646
Posted speed limit								
≤ 50 km/h	120	55.6	44	40.7	1.00			
≥ 60 km/h	96	44.4	64	59.3	1.60	1.17	2.20	0.003*

[a] Unadjusted OR (odds ratios) from GEE logistic regression accounting for clustering of sites within trips. Not controlling for any other variables * significant at p<0.05

6.2.5.4 Road infrastructure characteristics: unsafe events involving a motor vehicle

Table 6.8 presents the road infrastructure characteristics for the 108 unsafe event (case) sites involving a motor vehicle and the 216 control sites. In terms of traffic control, the majority of control sites (n=153, 70.8%) and unsafe event (case) sites (n=67, 62.0%) were at midblocks with no traffic control. Compared to midblock sites, roundabouts significantly increased the risk of an unsafe event (OR: 6.79, 95% CI: 2.87-16.08, $p<0.001$) (Table 6.8). For the 16 unsafe event sites at roundabouts, 75.0% involved a motor vehicle travelling in the same direction as the group, all occurred at single lane roundabouts and 62.5% of sites had bicycle lanes which ended on approach to the roundabout. A significantly higher proportion of unsafe event (case) sites (n=44, 40.7%) compared to control sites (n=50, 23.1%) had raised traffic islands in the vicinity of the location (OR: 2.03, 95%: 1.31-3.14, p=0.002) (Table 6.8). For the 44 unsafe event (case) sites at traffic islands, 81.8% of the events involved a motor vehicle travelling in the same direction as the group. A significantly higher proportion of control sites (n=49, 22.7%) had a bicycle lane than unsafe event (case) sites (n=14, 13.0%). Bicycle lanes significantly reduced the risk of an unsafe event (OR: 0.57, 95% CI: 0.37-0.89, p=0.013) (Table 6.8).

The large majority of control and unsafe event (case) sites were located at non-intersections, on straight, level roads, with smooth, dry surfaces and traffic in both directions and there were no significant differences for any of these variables (Table 6.8). In addition, the largest proportion of control and unsafe event (case) sites were located on undivided roads with no median, had one lane in the direction of travel, were four to seven metres wide in the direction of travel, had free flowing traffic with no lead traffic, were not located in construction zones, did not have a slow point/ speed humps and did not have adjacent parking. There were also no significant differences for these variables (Table 6.8).

Table 6.8 Road infrastructure characteristics for unsafe event (case) sites involving a motor vehicle and control sites

Road infrastructure characteristic	Control sites (n=216) N	%	Unsafe event (case) sites (n=108) N	%	OR[a]	95% CI		p-value
Intersection								
No	153	70.8	67	62.0	1.00			
Yes	63	29.2	41	38.0	1.44	0.94	2.21	0.099
Traffic control								
Midblock	153	70.8	67	62.0	1.00			
Priority control intersection	38	17.6	17	15.7	0.98	0.55	1.77	0.957
Roundabout intersection	4	1.9	16	14.8	6.79	2.87	16.08	<0.001*
Traffic signal intersection	21	9.7	8	7.4	0.86	0.33	2.24	0.758
Surface type								
Smooth	212	98.1	107	99.1	1.00			
Rough	4	1.9	1	0.9	0.53	0.07	3.83	0.532
Surface condition								
Dry	200	92.6	103	95.4	1.00			
Wet	16	7.4	5	4.6	0.70	0.44	1.10	0.122
Roadway alignment								
Straight	195	90.3	91	84.3	1.00			
Curved	21	9.7	17	15.7	1.64	0.87	3.09	0.128
One/two way								
Two way	211	97.7	105	97.2	1.00			
One way	5	2.3	3	2.8	1.17	0.30	4.59	0.819
Gradient								
Level	193	89.4	90	83.3	1.00			
Sloped	23	10.6	18	16.7	1.43	0.61	3.34	0.409
Divided road								
Not divided	115	53.2	49	45.4	1.00			
Divided	101	46.8	59	54.6	1.32	0.85	2.04	0.216
Median type								
None	115	53.2	49	45.4	1.00			
Non-physical	35	16.2	20	18.5	1.30	0.73	2.31	0.375
Physical	66	30.6	39	36.1	1.33	0.84	2.11	0.230
Traffic islands								
No	166	76.9	64	59.3	1.00			
Yes	50	23.1	44	40.7	2.03	1.31	3.14	0.002*
Lanes in direction of travel								
1 lane	150	69.4	72	66.7	1.00			
2 lanes	43	19.9	30	27.8	1.41	0.88	2.28	0.154
≥ 3 lanes	23	10.6	6	5.6	0.57	0.24	1.34	0.197

Width in direction of travel								
<4.0 m	70	32.4	38	35.2	1.00			
4.0-7.0 m	100	46.3	44	40.7	0.82	0.48	1.40	0.468
>7.0 m	46	21.3	26	24.1	1.03	0.59	1.80	0.922
Left lane width								
<3.0 m	16	7.4	7	6.5	1.00			
3.0-3.5 m	115	53.2	46	42.6	0.92	0.43	1.98	0.833
>3.5 m	85	39.4	55	50.9	1.14	0.67	3.08	0.351
Traffic density								
Free flow, no lead traffic	165	76.4	75	69.4	1.00			
Leading traffic or restricted flow	51	23.6	33	30.6	1.39	0.80	2.41	0.244
Construction Zone								
No	213	98.6	103	95.4	1.00			
Yes	3	1.4	5	4.6	3.16	0.82	12.11	0.094
Traffic calming								
None	204	94.4	101	93.5	1.00			
Slow point or speed hump	12	5.6	7	6.5	1.17	0.48	2.81	0.733
Adjacent Parking								
No	192	88.9	98	90.7	1.00			
Yes	24	11.1	10	9.3	0.84	0.43	1.64	0.607
Bicycle lane								
No	167	77.3	94	87.0	1.00			
Yes	49	22.7	14	13.0	0.57	0.37	0.89	0.013*

[a] Unadjusted OR (odds ratios) from GEE logistic regression accounting for clustering of sites within trips. Not controlling for any other variables * significant at p<0.05

6.2.6 Multivariate GEE logistic regression model: unsafe event sites involving a motor vehicle

Table 6.9 presents the results of the multivariate GEE logistic regression model examining variables associated with the risk of an unsafe event involving a motor vehicle. *‘Unsafe event site’* (no: control site, yes: case site) was entered as the dependent variable. Variables considered for inclusion as independent variables/ confounding factors were based on findings from the limited literature on factors associated with group riding crashes as well as bicycle crashes in general. These were: *‘traffic control’* (Cumming, 2010; Reynolds et al., 2009; Wilke, Lieswyn, & Munro, 2014), *‘posted speed limit’* (Cripton et al., 2015; Harris et al., 2013), *‘traffic density’* (Hamann & Peek-Asa, 2012) and *‘number of riders’* (Thompson, Wijnands, Mavoa, Scully, & Stevenson, 2018). Other variables which had p-values less than 0.25 in the univariate analyses were also considered for the model. These were *‘group position’*, *'rider manoeuvre'*, *'rolling'*, *'rider violation'*, *'road classification'*, *'intersection'*, *'surface condition'*, *'divided road'*, *'median type'*, *'traffic islands'*, *'lanes in direction of travel'*, *'construction zone'* and *'bicycle lane'*.

Since the number of potential variables was too large to model with the available sample size, they were reduced as follows. From the literature *'traffic control'*. *'posted speed limit'*, *'traffic density'* and *'number of riders'* in the group were entered in the model. *'Group position'* on the road was a variable of particular interest so this was then added to the model. It was a significant covariate and significantly improved the fit of the model. Multicollinearity between all independent variables considered for inclusion in the model was checked using Pearson Chi-Square or Fisher's Exact tests for two categorical variables and t-tests for categorical and continuous variables. Several variables were significantly associated. *'Traffic control'* was significantly associated with *'rider manoeuvre' (p=0.004)* and *'road classification'* ($p<0.001$). *'Speed limit'* and *'road classification'* were also associated ($p<0.001$). *'Bicycle lane'* was associated with *'group position'* ($p<0.001$) and *'divided road'* was associated with *'median type'* ($p<0.001$) as these variables were similar. The impact of each of these variables on model fit were compared and *'rider manoeuvre'*, *'road classification'*, *'bicycle lane'* and *'divided road'* were eliminated.

Each remaining variable listed above (*'rolling'*, *'rider violation'*, *'intersection'*, *'surface condition'*, *'median type'*, *'traffic islands'*, *'lanes in direction of travel'* and *'construction zone'*) were then separately added to the model and whether the variable was significant and /or it improved the fit of the model ($p<0.05$) was examined. Model fit was determined using the Quasi Likelihood under Independence Model Criterion (QIC) and Corrected Quasi Likelihood under Independence Model Criterion (QICC) values which were computed in SPSS using full log quasi-likelihood function (Cui & Qian, 2007; Pan, 2001). Smaller values indicate a better fit. The variables *'traffic islands'* and *'rider violation'* were significant and improved the fit of the model so these were retained. The other variables did not improve the fit of the model so were not included.

Interactions between the main effects on group riding crashes in the binary logistic regression models were investigated. Two-way interaction terms were tested in the model for each different combination of the significant main effects. None of the interaction terms were significant. The QIC and QICC values also confirmed that the exchangeable correlation matrix provided a better (though similar) model (QIC: 372.63, QICC: 381.32) than the independent, autoregressive (AR(1)) or unstructured correlation matrix.

The final multivariate GEE model included the following independent variables: *'traffic control'* (midblock, priority control intersection, roundabout, traffic signals), *'traffic islands'* (no, yes), *'posted speed limit'* (≤ 50 km/h, ≥ 60 km/h), *'group position'* (single file in traffic lane, 2 abreast in traffic lane, 2 abreast in bike and traffic lane, all riders in bike lane), *'rider violation'* (no, yes), *'traffic density'* (free flow – no leading traffic, leading traffic or restricted flow) and *'number of riders'* (count).

After controlling for potential confounding factors, roundabouts increased the risk of an unsafe event by over three times (OR: 3.63, 95% CI: 1.57-8.42, p=0.003), compared to midblock sites (Table 6.9). When reference categories were switched for this variable, it was also determined that roundabouts significantly increased the risk of an unsafe event, compared to both priority control intersections (OR: 4.36, 95% CI: 1.49-12.76, p=0.007) and traffic signal intersections (OR: 5.57, 95% CI: 1.42-21.79, p=0.014). The presence of raised traffic islands in the vicinity of the site also significantly increased the risk of an unsafe event (OR: 2.30, 95% CI: 1.41-3.78, p=0.001). Similarly, posted speed limits of 60 km/h or higher significantly increased the risk of an unsafe event by over two times (OR: 2.45, 95% CI: 1.55-3.86, p<0.001), compared to sites with speed limits of 50 km/h or less (Table 6.9).

Group position on the road was also significantly associated with the risk of an unsafe event. Compared to riding single file in the traffic lane, riding two abreast in the traffic lane significantly reduced the risk of an unsafe event by half (OR: 0.50, 95% CI: 0.32-0.76, p=0.002). Compared to riding single file in the traffic lane, riding with all riders in the bicycle lane, also significantly reduced the risk of an event by 86% (OR: 0.14, 95% CI: 0.04-0.51, p=0.003). However, riding two abreast with one rider in the bicycle lane and one next to them in the traffic lane did not significantly reduce the risk of an unsafe event, compared to riding single file in the traffic lane (p=0.070) (Table 6.9).

Group rider traffic violations at the site increased the risk of an unsafe event by over two times (OR: 2.51, 95% CI: 1.14-5.53, p=0.022). Finally, traffic density and number of riders were not significantly associated with the risk of an unsafe event in the multivariate model (Table 6.9).

Table 6.9 Multivariate GEE logistic regression model for unsafe event (case) sites involving a motor vehicle (n=108) and control sites (n=216)

Variable	Adjusted OR	Standard Error	95% CI		p-value
Intercept	0.32	0.22	0.20	0.49	<0.001
Traffic control					
Midblock	1.00				
Priority control intersection	0.83	0.35	0.42	1.66	0.605
Roundabout	3.63	0.43	1.57	8.42	0.003*
Traffic signals	0.65	0.55	0.22	1.91	0.436
Traffic islands					
No	1.00				
Yes	2.30	0.25	1.41	3.78	0.001*
Posted speed limit					
≤ 50 km/h	1.00				
≥ 60 km/h	2.45	0.23	1.55	3.86	<0.001*
Group position					
Single file in traffic lane	1.00				
2 abreast in traffic lane	0.50	0.22	0.32	0.76	0.002*
2 abreast in bike and traffic lane	0.56	0.32	0.30	1.05	0.070
All riders in bike lane	0.14	0.66	0.04	0.51	0.003*
Rider violation					
No	1.00				
Yes	2.51	0.40	1.14	5.53	0.022*
Traffic density					
Free flow, no lead traffic	1.00				
Leading traffic or restricted flow	1.52	0.28	0.88	2.64	0.136
Number of riders (count)	1.01	0.01	0.99	1.02	0.477

Quasi Likelihood under Independence Model Criterion (QIC): 372.63 and Corrected Quasi Likelihood under Independence Model Criterion (QICC); 381.32 * Significant at p<0.05

6.3 Part B: Unsafe events not involving motor vehicles

Section 6.3 describes the results of the case-crossover study examining road environment and group position-related risk factors for unsafe events that did not involve a motor vehicle.

6.3.1 Naturalistic video footage for unsafe events not involving motor vehicles

The case-crossover study of unsafe events not involving motor vehicles included only the trips which contained at least one unsafe event not involving a motor vehicle. There were 59 unsafe events which did not involve a motor vehicle observed in the footage and these occurred during 40 trips, recorded by 21 different groups. The duration of these trips ranged from 47 to 192 minutes with an average of 113.1 minutes (SD: 42.1). From the 40 trips, there was a total of 50.3 hours of video footage with 34.9 hours from both cameras (69.4%) and 15.4 hours from the front camera only (30.6%). This consisted of 1398 kilometres travelled with an average of 35.0 kilometres per trip (SD: 16.1). Each trip had between one and five unsafe events which did not involve a motor vehicle, with an average of 1.5 events (SD: 0.9). There was a total of 31.0 hours of available GPS data (61.6%) but all footage was included whether or not GPS data was available. Table 6.10 presents the naturalistic footage used for Part B of Phase 2.

Table 6.10 Naturalistic data included for Part B – unsafe events not involving a motor vehicle

Data collected	
Unsafe events not involving a motor vehicle (n)	59
Group riding trips (n)	40
Riding groups (n)	21
Eligible video footage (hours)	50.3
GPS data (hours)	31.0
Distance travelled (km)	1398

6.3.2 Temporal conditions for unsafe events not involving motor vehicles

Table 6.11 describes the temporal conditions for each of the 59 unsafe events (cases) which did not involve a motor vehicle. The majority of unsafe events occurred on weekends (n=44, 74.6%), in spring (n=23, 39.0%) or summer (n=17, 28.8%) and between 7am and 9am (n=42, 71.2%). Only six unsafe events (10.2%) occurred during peak hour traffic defined as 7-9am on a weekday. The majority of unsafe events also occurred during daylight (n=58, 98.3%) and in clear weather (n=55, 93.2%).

Table 6.11 Temporal conditions for unsafe events not involving motor vehicles

Temporal condition	N=59	%
Day of week		
Weekend	44	74.6
Weekday	15	25.4
Season		
Summer	17	28.8
Autumn	11	18.6
Winter	8	13.6
Spring	23	39.0
Time of day		
Before 7am	13	22.2
7-9am	42	71.2
After 9am	4	6.8
Peak traffic		
Off peak	53	89.8
Peak	6	10.2
Light conditions		
Daylight	58	98.3
Dawn	1	1.7
Weather		
Clear/ overcast	55	93.2
Rain	4	6.8

6.3.3 Characteristics of unsafe events not involving motor vehicles

Table 6.12 summarises the overall characteristics of the 59 unsafe events which did not involve a motor vehicle. In terms of unsafe event severity there were two *'crashes'* (3.4%) where a rider in the group came off their bicycle and hit the ground. Neither of these *'crashes'* involved any other riders. There were also 12 *'near crashes'* (20.3%) which required a rapid evasive manoeuvre by the rider/s to avoid a crash. The most common events were *'crash relevant'* events (n=45, 76.3%) which required a less urgent evasive manoeuvre to avoid a crash. Seven unsafe events (11.9%) involved another rider who was not part of the group. Fault was not determined for events which did not involve a motor vehicle. However, traffic violations by group riders were examined and four unsafe events (6.8%) involved violations. All four involved riding more than two abreast and for one, also riding on the wrong side of the road. Reckless behaviour of riders in the group was examined but these results were identical to group rider violations so was not included.

Table 6.12 Characteristics of unsafe events not involving motor vehicles

Unsafe event characteristics	N=59	%
Severity		
Crash	2	3.4
Near crash	12	20.3
Crash relevant	45	76.3
Involve rider/s outside group		
No	52	88.1
Yes	7	11.9
Group rider violation [a]		
No	55	93.2
Yes	4	6.8

[a] One or more violations per unsafe event

6.3.4 Nature of unsafe events not involving motor vehicles

Table 6.13 describes the nature of the 59 unsafe events (cases) which did not involve a motor vehicle. A total of 24 unsafe events (40.7%) involved a conflict between two or more riders within the group and seven events (11.9%) involved a conflict with at least one rider who was not part of the group. Twenty-three unsafe events (39.0%) involved a conflict with an obstacle or object on the roadway, while five events (8.5%) were single rider loss of control conflicts. The following sections describe the unsafe events, by category.

Table 6.13 Nature of unsafe events not involving motor vehicles

Event nature	N=59	%
Conflict between riders within group	24	40.7
Conflict with rider/s outside of group	7	11.9
Conflict with obstacle/ object on roadway	23	39.0
Single rider loss of control conflict	5	8.5

6.3.4.1 Conflict between riders within group

The most common type of unsafe event (case) which did not involve a motor vehicle was a conflict between at least two riders within the group (n=24). Seven (29.2%) of these were *'near crashes'* and 17 (70.8%) were *'crash-relevant'* events. Seven (29.2%) of the unsafe events involved riders in front suddenly braking, causing following riders to brake hard or swerve to avoid a crash. Six (25.0%) unsafe events occurred while the group was *'rolling'* and involved a rider changing lines into the path of another rider. Five (20.8%) unsafe events involved a conflict between adjacent riders when one was overtaking within the group. Six (25.0%) unsafe events involved a rider swerving into the path of an adjacent rider in the group (when not overtaking or rolling). All events involved riding in close proximity to each other. Seventeen groups (70.8%) were riding two abreast, five (20.8%) were riding single file and two (8.3%) were riding three abreast. Six (25.0%) of the unsafe events occurred on curved roads, two (8.3%) involved changing lanes and two (8.3%) involved the riders turning. Nine (37.5%) of the unsafe events occurred at intersections and 15 (62.5%) at midblocks. Two (8.3%) unsafe events occurred in construction zones. Bicycle lanes were present at four (16.7%) of the sites.

6.3.4.2 Conflict with riders outside of group

Seven unsafe events (cases) involved a conflict with riders outside of the group and included one (14.3%) *'near crash'* and six (85.7%) *'crash relevant'* events. Three (42.9%) unsafe events involved the group turning a corner and coming head on with another rider travelling in the opposite direction. For two (66.7%) of these the group took the corner wide on the wrong side of the road and for one (33.3%), the other rider was on the wrong side of the road. Two (28.6%) unsafe events involved other rider/s ahead of the group suddenly stopping or slowing. One (14.3%) unsafe event involved a rider ahead on an adjacent path suddenly changing to travel on the road in front of the group. The final event involved a rider within the group drifting right into the path of another group overtaking them. Three groups (42.9%) were riding two abreast, two (28.6%) were riding three abreast and two (28.7%) were riding single file. All were riding in close proximity to each other. Three (42.9%) occurred at intersections and four (57.1%) at midblock sites. No unsafe event (case) sites had bicycle lanes.

6.3.4.3 Conflict with obstacle/ object on roadway

A total of 23 unsafe events (cases) involved a conflict with an obstacle or object on the roadway. There were three (13.0%) *'near crashes'* and 20 (87.0%) *'crash-relevant'* events. The most common obstacle/ objects were potholes (n=6, 26.1%), sticks (n=2, 8.7%), manhole covers (n=2, 8.7%), speed humps (n=2, 8.7%) and metal/ nail (n=2, 8.7%). Other objects included a boom gate, plastic, a drain, a large puddle and a traffic island. Four (17.4%) unsafe events involved objects which could not be identified on the video. Thirteen groups (56.5%) were riding two abreast and 10 (43.5%) were riding single file and all groups except for one (95.7%) were riding in close proximity to each other. One (4.3%) unsafe event occurred at an intersection with the remaining 22 (95.7%) at midblock sites. Eleven (47.8%) unsafe event (case) sites had bicycle lanes present. Two (8.7%) unsafe events occurred in construction zones.

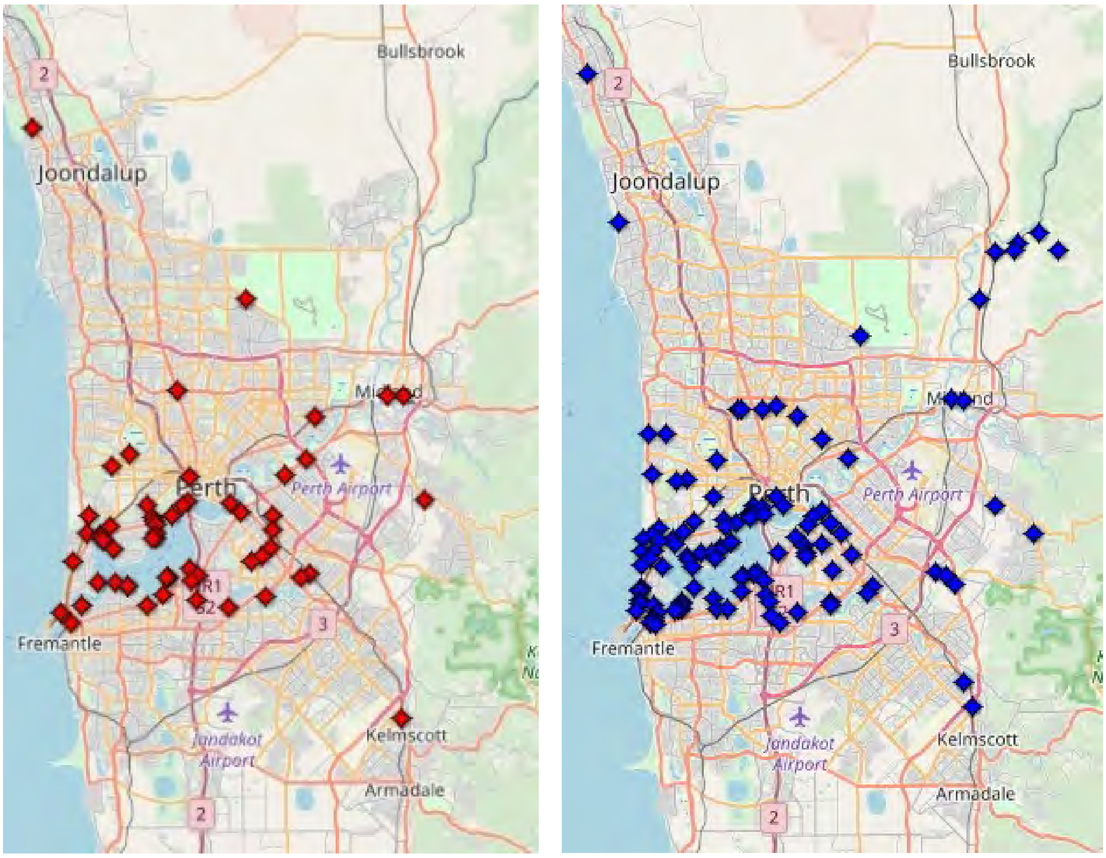
6.3.4.4 Single rider loss of control conflict

Five unsafe events (cases) involved a single rider within the group and no other objects or riders. Three (60.0%) unsafe events involved the rider slipping while making a manoeuvre (turning left, negotiating a roundabout and negotiating a curve). Two (66.7%) of these resulted in *'crashes'* (rider hit the ground) and one (33.3%) was a *'crash-relevant'* event. The other two (40.0%) unsafe events involved riders losing balance while changing lanes (*'near crash'*) and approaching roadworks (*'crash-relevant'*). Two (40.0%) groups were riding two abreast and three (60.0%) single file. Four (80.0%) groups were riding in close proximity. Two (40.0%) of the five events involved wet roads, two (40.0%) occurred at intersections and three (60.0%) at midblock sites. None of these unsafe event (case) sites had a bicycle lane.

6.3.5 Case crossover study: unsafe events not involving a motor vehicle

The following sections describe the results of the case-crossover study comparing the characteristics of the 59 unsafe event (case) sites which did not involve a motor vehicle to 118 control sites where no unsafe event occurred. Figure 6.3 shows the location of the 59 unsafe event (case) sites which did not involve a motor vehicle and 118 control sites in the Greater Perth area, mapped using GPS Visualizer (GPS Visualizer, 2018).

Figure 6.3 Location of the 59 unsafe event (case) sites not involving a motor vehicle and 118 control sites in the Greater Perth area



Unsafe event (case) sites *Control sites*

Mapped using GPS Visualizer, 2018

6.3.5.1 Group position and behavioural characteristics: unsafe events not involving a motor vehicle

Table 6.14 presents the group position and behavioural characteristics for the 59 unsafe event (case) sites which did not involve a motor vehicle and 118 control sites. Also presented are the unadjusted ORs and 95% CIs from GEE logistic regression that were initially calculated individually for each variable.

Although the groups were riding in close proximity to each other at the majority of control (n=98, 83.1%) and unsafe event (case) sites (n=57, 96.6%), riding staggered (>3 metres between the rear wheel and front wheel of riders) was associated with a significantly reduced risk of an unsafe event (OR: 0.2, 95% CI: 0.06-0.70, p=0.011). While the majority of groups were travelling straight at both control sites (n=98, 83.1%) and unsafe event (case) sites (n=37, 62.7%), performing another manoeuvre (e.g. turning, negotiating a curve, changing lanes or merging) significantly increased the risk of an unsafe event (OR: 2.71, 95% CI: 1.54-4.77, p=0.001).

For control and unsafe event (case) sites, the majority of groups were riding two abreast in the traffic lane. Only a small proportion of groups were *'rolling'*, sprinting/ racing or committed road traffic violations at both control and unsafe event (case) sites. There were no significant differences for any of these characteristics (Table 6.14).

Table 6.14 Group position and behavioural characteristics for unsafe event (case) sites not involving a motor vehicle and control sites

Group position/ behavioural characteristics	**Control sites (n=118)**		**Unsafe event (case) sites (n=59)**		**OR [a]**	**95% CI**		**p-value**
	N	%	N	%				
Group position								
Single file in traffic lane	28	23.7	17	28.8	1.00			
2 abreast in traffic lane	70	59.3	29	49.2	0.45	0.12	1.74	0.249
2 abreast in bike and traffic lane	10	8.5	9	15.3	0.94	0.33	2.67	0.912
All riders in bike lane	10	8.5	4	6.8	0.68	0.23	1.99	0.479
Rider proximity								
Close proximity (<3m)	98	83.1	57	96.6	1.00			
Staggered (≥3m)	20	16.9	2	3.4	0.20	0.06	0.70	0.011*
Rolling								
No	110	93.2	49	83.1	1.00			
Yes	8	6.8	10	16.9	2.50	0.82	7.62	0.108
Rider manoeuvre								
Straight	98	83.1	37	62.7	1.00			
Other	20	16.9	22	37.3	2.71	1.54	4.77	0.001*
Rider violation								
No	107	90.7	55	93.2	1.00			
Yes	11	9.3	4	6.8	0.73	0.21	2.58	0.626
Sprinting								
No	116	98.3	57	96.6	1.00			
Yes	2	1.7	2	3.4	3.59	0.38	33.70	0.263

[a] Unadjusted OR (odds ratios) from GEE logistic regression accounting for clustering of sites within trips. Not controlling for any other variables * significant at p<0.05

6.3.5.2 Number of riders, speed and location characteristics: unsafe events not involving a motor vehicle

Table 6.15 presents the rider characteristics for the 59 unsafe event (case) and 118 control sites. Unadjusted ORs and 95% CIs from GEE logistic regression were calculated individually for each variable. The number of riders (rider count at exact location) occasionally changed at different time points within a trip but the number of riders was very similar with an average of 15.2 riders (SD: 10.2) at control sites and 15.4 riders (SD: 10.1) at unsafe event (case) sites (p=0.147). Rider speed was only available for 73 control (61.9%) and 40 unsafe event (case) sites (67.8%) due to missing GPS data. Average rider speed was 27.2 km/h (SD: 10.2) for control sites and 30.6 km/h (SD: 9.1) for unsafe event (case) sites (p=0.062). Control sites were located on average, 53.2 minutes (SD: 34.8) into the trip, compared to 58.9 minutes (SD: 36.8) for unsafe event (case) sites (p=0.867).

Table 6.15 Rider count, speed and location characteristics for unsafe event (case) sites not involving a motor vehicle and control sites

Group rider characteristic	Control sites (n=118)		Unsafe event (case) sites (n=59)		OR [a]	95% CI		p-value
	Mean	SD	Mean	SD				
Number of riders (count)	15.2	10.2	15.4	10.1	1.01	1.00	1.02	0.147
Rider speed (km/h)[b]	27.2	10.2	30.6	9.1	1.03	0.99	1.07	0.062
Time into trip (minutes)	53.2	34.8	58.9	36.8	1.00	0.99	1.02	0.867

[a] Unadjusted OR (odds ratios) from GEE logistic regression accounting for clustering of sites within trips. Not controlling for any other variables
[b] missing data (speed data available for 40 unsafe event sites and 73 control sites only)

6.3.5.3 General road characteristics: unsafe events not involving a motor vehicle

Table 6.16 presents the general road characteristics for the 59 unsafe event (case) sites not involving a motor vehicle and the 118 control sites. The highest proportion of control sites were located on low-volume roads (access roads, local distributors and regional distributors) (n=48, 40.7%) and medium-volume roads (Distributor A and Distributor B roads) (n=48, 40.7%) (see Table 3.1 for definitions). The highest proportion of unsafe event (case) sites were located on low-volume roads (n=25, 42.4%) with no significant differences. The majority of control and unsafe event (case) sites were located on local roads, rather than State roads and on roads with speed limits of 50 km/h or less and there were no significant differences for these variables (Table 6.16).

Table 6.16 General road characteristics for unsafe event sites (cases) not involving a motor vehicle and control sites

General road characteristic	Control sites (n=118)		Unsafe event (case) sites (n=59)		OR[a]	95% CI		p-value
	N	%	N	%				
Road classification[b]								
Low-volume	48	40.7	25	42.4	1.00			
Medium-volume	48	40.7	23	39.0	0.93	0.51	1.70	0.809
High-volume	22	18.6	11	18.6	0.96	0.38	2.45	0.939
State or Local Road								
Local	96	81.4	48	81.4	1.00			
State	22	18.6	11	18.6	1.00	0.40	2.52	1.000
Posted speed limit								
≤ 50 km/h	62	52.5	35	59.3	1.00			
≥ 60 km/h	56	47.5	24	40.7	0.78	0.41	1.47	0.440

[a] Unadjusted OR (odds ratios) from GEE logistic regression accounting for clustering of sites within trips. Not controlling for any other variables
b Low-volume: Access Roads, Local Distributors, Regional Distributors; Medium-volume – Distributor A and Distributor B roads, High-volume: Primary Distributor

6.3.5.4 Road infrastructure characteristics: unsafe events not involving a motor vehicle

Table 6.17 presents the road infrastructure characteristics for the 59 unsafe event (case) sites which did not involve a motor vehicle and the 118 control sites. A higher proportion of unsafe event (case) sites (n=12, 20.3%) were located on curved roads, compared to control sites (n=8, 6.8%) and this difference was significant (OR: 3.24, 95% CI: 1.52-6.90, p=0.002) (Table 6.17). A higher proportion of unsafe event (case) sites (n=5, 8.5%) compared to control sites (n=1, 0.8%) were also located within or approaching a construction zone (roadworks). Construction zones significantly increased the risk of an unsafe event (OR: 9.09, 95% CI: 1.38-60.00, p=0.022) (Table 6.17). Two of the unsafe events in construction zones involved conflicts with other riders (40.0%), two involved conflicts with an object (40.0%) and one involved a single rider conflict (20.0%). Three of these events (60.0%) involved apparent rider confusion regarding which path to take or where to position themselves on the road through the roadworks.

Table 6.17 Road infrastructure characteristics for unsafe event (case) sites not involving a motor vehicle and control sites

Road infrastructure characteristic	Control sites (n=118)		Unsafe event (case) sites (n=59)		OR[a]	95% CI		p-value
	N	%	N	%				
Intersection								
No	84	71.2	45	76.3	1.00			
Yes	34	28.8	14	23.7	0.79	0.41	1.51	0.470
Traffic control								
Midblock	84	71.2	45	76.3	1.00			
Priority control intersection	20	16.9	6	10.2	0.58	0.28	1.22	0.152
Roundabout intersection	5	4.2	3	5.1	1.13	0.34	3.80	0.844
Traffic signal intersection	9	7.6	5	8.5	1.03	0.30	3.48	0.966
Surface type								
Smooth	114	96.6	57	96.6	1.00			
Rough	4	3.4	2	3.4	1.00	0.59	1.69	1.000
Surface condition								
Dry	103	87.3	51	86.4	1.00			
Wet	15	12.7	8	13.6	1.06	0.75	1.50	0.739
Roadway alignment								
Straight	110	93.2	47	79.7	1.00			
Curved	8	6.8	12	20.3	3.24	1.52	6.90	0.002*
Gradient								
Level	104	88.1	54	91.5	1.00			
Sloped	14	11.9	5	8.5	0.71	0.24	2.09	0.530
Divided road								
Not divided	62	52.5	31	52.5	1.00			
Divided	56	47.5	28	47.5	1.00	0.56	1.78	1.000
Median type								
None	62	52.5	31	52.5	1.00			
Non-physical	23	19.5	7	11.9	0.64	0.29	1.43	0.277
Physical	33	28.0	21	35.6	1.25	0.58	2.71	0.564
Traffic islands								
No	90	76.3	43	72.9	1.00			
Yes	28	23.7	16	27.1	1.18	0.57	2.45	0.652
Lanes in direction of travel								
1 lane	83	70.3	38	64.4	1.00			
2 lanes	25	21.2	12	20.3	1.04	0.50	2.17	0.915
≥ 3 lanes	10	8.5	9	15.3	1.88	0.65	5.43	0.244

Width in direction of travel								
<4.0 m	34	28.8	19	32.2	1.00			
4.0-7.0 m	58	49.2	20	33.9	0.65	0.34	1.27	0.208
>7.0 m	26	22.0	20	33.9	1.38	0.57	3.35	0.478
Left lane width								
<3.0 m	10	8.5	7	11.9	1.00			
3.0-3.5 m	58	49.2	27	45.8	0.69	0.24	1.97	0.490
>3.5 m	50	42.4	25	42.4	0.74	0.27	2.05	0.562
Traffic density								
Free flow, no lead traffic	103	87.3	56	94.9	1.00			
Leading traffic or restricted flow	15	12.7	3	5.1	0.39	0.12	1.29	0.123
Construction zone								
No	117	99.2	54	91.5	1.00			
Yes	1	0.8	5	8.5	9.09	1.38	60.00	0.022*
Traffic calming								
None	115	97.5	57	96.6	1.00			
Slow point or speed hump	3	2.5	2	3.4	1.30	0.37	4.61	0.687
Adjacent Parking								
No	105	89.0	50	84.7	1.00			
Yes	13	11.0	9	15.3	1.41	0.73	2.73	0.313
Bicycle lane								
No	89	75.4	44	74.6	1.00			
Yes	29	24.6	15	25.4	1.04	0.53	2.06	0.903

[a] Unadjusted OR (odds ratios) from GEE logistic regression accounting for clustering of sites within trips. Not controlling for any other variables * significant at p<0.05

None of the other characteristics in Table 6.17 were significantly associated with the risk of an unsafe event. For both control sites and unsafe event (case) sites, the highest proportion were located at midblocks, on smooth, level roads with dry surfaces, on undivided roads with no median, had one lane in the direction of travel, had left lane widths of 3.0 metres or greater and widths in the direction of travel of 4.0 metres or greater. In addition, the highest proportion of control and unsafe event (case) sites had free flowing traffic with no lead traffic and no adjacent parking. Approximately one quarter of control and unsafe event (case) sites had raised traffic islands and one quarter had bicycle lanes. Only a small proportion of sites were located at slow points or speed humps (Table 6.17).

6.3.6 Multivariate GEE logistic regression model: unsafe event sites not involving a motor vehicle

Table 6.18 presents the results of the multivariate GEE logistic regression model examining variables associated with the risk of an unsafe event which did not involve a motor vehicle. *'Unsafe event site'* (no: control site, yes: case site) was entered as the dependent variable. Variables considered for inclusion as independent variables/ confounding factors were based on findings from the limited literature on factors associated with individual rider and rider/ rider crashes. These were: *'rider proximity'*, *'roadway alignment'* and *'construction zone'* (Biegler et al., 2012; Boufous et al., 2012; Schepers & Klein Wolt, 2012; J. W. Shaw, Chitturi, Han, Bremer, & Noyce, 2016). Other variables which had p-values less than 0.25 in the univariate analyses were also considered for the model. These were *'number of riders', 'rider manoeuvre', 'rider speed', 'group position', 'traffic control', 'lanes in direction of travel', 'width in direction of travel'* and *'traffic density'*.

From the literature *'rider proximity'*, *'roadway alignment'* and *'construction zone'* were entered in the model and these were all significant. Multicollinearity between all independent variables considered for inclusion in the model was again checked using Pearson Chi-Square, Fisher's Exact and t-tests and several variables were significantly associated. *'Rider manoeuvre'* was significantly associated with *'roadway alignment'* ($p<0.001$) and *'traffic control'* ($p=0.003$). *'Traffic control'* was also significantly associated with *'width in the direction of travel'* ($p<0.001$) and *'traffic density'* ($p=0.028$). The effect of each of these variables on the fit of the model was examined and *'rider manoeuvre'* and *'traffic control'* were eliminated.

Each remaining variable listed above (*'number of riders', 'rider speed', 'group position', 'lanes in direction of travel', 'width in direction of travel'* and *'traffic density'*) was then separately added to the model and it was assessed if the variable was significant and/or it improved the fit of the model ($p<0.05$). Model fit was again determined using the QIC and QICC values computed in SPSS (Cui & Qian, 2007; Pan, 2001). Only *'traffic density'* improved the fit of the model so was the only variable retained. Interactions between the main effects on group riding crashes in the binary logistic regression models were investigated and none were found to be significant.

The QIC and QICC values also confirmed that the exchangeable correlation matrix provided the best model (QIC: 134.56, QICC: 138.71).

The final multivariate GEE model included the following independent variables: *'rider proximity'* (close proximity, staggered), *'roadway alignment'* (straight, curved), *'construction zone'* (no, yes) and *'traffic density'* (free flow no lead traffic, leading traffic or restricted flow).

Table 6.18 Multivariate GEE logistic regression model for unsafe event (case) sites not involving a motor vehicle (n=59) and control sites (n=118)

Variable	Adjusted OR	Standard Error	95% CI		p-value
Intercept	0.58	0.11	0.47	0.71	<0.001
Rider proximity					
Close proximity (<3m)	1.00				
Staggered (≥3m)	0.16	0.87	0.03	0.90	0.037*
Roadway alignment					
Straight	1.00				
Curved	3.29	0.50	1.22	8.83	0.018*
Construction zone					
No	1.00				
Yes	8.67	0.80	1.72	41.92	0.007*
Traffic density					
Free flow, no lead traffic	1.00				
Leading traffic or restricted flow	0.12	1.26	0.01	1.45	0.096

Quasi Likelihood under Independence Model Criterion (QIC): 134.555 and Corrected Quasi Likelihood under Independence Model Criterion (QICC); 138.706 * Significant at p<0.05

After controlling for confounding factors, riding staggered (at least three metres distance between the front and rear tyres of other riders in the group) significantly reduced the risk of an unsafe event which did not involve a motor vehicle, compared to riding in close proximity (OR: 0.16, 95% CI: 0.03-0.90, p=0.037). Curved roads increased the risk of an unsafe event by over three times, compared to straight roads (OR: 3.29, 95% CI: 1.22-8.83, p=0.018). Construction zones also significantly increased the risk of unsafe events by over eight times (adjusted OR: 8.67, 95% CI: 1.72-41.92, p=0.007). Finally, traffic density was not significantly associated with the risk of an unsafe event (Table 6.18).

6.4 Part C: Group rider violations

Section 6.4 describes the results of the cross-sectional study examining group and trip-related factors associated with group rider traffic violations. Descriptive statistics are provided for *'red light violations'*, *'stop sign violations'* and *'other violations'*. Multivariate analyses are performed only for *'other violations'* since there were adequate numbers of these violations.

6.4.1 Naturalistic video footage for group rider violations

The cross-sectional analysis of group rider violations included only the footage where both the front and rear cameras were operating simultaneously. Table 6.19 presents the naturalistic data included in Part C of Phase 2. A total of 91 trips (72.2%) recorded by 33 different groups had at least 20 minutes of eligible footage and were included. The duration of eligible footage per trip ranged from 20 minutes to 106 minutes with an average of 58.5 minutes (SD: 22.2). From the 91 trips, there was a total of 88.7 hours of video footage from both cameras. There were 64 *'red light violations'*, 103 *'stop sign violations'* and 232 *'other violations'* observed in the footage. For the analysis of *'red light violations'*, 91 trips during which there were any red lights, were included. For the analysis of *'stop sign violations'*, 58 trips in which there were any stop signs, were included. For the analysis of *'other violations'*, all 91 trips were included.

Table 6.19 Naturalistic data included for Part C – traffic violations

Data collected	
Total violations observed (n)	399
• *Red light violations*	*64*
• *Stop sign violations*	*103*
• *Other violations*	*232*
Group riding trips (n)	91
Riding groups (n)	33
Eligible video footage (hours)	88.7

6.4.2 Red light violations

'Red light violations' were recorded if any rider in the group proceeded beyond the stop line when the traffic control signal was displaying a red light or arrow. A total of 537 red lights were encountered (riders were required to stop at the red traffic light) during the 91 eligible trips and a *'red light violation'* occurred at 64 (11.9%) of these traffic lights. Groups in each of the 91 trips encountered at least one red traffic light and 19 of the 33 groups (57.6%) committed a violation at least one red traffic light. Due to the low number of *'red light violations'* and small number of these violations per group, only descriptive analyses were performed for *'red light violations'*.

6.4.2.1 Characteristics of red light violations

Table 6.20 describes the characteristics of the 64 *'red light violations'* compared to the 473 red lights where there was no violation. The majority of *'red light violations'* (n=38, 59.4%) and red lights with no violation (n=315, 66.6%) involved the group travelling straight at the intersection (p=0.224). The majority of *'red light violations'* (n=51, 79.7%) and red lights with no violation (n=393, 83.1%) also occurred on weekends (p=0.500). The average number of riders was 19.7 riders (SD: 9.9) for *'red light violations'* and 17.6 (SD: 9.3) for red lights with no violation (p=0.091).

Table 6.20 Characteristics of red light violations and red lights with no violation

Characteristic	No red light violation (n=473)		Red light violation (n=64)		p-value
	N	%	N	%	
Direction of travel					
Straight	315	66.6	38	59.4	
Turning left	87	18.4	11	17.2	
Turning right	71	15.0	15	23.4	0.224 [a]
Day of week					
Weekend	393	83.1	51	79.7	
Weekday	80	16.9	13	20.3	0.500 [a]
Number of riders (mean, SD)	17.6	9.3	19.7	9.9	0.091 [b]

[a] p-values from chi-square tests [b] p-value from t-test

6.4.2.2 Types of red light violations

The majority of the 64 *'red light violations'* (n=52, 81.3%) involved the leading rider/s entering the intersection while the traffic lights were green but at least one of the following riders in the group entering the intersection after the lights turned red, in order to stay with the group.

- Ten of these 52 violations (19.2%) occurred when the group had been stopped at a red light, entered the intersection when it turned green but the traffic light turned red again before all riders made it to the entry of the intersection;

The remaining 12 *'red light violations'* (18.8%) involved the leading rider/s in the group entering the intersection while the traffic light was red.

- Five (41.7%) of these occurred when a green light turned amber/ red when approaching;
- Three (25.0%) involved the rider/s entering the intersection on a red light, remaining stationary, then waiting for a green light to continue through the intersection;
- Three (25.0%) involved the rider/s purposely riding through a light that was already red on approach;
- One violation (8.3%) involved the road sensor not detecting the group waiting at the red light and after a long period, they rode through the red light.

One of the 64 *'red light violations'* resulted in an unsafe event occurring. This involved group riders who committed the red light violation, being in the path of a bus entering the intersection on a green light.

6.4.3 Stop sign violations

'Stop sign violations' were recorded if any rider in the group did not come to a complete stop at or as near as practicable to the stop line associated with a stop sign. There was a total of 129 stop signs during 58 trips and a *'stop sign violation'* occurred at 103 (79.8%) of these. A total of 25 groups encountered at least one stop sign and 23 groups (92.0%) committed at least one *'stop sign violation'*.

6.4.3.1 Characteristics of stop sign violations

Table 6.21 describes the characteristics of the 103 *'stop sign violations'* compared to the 26 stop signs where no violation occurred. A higher proportion of *'stop sign violations'* occurred when the group was turning left (n=56, 54.4%), compared to stop signs where no violation occurred (n=7, 26.9%) and a higher proportion of stop signs where no violation occurred involved the group turning right (n=11, 42.3%), compared to violations (n=21, 20.4%). These differences were statistically significant (p=0.024). The majority of *'stop sign violations'* (n=69, 67.0%) and stop signs where no violation occurred (n=17, 65.4%) took place on weekends (p=0.877). The average number of riders was 14.4 (SD: 8.6) for stop sign violations and 13.3 (SD: 6.7) for stop signs where no violation occurred (p=0.557).

Table 6.21 Characteristics of stop sign violations and stop signs where no violation occurred

Characteristic	No stop sign violation (n=26)		Stop sign violation (n=103)		p-value
	N	%	N	%	
Direction of travel					
Straight	8	30.8	26	25.2	
Turning left	7	26.9	56	54.4	
Turning right	11	42.3	21	20.4	0.024 [a] *
Day of week					
Weekend	17	65.4	69	67.0	
Weekday	9	34.6	34	33.0	0.877 [a]
Number of riders (mean, SD)	13.3	6.7	14.4	8.6	0.557 [b]

[a] p-values from chi-square tests [b] p-values from t-tests * significant at p<0.05

6.4.3.2 Circumstances of stop sign violations

All 26 incidents where there was no *'stop sign violation'*, involved riders having to stop and wait for traffic approaching from another direction in order to enter the intersection safely. All of the 103 *'stop sign violations'* did not involve close approaching traffic requiring riders to stop before entering the intersection safely. None of the 103 *'stop sign violations'* resulted in an unsafe event. It was apparent that all groups in the study consistently treated stop signs as give way signs and this was not indicative of group riding characteristics. Groups only came to a complete stop at stop signs if there was approaching traffic that required them to wait. Therefore, no further analyses were undertaken.

6.4.4 Other violations

Footage from all 91 eligible trips from 33 groups was included for *'other violations.'* There was a total of 232 *'other violations'* observed in the 88.7 hours of eligible video footage (2.6 *'other violations'* per hour). *'Other violations'* occurred in 62 of the trips (68.1%) and were committed by 30 of the groups (90.9%). Each trip had between zero and 32 *'other violations'* with a median of one violation (interquartile range (IQR)=3.0). Each group had between zero and 41 *'other violations'* with a median of five violations (IQR= 6.5).

6.4.4.1 Type of other violations

Table 6.22 presents the types of *'other violations'* observed in the video footage that were included in this study. The most common *'other violation'* was *'riding more than two abreast'* (n=156, 67.2%). These violations most commonly occurred for short durations and no groups rode more than two abreast for the entire ride. The next most frequent violation was *'riding on the wrong side of the road'* (n=44, 19.0%). These violations occurred in a variety of situations including on corners and when travelling to and from an off-road path. Fifteen additional violations (6.5%) involved riding both *'more than two abreast and on the wrong side of the road'*. There were also 12 *'right of way violations'* (5.2%), eight of which occurred at roundabouts, two at pedestrian crossings, one at a give-way sign and one at a stop sign. Finally, five violations (2.2%) involved riding in the wrong direction on a one-way street (*'one-way sign violation'*). Overall, 10 *'other violations'* (4.3%) were associated with unsafe events. This included five *'right of way'*, four *'wrong side of road'* and one *'riding more than two abreast'* violation.

Table 6.22 Types of other violations observed in the naturalistic video footage

Violation type	N=232	%
Riding more than two abreast	156	67.2
Riding on the wrong side of the road	44	19.0
Riding more than two abreast and on the wrong side of the road	15	6.5
Right of way violation	12	5.2
Riding the wrong direction on a one-way street	5	2.2

6.4.4.2 Characteristics of groups

The researcher-administered questionnaire collected in-depth information on several group-related characteristics which may be associated with *'other violations'* committed by group riders. These characteristics remained constant across each trip recorded by a specific group. As described in the Methods (section 5.3.6.1), five of the characteristics consistently resulted in the same responses within groups and these were: *'cost'*, *'uniform'*, *'written code of conduct'*, *'designated ride leader'* and *'committee/ business'*. These variables were replaced with a single variable *'organisational structure'*. Table 6.23 presents the group characteristics by *'organisational structure'* for the 33 groups. The five variables which resulted in consistent responses described above are presented first. All six groups which had a *'formal'* organisational structure (cycling clubs, charity training rides and paid training groups) had a cost, a uniform, a written code of conduct, a designated ride leader and a committee or were an incorporated business. All 10 of the groups which had an *'informal'* organisational structure (groups of friends) did not have a cost, uniform, written code of conduct, designated ride leader, or committee/ incorporated business. The 17 groups which had a *'semi-formal'* organisational structure (bike shops, cafes, Facebook groups and former charity ride groups) had a mix of these characteristics. The other four characteristics (*'open/ closed membership'*, *'drop riders'*, *'sprint points'* and *'group purpose'*) showed varied responses in terms of organisational structure and are also presented in Table 6.23. See the Methods, section 5.3.6.1 for definitions of group characteristics.

Table 6.23 Group characteristics by organisational structure of the group

Group characteristic	Organisational structure of group (n=33 groups)					
	Informal		Semi-formal		Formal	
	N=10	%	N=17	%	N=6	%
Cost						
No	10	100.0	17	100	0	0.0
Yes	0	0.0	0	0	6	100.0
Uniform						
No	10	100.0	3	17.6	0	0.0
Yes	0	0.0	14	82.4	6	100.0
Code of conduct						
No	10	100.0	14	82.4	0	0.0
Yes	0	0.0	3	17.6	6	100.0
Ride leader						
No	10	100.0	11	64.7	0	0.0
Yes	0	0.0	6	35.3	6	100.0
Committee or business						
No	10	100.0	17	100	0	0.0
Yes	0	0.0	0	0	6	100.0
Membership						
Closed	7	70.0	1	5.9	5	83.3
Open	3	30.0	16	94.1	1	16.7
Drop riders						
No	10	100.0	9	52.9	5	83.3
Yes	0	0.0	8	47.1	1	16.7
Sprint points						
No	5	50.0	6	35.3	3	50.0
Yes	5	50.0	11	64.7	3	50.0
Group purpose						
Social and training	4	40.0	14	82.4	5	83.3
Social only	6	60.0	3	17.6	1	16.7

6.4.4.3 Group characteristics and number of other violations

Table 6.24 presents the number and percentage of *'other violations'* (n=232) by each of the riding group characteristics described above. The majority of *'other violations'* were committed by semi-formal groups (n=130, 56.0%), followed by formal groups (n=72, 31.0%) and informal groups (n=30, 12.9%). The majority of *'other violations'* were also committed by groups which had open membership (n=159, 68.5%), did not drop riders (n=124, 53.4%), had sprint points on their rides (n=193, 83.2%) and had social and training purposes (n=195, 84.1%)

Table 6.24 Number of other violations by group characteristics

Group characteristic	Other violations	
	N=232	%
Organisational structure		
Semi-formal	130	56.0
Informal	30	12.9
Formal	72	31.0
Membership type		
Closed	73	31.5
Open	159	68.5
Drop riders		
No	124	53.4
Yes	108	46.6
Sprint points		
No	39	16.8
Yes	193	83.2
Group purpose		
Social and training	195	84.1
Social only	37	15.9

6.4.4.4 Group characteristics and rate of other violations

Table 6.25 presents the average number of *'other violations'* per hour (after replacement of outlier values), by riding group characteristics. Second, unadjusted IRRs and 95% CIs obtained from GEE negative binomial regression are presented. These were calculated individually for each variable, not controlling for other variables.

Compared to trips undertaken by *'semi-formal'* groups, *'informal'* groups (IRR: 0.53, 95% CI: 0.31-0.93, p=0.026) and *'formal'* groups (IRR: 0.54, 95% CI 0.30-0.99, p=0.048) had approximately half the rate of *'other violations'* (Table 6.25). Trips undertaken by groups which had sprint points had 2.5 times the rate of *'other violations'* (IRR: 2.47, 95% CI: 1.51-4.82, p=0.001), compared to groups which did not have sprint points. Group membership type, whether the group dropped riders, and group purpose were not significantly associated with the rate of *'other violations'* per trip.

Table 6.25 Rate of other violations and IRRs for group-related characteristics (n=91 trips)

Group characteristic	Other violations per hour		IRR[a]	95% CI		p-value
	Mean	SD				
Organisational structure						
Semi-formal	3.42	2.91	1.00			
Informal	2.01	2.36	0.53	0.31	0.93	0.026*
Formal	1.67	1.85	0.54	0.30	0.99	0.048*
Membership type						
Closed	1.93	2.36	1.00			
Open	2.65	2.51	1.32	0.77	2.29	0.316
Drop riders						
No	2.02	2.41	1.00			
Yes	2.91	2.46	1.49	0.86	2.58	0.156
Sprint points						
No	1.17	1.94	1.00			
Yes	3.11	2.47	2.70	1.51	4.82	0.001*
Group purpose						
Social and training	2.65	2.50	1.00			
Social only	1.63	2.24	0.72	0.37	1.38	0.326

[a] Unadjusted IRRs (incident rate ratios) from GEE negative binomial regression accounting for clustering of trips within groups and with ln(hours of eligible footage per trip) as the offset variable. Not controlling for any other variables. * significant at p<0.05

6.4.4.5 Trip characteristics and rate of other violations

There were a number of characteristics which may be associated with the rate of *'other violations'*, which varied from trip to trip, even within the same riding group. These included *'day of the week'* and *'average number of riders'* per trip. In addition, the self-reported variables *'usual distance travelled'* and *'average speed'* could also vary between trips within a group.

The average speed per trip was 29.8 km/h (SD: 5.0) and for every one km increase in average speed, the rate of *'other violations'* significantly increased by 1.06 times (IRR: 1.06, 95% CI: 1.02-1.12, p=0.010). The average number of riders per trip was 14.8 (SD: 8.7) and for each increase of one rider, the rate of *'other violations'* significantly increased by 1.04 times (IRR: 1.04, 95% CI: 1.02-1.06, p<0.001).

The average usual distance travelled per trip and day of the week were not significantly associated with rate of *'other violations'* per trip (Table 6.26).

Table 6.26 Trip-related characteristics and IRRs for rate of other violations (n=91 trips)

Trip characteristic	Mean	SD	IRR[a]	95% CI		p-value
Usual distance travelled	61.70	16.25	1.00	0.99	1.01	0.563
Average speed	29.81	4.97	1.06	1.02	1.12	0.010*
Average number of riders	14.77	8.70	1.04	1.02	1.06	<0.001*
Day of week						
Weekend	2.48[b]	2.56	1.00			
Weekday	1.99[b]	2.24	0.84	0.58	1.23	0.374

[a] Unadjusted IRRs (incident rate ratios) from GEE negative binomial regression accounting for clustering of trips within groups and with ln(hours of eligible footage per trip) as the offset variable. Not controlling for any other variables

[b] Mean number of other violations per hour * significant at p<0.05

6.4.4.6 Multivariate GEE negative binomial regression model: other violations

Table 6.27 presents the results of the multivariate GEE negative binomial regression model examining group and trip characteristics associated with rate of *'other violations'*. Group-level variables considered for inclusion as independent variables in the model were those with p-values of less than 0.25 in the univariate analyses. These were *'organisational structure', 'drop riders'* and *'sprint points'*. Model fit using QIC and QICC values as well as the significance of the co-variates were examined for each of the three variables separately and in combination. *'Drop riders'* worsened the fit of the model so was not included. *'Organisational structure'* and *'sprint points'* were retained in the model.

Trip-level variables considered for inclusion in the model were based on findings from the limited literature on factors associated with rider violations. These were *'average speed'* and *'average number of riders'* (Johnson et al., 2009; WestCycle, 2017a). These factors may also increase the opportunity for violations and were the only trip-level variables with p-values <0.25 in the univariate analyses. Multicollinearity between all independent variables considered for inclusion in the model was checked using Pearson Chi-Square or Fisher's Exact tests (two categorical variables), t-tests (one categorical, one continuous variable) and Pearson correlation coefficients (two continuous variables). *'Average speed'* was significantly associated with *'organisational structure'* (p=0.022), *'sprint points'* (p<0.001) and *'average number of riders'* (r= 0.34, p=0.001). The impact of *'average speed'* and the other variables on model fit were compared and *'average speed'* was eliminated. When added to the model containing *'organisational structure'* and *'sprint points'*, *'average number of riders'* was significant and improved the fit of the model (p<0.05), so was retained.

Interactions between the main effects on rate of *'other violations'* in the model were investigated. Two-way interaction terms were tested in the model for each different combination of the significant main effects. None of the interaction terms were significant. The QIC and QICC values also confirmed that the exchangeable correlation matrix provided a better (though similar) model (QIC: 77.6, QICC: 82.5) than the independent, AR(1) or unstructured correlation matrix.

The final multivariate GEE model included the following independent variables: *'organisational structure'* (semi-formal, informal, formal), *'sprint points'* (no, yes) and *'average number of riders'* (count).

After controlling for potential confounding factors, *'formal'* riding groups had less than half the rate of *'other violations'* (IRR: 0.46, 95% CI: 0.29-0.73, p=0.001), compared to *'semi-formal'* riding groups. There were no significant differences between *'informal'* and *'semi-formal'* groups (p=0.273) or between *'informal'* and *'formal'* groups (p=0.150) in terms of rate of *'other violations'*. Trips involving groups which had sprint points had over twice the rate of *'other violations'* (IRR: 2.28, 95% CI: 1.38-3.78, p=0.001), compared to groups which did not have sprint points. Finally, as the average number of riders per trip increased by one, the rate of *'other violations'* significantly increased by 1.03 times (IRR: 1.03, 95% CI: 1.01-1.04, p=0.003) (Table 6.27).

Table 6.27 Multivariate GEE negative binomial regression model for rate of other violations per trip (n=91 trips)

Variable	Adjusted IRR	Standard Error	95% CI		p-value
Intercept	1.22	0.22	0.79	1.88	0.371
Organisational structure					
Semi-formal	1.00				
Informal	0.73	0.28	0.42	1.28	0.273
Formal	0.46	0.24	0.29	0.73	0.001*
Sprint points					
No	1.00				
Yes	2.28	0.26	1.38	3.78	0.001*
Average number of riders	1.03	0.01	1.01	1.04	0.003*

Quasi Likelihood under Independence Model Criterion (QIC): 77.6 and Corrected Quasi Likelihood under Independence Model Criterion (QICC); 82.5 * significant at p<0.05

Since the *'organisational structure'* variable was based on five group characteristics (cost, committee/ incorporated business, written code of conduct, designated ride leader and uniform), it was of interest to determine which of these specific characteristics were associated with the rate of *'other violations'* per trip. To do this *'organisational structure'* was removed and the multivariate model was run with each of the five characteristics entered separately. When controlling for sprint points and average number of riders, cost to ride with the group (IRR:0.50, 95% CI: 0.31-0.81, p=0.005), the group having a committee or being an incorporated business (IRR:0.50, 95% CI: 0.31-0.81, p=0.005) and the group having a written code of conduct (IRR: 0.61, 95% CI: 0.39-0.95, p=0.030) were all significantly associated with a reduced rate of *'other violations'* per trip. The QIC and QICC values for these models (model fit) were all very similar to the model which included *'organisational structure'*. In addition, sprint points and average number of riders remained significant in each of the three models. Having a uniform available (IRR: 1.17, 95% CI: 0.69-1.99, p=0.563) and having a designated ride leader (IRR: 0.97, 95% CI: 0.59-1.60, p=0.903) were not significantly associated with the rate of *'other violations'* per trip.

CHAPTER 7

Discussion

7 DISCUSSION

Overall, this study aimed to gain a better understanding of safety issues for group riders in Perth, WA. To our knowledge, this was the first in-depth crash study to specifically compare the characteristics of crashes that occurred while group riding, to individual rider crashes. This was also the first naturalistic study to use bicycle-mounted video cameras to examine safety issues for group riders. Chapter seven discusses the results of Phase 1 and 2 in detail and compares findings with other published research. Interventions that may improve group rider safety are suggested throughout the chapter in relation to the relevant components of the Safe System Framework used in WA (described in section 2.1.3), including *'safer road users'* and *'safer roads and roadsides'* (Road Safety Council, 2009).

7.1 Phase 1: In-depth bicycle crash study

Phase 1 consisted of an in-depth crash study of 108 riders who experienced an on-road crash resulting in hospitalisation. Detailed information was collected from participant questionnaires and virtual crash site inspections and compared rider, injury, crash, road environment and contributing factors for 37 group rider and 71 individual rider crashes. Very little evidence previously existed on the characteristics of group rider crashes because whether a rider was alone or in a group is not typically recorded in Police crash or hospital records. The main findings of Phase 1 were:

- Group rider crashes were more likely to involve road-related contributing factors, than individual rider crashes.
- Those who did not participate in group riding before the crash, were at increased risk of reduced cycling exposure 12 months after the crash.

7.1.1 Group rider crashes

Firstly, the in-depth study revealed that a significant proportion (34%) of bicycle crashes resulting in hospitalisation, occurred while riding with at least one other known rider (group riding). The Victorian arm of the ARC-funded study reported that 19% of hospitalisation crashes involved *'bunch riding'* (B. Beck et al., 2016), however *'bunch riding'* was not defined. Otherwise, the proportion of bicycle crashes that involve group riding has not been previously reported. This finding highlights that group rider crashes are a common and significant issue that has largely been ignored in the literature and in road safety research, policy and practice.

7.1.2 Demographic, cycling and trip characteristics

Overall, the demographic and cycling characteristics of participants involved in group rider and individual rider crashes were quite similar. However, the results highlighted that a large proportion of crashes occurred on cycling trips undertaken for recreation purposes (69%), as opposed to commuting or utilitarian purposes. This contrasts with findings from Police data in Victoria and survey data in NSW which reported a higher number of crashes with commuter/ transport cycling (Garratt, Johnson, & Cubis, 2015; Poulos et al., 2015b). This difference may be due to less recreational than commuter cycling crashes being reported to Police and/ or a larger proportion of commuter crashes occurring on shared paths in WA (which were not included in this study), rather than roads (Department of Transport, 2014). It is important to note that some of the observed differences between group rider and individual rider crashes in this study may be due to the higher proportion of riding for training/ recreational purposes among group riders.

7.1.3 Injury characteristics

In this study, injuries resulting from group and individual rider crashes were similar in terms of severity and body region injured. This finding was interesting since more individual rider crashes (58%) involved a motor vehicle, compared to group rider crashes (16%). While this may be due to the strict exclusion criteria of this study, a Victorian study using Police and hospitalisation data also found that injuries associated with on-road single-vehicle bicycle crashes were as severe as multi-vehicle crashes (Boufous, de Rome, Senserrick, & Ivers, 2013). In contrast, an online survey of Queensland cyclists which included all severities of injuries, reported that motor vehicle involvement increased the risk of serious injury (Heesch, Garrard, et al., 2011). The contrasting findings may be due to the current study and the Victorian study only including on-road crashes resulting in hospitalisation. In addition, the Queensland study reported that bicycle crashes involving another rider/ pedestrian/ animal also increased the risk of serious injury, compared to falling off the bike (Heesch, Garrard, et al., 2011). Since more group rider crashes involved another rider, this may also explain the similar injury characteristics between the two groups. To further the understanding of the injury outcomes resulting from group rider crashes, future research should also include lower severity crashes requiring an ED visit only.

7.1.4 Road environment characteristics

This study highlighted some important differences in road characteristics for crash sites involving group riders, compared to individual riders. For example, significantly more group rider crashes occurred at midblocks (65%), compared to individual rider crashes (41%). Two studies examining group rider crashes in Victoria similarly reported that 57-63% occurred at midblock sites (Biegler et al., 2012; Johnson et al., 2009). The contrast with individual rider crashes is probably because group rider crashes are more likely to involve another rider and less likely to involve a motor vehicle at an intersection (B. Beck et al., 2016). It is also possible that more group rider crashes occur at midblocks since this may be where they undertake training activities such as riding two abreast, *'rolling'* and sprinting. These activities involve riding in close proximity, at higher speeds and performing precise manoeuvres, which may increase the vulnerability of group riders to unsafe road conditions at midblocks and warrants further research. In line with the *'safer roads and roadsides'* component of the Safe System Framework, this finding highlights the importance of ensuring safe, well maintained midblocks which are free of debris and hazards, for group riders.

The study also found that a significantly larger proportion of group rider crashes occurred in land use areas other than urban or central city (38%), compared to individual rider crashes (14%). This likely reflects the recreational nature of group riding trips which commonly take place on coastal and riverside routes in metropolitan Perth. In addition, longer rides often travel outside urban areas to parks/ recreation and State forest land use areas, e.g. the Perth Hills area. A significantly larger proportion of group rider crashes also occurred on roads with speed limits of ≥70 km/h (30%), compared to individual rider crashes (9%). Since only a small proportion of group rider crashes in this study involved motor vehicles, this finding likely reflects the greater exposure of group riders to higher speed roads including those located outside of urban land use areas. These findings further indicate that providing *'safer roads and* *roadsides'* on popular recreational cycling routes within metropolitan Perth and on the outskirts of the urban area could provide safety benefits for group riders.

7.1.5 Group riding crash types

This study also provided new information about the different types of group riding crashes. Interestingly, only a small proportion (16%) of group rider crashes involved a collision with a motor vehicle, compared to 58% of individual rider crashes. These crashes commonly involved a failure of the motor vehicle to give way at an intersection. It is important to note that five of the six group rider crashes involving a motor vehicle involved groups of only two riders, with the sixth involving a small group of five riders. This suggests that riding in larger groups may reduce the risk of a crash involving a motor vehicle due to increased size and visibility to motorists.

The *'safety in numbers'* effect originally proposed that more cyclists on the road results in better cyclist safety outcomes due to motorists learning to drive safely around them (Beanland, Lenne, & Underwood, 2014; Jacobsen, Ragland, & Komanoff, 2015). However, more recent studies have suggested that an important causal mechanism behind the *'safety in numbers'* effect is actually the formation of higher-density cyclist groups resulting from increasing numbers of cyclists on the road, or rather a *'safety in density'* effect (Thompson et al., 2018). Studies on *'safety in density'* have examined individual riders only but have reported a reduced risk of crashes involving motor vehicles with increased cyclist density (Thompson, Savino, & Stevenson, 2015; Thompson et al., 2018). It is therefore possible that group-riding reduces the risk of a crash involving a motor vehicle due to the increased density of riders involved.

Despite the possibly lower risk of a motor vehicle crash while group riding, crashes involving collisions with other riders in the group were very common (38%). As mentioned, bicycle crashes which involve other road users result in more severe injuries than falling off the bike (Heesch, Garrard, et al., 2011). These findings as well as those from the Victorian arm of the study (B. Beck et al., 2016), suggest that rider/ rider crashes are common among group riders and have the potential to result in serious injury. Therefore, under the Safe System pillar of *'safe roads and roadsides'*, countermeasures such as road maintenance on group riding routes could reduce these types of crashes. In addition, rider training for group riders on skills, safe riding practices and avoidance of crashes involving another rider, could represent an effective countermeasure. This comes under the Safe System component of *'safer road users'* and could either be run through formal training programs or informally by group riding leaders.

Finally, a frequent crash type involved the rider hitting an object on the road or losing control of the bicycle on the carriageway, resulting in a crash. This confirms previous reports of the significance of single vehicle bicycle crashes (B. Beck et al., 2019; Boufous et al., 2013), since they can result in serious injuries for both group and individual riders. A possible explanation for the lower proportion of loss of control on carriageway: no object hit crashes among group riders, compared to individual riders may be because when riders lose control in a group, it can result in a collision with another rider. Unfortunately, this information could not be collected.

7.1.6 Factors contributing to group riding crashes

This study also compared the involvement of human, environmental and vehicle-related factors in group and individual rider crashes. The main finding was that group rider crashes were over three times more likely to involve road-related contributing factors than individual rider crashes. Very few studies have conducted in-depth analyses of the factors contributing to bicycle crashes. Two Belgian studies of commuter and adolescent rider crashes also reported that poorly maintained infrastructure or surfaces (e.g. tracks, loose gravel, steel plates) contributed to over 20% of the crashes (de Geus et al., 2012; Vanparijs et al., 2016). This is consistent with the findings of this study for individual rider crashes.

There are several possible explanations for why group riders may be more vulnerable to road-related hazards than individual riders. The nature of group riding often involves travelling at high speeds, in close proximity to the other riders, sometimes while *'rolling'* (Figure 2.1) (WestCycle, 2017a). This means that rider visibility of the road ahead is obscured by other riders in the group, reducing their ability to detect road-related hazards. In addition, the high speeds and close proximity gives riders less time and opportunity to respond to and manoeuvre around hazards on the road, resulting in a hit object or rider/ rider crash (Albert, 1999).

These findings suggest that interventions targeting the *'safer roads and roadsides'* and *'safer road users'* components of the Safe Systems Framework could be effective in reducing group rider crashes. As previously suggested, targeting popular recreational riding routes for treatments could improve safety for group riders. These treatments may include simple road surface repair/ maintenance measures as well as clearing of temporary hazards on these roads. In addition, group rider training on detecting, communicating and calling hazards could also reduce crashes involving road-related factors. Since over half of group rider crashes involved road-related factors, these measures have the potential to prevent around half of the crashes that occur while group riding.

7.1.7 Reduced cycling exposure 12 months after crash

The Phase 1 follow-up study examined factors associated with reduced cycling exposure 12 months after the hospitalisation crash. Results found that those who did not participate in group riding before the crash had nearly four times the risk of reduced cycling exposure at follow-up, even after controlling for their level of function 12 months after the crash.

Reasons for this finding may include that group riders who participate in cycling for social, enjoyment or training reasons, may be more likely to return to cycling than commuters who can choose other transport options. It should be noted that group riders were defined as those who rode with a group of five or more riders before the crash, so represents a different group to those defined as group riders in Part A. Anecdotal evidence also suggests that for more serious group riders, involvement in a crash may be a normalised or expected part of participation, with other group members assuming the rider will return as soon as possible (Albert, 1999). An observational study in the USA also reported that serious club-level riders continue to train intensely despite pain or injury (Dahlquist, Leisz, & Finkelstein, 2015). While group riding does not have the same benefits as commuter cycling in terms of reducing traffic congestion and motor vehicle pollution (de Hartog et al., 2010), it has benefits for health and fitness

(Oja et al., 2011) and those who participate in cycling for leisure are more likely to also take up commuter cycling (Park, Lee, Shin, & Sohn, 2011). The findings of this study also suggest that group riders are less likely to give up or reduce their riding following involvement in a crash.

Overall, this study found reductions in cycling exposure one year after a hospitalisation crash. Since the WA government aims to increase cycling participation (B. Beck et al., 2016), this highlights the importance of preventing bicycle crashes. Since an earlier study reported that nearly 20% of cyclists experience PTSD, anxiety and/ or travel phobia in the year following a crash (Mayou & Bryant, 2003), better access to counselling may improve return to cycling rates. Finally, it is possible that participants may continue to increase their cycling participation after the 12-month follow up and it would be useful for future studies to examine cycling outcomes for longer periods following the crash.

7.1.8 Under-reporting of group riding crashes

This study found that only 40% of the bicycle crashes resulting in hospitalisation were recorded in the IRIS database, indicating they had been reported to the WA Police or the Insurance Commission of WA. A considerably lower proportion of group rider crashes (19%) were reported in the IRIS, compared to individual rider crashes (51%). The lower level of reporting of group riding crashes is most likely due to the majority not involving a motor vehicle. In WA, cyclists are required to report crashes to the Police if the incident resulted in bodily harm to any person or the total value of property damage exceeded $3000 (Insurance Commission of WA/ WA Police, 2017). However, the online crash reporting facility, a joint initiative of the Insurance Commission of WA and the WA Police, only allows the reporting of crashes involving a motor vehicle. Crashes not involving a motor vehicle need to be reported directly to Police and this likely explains the low reporting levels.

Under-reporting of bicycle crashes is a worldwide phenomenon (Shinar et al., 2018). A recent survey of cyclists in 17 countries including Australia, found that an average of only 10% of bicycle crashes resulting in some form of injury, were reported to Police. This was significantly higher when a motor vehicle was involved (25%) and also when the cyclist was hospitalised due to injury (38%) (Shinar et al., 2018). This reflects the findings of this study with a total of 40% of all hospitalised cyclists reporting the crash to the Police or the Insurance Commission of WA.

Our findings indicate that group-riding crashes are under-represented in current crash records. Therefore, it is likely that available crash data currently underestimates the prevalence and burden of group riding crashes in WA. This prevents potential countermeasures to reduce group-riding crashes being developed or implemented. Potential solutions include allowing bicycle crashes which do not involve a motor vehicle to be reported online, campaigns encouraging riders to report their crash and recording whether a cyclist was riding alone or with others at the time of the crash. This would allow comprehensive, large-scale investigations of group-riding crashes in WA, using Police crash data.

7.1.9 Strengths of Phase 1

There were several strengths of Phase 1 of the study. Most importantly, this was the first study to provide in-depth information on the differences in the characteristics and factors involved in group rider crashes, compared to individual rider crashes. The study also had a good participant response rate (85%) and the in-depth data collection methods allowed the group riding status of the cyclists at the time of the crash to be accurately identified. Previous studies describing group riding crashes have been limited by extremely small sample sizes and the likely inclusion of crashes that did not involve group riding in the analyses. The extensive self-reported data collected from the participant questionnaires, as well as the objective data collected from site inspections, crash records and State Trauma Registry, provided in-depth information on rider, crash site and injury characteristics. The inclusion of the objective data was a major strength of the study as it assisted in validating the self-reported data from cyclists.

The use of in-depth methods also allowed the inclusion of many crashes which would have been missed in crash databases due to the under-reporting of bicycle crashes, and group riding crashes in particular. It also enabled the analysis of contributing factors to group rider and individual rider crashes while controlling for many potential confounding factors. This has added substantially to the current body of knowledge. Finally, the prospective design was another strength of the study and minimal loss to follow-up was experienced (23%). This design permitted the examination of risk factors for reduced cycling exposure 12 months after the crash in Part B, which had not previously been examined.

7.1.10 Limitations of Phase 1

There were also limitations to Phase 1 of the study. Firstly, this study only compared group rider and individual rider crashes which occurred on-road. Since a substantial proportion of individual riding takes place on paths, it is important to note that crashes occurring on these paths may have quite different characteristics to those occurring on-road. Secondly, the cross-sectional design of the baseline crash analysis makes it difficult to establish cause and effect and findings can only be considered to be associations. In addition, the insignificance of some results and wider confidence intervals may be due to limited power resulting from the small sample size. The small sample size also meant it was impossible to perform logistic regression modelling to examine the association between group riding and *'road-related factors'* contributing to the crash, for crashes involving a motor vehicle separately. For the baseline analysis of crashes, riding in a group was defined as two or more riders. While it is likely that different safety issues and crash risks exist for smaller compared to larger groups, the sample size of this study was not large enough to compare the crash characteristics for different group sizes. This is an area requiring further research.

Another potential limitation was that the assessments of the human, environmental and vehicle factors involved in each crash were not strictly objective but were made by the researchers, based on the available data. However, the use of previously published contributing factor classification schemes and the requirement of agreement to be reached between two researchers minimised any potential bias. Finally, it should be noted that this study only included crashes that were severe enough to result in hospitalisation but not so severe that riders were unable to recall the events of the crash or resulted in a fatality. Therefore, the findings of this study may not apply to crashes resulting in fatal injuries, extremely severe injuries, or less severe injuries not requiring hospitalisation. The exclusion of fatal crashes may have meant that crash types resulting in more severe injuries were under-represented in this study. However, since there are approximately five fatal cyclist crashes in WA per year (Road Safety Commission, 2016), it is unlikely that this number would have had a major impact on the findings of the study. Future studies should also include crashes resulting in ED or GP presentations.

7.2 Phase 2: Naturalistic group riding study

Phase 2 consisted of a naturalistic study of unsafe events and traffic violations observed among group riders in Perth. Part A of Phase 2 examined unsafe events involving a motor vehicle, Part B examined unsafe events not involving a motor vehicle and Part C focused on traffic violations that occurred while group riding. The results of Phase 2 are discussed and compared and contrasted with the findings from Phase 1. Potential countermeasures for reducing unsafe events and violations involving group riders are also suggested, in relation to the Safe System Framework.

7.2.1 Unsafe events involving a motor vehicle

Part A of Phase 2 consisted of a description of the 108 unsafe events involving a motor vehicle observed in the naturalistic video footage. It also involved a case-crossover study examining road environment and group position-related risk factors for these unsafe events that occurred while group riding.

7.2.1.1 Types of unsafe events involving a motor vehicle

The study found that over 80% of unsafe events involved a conflict with a motor vehicle originally travelling in the same direction as the group and this frequently involved passing the group (66% of events). Less than 20% of the unsafe events involved motor vehicles which were originally travelling in a different direction to the group. A Victorian naturalistic study of individual riders similarly reported that the majority (72%) of unsafe events involved motor vehicles travelling in the same direction as the rider (Johnson et al., 2010). However, these event types most commonly involved a motorist in the adjacent lane turning or merging left across the path of the rider at an intersection (Johnson et al., 2010), which was uncommon in the current study. A naturalistic study in the ACT reported that only 37% of unsafe events involved a motor vehicle travelling in the same direction as the rider and that 33% involved a motor vehicle travelling in a different direction at an intersection (Johnson, Chong, et al., 2014), which was higher than in the current study. In a German study of bicycle and e-bike riders, only 20% of unsafe events involved a motor vehicle travelling in the same direction as the rider (Petzoldt et al., 2016). Bicycle crash studies from Queensland, South Australia and Victoria have also reported that crashes involving motor vehicles travelling in the same direction as the rider made up only 17-19% of crashes (B. Beck et al., 2016; Haworth & Debnath, 2013; Lindsay, 2013).

The findings suggest that the most common unsafe events involving motor vehicles that affect group riders, may differ from those affecting individual riders. Specifically, unsafe events resulting from motor vehicles attempting to pass the group were the leading issue. This is likely due to groups taking up a larger amount of space on the road making them more difficult to pass, as well as reduced motorist visibility of the road, infrastructure and traffic ahead when passing groups, compared to passing an individual rider. This study also revealed that unsafe close passing by motor vehicles also affects groups and not just individual riders. This is consistent with findings from a Queensland study using roadside cameras which reported no significant difference between individual and group riding in terms of motorist passing distance (Debnath, Haworth, Schramm, Heesch, & Somoray, 2018).

There were also a lower proportion of unsafe events involving motor vehicles travelling in a different direction to the group at intersections or a vehicle in an adjacent lane turning or merging across the path of the group, compared to studies of individual riders (Johnson et al., 2010; Johnson, Chong, et al., 2014; Petzoldt et al., 2016). This may be due to the previously discussed *'safety in density'* effect (section 7.1.5) (Thompson et al., 2018), where the increased size and visibility of groups, increases the chance of motorists seeing them at intersections and subsequently reduces right of way errors. However, the lower proportion of unsafe events involving motor vehicles travelling in a different direction to the group may also reflect that there was a higher proportion of unsafe events resulting from motor vehicles passing the group.

It is also important to note that the findings from Phase 2 contrasted with the six group riding crash scenarios reported in Phase 1 of this study. Only two of the six group riding crashes in Phase 1 involved a motor vehicle passing the group in the same direction, while four involved motorist right of way errors at intersections. While these differences should be interpreted with caution due to the small number of group riding crashes involving a motor vehicle in Phase 1, a possible explanation for this is the inclusion of smaller, less conspicuous groups of less than five riders in the in-depth crash study, but not in the naturalistic study. Another possible explanation is that crashes involving a passing motor vehicle, involved lower Delta-V (change in velocity between pre and post collision trajectories), thus resulting in less severe injuries not requiring hospitalisation.

These findings, alternatively may indicate that the most common unsafe event types observed between group riders and motorists (passing issues) may not necessarily be the most common types resulting in hospitalisation crashes. For example, conflicts involving motor vehicles travelling in the same direction as the group may allow more time and opportunity for rider/s and motorists to take evasive action to avoid a crash, compared to conflicts involving right of way errors at intersections. In support of this, Sanders found that in the USA, the most common bicycle crash types appearing in official crash statistics, did not align well with the crash types that riders reported they were most concerned about experiencing (Sanders, 2013). This may be due to riders' experiences of unsafe events not resulting in a crash. In fact, a NSW-based prospective study of self-reported near-misses found that near-misses were over 1000 fold higher than hospitalisation crashes (Poulos et al., 2017).

It is known that riders' experience of unsafe events affects their perceptions of safety and in turn, their participation in cycling (Aldred & Goodman, 2018; Sanders, 2015). It is likely that involvement in unsafe events also affects motorists' attitudes towards group riders, possibly growing the anti-cycling sentiment that is prevalent among segments of the community and in turn, affecting motorist behaviour towards group riders (Fruhen, Rossen, & Griffin, 2018; Johnson, Oxley, Newstead, & Charlton, 2014). This highlights the importance of reducing all types of unsafe events between group riders and motorists, even if those events may not commonly result in crashes. In fact, the importance of incidents and near misses involving cyclists has been recently recognised in the UK with the establishment of the '*UK Near Miss Project*' as well as prevention of these events being incorporated into policy and practice (Aldred & Goodman, 2018).

7.2.1.2 Fault and reckless behaviour for unsafe events involving a motor vehicle

Overall, motorists were at fault for 83% of unsafe events involving a motor vehicle. Two previous naturalistic cycling studies of individual riders also examined fault for unsafe events involving motor vehicles. The results were consistent, with fault being assigned to the motorist in 87% of unsafe events in a Victorian study (Johnson et al., 2010), and 93% of events in an ACT-based study (Johnson, Chong, et al., 2014). Similarly, it has been reported that motorists were at fault for 79% of bicycle crashes resulting in hospitalisation in South Australia (Lindsay, 2013) and 57% of severe Police-reported crashes in Queensland (Haworth & Debnath, 2013). Motorist error was also found to have contributed to all six crashes involving a motor vehicle in Phase 1 of the study.

This study provided important new insights into the type of motorist behaviour which led to these at-fault events involving group riders. While motorists were at fault for 83% of the unsafe events, these were predominantly the result of errors and misjudgements. The study of Police-reported crashes in Queensland similarly reported *'illegal'* motorist behaviour for only 10% of bicycle crashes (Haworth & Debnath, 2013). These findings suggest that while motorist behaviour is an important contributor to unsafe events involving group riders, this behaviour is usually not deliberate or aggressive. It is therefore possible that other factors such as the road environment/ design as well as a lack of motorist knowledge and training on how to drive around groups of riders, led to the motorist errors. This is encouraging as it indicates that interventions targeting the road environment and driver training could reduce the number of unsafe events between motorists and group riders on the roads.

The group rider/s in this study were at fault for only 17% of the unsafe events involving motor vehicles, consistent with previous naturalistic and crash studies of individual riders (Haworth & Debnath, 2013; Johnson et al., 2010; Johnson, Chong, et al., 2014; Lindsay, 2013). However, the group rider/s behaviour was determined to be *'reckless'* in 53% of these at-fault events. This means that overall, 11% of the total unsafe events involving motor vehicles consisted of motorist reckless behaviour and 9% consisted of group rider reckless behaviour. Johnson et al. also reported that the pre-incident behaviour of individual riders was *'unsafe'* for 11% of events involving motor vehicles in the Victorian naturalistic study (Johnson et al., 2010). These findings reinforce anecdotal reports that a small minority of both motorists and group riders engage in dangerous or reckless behaviour which result in unsafe events on the road.

7.2.1.3 Aggressive behaviour for unsafe events involving a motor vehicle

Obvious aggressive behaviour was present before, during or after 15% of the unsafe events involving motor vehicles in this study. This highlights that rider/ motorist aggression is a significant issue in WA. Similarly, riders surveyed in Queensland reported that harassment from motorists was common including *'driving too close'*, *'shouting abuse'*, *'obscene gestures or sexual harassment'*, *'deliberately blocking their path'* and *'throwing objects'* (Heesch, Sahlqvist, & Garrard, 2011). Studies of motorist attitudes have suggested that aggression towards cyclists may come from the strong *'car-culture'* in Australia (Fruhen et al., 2018), lower rates of cycling (Garrard, Crawford, & Hakman, 2006; Johnson, Oxley, et al., 2014; Rissel, Campbell, Ashley, & Jackson, 2002), perceptions of cyclists as an *'out-group'* (Basford, Reid, Lester, Thomson, & Tolmie, 2002; D. Horton, 2007) and poor motorist knowledge of road rules (Rissel et al., 2002).

Limited evidence suggests that motorist attitudes towards group riders may actually be more negative than towards individual riders. For example, it has been suggested that groups of cyclists in the UK are perceived to be deliberately obstructive to motorists (Basford et al., 2002). In Australia, riding two abreast was rated the fifth most annoying road behaviour by motorists (the top four behaviours involved other drivers) (M. Beck, 2016). These perceptions possibly make group riders the target of greater hostility and aggression on the road (O'Connor & Brown, 2010).

Reducing aggression between group riders and motorists is essential for several reasons. Firstly, similar to unsafe events, experiencing aggression from motorists can affect riders' perception of safety and subsequently discourage their participation in riding (Aldred & Goodman, 2018; Sanders, 2015). The qualitative study of serious leisure riders reported that the perception of an abusive and adversarial environment with motorists was pervasive and a strong barrier to participation, even more so than fears of safety from traffic (O'Connor & Brown, 2010). In addition, motorists' experience of aggression from group riders could build or reinforce negative attitudes towards them and these negative attitudes have been shown to be associated with unsafe motorist behaviours towards cyclists (Basford et al., 2002; Fruhen & Flin, 2015; Fruhen et al., 2018; Johnson, Oxley, et al., 2014)

For these reasons, it is important that interventions are implemented to reduce the aggression or *'war on our roads'* mentality between motorists and group riders in WA. Potential interventions targeting *'safer road users'*, could focus on improving attitudes and behaviours surrounding group riders. This may include increasing motorist knowledge about the road rules surrounding group riding (e.g. riding two abreast and riding in the centre of the lane) and importantly, about the safety reasons behind these group rider behaviours. In addition, driver education about how to drive around group riders delivered through mass media and/ or in the driver training curriculum could reduce driver discomfort, confusion and hostility. It has also been suggested that campaigns that frame non-aggressive behaviours as normative could be an effective approach (Fruhen et al., 2018) for reducing both motorist and group rider aggression.

7.2.1.4 Road and group position factors associated with unsafe events involving a motor vehicle

Roundabouts

Results of the case-crossover study found that roundabouts significantly increased the risk of an unsafe event involving a motor vehicle by over three times compared to midblock sites, over four times compared to priority control intersections and over five times compared to traffic signal intersections. These findings are consistent with previous research showing that while roundabouts lower crash rates and severity for motorists (Jurewicz, Tofler, & Makwasha, 2015), the risk is higher for cyclists than at other intersection types (Cumming, 2011; Jurewicz et al., 2015; Reynolds et al., 2009; Wilke et al., 2014).

This study also revealed that the most common types of unsafe events which occurred at roundabouts for group riders, differed from the commonly reported crash types for individual riders. In Victoria, 83% of bicycle crashes at roundabouts involved motor vehicles from an adjacent direction and 11% from the same direction (Cumming, 2010). The majority (75%) of unsafe events at roundabouts in the current study involved a motor vehicle travelling in the same direction attempting to pass the group, but facing road infrastructure (the roundabout). No other naturalistic studies have examined the association between roundabouts and unsafe events.

It is apparent that for group riders, the increased risk of unsafe events involving motor vehicles at roundabouts, was predominantly related to motorist passing issues, rather than right of way errors. As previously mentioned, groups take up a larger amount of space on the road than individual riders, making them more difficult to pass. It is also likely that groups reduce motorists' visibility of the road ahead, meaning they were unaware they were approaching a roundabout when they attempted to pass the group. While roundabouts are very common on Perth roads, advanced signage warning road users of upcoming roundabouts is uncommon, making the road environment unpredictable for motorists and riders.

Previous studies have reported an increased risk of bicycle crashes on larger roundabouts with at least two circulating lanes, compared to single lane roundabouts (DiGioia et al., 2017). In contrast, the unsafe events relating to passing issues in this study occurred exclusively at single lane roundabouts. This was expected since passing difficulties are more likely to occur when there is only one lane available for traffic to pass in, so single lane roundabouts should be targeted for road safety treatments.

None of the unsafe event (case) sites involving passing motorists had bicycle lanes which continued through the roundabout, as these are known to be unsafe (Cumming, 2010; Wilke et al., 2014) and are not used in WA. However, 63% of the roundabout sites had a bicycle lane which ended on approach to the roundabout. It is recommended by Austroads that midblock bicycle lanes should end around 20 metres behind the holding line (Wilke et al., 2014). In WA, the distance bicycle lanes terminate before a roundabout and the markings used when the lanes end, vary considerably. For example, bicycle lanes may simply end without warning, disappear into the kerb, have dashed line markings or lead to off-road paths that deviate around the roundabout. In addition, road markings and signage encouraging lane sharing are uncommon. It is likely that this inconsistency in road markings on approach to roundabouts makes the road environment as well as road user behaviour unpredictable and confusing, contributing to the increased risk of unsafe events involving motorists passing group riders.

Treatments that increase road predictability could potentially reduce these unsafe events. Treatments such as advanced signage at roundabouts (particularly single lane roundabouts) on popular group riding routes, could be a simple way to reduce both unsafe events and motorist frustration surrounding failed passing attempts. In addition, previous research has shown that the risk of crashes decrease if cyclists claim the lane at roundabouts (Cumming, 2011). One of the reasons for this is that it discourages motorists attempting to pass when unsafe (Cumming, 2011; Wilke et al., 2014). Several simple treatments can be used to encourage riders to claim the lane on approach and through roundabouts. These include vehicle speed reduction treatments, ending bicycle lanes well before the roundabout, narrow approach lanes of three metres or less, *'sharrows'* (road markings consisting of two inverted V-shapes above a bicycle image indicating that motorists and riders should share the lane) and signage encouraging motorists to merge with riders (Cumming, 2010; Wilke et al., 2014). Fortunately, these recommended roundabout treatments would likely also be effective for reducing the more common right-of -way-related crash types for individual riders since they slow traffic, reduce conflict points and increase rider visibility (Cumming, 2011; Wilke et al., 2014).

Traffic islands

The case-crossover study also found that the presence of raised traffic islands significantly increased the risk of an unsafe event involving a motor vehicle for group riders. Traffic islands improve safety for motorists by separating opposing traffic and reducing vehicle speeds at midblocks and intersections, while still allowing traffic to turn between islands (Austroads, 2016). Previous crash studies have reported that median treatments including traffic islands provide refuge and improve safety for riders who are crossing the road (National Transportation Center, 2017; Raihan, Alluri, Wu, & Gan, 2019). Less is known about the impact of traffic islands for cyclists actually riding on the road, but it is acknowledged that they can create squeeze points when being overtaken by motor vehicles (Austroads, 2016). The findings of this study suggest that, similar to roundabouts, traffic islands contribute to unsafe events involving motor vehicles passing groups of riders. This is likely due to traffic islands reducing the lane width and their presence on the road being unpredictable to motorists.

While the narrower lane widths created by traffic islands may improve group rider safety by slowing vehicle speeds, it has also been shown that narrower lane widths increase the likelihood of close passing of riders by motorists (Debnath et al., 2018; Love et al., 2012; Mehta, Mehran, & Hellinga, 2015). It is therefore likely that raised traffic islands are not an ideal traffic calming treatment on roads frequently used by cyclists, including group riding routes. Alternative countermeasures fitting within the *'safer roads and roadsides'* component of the Safe System Framework, instead need to be considered. Flush traffic islands could be a better option on group riding routes as they reduce lane width using painted or textured islands without physically limiting motor vehicle movement and still allow for the overtaking of riders (Austroads, 2016). These treatments however, provide less protection for pedestrians and riders crossing the road than raised islands (Austroads, 2016), so locations for use have to be carefully considered. Alternatively, vehicle speeds and traffic lane widths could be reduced on popular group riding routes by adding a wide on-road bicycle lane on the side of the road, allowing groups to ride two abreast.

Posted speed limit

The study also revealed that posted speed limits of ≥ 60 km/h significantly increased the risk of an unsafe event involving a motor vehicle, compared to speed limits of ≤ 50 km/h. Previous research has consistently reported higher bicycle crash risk and crash severity with faster motor vehicle speeds (Boufous et al., 2013; Cripton et al., 2015; Harris et al., 2013; O'Hern & Oxley, 2018; Robartes & Chen, 2017). While previous naturalistic studies have not specifically examined the impact of speed limits, these findings suggest that like for crashes, higher motor vehicle speeds afford motorists and group riders less time to react to a conflict, resulting in more unsafe events occurring (O'Hern & Oxley, 2018).

For the unsafe event (case) sites with speed limits of ≥ 60km/h, the majority (84%) involved a motor vehicle passing the group. Similarly, a study in Queensland which used roadside cameras to examine passing distances reported that the likelihood of motorist non-compliance with passing distance laws was higher on roads with higher speed limits (70-80 km/h) (Debnath et al., 2018). This highlights higher speed roads as an important area to target for group rider safety issues related to motorist passing behaviour.

Recommendations based on the Safe System approach suggest that bicycles and motor vehicles should be physically separated on roads and at intersections where the vehicle speed is greater than 30 km/h, in order to protect riders from severe injury (Woolley, Stokes, Turner, & Jerewicz, 2018) This can be achieved through separated off-road bicycle paths on higher speed roads (Woolley et al., 2018). However, group riders are distinct from individual riders in terms of their size and higher travel speeds. This means that riding on separated paths shared with pedestrians or even other riders, is usually undesirable and often unsafe, especially for larger, faster groups. In addition, the nature of group riding means groups choose roads that allow for riding two abreast and *'rolling'* (O'Connor & Brown, 2007; WestCycle, 2017a) and these are often larger dual carriageways, with higher speed limits. Groups in this study also frequently chose routes consisting of low volume roads located on the outskirts of Perth, with challenging hills for training. Such roads however, usually have high speed limits, often ≥ 80 km/h.

This presents a challenge for the prevention of unsafe events involving motor vehicles for group riders. Solutions which have shown to be effective in reducing crashes on high speed roads for individual riders include lower speed limits, designing roads/ intersections to reduce vehicle speeds, off-road bicycle facilities and bicycle-friendly traffic calmed routes adjacent to high speed roads (Lusk et al., 2011; Wall et al., 2016; Woolley et al., 2018). Several of these solutions however, are unlikely to be practical, utilised or effective for group riders. This study showed that the provision of on-road bicycle lanes was low (17%) at unsafe event (case) sites with speed limits ≥ 60 km/h. Previous studies found on-road bicycle lanes to be differentially effective in preventing crashes depending on the type of lane and road characteristics (Kaplan & Giacomo

Prato, 2015; Morrison, Thompson, Kondo, & Beck, 2019; Thomas & DeRobertis, 2013). However, it has generally been reported that on-road bicycle lanes have a greater impact on crash prevention on roads with higher speed limits (Kaplan & Giacomo Prato, 2015; Morrison et al., 2019), higher traffic volumes and narrower traffic lanes (Morrison et al., 2019). Another study reported that bicycle lanes only have a positive effect on increasing motorist passing distances if the lanes are wide (>1.4m) (K. Stewart & McHale, 2014).

Considering this evidence, as well as the unique needs of group riders, potential solutions for reducing unsafe events involving motor vehicles need to address the *'safer roads and roadsides'* as well as the *'safer road users'* components of the Safe Systems Framework. One potential solution is the provision of wide bicycle lanes that allow for riding two abreast on popular higher speed roads, in order to provide a level of separation for group riders. Another potential intervention is the use of signage and road markings on popular higher-speed roads that alert motorists to the presence of riders and encourage them to share the road.

Group rider violations

Another finding was that group rider traffic violations increased the risk of an unsafe event involving a motor vehicle by over two times. Similarly, a German study of individual riders reported that violations by riders increased the risk of an unsafe event by over two times (Petzoldt et al., 2016). In the current study, the most common group rider violations involved in unsafe events were *'right of way'* violations, followed by *'wrong side of road'* violations. This suggests that group rider violations increase the risk of unsafe events involving crossing paths with motor vehicles or with oncoming motor vehicles, rather than the more commonly observed passing issues.

Evidence is conflicting on whether violations by riders are associated with actual crashes involving a motor vehicle. An analysis of bicycle crashes in Queensland found that violations by riders were involved in 28% crashes with motor vehicles where the rider was at fault (Schramm et al., 2010). While another Australian study reported an association between self-reported violations by riders and crash risk (Johnson et al., 2013), a similar survey in Brazil found no association (Bacchieri et al., 2010).

While it is clear that group rider violations only contributed to a minority of unsafe events involving motor vehicles, the current study suggests that group rider violations still increase the risk of these events. It has also been suggested that violations by riders can contribute to negative motorist attitudes towards them, in turn affecting motorist behaviour towards riders (Johnson et al., 2013). It is therefore important to reduce violations among group riders. Interventions related to *'safer road users'* that may reduce group rider violations include targeted education campaigns and leadership from clubs and ride leaders to create a culture of obeying road rules.

Group position: Riding two abreast

The study found that riding two abreast in the traffic lane significantly reduced the risk of an unsafe event by half, compared to riding single file in the traffic lane. A possible reason for this finding is that riding two abreast makes riders more visible to motorists (Amy Gillett Foundation, 2017; WestCycle, 2017b). In addition, the reduced risk associated with riding two abreast in the traffic lane may also be related to a reduction in motor vehicle passing issues. Unsafe events involving motor vehicles that occurred while riding single file in the traffic lane in this study, most commonly involved a vehicle passing the group (75%). In contrast, 53% of the unsafe events that occurred while riding two abreast in the traffic lane, involved a motor vehicle passing the group.

It has been anecdotally reported that riding two abreast can make passing easier for motorists as it shortens the length of the group by half (Amy Gillett Foundation, 2017; WestCycle, 2017b). It also allows the group to claim the lane, discouraging or completely preventing motorists from attempting to pass when unsafe (WestCycle, 2017b). The recent evaluation of passing distance compliance in Queensland reported that motorist's mean passing distance was greater when passing a group riding two abreast, compared to single file (2.2 vs 1.9m), but there was no significant difference in the percentage of non-compliant passing events (Debnath et al., 2018).

In light of the finding that riding two abreast may reduce the risk of unsafe events involving a motor vehicle, it is also important to consider that riding two abreast has been cited as one of the most *'annoying'* behaviours for motorists (M. Beck, 2016). In fact, in the current study, motorists displayed aggressive behaviour in 13% of the unsafe events that occurred while groups were riding two abreast in the traffic lane, compared to four percent when riding single file in the traffic lane. This highlights the importance of groups balancing safety with being courteous and sharing the road with motor vehicles. The WestCycle *'Best Practice Guide to Riding Safely in a Group'* encourages courtesy and states that groups should *'consider riding single file when the road narrows, when going uphill or if traffic is building from behind'* (WestCycle, 2017a) (p.13).

These findings suggest that interventions targeting *'safer road users'* aimed at both group riders and motorists may be effective. For example, campaigns that encourage road sharing by group riders, education on when it is safe and appropriate to ride two abreast or single file and leadership from clubs and ride leaders on courteous behaviour on the road, may be strategies for reducing unsafe events for group riders. This finding also provides support for previously suggested interventions directed at motorists. These could involve education through the mass media and/ or in the driver training curriculum. This could cover the road rules surrounding riding two abreast, the reasons why groups ride two abreast, the safety benefits of riding two abreast for both riders and drivers and how to drive around groups riding two abreast.

Group position: Riding in the bicycle lane

This second finding relating to group position was that having all riders in the bicycle lane significantly reduced the risk of an unsafe event, compared to riding single file in the traffic lane and compared to riding two abreast in the bicycle and traffic lane. These results suggest that there is no safety benefit to riding two abreast with one rider in the bicycle lane and one in the traffic lane. Since this positioning involves in a single line of riders in the traffic lane, it is likely that the same motorist passing issues result.

Previous studies have shown on-road bicycle lanes to be differentially effective for preventing crashes among individual riders, depending on road characteristics (Kaplan & Giacomo Prato, 2015; Morrison et al., 2019; Thomas & DeRobertis, 2013). The WA Road Traffic Code states that when an on-road bicycle lane is provided and it is in reasonable condition, a cyclist must use only the bicycle lane and no other part of the carriageway ("Western Australia Road Traffic Code," 2000). However, riding with all group members in the bicycle lane was uncommon at unsafe event sites (<3%) and control sites (10%) in this study. This is likely due to this law being somewhat ambiguous for group riders, most bicycle lanes not being wide enough to allow riding two abreast, and low provision of bicycle lanes. Therefore, while having all riders in the bicycle lane is likely safer, it is usually not desirable or practical for groups (especially larger groups) to do this. These findings further support the previous suggestion for wider bicycle lanes that allow for riding two abreast on popular group riding routes, in order to provide a level of separation and safety for group riders.

7.2.1.5 Summary of potential interventions

The findings of the naturalistic study suggest that several relatively simple road infrastructure treatments on group riding routes, could improve safety for group and also individual riders. These include surface repair/ maintenance, clearing of on-road hazards, wider bicycle lanes and use of different roundabout designs/ markings. However, it should be acknowledged that roads shared with motorised traffic are not designed for the purpose of cycling in groups, often at high speeds. This presents a challenge for improving group rider safety. The Netherlands is a world leader in cyclist safety and have developed a system that is inclusive of cyclists (Schepers, Heinen, Methorst, & Wegman, 2013). On roads with speed limits of 30 km/h, cyclists mix with motorised traffic. On roads with speed limits of 50-70km/h, cyclists are separated from motorists by bicycle lanes or off-road paths. On roads with speed limits of 100 or 120 km/h, cyclists are prohibited (Schepers et al., 2013). This situation is quite different to Perth where cyclists and motorists frequently share roads with high speed limits. This Dutch system is considered the gold standard for cyclists and if implemented in Perth, would surely have substantial safety benefits for individual cyclists. However, the *‘serious leisure’* group riders examined in this study clearly would not fit into this road classification system. In addition to the road modifications suggested, alternative solutions could include the separation of group riders in time from motorised traffic during the early hours of the morning on weekends. This may include closing the road to motor vehicles entirely, designating one lane for bicycle use only on dual carriageways (similar to peak hour bus lanes), or restricting motor vehicle parking during these times.

7.2.2 Unsafe events not involving a motor vehicle

Part B of Phase 2 consisted of a description of the 59 unsafe events not involving a motor vehicle observed in the naturalistic video footage and a case-crossover study examining road environment and group position-related risk factors for these unsafe events that occurred while group riding.

7.2.2.1 Proportion of unsafe events not involving a motor vehicle

Unsafe events not involving a motor vehicle made up 35% of the total unsafe events observed in the group riding video footage. Interestingly, this contrasts with findings from the Phase 1 crash study where non-motor vehicle crashes accounted for 84% of the hospitalisations among group riders. Other naturalistic studies of individual riders have reported that only 15-33% of unsafe events involved motor vehicles (Dozza et al., 2016; Dozza & Werneke, 2014; Hamann & Peek-Asa, 2017), however these included both on and off-road riding. This suggests that while unsafe events involving a motor vehicle are common for group riders, they may result in fewer actual crashes than events which do not involve a motor vehicle.

7.2.2.2 Types of unsafe events not involving a motor vehicle

Group riding differs from individual riding in that it often involves periods of training-type activities including riding two abreast, *'rolling'* (rotating the lead), riding in close proximity to other riders (within one metre) and at high speeds (up to 60 km/h). In order to undertake training-type activities safely, group riders require low motorised traffic volume, dual lane roads so they can claim a lane, wide bicycle lanes allowing for riding two abreast, a low number of intersections requiring riders to stop and roads free from temporary hazards such as debris. Groups choose when to undertake these training-type activities depending on the road conditions, often riding single file and at much lower speeds when the road environment requires it (WestCycle, 2017a). It is likely that some of the unsafe events which did not involve a motor vehicle in this study were the result of these training-type activities and this warrants further research. However, it is also very likely that undertaking these legal activities increased the vulnerability of group riders in this study to unsafe events resulting from hazardous road conditions.

The most common types of unsafe events which did not involve a motor vehicle were conflicts between at least two riders within the group (41%) and conflicts with an obstacle or object on the roadway (39%). These findings are consistent with the findings of Phase 1. These results are also consistent with a Victorian study which reported that another rider in the group contributed to 70% of *'bunch riding'* crashes resulting in hospitalisation (B. Beck et al., 2016). A study in Queensland found that nearly half of the serious injury bicycle crashes which did not involve a motor vehicle, involved hitting an object on the road (Heesch, Garrard, et al., 2011). These findings highlight the importance and severity of conflicts between riders for groups and conflicts with obstacles or objects on the road for both group and individual riders.

It is difficult to compare findings on the prevalence of different types of unsafe events which did not involve a motor vehicle to the naturalistic studies of individual riders. This is because they either included only unsafe events involving motor vehicles (Johnson et al., 2010; Johnson, Chong, et al., 2014), or combined on-road/ off-road and motor vehicle/ non-motor vehicles events in the analyses (Dozza et al., 2016; Dozza & Werneke, 2014; Hamann & Peek-Asa, 2017; Petzoldt et al., 2016; Schleinitz et al., 2015). For example, a Swedish naturalistic study of individual riders including both on and off-road riding reported quite different unsafe event types (Dozza & Werneke, 2014). They found that 43% of non-motor vehicle events involved a pedestrian, 24% involved an unknown rider and only 16% involved an object/ obstacle or single rider loss of control (Dozza & Werneke, 2014).

The results suggest differences between group and individual riders in terms of the unsafe events not involving a motor vehicle they experience. This is not surprising since conflicts involving another rider in the group can only occur among group riders. The results of the study found that unsafe events between group riders predominantly occurred while riding two abreast (79%) and a quarter were *'rolling'* at the time. The findings from Phase 1 and 2 of the study suggest that interventions aimed at reducing conflicts between riders within the group and conflicts with objects or hazards on the roadway, would reduce both unsafe events and hospitalisation crashes.

7.2.2.3 Road and group position factors associated with unsafe events not involving a motor vehicle

Riding in close proximity

The results of the study found that riding staggered (at least three metres distance between the front and rear tyres of other riders in the group) significantly reduced the risk of an unsafe event which did not involve a motor vehicle, compared to riding in close proximity. This is a logical finding since distance reduces the risk of conflicts with other riders and would likely make them more able to detect and avoid obstacles on the road. However, as previously discussed (section 7.1.5), riding in close proximity in a pack also has benefits in terms of the *'safety in density'* effect (Thompson et al., 2018) which increases rider visibility while on the road and reduces right of way errors by motorists.

While riding staggered may decrease the risk unsafe events not involving a motor vehicle, it may increase the risk of certain types conflicts with motor vehicles, as well as being unappealing to group riders. Therefore, recommending riding staggered would be unlikely to be accepted or effective. It would be more reasonable to suggest interventions that fit within the *'safer road users'* and *'safer roads and roadsides'* components of the Safe Systems Framework. For example, groups/ clubs could conduct rider training on how to avoid conflicts with other riders as well as calling and avoiding hazards on the road. In addition, regular road maintenance and clearing of on-road hazards on popular group riding routes could be an effective way to reduce the number of unsafe events for group riders who have reduced visibility and less opportunity for evasive manoeuvres, compared to individual riders.

Curved roads

The study found that curved roads increased the risk of an unsafe event not involving a motor vehicle by over three times, compared to straight roads. This is consistent with the findings of previous bicycle crash studies (Boufous et al., 2013; Kim et al., 2007; Moore et al., 2011; Robartes & Chen, 2017). The increased risk of unsafe events on curved roads is likely due to reduced visibility, increased cognitive workload and greater difficulty compensating for imbalance due to sudden evasive manoeuvres (Kim et al., 2007; Robartes & Chen, 2017). While it is impossible to remove curves from the road environment, potential interventions targeting *'safer road users'* and *'safer roads and roadsides'* could reduce unsafe events for group riders. Firstly, rider training on negotiating curves and calling and avoiding hazards on the road could be effective. Secondly, potential road treatments include advance warning signs on approach to curves as well as frequent road maintenance to minimise the impact of uneven road surfaces and hazards, which provide a particular risk to group riders on curved sections of road.

Construction zones

Construction zones (roadworks) also significantly increased the risk of unsafe events not involving a motor vehicle. However, these results should be interpreted with caution due to the low number of crashes occurring in construction zones and further research with a larger sample is needed. The naturalistic study of individual riders in Sweden, conducted by Dozza et al. reported that 11% of unsafe event sites were located in construction zones, compared to five percent of control sites, although this difference was not significant (Dozza & Werneke, 2014). In the current study, 60% of the unsafe events in construction zones involved apparent rider confusion regarding which path to take through the roadworks or where to position themselves on the road. The other 40% involved conflicts with objects/ obstacles on the road. An evaluation of 219 pedestrian and bicyclist crashes in construction zones in the USA similarly found that discontinuous or inadequate pedestrian/ bicycle facilities, hazards and visual obstructions were common in these crashes (J. W. Shaw et al., 2016).

Interventions to reduce unsafe events which occur in construction zones fit within the *'safer roads and roadsides'* component of the Safe Systems Framework. Firstly, the needs and safety of bicycles should be considered and planned for throughout the construction process. The Main Roads WA *'Policy for Cycling Infrastructure'* states that traffic management plans for roadworks should make clear provisions for riders and adequate advance warning should be provided on the road (Main Roads Western Australia, 2000). In addition, clear warning signs and markings indicating the route rider should take are necessary to reduce unsafe events resulting from rider confusion. Second, consideration should be given to the condition of the road surface for riders and the area cleared of hazards. Finally, it should also be noted that it may not be practical for larger groups to use off-road diversions or paths around construction zones that are shared by pedestrians. If the construction zone is located on a popular group riding route, developers need to plan for groups sharing the road with motor vehicles through the roadworks and take their safety into consideration.

7.2.3 Group rider traffic violations

Part C of Phase 2 consisted of a cross-sectional study examining group rider traffic violations observed in the naturalistic footage.

7.2.3.1 Red light violations

This study found that group riders committed a violation at 12% of red lights. The naturalistic study of group riders in Victoria reported that riders committed violations at 46% of red lights in the 2005 footage, but there were no red light violations in the 2007 footage (Johnson et al., 2009). It is possible these differences were due to groups being very large in 2005 (100-140 riders), compared to approximately 40 riders in 2007 (Johnson et al., 2009). The current study also did not contain any groups as large as those in the 2005 Victorian footage. A recent naturalistic study from Germany found that individual riders committed violations at 16% of red lights (Schleinitz, Petzoldt, Kroling, Gehlert, & Mach, 2019). Several other studies have used roadside cameras to examine the prevalence of red light violations among individual riders. Estimates have ranged widely from seven percent in Victoria (Johnson et al., 2011), to 16% in Taiwan (Pai & Jou, 2014), 19% in Ireland (Richardson & Caulfield, 2015), 56% in China (Wu et al., 2012) and 63% in Italy (Fraboni et al., 2016). While these studies used different methodologies and had larger sample sizes, this suggests that red light violations may be slightly higher among group riders than previously reported for individual riders in Australia, but still lower than in other countries.

It has also been reported that individual riders were significantly more likely to commit a red light violation when they were turning left (or right in countries with right side traffic) (Johnson et al., 2011; Schleinitz et al., 2019), when they were unable to activate the traffic detector (Johnson et al., 2013) and when no other road users were present (Johnson et al., 2013). In the current study, the majority of red light violations (59%) occurred when groups were travelling straight and there were no significant differences for direction of travel. Only one violation involved the group being unable to activate the detector. This suggests that the circumstances surrounding red light violations among group riders differ from those reported for individual riders. This study suggests that most red light violations are the result of following riders wanting to remain with the group, rather than be left behind at the red light.

One of the 64 red light violations in this study resulted in an unsafe event, which is consistent with the findings of previous studies. In Germany, none of the 1210 red light violations observed resulted in an unsafe event (Schleinitz et al., 2019) and in Victoria, none of the 292 red light violations resulted in a crash (Johnson et al., 2011). Crash studies have also reported low involvement of rider red light violations in crashes, being involved in two percent of crashes in the UK (Lawson, 1991), six percent in Queensland (Schramm et al., 2010) and not significantly associated with crashes in Brazil (Bacchieri et al., 2010). Despite this, red light violations by riders are obvious to other road users (Johnson et al., 2011) and it is possible that observing these violations negatively affects motorists' attitudes and behaviour towards group riders (Fruhen et al., 2018; Johnson, Oxley, et al., 2014).

Therefore, it is still important to prevent red light violations. Reducing red light violations among group riders requires rider behaviour change which comes under the *'safer road users'* component of the Safe System Framework. This would likely require leadership from clubs to promote red light compliance as important and the norm amongst their groups. Adopting the practice of waiting for riders left behind due to obeying traffic signals, could also reduce red light violations among group riders. Lastly, several of the observed violations occurred at traffic lights when the whole group could not make it through the lights on the green light cycle. These tended to be located on the minor legs of the intersection, often on popular group riding routes. Therefore, extending the green phases for problematic traffic lights on these particular routes, on weekend mornings only, would certainly reduce these specific red light violations by group riders.

7.2.3.2 Stop sign violations

This study found that group riders did not come to a complete stop at 80% of stop signs. Instead, they consistently treated stop signs as give way signs, slowing but only coming to a complete stop if there was approaching traffic that required them to wait. This finding is consistent with previous research examining individual riders. Hamann et al. reported that stop sign violations were common among adult riders in a naturalistic study in the USA (6.2 violations per 100 minutes) (Hamann & Peek-Asa, 2017). Also, in the USA, roadside camera studies reported that 96% of riders failed to stop at stop signs on a college campus (Lavetti & McComb, 2014) and only three percent of riders came to a complete stop when there was no conflicting traffic (Ayres, Kensington, Kelkar, Kubose, & Shekhawat, 2015). However, these studies reported that riders usually exercised caution at the stop signs (Ayres et al., 2015; Hamann & Peek-Asa, 2017; Lavetti & McComb, 2014). Similarly, another GPS-based naturalistic study in the USA, found that 80% of stop sign violations involved *'rolling stops'* performed at low speeds of less than 6 km/h (Langford et al., 2015). Interestingly, none of the 103 stop sign violations in the current study were associated with an unsafe event.

Globally, riders are usually subject to the same laws as motorists regarding stop signs, meaning they must come to a complete stop ("Western Australia Road Traffic Code," 2000). However, coming to a complete stop has very different implications for riders, compared to drivers. Accelerating from a complete stop is strenuous for riders, especially if the sign is located on an uphill grade (Fajans & Curry, 2001). For example, a rider who slows to 8 km/h at a stop sign needs 25% less energy to return to a speed of 16 km/h, compared to a rider who completely stops (Fajans & Curry, 2001). In addition, cleats (a mechanism that allows riders to clip their shoes into the pedals) are very common among group riders. This means completely stopping is particularly inconvenient because they have to unclip, then immediately clip back into the pedal if there is no approaching traffic.

For these reasons, a small number of jurisdictions (e.g. Idaho, USA and Paris, France) have passed laws allowing riders to treat stop signs as give way signs. In the year after the introduction of this law in Idaho in 1982, there was a 14% reduction in bicycle fatalities (Meggs, 2010). While such a law would be unlikely to negatively affect bicycle safety in WA and may even have benefits, this change is improbable in the near future. WestCycle WA states that despite their merits, stop sign law changes for riders are not on the agenda in WA because other road users are not ready to accept them (WestCycle, 2017c).

7.2.3.3 Other violations

The most common *'other violations'* observed amongst group riders in this study included: *'riding more than two abreast'* (67%) and *'riding on the wrong side of the road'* (19%). There was no evidence of groups committing continuous violations like observed in the 2005 group riding naturalistic study from Victoria (Johnson et al., 2009). In 2005, groups rode more than two abreast for 100% of the footage, usually four and up to 16 abreast, and occupied more than one lane for 90% of the time (Johnson et al., 2009). In the 2007 footage from Victoria, groups only rode more than two abreast for five percent of the time and in more than one lane for two percent (Johnson et al., 2009). This difference could be due to the fact that the current study did not contain any groups as large as those in the 2005 footage and did not contain a stretch of road specifically known for attracting large numbers of group riders like in the Victorian study (Johnson et al., 2009).

Overall, four percent of the 232 *'other violations'* observed, were associated with an unsafe event. Consistent with the findings of Part A, although *'right of way'* violations were infrequent, this was the violation most commonly associated with unsafe events.

7.2.3.4 Group-related factors associated with other violations

This study found that formal groups had less than half the rate of *'other violations'*, compared to semi-formal groups. However, informal groups showed no significant differences in the rate of *'other violations'* compared to formal or semi-formal groups. This may be because informal groups can vary widely in terms of behaviour, speed and skills.

Further examination revealed that the features of formal groups associated with the reduced rate of *'other violations'* were: *'cost to ride with the group'*; group had a *'committee or was an incorporated business'*; and a *'written code of conduct'*. These features likely reduced violations by ensuring formal lines of communication between organisers and riders, providing avenues for reporting bad behaviour and the ability to remove riders from the group if their behaviour was an issue. Having a written code of conduct also spells out expected rider behaviour (such as obeying road rules) and this may reduce violations by making riders more accountable for their actions.

This study also found that groups which had sprint points had over twice the rate of *'other violations'*, compared to groups which did not have sprint points. Sprint points are parts of the route where riders increase speed and informally *'race'* to a pre-determined finish point (O'Connor & Brown, 2007). Since these sections of the ride have aspects in common with competitive racing (O'Connor & Brown, 2007), it is expected that more risks would be taken and violations like riding two abreast and on the wrong side of the road would occur. However, none of the unsafe events involving motor vehicles and only three percent of the unsafe events not involving motor vehicles, occurred while the group was sprinting. This may be because groups choose quiet, open stretches of road for sprints, minimising the risk of unsafe events.

Interestingly, whether groups wore uniforms, had open or closed membership, had a designated ride leader, or dropped riders were not associated with the rate of *'other violations'*. In terms of uniforms, it is possible that being identifiable to other road users and Police may decrease group rider violations. However, uniforms may be associated with an increased level of informal competitiveness within the group, which may result in more violations. It could also be assumed that groups with open membership would experience more rider violations due to unfamiliar and possibly risky riders joining the group at any time. However, O'Connor and Brown suggest that each group varies in terms of acceptable behaviour and level of risk and it is possible that this has a stronger impact on group rider violations than a single risky rider joining the group (O'Connor & Brown, 2007). In terms of whether the group drops riders (leaves them behind), it is likely that this has more impact on red light violations than the *'other violations'* included in this analysis. Unfortunately, red light violations could not be included and this may explain the lack of significance. Finally, whether the group had a designated ride leader was not associated with the rate of *'other violations'*. The WestCycle guidelines support nominating a ride leader so they can ensure riders obey road rules and abide by the group's standards (WestCycle, 2017a). However, the effectiveness of a ride leader at reducing violations may depend on the qualities of the individual leader as well as the scope of their leadership role. It is also possible that a designated group leader would have little effect on violations among the informal groups of friends. This is an area for further research.

Motorists are known to be frustrated by group rider violations such as riding more than two abreast (M. Beck, 2016). This means it is important to minimise such violations through interventions that fall under the *'safer road users'* component of the Safe Systems Framework. Formal groups were found to have a reduced rate of *'other violations'*, compared to semi-formal groups. However, it has been found that formal clubs do not appeal to many riders due to the perceived level of commitment required (O'Connor & Brown, 2007). While it is impractical to promote that all group riders join clubs, some of the features of formal groups that were shown to be associated with reduced violations (e.g. a written code of conduct), could be promoted and incorporated into semi-formal groups. Semi-formal groups organised through bike shops would be ideal to target for this type of intervention since they already have some level of organisational structure.

7.2.4 Strengths of Phase 2

This was one of the first studies to comprehensively examine safety issues for group riders. This filled a gap in the evidence as previous studies focused on individual, usually commuter riders. The use of naturalistic road safety research methods was a major strength of the study. These methods allowed the unobtrusive observation of crashes of lesser severity, near crashes and crash-relevant events, as well as group rider violations, which are far more common than hospitalisation or Police-reported crashes. The high-quality video footage collected also allowed accurate viewing of the behaviour of group riders and other road users leading up to the unsafe event, as well as the presence of road and environmental factors, providing a comprehensive picture of the safety issues surrounding group riding in Perth.

The continuous information obtained from the video footage overcame the limitations associated with use of crash data, hospital data and surveys, which rely on road user recall, physical evidence and are subject to reporting biases (Dingus et al., 2006; Regan et al., 2012). A weakness of previous naturalistic cycling studies was the use of only one forward-facing camera (Gustafsson & Archer, 2013; Hamann & Peek-Asa, 2017; Johnson et al., 2010; Johnson, Chong, et al., 2014). Wherever possible, two cameras were used (front and rear facing), capturing unsafe events which occurred behind the participant, resulting in more complete and comprehensive data. This study also minimised observer bias by requiring two researchers to reach an agreement on the inclusion and coding of unsafe events and violations. In addition, the coding was based on data dictionaries which had been previously developed for naturalistic road safety studies.

The majority of earlier naturalistic cycling studies only described the unsafe events and/ or violations observed, without providing any information on the risk factors for these. The use of the case-crossover study design for Parts A and B of this study provided an effective methodology for examining the association between transient road environment and group position-related factors and unsafe events, while controlling for group and trip-related characteristics. In addition, using GEE multivariate modelling to examine risk factors for unsafe events allowed the clustering of case and control sites within riding trips to be accounted for, while also controlling for potential confounding factors.

A final strength of Phase 2 was the examination of unsafe events and group rider violations which occurred exclusively on-road. Unsafe events were also separated into those involving a motor vehicle and those not involving a motor vehicle. Several previous studies have combined unsafe events which occurred on and off-road, those involving a motor vehicle and those not involving a motor vehicle in the analyses, resulting in insignificant or inconsistent results. By separating these, this study was able to uncover the distinctive circumstances and risk factors surrounding the different types of unsafe events involving group riders.

7.2.5 Limitations of Phase 2

Phase 2 used case-crossover study designs where unsafe events and control sites were selected from within the same trip. This meant that the association between group, trip characteristics and unsafe events could not be examined. The sample size of unsafe events and violations in this study was relatively small, although comparable to previous naturalistic cycling studies. This means some of the insignificant results could be due to the limited power of the study and results with wide confidence intervals should be interpreted with caution. In addition, while valuable information was obtained by examining unsafe events separately in terms of whether they involved a motor vehicle or not, the sample size did not allow further analyses by specific types of events (e.g. unsafe close passing or rider/ rider events). This is an area for further research.

This study also used a convenience sample of group riders as participants. This means the results could be subject to selection and volunteer bias and the sample may not be fully representative of the population of group riders in Perth. These risks were minimised by using a wide range of recruitment methods and placing restrictions on the number of participants per group, but it is still possible that those who volunteered to participate were more safety-conscious group riders. The Phase 2 study also only included group riders, so it could not be determined whether the unsafe events occurred due to group riding, or related to cycling in general. In future, a larger study with more resources could collect naturalistic video data on individual and group riders so that the unsafe events experienced could be compared and contrasted for these types of riders.

Due to the naturalistic method of data collection, it is possible that the Hawthorne effect was present in this study, where individuals modify their behaviour in response to being observed (Gillespie, 1991). The 100-car naturalistic study reported that the installation of the cameras had little effect on participant driving patterns after the first hour (Dingus et al., 2006). Since this study collected less than six hours of group riding footage per participant due to camera data storage limits, it is possible that they rode more cautiously than usual during some of this time. However, since the use of cameras and GPS devices is very common in group riding, this effect should be minimal, especially for other riders in the group. In addition, the behaviour of motorists and riders outside of the group would obviously not have been affected. Nevertheless, it would be useful for future studies to collect more than six hours of footage per participant in order to minimise these issues.

There were several technological issues related to the Contour cameras used to record the naturalistic group riding video footage and GPS data. Issues included shorter than expected battery life, missing GPS data (40%) and a portion of the video (36%) having front camera footage only. It is therefore possible that some of the unsafe events which occurred behind the rider with the camera were not detected. Footage from both cameras was required to accurately observe group rider violations, so front camera footage only had to be excluded from Part C of the study. For future studies, installing a unit on the bicycle that integrated the front and rear cameras as well as GPS, allowing all to be activated with the push of a button, would largely overcome these issues. In addition, equipment such as accelerometers and sensors which detect vehicle passing distances could be installed. However, group riders are particular about the size, weight and removability of any devices installed on their bicycles, as well as any potential damage caused, so this would require very careful planning and design.

Finally, all unsafe events and violations were identified and analysed manually by the researchers who watched all of the footage. The subjective nature of the observations means the results could be subject to observer bias. The process of identifying unsafe events manually was also extremely time consuming. Using kinematic triggers based on deceleration, acceleration and swerve thresholds is now common practice for identifying unsafe events in naturalistic driving studies and is a more time efficient method (Perez et al., 2017). Such thresholds have yet to be determined for naturalistic cycling research but is an area for future research. This presents a particular challenge for group riding because unsafe events affecting riders in the group may not actually affect the movement of the participant with the instrumented bicycle, resulting in undetected events. Through watching the footage, it was discovered that sound from the video (riders calling/ yelling) was very useful for identifying unsafe events. This could be an area for further investigation in terms of automating the process of identifying unsafe events from group riding footage.

CHAPTER 8

Conclusion and recommendations

8 CONCLUSION AND RECOMMENDATIONS

This study provided a comprehensive picture of the safety issues surrounding on-road group riding. Phase 1 highlighted group rider crashes (defined as crashes that occurred while riding in a group) as a significant issue and also revealed that group rider crashes were more likely to involve road-related contributing factors than individual rider crashes. This suggests that group riders are more vulnerable to road maintenance issues, slippery road surfaces and temporary traffic hazards or objects on the road, than individual riders. In addition, 12 months after the crash, 60% of participants rode less than before the crash. Interestingly, those who did not participate in group riding before the crash, were at nearly four times the risk of reduced cycling exposure. It was an encouraging finding that those who participated in group riding, were less likely to reduce their cycling exposure after a crash.

The naturalistic study conducted in Phase 2 provided new information on the types of unsafe events and traffic violations that occur while group riding, as well as road environment and group-related risk factors. For unsafe events involving a motor vehicle, the majority involved a motorist travelling in the same direction, attempting to pass the group, which differed from the type of events which had been previously reported for individual riders. While motorists were at fault for most of the unsafe events, these were predominantly the result of errors and misjudgements. Nevertheless, the finding that 15% of unsafe events involved some form of aggressive behaviour confirmed that rider/ motorist aggression is a significant issue in WA that requires further attention. The study also found that roundabouts, traffic islands, speed limits of 60 km per hour or higher, group rider violations and riding single file in the traffic lane, increased the risk of unsafe events involving motor vehicles.

The most common unsafe events not involving a motor vehicle consisted of conflicts between two or more riders in the group and conflicts with an obstacle or object on the road. Riding staggered significantly reduced the risk of an unsafe event not involving a motor vehicle, while curved roads and construction zones significantly increased the risk. Finally, the examination of group rider traffic violations determined that red light violations were uncommon, while stop sign violations were extremely common. The most frequent *'other violations'* were *'riding more than two abreast'* and *'riding on the wrong side of the road'*. However, these four types of rider violations were rarely associated with unsafe events. This study also found that formal riding groups had less than half the rate of *'other violations'* compared to semi-formal riding groups.

Since the WA government is actively promoting participation in cycling, it is essential to improve safety for all types of riders, including group riders. The findings of this study have led to the development of recommendations which have the potential to improve group rider safety in Perth. These include both recommendations for improvement in the safety behaviours of group riders as well as road infrastructure improvements on popular group riding routes. These recommended improvements would promote a safer, more inclusive shared road environment for group riders, while also benefiting individual riders. The interventions are presented in terms of the components of the Safe System Framework.

8.1 Recommendations

8.1.1 Recommendations for further research

1. That an in-depth crash study be undertaken including lower severity group riding crashes resulting in an ED visit. Crashes resulting in an ED visit are more common than those resulting in hospitalisation (Palmer et al., 2015), meaning they contribute to a significant burden of injury. Their inclusion would allow a larger sample of crashes to be obtained, representing a wider spectrum of injuries which could be analysed by crash type and size of the riding group.
2. That future studies examining cycling-related outcomes of crashes follow-up participants for a longer period of two years.
3. That a larger naturalistic group riding study be undertaken involving more groups, collecting more footage per group and using additional bicycle instrumentation including accelerometers and sensors. This larger sample of data would enable different types of unsafe events to be analysed separately as well as the objective evaluation of passing distances by motorists.

4. That methods for automating the process of identifying unsafe events from naturalistic data obtained from group riders be investigated. This would allow more time efficient data processing and reduction.
5. That future studies interview motorists regarding their attitudes, behaviour and experiences surrounding group riders on the road. This information would be useful in the design and targeting of interventions which aim to reduce conflicts between group riders and motorists.

8.1.2 Recommendations for crash recording

6. That the Online Crash Reporting Facility managed by the Insurance Commission of WA/ WA Police be extended to allow the reporting of bicycle crashes that do not involve a motor vehicle, as these are severely under-reported.
7. That an item be included in the Online Crash Reporting Facility, Police crash reports and hospital records asking cyclists how many other riders they were riding with at the time of the crash. This would provide an efficient method for identifying and analysing group riding crashes using the IRIS database and hospital records in the future.

8.1.3 Recommendations for interventions

Safer roads and roadsides

8. That popular recreational cycling routes are targeted for road safety treatments in Perth, since the majority of both group and individual rider hospitalisation crashes occurred on cycling trips undertaken for recreation purposes.
9. That attention is given to road condition and maintenance on cycling routes, in particular at midblocks and on curved roads. These treatments may include road surface repair/ maintenance measures and clearing of on-road hazards. Since a large proportion of both group and individual rider crashes involved road-related factors, these simple treatments could reduce crashes and unsafe events for all cyclists.
10. To investigate the safety benefits of wide bicycle lanes that allow for riding two abreast, on roads with speed limits of 60 km/h or higher, on popular riding

routes. These could be used as an alternative to traffic islands for traffic calming effects and provide a level of separation for riders. The benefits should be examined for both group and individual riders.

11. That single-lane roundabouts located on popular riding routes be designed or treated in a way that encourages riders to claim the traffic lane on approach to and through the roundabout. These treatments include vehicle speed reduction treatments, ending bicycle lanes well before the roundabout, narrow approach lanes of less than three metres, *'sharrows'* and advanced signage encouraging motorists to merge with riders. These treatments could potentially reduce the risk of unsafe events related to motorists attempting to pass groups at roundabouts. These treatments would certainly have benefits for individual riders at roundabouts who experience similar unsafe passing issues.
12. That developers consider and plan for the safety of group and individual riders in road construction projects. This includes clear warning signs and markings indicating the route riders should take through the area, the condition of the road surface and the regular clearing of on-road hazards. This could reduce the risk of unsafe events not involving a motor vehicle for group and individual riders, that occur in construction zones.
13. That consideration be given to restricting motor vehicle traffic on roads located on specific group riding routes, during the early hours of the morning on weekends. This may include closing the road to motor vehicles entirely, designating one lane for bicycle use only on dual carriageways (similar to peak hour bus lanes), or restricting motor vehicle parking during these times.

Safer road users

14. That group rider training is promoted both through formal training programs and informally by riding group organisers/ leaders. This could include safe riding practices, avoiding conflicts with other riders, detection and calling of hazards, negotiating curves safely, road sharing with motorists (including when it is safe and appropriate to ride single file or two abreast) and acceptable behaviour in terms of traffic violations. This has the potential to reduce group riding crashes, unsafe events and violations.

15. That motorist education be undertaken to improve knowledge, attitudes and behaviours surrounding group riders, through mass media campaigns and the driver training curriculum. This may include improving driver knowledge about the road rules affecting group riders, how to drive safety around groups, the safety reasons behind why groups ride two abreast and campaigns framing non-aggressive behaviours as normative. This has the potential to reduce motorist frustration, aggressive behaviour, unsafe events and crashes involving group riders.
16. That the benefits of having a written code of conduct for rider behaviour are promoted to riding groups. This could be incorporated into WestCycle's *'Best practice guide: riding safely in a group'* document and could reduce group rider traffic violations.

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APPENDICES

APPENDIX 1: PARTICIPANT INFORMATION SHEET AND CONSENT FORM (PHASE 1: CRASH STUDY)

Royal Perth Hospital

Fremantle Hospital & Health Service

FIONA STANLEY hospital

MONASH University Accident Research Centre

Curtin University

PARTICIPANT INFORMATION SHEET

SAFER CYCLING AND THE URBAN ROAD ENVIRONMENT
Part 1

Invitation
You are invited to participate in a research study about safer cycling in the urban road environment.

The study is being conducted by Professor Lynn Meuleners, Curtin-Monash Accident Research Centre. The study is funded by an Australian Research Council Linkage grant and is part of a national collaborative study coordinated by Monash University in Melbourne.

Before you decide whether or not you wish to participate in this study, it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully and discuss it with others if you wish.

If you wish to discuss any details of this study or if you have any questions relating to your participation in this research, you may contact Denice ______ from RPH on 04_______ or Denice.Wallis@health.wa.gov.au or Professor Lynn Meuleners on 08 9266 4636 or l.meuleners@curtin.edu.au.

If you agree to participate in this study, you will be asked to sign the attached Participant Consent Form.

1. **'What is the purpose of this study?'**

The purpose is to investigate the issues contributing to cyclist injury with a particular focus on the urban road environment. The outcomes will allow the development of new road designs which will improve the urban cycling experience. In addition, a PhD sub-study will investigate behavioural risk factors for bicycle crashes and compare the characteristics of crashes where cyclists were riding alone or in groups.

2. **'Why have I been invited to participate in this study?'**

You have suffered a cycling-related injury and were admitted to Royal Perth Hospital, Sir Charles Gairdner Hospital, Fremantle Hospital or Fiona Stanley Hospital.

3. **'What if I don't want to take part in this study or if I want to withdraw later?'**

Participation in this study is voluntary. It is completely up to you whether or not you participate.

4. 'What are the alternatives to participating in this study?'

If you decide not to participate in this study, you will still receive the standard treatment available for your condition.

5. 'What does this study involve?'

If you agree to participate in this study, you will be asked to complete two interviews with a research associate or nurse from Curtin University or Royal Perth Hospital. The first interview will include questions on demographic information, details on cycling exposure, cycling behaviours, a description of the crash, events leading up to the crash and post-crash information. It will take approximately 30-40 minutes.

We will also access your trauma registry record to find out information on your length of stay in hospital, the type and severity of your injuries, details of the crash (date, time, postcode and other vehicles involved) and results of any alcohol and drug tests performed in relation to the crash. We will then examine the road environment at the site of your crash.

The second interview will take place in 12 months time via telephone and will ask about your recovery and cycling behaviour. This will take approximately 15-20 minutes.

6. 'How is this study being paid for?'

The study is being sponsored by an Australian Research Council Linkage grant.

7. 'Are there risks to me in taking part in this study?'

There are no risks associated with taking part in this study as you will only be submitted to an interview and we will not interfere with any standard treatment you may be receiving.

8. 'Will I benefit from the study?'

This study aims to improve the safety of cyclists while maintaining mobility in the urban road environment. By focusing on the safety of one of the most vulnerable road user groups the safety gains will benefit all road users, however it will not directly benefit you.

9. 'Will taking part in this study cost me anything, and will I be paid?

Participation in this study will not cost you anything. You will not be paid.

10. 'How will my confidentiality be protected?'

All research data will be stored in a stand-alone and password-protected computer at the Curtin-Monash Accident Research Centre (C-MARC), Curtin University. All hardcopies of the research data will be locked in a cupboard at C-MARC. After study completion, the research data will be retained for a period of seven years after which they will be destroyed.

No information about the cycling crash will be provided to a third party unless subpoenaed by a court of law.

Fremantle Hospital & Health Service

11. 'What happens with the results?'

In the event of any publication regarding this study, your identity will remain confidential. A summary of the study results will be made available to you upon request at the conclusion of the study.

12. 'What should I do if I want to discuss this study further before I decide?'

When you have read this information, the research assistant or nurse will discuss it with you and any queries you may have. If you would like to know more at any stage, please do not hesitate to contact Denice ______ from RPH on 04_________ or Denice.Wallis@health.wa.gov.au, Professor Lynn Meuleners on 9266 4636 or l.meuleners@curtin.edu.au or Michelle Fraser on 04________ or m.fraser@curtin.edu.au

13. 'Who should I contact if I have concerns about the conduct of this study?'

This study has been approved by Curtin University Human Research Ethics Committee (Approval number HR 189/2013). The committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. If needed, verification of approval can be obtained by either writing to the Human Research Ethics Committee, C/O Office of Research and Development, Curtin University, GPO Box U1987, Perth, 6845 or by telephoning 9266 9223 or emailing hrec@curtin.edu.au.

This study has also been approved by the Royal Perth Hospital Human Research Ethics Committee (Approval number 14-038) which can be contacted on (08) 9224 7006 or rph.hrec@health.wa.gov.au

Thank you for taking the time to consider this study.
If you wish to take part in it, please sign the attached consent form.
This information sheet is for you to keep.

Royal Perth Hospital — Sir Charles Gairdner Hospital — Fremantle Hospital & Health Service — Fiona Stanley Hospital — Monash University Accident Research Centre — Curtin University

PARTICIPANT CONSENT SHEET:

SAFER CYCLING AND THE URBAN ROAD ENVRONMENT: PART 1

1. I,..
   of..
   agree to participate in the study described in the participant information statement set out above.
2. I acknowledge that I have read the participant information statement, which explains why I have been selected, the aims of the study and the nature and the possible risks of the investigation, and the statement has been explained to me to my satisfaction.
3. Before signing this consent form, I have been given the opportunity of asking any questions relating to any possible physical and mental harm I might suffer as a result of my participation and I have received satisfactory answers.
4. I understand that I can withdraw from the study at any time without prejudice to my relationship to Curtin University, Monash University, the Royal Perth Hospital, Sir Charles Gairdner Hospital, Fremantle Hospital or Fiona Stanley Hospital.
5. I agree that research data gathered from the results of the study may be published, provided that I cannot be identified.
6. I understand that if I have any questions relating to my participation in this research, I may contact Professor Lynn Meuleners on telephone 08 9266 4636, who will be happy to answer them.
7. I acknowledge receipt of a copy of the Participant Information Sheet.

Complaints may be directed to the Curtin University Human Research Ethics Committee on (08) 9266 9223 or at hrec@curtin.edu.au or the Royal Perth Hospital Human Research Ethics Committee on (08) 9224 7006 or rph.hrec@health.wa.gov.au.

Signature of participant	**Please PRINT name**	**Date**
____________________	______________________________	__________
Signature of investigator	**Please PRINT name**	**Date**
____________________	______________________________	__________

Crash study consent form, 11/02/2015

APPENDIX 2: SUPPORT SERVICES SHEET (PHASE 1: CRASH STUDY)

Royal Perth Hospital

Fremantle Hospital & Health Service

SUPPORT SERVICES

Involvement in a crash can be distressing.

If you are feeling distressed, please contact one of these support services.

Road Trauma Support WA:

Phone: 9420 7262 or 1300 004 814

Road Trauma Support WA provide in-person, telephone or online counselling, free of charge for anyone involved in road trauma. Volunteer peer-supporters and support groups are also available.

Lifeline

Phone: 13 11 14

24 hour telephone crisis support

GP

You can also speak to your GP about any distress you experience as a result of your crash.

Support services sheet: 11/02/15

APPENDIX 3: INVITATION LETTER (PHASE 1: CRASH STUDY)

Fremantle Hospital & Health Service

Name:
Address:
Address:

Professor Lynn Meuleners
Curtin-Monash Accident Research Centre
Curtin University
GPO Box U1987
Perth WA 6845

Date:

Dear Mr/Mrs

Re. Safer cycling and the urban road environment study

We are a team of researchers from the Curtin-Monash Accident Research Centre, Royal Perth, Sir Charles Gairdner, Fremantle and Fiona Stanley Hospitals. We are conducting an important research study with the aim of designing safer roads for cyclists and would like to invite you to take part.

You have been identified for this study since you were recently admitted to hospital following a bike crash. Participation in the study involves two telephone interviews. The first will take place soon and is about you, your health, your cycling experience, group riding experience, cycling behaviours and your recent crash. The second will take place in 12 months and will ask about your recovery and cycling behaviour. If you are available and interested, we would most appreciate your participation.

We have included a detailed Participant Information Sheet about the study with this letter and we will give you a follow up call next week. If you have any queries please contact the RPH research nurse Denice _____ on 04________ or Denice.Wallis@health.wa.gov.au or myself on 9266 4636 or l.meuleners@curtin.edu.au

Thank you.

Yours sincerely,

Professor Lynn Meuleners

Curtin University

Crash study Invitation letter, 11/02/2015

APPENDIX 4: BASELINE QUESTIONNAIRE (PHASE 1: CRASH STUDY)

Bicycle crash study: baseline questionnaire

Q1 Bicycle crash study baseline questionnaire

Q2 Participant details. To be completed by interviewer prior to start of questionnaire

Q3 Participant ID

Q4 Gender
- ○ Male
- ○ Female

Q5 Hospital
- ○ RPH
- ○ Fremantle
- ○ SCGH
- ○ Fiona Stanley

Q6 Interviewer
- ○ Denice
- ○ Michelle
- ○ Other (please specify) ____________________

Q7 Interview mode
- ○ Face to face
- ○ Phone

Q8 Date and time of interview

Date

Time

Q9 Section 1: Some questions about you
First, I'll ask you some questions about you and your health

Q10 What is your age?
- ○ Age in years ____________________
- ○ Declined
- ○ Missing

Q11 What is your height?
- ○ Height in cm or ft/in ____________________
- ○ Declined
- ○ Missing
- ○ Unknown/ can't remember

Q12 What is your weight?
- ○ Weight in kg or st/lb ____________________
- ○ Declined
- ○ Missing
- ○ Unknown/ can't remember

Q13 What is your postcode?
- ○ Postcode (or suburb if unknown) ____________________
- ○ Declined
- ○ Missing
- ○ Unknown/ can't remember

Baseline Questionnaire (Part 1. Crash study), version 2, 01/05/2015

Q14 What is your current employment status?

- ❍ Full time work
- ❍ Part time work
- ❍ Casual work
- ❍ Keeping house
- ❍ Currently unemployed
- ❍ Retired
- ❍ Other (please specify) ____________________
- ❍ Declined
- ❍ Missing

Q15 What is your current study status?

- ❍ Not studying
- ❍ Full time university/ TAFE
- ❍ Part time university/ TAFE
- ❍ Secondary school
- ❍ Other (please specify) ____________________
- ❍ Declined
- ❍ Missing

Q16 What is the highest level of education you have completed?

- ❍ Primary school
- ❍ Secondary school
- ❍ Technical school/ TAFE
- ❍ University degree
- ❍ Higher degree
- ❍ Other (please specify) ____________________

Q17 What is your nationality?

- ❍ Australian
- ❍ Other ____________________
- ❍ Declined
- ❍ Missing

Q18 Are you an Australian resident or a visitor?

- ❍ Australian resident
- ❍ Visitor
- ❍ Declined
- ❍ Missing

Q19 How long have you been in Australia?

- ❍ Length of time in years/ months/ weeks ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q20 Do you have a driver's licence (from any country)?

- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q21 What type of vehicles do you hold a licence for? (tick all that apply)

- ☐ Car
- ☐ Truck
- ☐ Motorcycle
- ☐ Other (please specify) ___________________
- ☐ Declined
- ☐ Missing
- ☐ Unknown/ can't remember

Q22 Do you have an Australian licence?

- ○ Yes
- ○ No
- ○ Declined
- ○ Missing
- ○ Unknown/ can't remember

Q23 The following questions relate to medication you may have been taking before the crash and/ or any medical conditions you may have been diagnosed with

Q24 Were you taking any medication prescribed by a doctor before the crash?

- ○ Yes
- ○ No
- ○ Declined
- ○ Missing
- ○ Unknown/ can't remember

Q25 What was the name of the medication(s) and frequency of use (e.g. daily)?

Q26 Before the crash, did you have any visual impairments?

- ○ Yes
- ○ No
- ○ Declined
- ○ Missing
- ○ Unknown/ can't remember

Q27 Please describe what type of visual impairment

Q28 Before the crash, did you have any hearing impairments?

- ○ Yes
- ○ No
- ○ Declined
- ○ Missing
- ○ Unknown/ can't remember

Q29 Please describe what type of hearing impairment

Q30 Before the crash, did you have any physical impairment resulting in reduced mobility of movement (e.g. difficulty turning your head)?

- ○ Yes
- ○ No
- ○ Declined
- ○ Missing
- ○ Unknown/ can't remember

Q31 Please describe what type of physical impairment

Q32 Before the crash, had you been diagnosed with any medical conditions?

- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q33 Which medical conditions had you been diagnosed with?

Q34 Section 2: Your bicycle riding experience
Next, I'll ask you some questions about your bicycle riding

Q35 How long have you been riding a bicycle in Australia?

- ❍ Time in years or months ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q36 Have you ridden a bicycle in a country outside Australia?

- ❍ Yes
- ❍ No

Q37 How long did you ride a bicycle in other countries?

- ❍ Time in years or months ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q38 What country did you do most of your riding outside Australia?

Q39 What days of the week do you usually ride? (tick all that apply)

- ❑ Monday
- ❑ Tuesday
- ❑ Wednesday
- ❑ Thursday
- ❑ Friday
- ❑ Saturday
- ❑ Sunday
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q40 Over the last year, on average, how frequently did you ride a bicycle? (read responses)

- ❍ Less than once a month
- ❍ Once a month
- ❍ Once a fortnight
- ❍ Once a week
- ❍ 2-3 times a week
- ❍ More than 3 times a week
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q41 Over the last year, on average, how many kilometres have you usually ridden a bicycle each week? (read responses - for new riders riding less than one year, average the total over a year)
- ❍ Less than 10 kms
- ❍ 10-30 km
- ❍ 31-50 kms
- ❍ 51-100 kms
- ❍ 101-200 kms
- ❍ More than 201 kms
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q42 Is your answer to the last question estimated or based on a cycle odometer (bicycle computer)?
- ❍ Own estimate
- ❍ Odometer
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q43 Over the last year, on average, what percentage of your cycling took place with at least one other cyclist?
- ❍ None
- ❍ Other (specify %) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q44 Now I will ask you how much you have cycled in the last month

Q45 Over the last month, on average, how frequently did you ride a bicycle? (read responses)
- ❍ Less than once a month
- ❍ Once a month
- ❍ Once a fortnight
- ❍ Once a week
- ❍ 2-3 times a week
- ❍ More than 3 times a week
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q46 Over the last month, on average, how many kilometres have you usually ridden a bicycle each week? (read responses)
- ❍ Less than 10 kms
- ❍ 10-30 km
- ❍ 31-50 kms
- ❍ 51-100 kms
- ❍ 101-200 kms
- ❍ More than 201 kms
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q47 Is your answer to the last question estimated or based on a cycle odometer (bicycle computer)?
❍ Own estimate
❍ Odometer
❍ Declined
❍ Missing
❍ Unknown/ can't remember

Q48 Over the last year, what percentage of your cycling took place on roads?
❍ None
❍ Percentage (please specify) ____________________
❍ Declined
❍ Missing
❍ Unknown/ can't remember

Q49 What is the purpose of the majority of your riding? (select one response)
❍ Recreation
❍ Commuting
❍ Domestic e.g. shopping
❍ Fitness
❍ Work-related travel
❍ To/ from social venue
❍ To/ from sport
❍ Social e.g. visiting friends/ family
❍ Training (please specify type) ____________________
❍ Other (please specify) ____________________
❍ Declined
❍ Missing
❍ Unknown/ can't remember

Q50 Over the last month, how many days per week did you ride for ${q://QID41/ChoiceGroup/SelectedChoices}

Q51 Over the last month, did you ride for any other purposes?
❍ Yes
❍ No

Q52 What were the other purposes for your riding? (select all responses that apply)
❑ Recreation
❑ Commuting
❑ Domestic e.g. shopping
❑ Fitness
❑ Work-related travel
❑ To/ from social venue
❑ To/ from sport
❑ Social e.g. visiting friends/ family
❑ Training (please specify type) ____________________
❑ Other (please specify) ____________________
❑ Other 2 (please specify) ____________________

Q53 Over the past month, how many days per week did you ride for the purpose of ${lm://Field/1}

Q54 Over the last month, what percentage of your cycling took place with at least one other cyclist?
❍ None
❍ Other (specify %) ____________________
❍ Declined
❍ Missing
❍ Unknown/ can't remember

Q55 Over the last month how many cyclists were in each group you rode with (including yourself)? (answer as many as apply)

- ❑ 2
- ❑ 3-4
- ❑ 5-10
- ❑ 11-20
- ❑ 21-30
- ❑ Over 30

Q56 Over the last month who did you ride in a group with? (answer as many as apply)

- ❑ Family (adults)
- ❑ Family (children)
- ❑ Friends
- ❑ Spouse/ partner
- ❑ Workmates
- ❑ Cycling group/ club
- ❑ Other (please specify) ____________________

Q57 What was the purpose of your cycling when you rode in a group of ... ? (answer as many as apply)

	Recreation	Commuting	Domestic e.g. shopping	Fitness	Work-related travel	To/ from social venue	To/ from sport	Social e.g. visiting friends	Training	Not applicable
2	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
3-4	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
5-10	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
11-20	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
21-30	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
Over 30	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Q58 Over the last month, approximately how many days per week did you ride in a group of ${lm://Field/1} cyclists?

Q59 Do you participate in bunch riding?

- ❍ Yes
- ❍ Unsure (specify) ____________________
- ❍ No, never participated
- ❍ No longer participate
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q60 Over the last month, what percentage of your cycling was in a bunch?

- ❍ Percentage (please specify) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q61 Do you belong to a cycling club or group?

- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q62 Please specify the type of club or group

Q63 What would be your main reasons for not cycling in a group?

Q64 What, if anything would encourage you to try group cycling?

Q65 What would be your main reasons for cycling in a group?

Q66 What, if anything would stop you from cycling in a group?

Q67 To what extent would you agree, or disagree that:

	Disagree strongly	Disagree somewhat	Don't know	Agree somewhat	Agree strongly
Riding in a group is safer than riding alone	❍	❍	❍	❍	❍
Riding in a group would increase my chance of being involved in a crash with a motor vehicle, compared to riding alone	❍	❍	❍	❍	❍
Roads in Perth are well suited to group riding	❍	❍	❍	❍	❍
Riding alone would decrease my chance of being involved in a single bicycle crash, compared to riding in a group	❍	❍	❍	❍	❍
I am less likely to experience aggression from drivers when riding alone than in a group	❍	❍	❍	❍	❍
Riding in a group would increase my chance of being involved in a crash with another cyclist, compared to riding alone	❍	❍	❍	❍	❍

Q68 Please indicate which categories of bicycles you feel competent to ride based on your cycling experience? (select all that apply)

- ❑ Road bicycle (drop handlebars)
- ❑ Road bicycle (flat handlebars)
- ❑ Time trial bicycle (aero handlebars)
- ❑ Mountain bicycle (front or rear shock absorbers)
- ❑ Hybrid
- ❑ Hand powered bicycle
- ❑ Motor assisted bicycle
- ❑ BMX
- ❑ Recumbent
- ❑ Other (please specify) ____________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q69 Please indicate your experience with bicycle pedals/ shoes (select all that apply)

- ❑ Usually ride with shoes - separate pedals
- ❑ Usually ride with clip-less pedals (eg SPD)
- ❑ Usually ride with pedals with toe clips
- ❑ Other (please specify) ____________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q70 Have you undertaken any rider training courses?

- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q71 Have you completed a rider training course or received mentoring in group riding skills specifically?

- ❍ Yes - rider training
- ❍ Yes - mentoring
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q72 In the last 3 years, how many crashes have you been involved in as a bicycle rider on the road or path, not including your most recent crash, resulting in injury requiring medical treatment

- ❍ None
- ❍ One
- ❍ Two
- ❍ More than two
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q73 In the last 3 years, how many crashes have you been involved in as a bicycle rider on the road that resulted in an ED visit or hospital admission (not including your current crash)?

- None
- One
- Two
- Three
- Four
- Five
- Six
- Declined
- Missing
- Unknown/ can't remember

Q74 How many other cyclists were you riding with at the time of each of these crashes resulting in ED or hospital admission? (if cycling alone, enter 0)

Crash 1
Crash 2
Crash 3
Crash 4
Crash 5
Crash 6

Q75 Section 3: Cycling behavior. Now I'm going to ask you about certain behaviours while cycling. Your answers are completely confidential

Q76 How often do you answer your mobile phone if it rings while you are cycling? Would you say... (read responses - note includes being stopped at traffic lights)

- Always
- Very Often
- Fairly often
- Just occasionally
- Rarely
- Never
- Declined

Q77 When you answer calls while cycling, how often do you use a hands-free device? (read responses)

- Always
- Very Often
- Fairly often
- Just occasionally
- Rarely
- Never
- Declined

Q78 Do you ever answer you mobile phone if it rings while riding in a group? (includes being stopped at traffic lights)

- Yes
- No
- Declined

Q79 How often do you make calls on your mobile phone while you are cycling? Would you say... (read responses - note includes being stopped at traffic lights)

- ❍ Always
- ❍ Very Often
- ❍ Fairly often
- ❍ Just occasionally
- ❍ Rarely
- ❍ Never
- ❍ Declined

Q80 When you make calls while cycling, how often do you use a hands-free device? (read responses)

- ❍ Always
- ❍ Very Often
- ❍ Fairly often
- ❍ Just occasionally
- ❍ Rarely
- ❍ Never
- ❍ Declined

Q81 Do you ever make calls on your mobile phone while group riding? (includes being stopped at traffic lights)

- ❍ Yes
- ❍ No
- ❍ Declined

Q82 How often do you read text messages or emails on your mobile phone while you are cycling? Would you say... (read responses - note includes being stopped at traffic lights)

- ❍ Always
- ❍ Very Often
- ❍ Fairly often
- ❍ Just occasionally
- ❍ Rarely
- ❍ Never
- ❍ Declined

Q83 How often do you send text messages or emails on your mobile phone while you are cycling? Would you say... (read responses - note includes being stopped at traffic lights)

- ❍ Always
- ❍ Very Often
- ❍ Fairly often
- ❍ Just occasionally
- ❍ Rarely
- ❍ Never
- ❍ Declined

Q84 Do you ever send or read text messages or emails while group riding? (select all that apply - includes being stopped at traffic lights)

- ❑ Yes send
- ❑ Yes read
- ❑ No
- ❑ Declined

Q85 How often do you use portable audio equipment (including audio on your mobile phone) while you are cycling? Would you say... (read responses - note includes being stopped at traffic lights)
- ❍ Always
- ❍ Very Often
- ❍ Fairly often
- ❍ Just occasionally
- ❍ Rarely
- ❍ Never
- ❍ Declined

Q86 Do you have a device in your ears while listening to portable audio equipment?
- ❍ Yes
- ❍ No
- ❍ Declined

Q87 Do you ever use portable audio equipment while group riding? (select all that apply - includes being stopped at traffic lights)
- ❍ Yes
- ❍ No
- ❍ Declined

Q88 Do you use your phone for any other purpose while cycling?
- ❍ Yes
- ❍ No
- ❍ Declined

Q89 What is the purpose?

Q90 Please bear with me, I have to ask everyone this question

Q91 In the past 12 months, how likely is it that you may have cycled when over the legal blood alcohol limit?... (Read responses, Note: includes cycling on road or path)
- ❍ Very likely
- ❍ Fairly likely
- ❍ Fairly unlikely
- ❍ Very unlikely
- ❍ Definitely not
- ❍ Declined

Q92 In the past 12 months, on how many occasions did you cycle when you may have been over the legal blood alcohol limit?

Q93 Were any of these occasions while group riding?
- ❍ Yes
- ❍ No
- ❍ Declined

Q94 In the past 12 months, how likely is it that you may have cycled while under the influence of an illicit drug?... (Read responses, Note: includes cycling on road or path)
- ❍ Very likely
- ❍ Fairly likely
- ❍ Fairly unlikely
- ❍ Very unlikely
- ❍ Definitely not
- ❍ Declined

Q95 In the past 12 months, on how many occasions did you cycle when you may have been under the influence of an illicit drug?

Q96 Please specify which drug(s)

Q97 Were any of these occasions while group riding?
- ❍ Yes
- ❍ No
- ❍ Declined

Q98 Section 5: Your bicycle, clothing and safety equipment in the crash
The following questions relate to the bike you were riding and clothes you were wearing at the time of the crash

Q99 Please give the following information about your bicycle

Make
Model

Q100 How many years old is your bicycle?
- ❍ Years (please specify) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q101 Could you tell me the cost of the bicycle when you purchased it?
- ❍ Cost (please specify) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q102 Please state the category that best describes the bicycle you were riding when you crashed
- ❍ Road bicycle (drop handlebars)
- ❍ Road bicycle (flat handlebars)
- ❍ Time trial bicycle (aero handlebars)
- ❍ Mountain bicycle (front or rear wheels shock absorbers)
- ❍ Hybrid
- ❍ BMX
- ❍ Recumbent
- ❍ Hand powered bicycle
- ❍ Motor assisted bicycle
- ❍ Child bicycle with training wheels
- ❍ Child bicycle - no training wheels
- ❍ Other (please specify) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q103 Was the bicycle fixed wheel or geared?
- ❍ Fixed wheel
- ❍ Geared
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q104 What type of tyres were on your bicycle? (please select all which apply)

- ❑ Road tyre (slick)
- ❑ Mountain bike tyre (knobbly)
- ❑ Other (please specify) ___________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q105 What type of brakes were on your bicycle? (please select all which apply)

- ❑ Front hand brake
- ❑ Rear hand brake
- ❑ Foot brake
- ❑ No brake
- ❑ Other (please specify) ___________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q106 Did the bicycle have a top tube or no top tube (e.g. girl's bicycle)

- ❍ Top tube
- ❍ No top tube
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q107 Was the bicycle fitted with lighting (please select all which apply)

- ❑ No lighting fitted
- ❑ Front facing
- ❑ Rear facing
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q108 Was the bicycle fitted with any of the following reflective devices (please select all which apply)

- ❑ None
- ❑ Front wheel reflector
- ❑ Rear wheel reflector
- ❑ Pedal reflectors
- ❑ Front frame attached reflector
- ❑ Rear frame attached reflector
- ❑ Other (please specify) ___________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q109 Please describe the clothing you were wearing above the waist at the time of the crash (please select all which apply)

- ❑ Cycling jersey (long sleeves)
- ❑ Cycling jersey (short sleeves)
- ❑ Arm warmers
- ❑ Shirt or t shirt
- ❑ Safety colours e.g. fluro - torso only
- ❑ Safety colours e.g. fluro - torso and arms
- ❑ Gloves
- ❑ Other (please specify) ___________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q110 What was the main colour of the clothing you were wearing from your waist up? (if unclear, state light or dark)

- ❍ Colour (please write) ___________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q111 Please describe the clothing you were wearing below the waist at the time of the crash (please select all which apply)

- ❑ Cycling knicks (long)
- ❑ Cycling knicks (short)
- ❑ Leg warmers
- ❑ Shorts
- ❑ Safety colours e.g. fluro - legs
- ❑ Skirt
- ❑ Long pants/ trousers (please specify fabric) ___________________
- ❑ Other (please specify) ___________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q112 Were you wearing any clothing or other articles that were reflective (not fluorescent)

- ❍ Yes (please describe) ___________________
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q113 Were you wearing any additional clothing, including protective equipment (not including helmet)

- ❍ Yes (please describe) ___________________
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q114 What were you wearing on your feet?

- ❑ Nothing
- ❑ Cleated cycling shoes
- ❑ Closed shoes (e.g. runners)
- ❑ Open shoes (e.g. sandals, thongs)
- ❑ Other (please specify) ____________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q115 Were you wearing a backpack at the time of the crash?

- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q116 What colour was the backpack?

- ❍ Colour (please specify) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q117 Did the backpack have reflective material or lights on it?

- ❑ Reflective material
- ❑ Lights
- ❑ Neither
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q118 At the time of the crash, what eyewear were you wearing?

- ❑ None
- ❑ Spectacles (prescription)
- ❑ Contact lenses (prescription)
- ❑ Clear glasses
- ❑ Sunglasses
- ❑ Sunglasses with prescription lenses
- ❑ Other eyewear (please specify) ____________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q119 Were you wearing a helmet at the time of the crash?

- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q120 Was your helmet buckled under your chin at the time of the crash?

- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q121 Was your helmet in position after the crash

- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q122 Was your helmet damaged in the crash?

- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q123 Why weren't you wearing a helmet?

Q124 Section 4: Events of the crash
Now I'm going to ask you some questions specifically relating to your crash. Please remember that you can stop at any time if you feel distressed

Q125 We'd like some specific information on the location of the crash. Could you tell me the ... (Read questions)

Street name
Intersection (if relevant)
Nearest corner (if not intersection)
Before or after nearest corner
Direction of travel
Landmarks at crash location
Any other location information

Q233 Was the crash at an intersection? (Includes any intersection: traffic light, give way, stop sign, roundabout, T-junction, Y-junction intersections. May be controlled or uncontrolled intersection)

- ❍ No
- ❍ Yes
- ❍ Unknown/ can't remember

Q126 What was the date of the crash?

Q127 What was the time of the crash?

- ❍ AM (please specify) ____________________
- ❍ PM (please specify ____________________

Q128 Could you please describe the crash, the actual events as best you can remember, I will then ask you some specific questions (If interviewing in person, ask participant to sketch crash. If interviewing on phone, ask participant to sketch crash and return)

Q129 What were you predominantly doing at the time of the crash? (select one)

- ❍ Stationary
- ❍ Moving forward
- ❍ Cornering
- ❍ Turning left into a street
- ❍ Turning right into a street
- ❍ Overtaking
- ❍ Accelerating
- ❍ Swerving to avoid a collision
- ❍ Braking
- ❍ Other (please specify) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q130 When you crashed, what distance were you from the end of your trip?

Q131 What type of crash was it? Was it a... (read responses, select all that apply)

- ❑ Impact with object
- ❑ Impact with vehicle
- ❑ Impact with pedestrian
- ❑ Impact with other cyclist
- ❑ Loss of control before collision
- ❑ Loss of control but no collision
- ❑ Other (please specify) ____________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q132 How many collisions with other vehicles, people or objects (not including the ground) occurred in the crash?

- ❍ Specify number ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q133 How many vehicles were involved in the crash? (including your bicycle, vehicles stopped in traffic, other bicycles but NOT parked cars)

- ❍ My bike only
- ❍ Specify number of vehicles including own bike ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q134 In the single vehicle crash, what objects did you (the rider) hit? (select all that apply)

- ❑ Not applicable
- ❑ Nothing - slid/ rolled along ground
- ❑ Power/ light pole
- ❑ Embankment
- ❑ Kerb/ gutter
- ❑ Traffic sign (e.g. stop sign)
- ❑ Traffic lights
- ❑ Tree
- ❑ Vegetation (other than trees, e.g. shrubs
- ❑ Barrier (please specify) ____________________
- ❑ Other (please specify) ____________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q135 Was the crash a low-side (bicycle dropped and slid) or high side (catapulted over) crash?

- ❍ Low-side crash (bicycle dropped and slid)
- ❍ High side crash (catapulted over)
- ❍ Other (please specify) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q136 In the multiple vehicle crash, what objects did you (the rider) hit? (select all that apply)

- ❑ Not applicable
- ❑ 4WD
- ❑ Car - moving (station wagon, car-based ute)
- ❑ Car - stationary (station wagon, car-based ute)
- ❑ Bus/ coach
- ❑ Truck - articulated, semi trailer, B double
- ❑ Van/ minibus
- ❑ Motorcycle/ moped
- ❑ Cyclist
- ❑ Rollerblader, skater, skateboarder
- ❑ Pedestrian
- ❑ Barrier (please specify) ____________________
- ❑ Embankment
- ❑ Kerb/ gutter
- ❑ Power/ light pole
- ❑ Traffic lights
- ❑ Traffic sign (e.g. stop sign)
- ❑ Tree
- ❑ Other (please specify) ____________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q137 Was your first contact with a motor vehicle?

- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q138 What was the movement of that motor vehicle at the time of the crash?

- ❑ Moving forward
- ❑ Coming to a stop in traffic lane
- ❑ Decelerating in traffic lane
- ❑ Accelerating in traffic lane
- ❑ Leaving a parked position
- ❑ Entering a parked position
- ❑ Turning right
- ❑ Turning left
- ❑ Merging
- ❑ Starting from a rest position in traffic lane
- ❑ Stationary
- ❑ Overtaking another vehicle
- ❑ Broken down or parked in traffic lane
- ❑ Reversing
- ❑ Making a U turn
- ❑ Negotiating a curve
- ❑ Changing lanes
- ❑ Completion of successful avoidance manoeuvre
- ❑ Other (please specify) ____________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q139 At what point did you separate from the bicycle?

- ❍ Immediately on impact
- ❍ At the beginning of the slide
- ❍ At some point in the collision sequence
- ❍ Stayed with the bicycle
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q140 Please briefly describe

Q141 Section 6: Events leading up to the crash and the road environment

The following questions relate to the events leading up to the crash and the road environment. Please remember that all information you provide is confidential and will be used only for the purposes of this study

Q142 What was the main purpose of your trip?

- ❍ Recreation
- ❍ Commuting
- ❍ Domestic (e.g. shopping)
- ❍ Fitness
- ❍ Work related travel
- ❍ To/ from social venue
- ❍ To/ from sport
- ❍ Social - visiting friends, family
- ❍ Training (please specify type) ____________________
- ❍ Other (please specify) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q143 On average, over the last 12 months, how often have you ridden on the road where the crash occurred?

- Daily
- 2-3 times per week
- Once a week
- Once a month
- Rarely used
- First time used
- Other (please specify) ____________________
- Declined
- Missing
- Unknown/ can't remember

Q144 What was the speed limit on the road where the crash occurred?

- Speed limit (km/hr) ____________________
- Declined
- Missing
- Unknown/ can't remember

Q145 What was your speed before the crash?

- Speed (km/hr) ____________________
- Declined
- Missing
- Unknown/ can't remember

Q146 Was your speed before the crash an estimate or based on a cycle computer reading?

- Estimate ____________________
- Cycle computer reading
- Declined
- Missing
- Unknown/ can't remember

Q147 What was your expected travelling time for the trip?

- Time (hours or minutes) ____________________
- Declined
- Missing
- Unknown/ can't remember

Q148 What was your expected travelling distance for the trip?

- Distance (km) ____________________
- Declined
- Missing
- Unknown/ can't remember

Q149 Were you riding alone at the time of the crash?

- Yes
- No
- Declined
- Missing
- Unknown/ can't remember

Q150 How many riders were in the group?

- Number (please specify) ____________________
- Declined
- Missing
- Unknown/ can't remember

Q151 Is this number exact or an estimate?
- Exact
- Estimate
- Declined
- Missing
- Unknown/ can't remember

Q152 How many abreast were you riding at the time of the crash?
- Number (please specify) ____________________
- Declined
- Missing
- Unknown/ can't remember

Q153 What was your distance to the nearest rider at the time of the crash
- Distance (specify measure) ____________________
- Declined
- Missing
- Unknown/ can't remember

Q154 Were you riding in a bunch at the time of the crash?
- Yes
- No
- Declined
- Missing
- Unknown/ can't remember

Q155 What is your level of experience in group riding?
- Experienced
- Intermediate (some experience)
- Beginner (little or no experience)
- Declined
- Missing
- Unknown/ can't remember

Q156 Please specify how many years you have been group riding?
- Years (please specify) ____________________
- Declined
- Missing
- Unknown/ can't remember

Q157 How long have you been riding with the group you were with at the time of the crash?
- Time (please specify) ____________________
- Declined
- Missing
- Unknown/ can't remember

Q158 How frequently do you ride with the group you were with at the time of the crash?
- Less than once a month
- Once a month
- Once a fortnight
- Once a week
- 2-3 times a week
- More than 3 times a week
- Declined
- Missing
- Unknown/ can't remember

Q159 Was the ride organised through a club?

- ❍ Yes (please specify) ___________________
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q160 How is the group organised and how do people find out about the rides? - please elaborate (e.g. through bike shop, online, word of mouth, paid membership to group?)

Q161 How would you describe the level of the group you were riding with at the time of the crash?

- ❍ Fast
- ❍ Medium
- ❍ Slower
- ❍ Other (please specify) ___________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q162 What are the purposes of the group you were riding with at the time of the crash? (select all that apply)

- ❑ Social
- ❑ Training
- ❑ Racing
- ❑ Other (please specify) ___________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q163 What was your position in the group at the time of the crash?

- ❍ Position (please specify) ___________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q164 Was there a leader at the time of the crash?

- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q165 Can you describe the leadership structure of the group you were riding with at the time of the crash? (e.g. designated leader, rolling leadership, no leader)

Q166 Who were you riding with at the time of the crash? (select all that apply)

- ❑ Family members (adults)
- ❑ Family members (children)
- ❑ Friends
- ❑ Spouse/ partner
- ❑ Workmates
- ❑ Cycling group/ club
- ❑ Other (please specify) ___________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q167 In your opinion, did riding with the group contribute to the crash?
- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q168 How did riding with the group contribute to the crash?

Q169 What were the weather conditions at the time of the crash (select as many as apply)
- ❑ Clear
- ❑ Cloudy/ overcast
- ❑ Blinding sunlight
- ❑ Light rain
- ❑ Heavy rain
- ❑ Hail
- ❑ Fog
- ❑ Smoke
- ❑ Dust
- ❑ Strong headwind
- ❑ Strong crosswind
- ❑ Other (please specify) ____________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q170 In your opinion, did the weather conditions contribute to the crash?
- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q171 How did the weather conditions contribute to the crash?

Q172 What were the lighting conditions at the time of the crash (select as many as apply)
- ❑ Daylight
- ❑ Dusk
- ❑ Dawn
- ❑ Dark, street lights on
- ❑ Dark, street lights off
- ❑ Dark, no street lights
- ❑ Dark, street lights unknown
- ❑ Other (please specify) ____________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q173 In your opinion, did the lighting conditions contribute to the crash?
- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q174 How did the lighting conditions contribute to the crash?

Q175 Did you have your light(s) turned on?

- ❍ Yes
- ❍ No
- ❍ Not fitted
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q176 Please provide details on your front and rear lights (select all that apply)

	Solid	Flashing	White	Red	Not used
Front light	❑	❑	❑	❑	❑
Rear light	❑	❑	❑	❑	❑

Q177 What was the road surface immediately before the crash?

- ❍ Sealed road
- ❍ Sealed road, unsealed shoulder
- ❍ Sealed road, sealed shoulder
- ❍ Unsealed road
- ❍ Other (please specify) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q178 Was there a bicycle lane present?

- ❍ Yes
- ❍ No
- ❍ Other (please specify) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q179 Were you travelling in the bicycle lane?

- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q180 Were any members of your group travelling in the bicycle lane?

- ❍ Yes (please specify) ____________________
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q181 What was the condition of the road surface? (select all that apply)

- ❑ Dry
- ❑ Wet
- ❑ Muddy
- ❑ Bumpy, broken, cracked
- ❑ Slippery (please specify e.g. paint) ____________________
- ❑ Damp
- ❑ Gravel
- ❑ Other ____________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q182 Was there any debris on the road surface? (select all that apply)

- ❑ No
- ❑ Broken glass
- ❑ Oil
- ❑ Sand
- ❑ Other (please specify) ____________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q183 In your opinion, did the condition of the road or debris contribute to the crash? (select all that apply)

- ❑ Yes - road condition
- ❑ Yes - debris
- ❑ No
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q184 Please describe how the road condition or debris contributed to the crash

Q185 What were you predominantly looking at immediately before the crash? (please select one)

- ❍ The road ahead
- ❍ Oncoming traffic
- ❍ A side road
- ❍ Rear wheel of cyclist in front
- ❍ Another bicycle rider
- ❍ Water bottle/ cage/ holder (to retrieve)
- ❍ Water bottle/ cage/ holder (to replace)
- ❍ Mobile phone
- ❍ Your chain rings or cassette (rear cogs)
- ❍ Portable audio device (e.g. ipod)
- ❍ Other (please specify) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q186 Was your vision obstructed in any way before the crash?

- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q187 What was your vision obstructed by? (please select all that apply)
- ❑ Parked vehicle
- ❑ Road works
- ❑ Building
- ❑ Vegetation
- ❑ Cyclist in front of you
- ❑ Pedestrians
- ❑ Bend in road
- ❑ Slope in road (crest of hill)
- ❑ Dazzling sunlight
- ❑ Dazzling headlights
- ❑ Misted eyewear
- ❑ Damaged eyewear
- ❑ Scratched eyewear
- ❑ Dirty eyewear
- ❑ Vehicle (please specify) ____________________
- ❑ Other (please specify) ____________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q188 In your opinion, did your vision being obstructed contribute to the crash?
- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q189 Please describe how your vision being obstructed contributed to the crash

Q190 What avoidance action(s) did you take? (please select all that apply)
- ❑ None
- ❑ Stopped
- ❑ Steered away - left
- ❑ Steered away - right
- ❑ Braked
- ❑ Swerved
- ❑ Accelerated
- ❑ Rang bell
- ❑ Yelled
- ❑ Made contact with other cyclist e.g. push
- ❑ Made contact with motor vehicle e.g. push
- ❑ Made contact with pedestrian e.g. push
- ❑ Other (please specify) ____________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q191 What type of braking action did you use? (please select one)

- None
- Front hand brake only
- Rear hand brake only
- Foot brake only
- Braked but don't know which ones
- Front hand brake and rear foot brake
- Other (please specify) ____________________
- Declined
- Missing
- Unknown/ can't remember

Q192 In your opinion did a bicycle malfunction or mechanical problem contribute to the crash? (e.g. brake failure)

- Yes
- No
- Declined
- Missing
- Unknown/ can't remember

Q193 What was the nature of the malfunction/ mechanical problem?

Q194 Please describe how the malfunction/ mechanical problem contributed to the crash

Q195 Did another road user contribute to the crash occurring?

- Yes
- No
- Declined
- Missing
- Unknown/ can't remember

Q196 What type of road user?

- Driver
- Motorcyclist
- Cyclist
- Pedestrian
- Other ____________________
- Declined
- Missing
- Unknown/ can't remember

Q197 In your opinion, did any of the following factors contribute to the crash? (please select all that apply)

- ❑ Late/ in a hurry
- ❑ Racing with another rider
- ❑ Feeling fatigued
- ❑ Feeling sleepy
- ❑ Feeling unwell
- ❑ Distracted by riding companion e.g. talking
- ❑ Pressure from other road user e.g. road rage
- ❑ Distracted by street names/ road signs
- ❑ Merging of a bicycle lane with traffic lane
- ❑ Poorly positioned road sign
- ❑ Traffic lights not working
- ❑ Road works
- ❑ Unexpected tightening of corner
- ❑ Road layout was misleading
- ❑ Carrying items in hands or on bike (please specify) ____________________
- ❑ Other (please specify) ____________________
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q198 Were you using a mobile phone before, or at the time of the crash?

- ○ Yes
- ○ No
- ○ Declined
- ○ Missing
- ○ Unknown/ can't remember

Q199 Please specify what you were using the mobile phone for?

- ○ Talking, hands free
- ○ Talking, hand held
- ○ Texting
- ○ Reading text
- ○ Other ____________________
- ○ Declined
- ○ Missing
- ○ Unknown/ can't remember

Q200 Were you using portable audio equipment or did you have any other device in your ear or ears?

- ○ Yes
- ○ No
- ○ Declined
- ○ Missing
- ○ Unknown/ can't remember

Q201 Did you have the device in one or both ears?

- ○ In one ear
- ○ In both ears
- ○ Declined
- ○ Missing
- ○ Unknown/ can't remember

Q202 How loud was the volume?
- ❍ Low - mainly heard surrounding sound
- ❍ High - mainly heard headphones
- ❍ Other volume (please specify) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q203 What were you listening to?
- ❍ Music (please specify) ____________________
- ❍ Non-music/ podcast (please specify) ____________________
- ❍ Other (please specify) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q204 Was your hearing reduced by wind noise immediately before the crash?
- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q205 How much sleep did you have in the 24 hours before the crash?
- ❍ Sleep (hours and minutes) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q206 Did anything stressful or exciting happen to you in the 24 hours before the crash?
- ❑ No
- ❑ Yes - stressful
- ❑ Yes - exciting
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q207 What was the event?

Q208 Do you think it affected your riding?
- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q209 Did you have anything stressful or exciting planned in the 24 hours after the crash?
- ❑ No
- ❑ Yes - stressful
- ❑ Yes - exciting
- ❑ Declined
- ❑ Missing
- ❑ Unknown/ can't remember

Q210 What was the event?

Q211 Do you think it affected your riding?
- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q212 Can you think of anything else not already mentioned to do with you, your bicycle, another road user or the environment that may have led to the crash? (please specify)

Q213 We've reached the end of the questionnaire. Thank you for your time. For the purposes of further research, would you agree to us contacting you again in 12 months time to find out about your recovery and cycling?
- ❍ Yes
- ❍ No

Q214 Contact details

Phone 1 (specify mobile/ home/ work)
Phone 2 (specify mobile/ home/ work)
Email
Email 2
Best contact day (weekend or weekday)
Best contact time (e.g. work hours/ after hours)

APPENDIX 5: CRASH SKETCH (PHASE 1: CRASH STUDY)

SERVIO Royal Perth Hospital | SIR CHARLES GAIRDNER HOSPITAL | Fremantle Hospital & Health Service | FIONA STANLEY hospital | MONASH University Accident Research Centre | Curtin University

SAFER CYCLING AND THE URBAN ROAD ENVRONMENT
CRASH LOCATION SKETCH

If you decide to participate in this study, please sketch the location and circumstances of your crash to the best of your ability.

Sketch - please clearly label the cyclist (C) and the other road user (OR). Please indicate the direction of travel and name of the road(s) at the location.

Please return this page and your signed consent form to the research nurse either in person, by mail in the reply paid envelope, by fax or scan and email to:

Fax: (08) --- ---- **Email: ---@health.wa.gov.au**

Crash sketch 11/02/15

APPENDIX 6: FOLLOW-UP QUESTIONNAIRE (PHASE 1: CRASH STUDY)

Bicycle crash study: follow-up questionnaire

Q1 Bicycle crash study: follow-up questionnaire

Q2 Participant details. To be completed by interviewer

Q3 Participant ID ________

Q4 Date and time of interview
Date _________
Time _________

Q5 Section 1: Injury, pain and functioning. First, I'd like to ask you about your physical recovery from the crash and your current level of functioning

Q6 Do you currently experience any physical effects due to injuries resulting from your crash 12 months ago?

- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing

Q7 Please describe the physical effects

Q8 Have you experienced any pain from injuries resulting from your crash in the last 24 hours?

- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing

Q9 Please indicate the intensity of current pain levels (due to injuries resulting from the crash) on a scale of 0 (no pain) to 10 (worst pain imaginable)

	None (0)	Mild (1)	Mild (2)	Mild (3)	Moderate (4)	Moderate (5)	Moderate (6)	Severe (7)	Severe (8)	Severe (9)	Severe (10)
Pain level	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q10 Please indicate the intensity of BEST pain levels over the last 24 hours on a scale of 0 (no pain) to 10 (worst pain imaginable)

	None (0)	Mild (1)	Mild (2)	Mild (3)	Moderate (4)	Moderate (5)	Moderate (6)	Severe (7)	Severe (8)	Severe (9)	Severe (10)
Pain level	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q11 Please indicate the intensity of WORST pain levels over the last 24 hours on a scale of 0 (no pain) to 10 (worst pain imaginable)

	None (0)	Mild (1)	Mild (2)	Mild (3)	Moderate (4)	Moderate (5)	Moderate (6)	Severe (7)	Severe (8)	Severe (9)	Severe (10)
Pain level	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q12 Glasgow Outcome Scale - Extended (GOS-E)

Q13 Interviewer answer this question! Is the participant able to obey simple commands or say any words?
- Yes
- No

Q14 Is the assistance of another person at home essential every day for some activities of daily living? Note: 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 needing prompting or reminding and should be capable of being left alone overnight.
- Yes
- No
- Declined
- Missing

Q15 Do you need frequent help of someone to be around at home most of the time? Note: for a NO answer they should be able to look after themselves at home up to eight hours during the day if necessary, though they need not actually look after themselves
- Yes
- No
- Declined
- Missing

Q16 Were you independent at home before the injury?
- Yes
- No
- Declined
- Missing

Q17 Are you able to shop without assistance? Note: 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.
- Yes
- No
- Declined
- Missing

Q18 Were you able to shop without assistance before?
- Yes
- No
- Declined
- Missing

Q19 Are you able to travel locally without assistance? Note: 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.
- Yes
- No
- Declined
- Missing

Q20 Were you able to travel locally without assistance before the injury?
- Yes
- No
- Declined
- Missing

Follow-up questionnaire, crash study 02/11/15

Q21 Are you currently able to work (or look after others at home) to your previous capacity?

- Yes
- No
- Declined
- Missing

Q22 How restricted are you?

- Reduced work capacity
- Able to work only in a sheltered workshop or non-competitive job or unable to work
- Declined
- Missing

Q23 Does the level of restriction represent a change in respect to the pre-trauma situation

- Yes
- No
- Declined
- Missing

Q24 Are you able to resume regular social and leisure activities outside the home? Note: they need not have resumed all their previous leisure activities, but should not be prevented by physical or mental impairment. If they have stopped the majority of activities because of loss of interest or motivation, then this is considered a disability

- Yes
- No
- Declined
- Missing

Q25 What is the extent of restriction on your social and leisure activities?

- Participate a bit less: at least half as often as before injury
- Participate much less: less than half as often
- Unable to participate: rarely, if ever, take part
- Declined
- Missing

Q26 Does the extent of restriction in regular social and leisure activities outside home represent a change in respect to pre-trauma?

- Yes
- No
- Declined
- Missing

Q27 Has there been family or friendship disruption due to psychological problems? Note: typical post-traumatic personality changes are: quick temper, irritability, anxiety, insensitivity to others, mood swings, depression and unreasonable or childish behaviour

- Yes
- No
- Declined
- Missing

Q28 What has been the extent of disruption or strain?

- Occasional - less than weekly
- Frequent - once a week or more, but not tolerable
- Constant - daily and intolerable
- Declined
- Missing

Q29 Does the level of disruption or strain represent a change in respect to pre-trauma situation? Note: if there were some problems before injury, but these have become markedly worse since the injury then answer yes

- Yes
- No
- Declined
- Missing

Q30 Are there any other current problems relating to the injury which affect daily life? Note: other typical problems: headaches, dizziness, sensitivity to noise or light, slowness, memory failures and concentration problems

- Yes
- No
- Declined
- Missing

Q31 If similar problems were present before the injury, have these become markedly worse?

- Yes
- No
- Declined
- Missing

Q32 What is the most important factor in outcome?

- Effect of head injury
- Effects of illness or injury to another part of the body
- A mixture of these
- Missing

Q33 Were you ever diagnosed with post-traumatic stress disorder as a result of your crash 12 months ago?

- Yes
- No
- Declined
- Missing

Q34 Did you undergo any counselling as a result of your crash?

- Yes (please specify) ____________________
- No
- Declined
- Missing

Q35 Section 2: Cycling exposure. The next questions relate to the amount and type of cycling you've done since the crash

Q36 Have you cycled since your crash 12 months ago?

- Yes
- No
- Declined
- Missing

Q37 How long after your crash (12 months ago) did you resume cycling

Q38 Have you been involved in any further crashes as a cyclist since your crash 12 months ago?

- Yes
- No
- Declined
- Missing

Q39 How many crashes?
- 1
- 2
- 3
- 4

Q40 How many of these crashes required hospital admission or a ED visit?
- 0
- 1
- 2
- 3
- 4

Q41 Over the last month, on average, how frequently did you ride a bicycle? (read responses)
- Less than once a month
- Once a month
- Once a fortnight
- Once a week
- 2-3 times a week
- More than 3 times a week
- Declined
- Missing
- Unknown/ can't remember

Q42 Over the last month, on average, how many kilometres have you usually ridden a bicycle each week? (read responses)
- Less than 10 kms
- 10-30 km
- 31-50 kms
- 51-100 kms
- 101-200 kms
- More than 201 kms
- Declined
- Missing
- Unknown/ can't remember

Q43 Is your answer to the last question estimated or based on a cycle odometer (bicycle computer)?
- Own estimate
- Odometer
- Declined
- Missing
- Unknown/ can't remember

Q44 What was the purpose of the majority of your riding (over the past month)? (select one response)
- Recreation
- Commuting
- Domestic e.g. shopping
- Fitness
- Work-related travel
- To/ from social venue
- To/ from sport
- Social e.g. visiting friends/ family
- Training (please specify type) ____________________
- Other (please specify) ____________________
- Declined
- Missing
- Unknown/ can't remember

Q45 Over the last month, how many days per week did you ride for ${q://QID48/ChoiceGroup/SelectedChoices}

Q46 Over the last month, did you ride for any other purposes?
- ❍ Yes
- ❍ No

Q47 What were the other purposes for your riding? (select all responses that apply)
- ❑ Recreation
- ❑ Commuting
- ❑ Domestic e.g. shopping
- ❑ Fitness
- ❑ Work-related travel
- ❑ To/ from social venue
- ❑ To/ from sport
- ❑ Social e.g. visiting friends/ family
- ❑ Training (please specify type) ____________________
- ❑ Other (please specify) ____________________
- ❑ Other 2 (please specify) ____________________

Q48 Over the past month, how many days per week did you ride for the purpose of ${lm://Field/1}

Q49 Over the last month, what percentage of your cycling took place on roads?
- ❍ None
- ❍ Percentage (please specify) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q50 Over the last month, what percentage of your cycling took place with at least one other cyclist?
- ❍ None
- ❍ Other (specify %) ____________________
- ❍ Declined
- ❍ Missing
- ❍ Unknown/ can't remember

Q51 Over the last month how many cyclists were in each group you rode with (including yourself)? (answer as many as apply)
- ❑ 2
- ❑ 3-4
- ❑ 5-10
- ❑ 11-20
- ❑ 21-30
- ❑ Over 30

Q52 Over the last month who did you ride in a group with? (answer as many as apply)
- ❑ Family (adults)
- ❑ Family (children)
- ❑ Friends
- ❑ Spouse/ partner
- ❑ Workmates
- ❑ Cycling group/ club
- ❑ Other (please specify) ____________________

Q53 What was the purpose of your cycling when you rode in a group of ... ? (answer as many as apply)

	Recreation	Commuting	Domestic e.g shopping	Fitness	Work-related travel	To/ from social venue	To/ from sport	Social e.g visiting friends	Training	Not applicable
2	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
3-4	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
5-10	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
11-20	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
21-30	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
Over 30	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Q54 Over the last month, approximately how many days per week did you ride in a group of ${lm://Field/1} cyclists?

Q55 Would you say you cycle more, the same amount or less overall than before your crash 12 months ago?
❍ More
❍ Same
❍ Less
❍ Declined
❍ Missing
❍ Unknown/ can't remember

Q56 Would you say you cycle less due to the crash you experienced 12 months ago?
❍ Yes
❍ No
❍ Declined
❍ Missing

Q57 What are the reasons you cycle less than before your crash?

Q58 Is this because of physical injury and/ or other reasons related to the crash? Select as many as appropriate
❑ Physical injury
❑ Other (please specify) ____________________
❑ Declined
❑ Missing

Q59 Have you replaced cycling with another form of physical activity? Please specify
❍ Yes (please specify) ____________________
❍ No
❍ Declined
❍ Missing

Q60 Would you say you cycle more, the same amount, or less for commuting purposes than before your crash 12 months ago?

- ○ More
- ○ Same
- ○ Less
- ○ Declined
- ○ Missing
- ○ Unknown/ can't remember

Q61 Would you say you cycle less for commuting purposes due to the crash you experienced 12 months ago?

- ○ Yes
- ○ No
- ○ Declined
- ○ Missing

Q62 What method(s) of commuting do you use instead of cycling?

- ☐ Car
- ☐ Motorbike
- ☐ Public transport
- ☐ Walking
- ☐ Other (please specify) ____________________
- ☐ Declined
- ☐ Missing

Q63 Section 3: Cycling avoidance and behaviour. Please answer the following questions by selecting the appropriate box for each

Q64 During the past month, have you avoided cycling when it was raining?

- ○ Never
- ○ Rarely
- ○ Sometimes
- ○ Often
- ○ Always
- ○ Declined
- ○ Missing
- ○ Unknown/ cant remember

Q65 Have you avoided cycling when it was raining due to your crash 12 months ago?

- ○ Yes
- ○ No
- ○ Declined
- ○ Missing

Q66 During the past month, have you avoided cycling alone?

- ○ Never
- ○ Rarely
- ○ Sometimes
- ○ Often
- ○ Always
- ○ Declined
- ○ Missing
- ○ Unknown/ cant remember

Q67 Have you avoided cycling alone due to your crash 12 months ago?
- Yes
- No
- Declined
- Missing

Q68 During the past month, have you avoided cycling in a group?
- Never
- Rarely
- Sometimes
- Often
- Always
- Declined
- Missing
- Unknown/ cant remember

Q69 Have you avoided cycling in a group due to your crash 12 months ago?
- Yes
- No
- Declined
- Missing

Q70 During the past month, have you avoided cycling on the road?
- Never
- Rarely
- Sometimes
- Often
- Always
- Declined
- Missing
- Unknown/ cant remember

Q71 Have you avoided cycling on the road due to your crash 12 months ago?
- Yes
- No
- Declined
- Missing

Q72 During the past month, have you avoided cycling on high speed roads?
- Never
- Rarely
- Sometimes
- Often
- Always
- Declined
- Missing
- Unknown/ cant remember

Q73 Have you avoided cycling on high speed roads due to your crash 12 months ago?
- Yes
- No
- Declined
- Missing

Q74 During the past month, have you avoided cycling on high traffic roads?
- Never
- Rarely
- Sometimes
- Often
- Always
- Declined
- Missing
- Unknown/ cant remember

Q75 Have you avoided cycling on high traffic roads due to your crash 12 months ago?
- Yes
- No
- Declined
- Missing

Q76 During the past month, have you avoided cycling in peak hour traffic?
- Never
- Rarely
- Sometimes
- Often
- Always
- Declined
- Missing
- Unknown/ cant remember

Q77 Have you avoided cycling in peak hour traffic due to your crash 12 months ago?
- Yes
- No
- Declined
- Missing

Q78 During the past month, have you avoided cycling in the dark?
- Never
- Rarely
- Sometimes
- Often
- Always
- Declined
- Missing
- Unknown/ cant remember

Q79 Have you avoided cycling in the dark due to your crash 12 months ago?
- Yes
- No
- Declined
- Missing

Q80 During the past month, have you avoided cycling in any other situations due to your crash? (please specify)

Q81 Since your crash 12 months ago, have you made any modifications to your bike for the purpose of safety?
- Yes (please specify) ____________________
- No
- Declined
- Missing

Q82 Since your crash 12 months ago, have you made any modifications to the clothing/ gear you wear for the purpose of safety?

- ❍ Yes (please specify) ____________________
- ❍ No
- ❍ Declined
- ❍ Missing

Q83 Since your crash 12 months ago, have you made any modifications to your behaviour when cycling for the purpose of safety?

- ❍ Yes (please specify) ____________________
- ❍ No
- ❍ Declined
- ❍ Missing

Q84 Questions for those who have not cycled since their crash

Q85 Would you say it is due to the crash that you haven't cycled in the last 12 months?

- ❍ Yes
- ❍ No
- ❍ Declined
- ❍ Missing

Q86 What are the reasons you haven't cycled since your crash?

Q87 Is this because of physical injury and/ or other reasons related to the crash? Select as many as appropriate

- ❑ Physical injury
- ❑ Other (please specify) ____________________
- ❑ Declined
- ❑ Missing

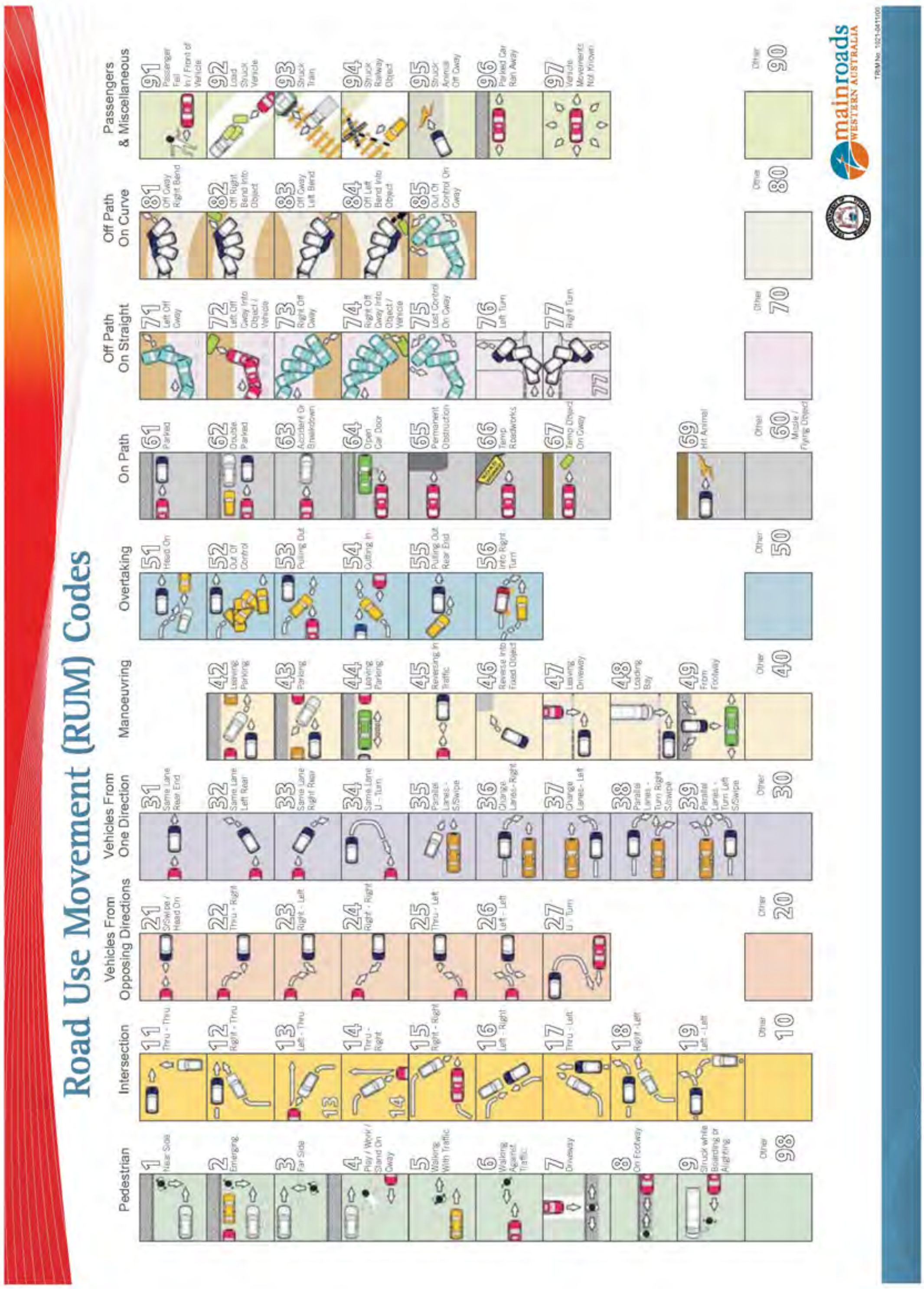
Q88 Have you replaced cycling with another form of physical activity? Please specify

- ❍ Yes (please specify) ____________________
- ❍ No
- ❍ Declined
- ❍ Missing

Q89 Do you intend to ever return to cycling

- ❍ Yes
- ❍ No
- ❍ Undecided
- ❍ Declined
- ❍ Missing

APPENDIX 7: ROAD USE MOVEMENT (RUM) CODES (PHASE 1: CRASH STUDY)



(Main Roads Western Australia, 2015)

APPENDIX 8: ETHICS COMMITTEE AND RESEARCH GOVERNANCE APPROVALS (PHASE 1 AND 2)

Curtin University

Memorandum

To	Associate Professor Lynn Meuleners, Public Health
From	Professor Stephan Millett, Chair, Human Research Ethics Committee
Subject	Protocol Approval **HR 189/2013**
Date	3 December 2013
Copy	

Office of Research and Development
Human Research Ethics Committee

TELEPHONE 9266 2784
FACSIMILE 9266 3793
EMAIL hrec@curtin.edu.au

Thank you for providing the additional information for the project titled "*Safer Cycling in the Urban Road Environment*". The information you have provided has satisfactorily addressed the queries raised by the Committee. Your application is now **approved**.

- You have ethics clearance to undertake the research as stated in your proposal.
- The approval number for your project is **HR 189/2013.** *Please quote this number in any future correspondence*.
- Approval of this project is for a period of four years **03-12-2013** to **03-12-2017**.
- Your approval has the following conditions:
  i) Annual progress reports on the project must be submitted to the Ethics Office.
- **It is your responsibility, as the researcher, to meet the conditions outlined above and to retain the necessary records demonstrating that these have been completed.**

Applicants should note the following:

It is the policy of the HREC to conduct random audits on a percentage of approved projects. These audits may be conducted at any time after the project starts. In cases where the HREC considers that there may be a risk of adverse events, or where participants may be especially vulnerable, the HREC may request the chief investigator to provide an outcomes report, including information on follow-up of participants.

The attached **Progress Report** should be completed and returned to the Secretary, HREC, C/- Office of Research & Development annually.

Our website https://research.curtin.edu.au/guides/ethics/non_low_risk_hrec_forms.cfm contains all other relevant forms including:

- Completion Report (to be completed when a project has ceased)
- Amendment Request (to be completed at any time changes/amendments occur)
- Adverse Event Notification Form (If a serious or unexpected adverse event occurs)

Yours sincerely

Professor Stephan Millett
Chair Human Research Ethics Committee

MEMORANDUM

Curtin University

To:	Associate Professor Lynn Meuleners Public Health
CC:	
From	Professor Peter O'Leary, Chair HREC
Subject	Amendment approval Approval number: HR189/2013
Date	03-Mar-15

Office of Research and Development
Human Research Ethics Office

TELEPHONE 9266 2784
FACSIMILE 9266 3793
EMAIL hrec@curtin.edu.au

Thank you for submitting an amendment to the Human Research Ethics Office for the project:

HR189/2013 Safer Cycling in the Urban Road Environment

The Human Research Ethics Office approves the amendment to the project.

Amendment number: HR189/2013/AR1

Approval date: 03-Mar-15

The following amendments were approved:

1. Case cyclists from Fremantle Hospital will no longer be recruited
2. Michelle Fraser, PhD student, will have access to participant information
3. Michelle Fraser will conduct a sub-study within the larger project specifically focusing on group and bunch riding safety, entitled "Group riding in Western Australia: an examination of rashes, outcomes and behaviour".

3a. Using additional recruitment methods to achieve a larger sample of bunch cyclists specifically for the video camera and interview component.
3b. Modifications made to the Participant Information Sheet
3c. A new PIS created for bunch cyclists recruited through the new additional methods who participate in the sub-study only.
3.d. The study website that all controls are directed to at recruitment modified to include more details of the sub-study.
3e. The sub-study will involve more detailed analysis of the bunch riding video identifying unsafe events and behaviours and determining bunch-related and road-environment related risk factors for these.

Please ensure that all data are stored in accordance with WAUSDA and Curtin University Policy.

Yours sincerely,

Professor Peter O'Leary
Chair, Human Research Ethics Committee

Government of Western Australia
Department of Health
South Metropolitan Health Service

Royal Perth Hospital

29 April 2014

Dr Sudhakar Rao
Trauma Unit
Royal Perth Hospital

Dear Sudhakar

Project Title: **Safer Cycling and the Urban Road Environment**
Protocol No: **N/A**
HREC Reference: **REG 14-038**

The ethics application for the project referenced above has been **approved** by the Royal Perth Hospital Human Research Ethics Committee (EC00270).

The following documents have been approved for use in this project:

- Research Protocol
- Patient Information and Consent Form
- Invite Letter
- Safer Cycling in the Urban Road Environment – Telephone Script
- Improving Bicycle Safety Study Questionnaire
- Support Services Information Sheet

The approval is **valid to 29/04/2017** and on the basis of compliance with the 'Conditions of HREC Approval for a Research Project' (attached).

The nominated participating site in this project is:

Royal Perth Hospital

- If additional sites are recruited prior to the commencement of, or during the research project, the Coordinating Principal Investigator is required to notify the RPH HREC. Notification of withdrawn sites should also be provided to the HREC in a timely fashion.

- A copy of this ethical approval letter must be submitted by all site Principal Investigators to the Research Governance Office or equivalent body or individual at each participating institution in a timely manner to enable the institution to authorise the commencement of the project at its site/s.

This letter constitutes ethical approval only. This project cannot proceed at any site until separate site authorisation has been obtained from the Chief Executive, or delegate, of the site under whose auspices the research will be conducted.

The RPH Ethics Committee is registered with the Australian Health Ethics Committee and operates according to the NHMRC National Statement on Ethical Conduct in Human Research and International Conference on Harmonisation – Good Clinical Practice.

Should you have any queries about the HREC's consideration of your project, please contact (08) 9224 2292. The HREC's Terms of Reference, Standard Operating Procedures, membership and standard forms are available from the Ethics Office, (08) 9224 2292 or rph.hrec@health.wa.gov.au.

Yours sincerely

PROF FRANK VAN BOCKXMEER
Chairman, RPH Human Research Ethics Committee

Royal Perth Hospital **Research Ethics & Governance (REG) Office**
Level 5 Colonial House, Royal Perth Hospital, GPO Box X2213 Perth WA 6001
Tel (08) 9224 2292 | Fax (08) 9224 3688 | Email rph.hrec@health.wa.gov.au

Government of **Western Australia**
Department of **Health**

Our Ref: 2014-098 approval SCGOPHCG

Sir Charles Gairdner Hospital

13 October 2014

Professor Lynn Meuleners
Curtin-Monash Accident Research Centre
Curtin University
GPO Box U1987
PERTH WA 6845

Dear Professor Meuleners

HREC No: 2014-098
Project Title: Cycling and the Urban Road Environment

On behalf of the Sir Charles Gairdner Osborne Park Health Care Group, I give authorisation for your research project to be conducted at the following site(s):

Sir Charles Gairdner Hospital

The following site specific documents are to be used in addition to those approved by the Human Research Ethics Committee (HREC).

Document
SCGH Participant Information Sheet
Consent Form

This authorisation is based on the approval from the Royal Perth Hospital Human Research Ethics Committee and the review from the Research Governance Office. This authorisation is valid subject to the ongoing approval from the HREC, and on the basis of compliance with the 'Conditions of Site Authorisation to Conduct a Research Project' (attached) and with the compliance of all reports as required by the Research Governance Office and approving HREC. Noncompliance with these requirements could result in the authorisation be withdrawn.

The responsibility for the conduct of this project remains with you as the Principal Investigator at the site.

Yours sincerely

Dr Victor Cheng
A/EXECUTIVE DIRECTOR
SIR CHARLES GAIRDNER AND
OSBORNE PARK HEALTH CARE GROUP

Sir Charles Gairdner Group Human Research Ethics Committee, Level 2 A Block, Hospital Ave, Nedlands, WA 6009
Telephone (08) 9346 2999 Fax (08) 9346 3307 ABN: 13 993 250 709
email HREC.SCGH@health.wa.gov.au Website www.scgh.health.wa.gov.au

Government of Western Australia
Department of Health
South Metropolitan Health Service

cg
R/14/53
3 September 2014

Professor Lynn Meuleners
Curtin-Monash Accident Research Centre
Curtin University
GPO Box U1987
Perth WA 6845

Dear Professor Meuleners

Project Title: Safer Cycling and the Urban Road Environment
HREC Reference: REG 14-038 (RPH)

On behalf of the South Metropolitan Health Service, I give authorisation for your research project to be conducted at the following site(s):

Fremantle Hospital – *PI Dr Anthony Mattick*

The following documents have been approved for this project:

Document
• **Research Protocol** • **Fremantle Hospital Participant Information Sheet** • **Invite Letter** • **Safer Cycling in the Urban Environment – Telephone Script** • **Improving Bicycle Safety Study Questionnaire** • **WA Case Follow Up Questionnaire** • **Support Services Information Sheet**

This authorisation is based on the approval from the Royal Perth Hospital Ethics Committee (HREC) and the review from the Research Governance Office at Fremantle Hospital. This authorisation is valid subject to the ongoing approval from the RPH HREC.

This authorisation is based on the ethical approval from the Lead HREC, and on the basis of compliance with the 'Conditions of Authorisation to Conduct a Research Project at Site' (attached) and with the compliance of all reports as required by the Research Governance Office and approving HREC. Non-compliance with these requirements could result in the authorisation be withdrawn.

Research Governance & Ethics Office
Fremantle Hospital
Demountable 3, G Block
Postal Address: PO 480 Fremantle WA 6959
Telephone: (08) 94312929 Facsimile: (08) 9431 3930
http://www.fhhs.health.wa.gov.au ABN 13 993 250 709

The responsibility for the conduct of this project remains with you as the Principal Investigator at the site.

Yours sincerely

DR DAVID BLYTHE
EXECUTIVE DIRECTOR
FREMANTLE HOSPITAL & HEALTH SERVICE

cc: Dr Anthony Mattick, Emergency Medicine Research Unit, Fremantle Hospital
Mark Woodman, Ethics Coordinator RPH (REG 14-038)

Government of **Western Australia**
Department of **Health**

FIONA STANLEY hospital

Our ref : FSH–2015-056
Enquiries : TEL 08) 6151 1180

Professor Yusuf Nagree
Centre for Clinical Research in Emergency Medicine
Fiona Stanley Hospital
Locked Bag 100
PALMYRA WA 6961

Dear Professor Nagree

FSH Project No: 2015- 56
HREC No: REG 2014- 038-2
Project Title: "Safer Cycling and the Urban Road Environment (Safer Cycling)"

On behalf of Fiona Stanley Hospital, I give authorisation for your research project to be conducted at Fiona Stanley Hospital.

The following site specific documents are to be used in addition to those approved by the Human Research Ethics Committee (HREC) in the letter dated 22 June 2015.

Document
Fiona Stanley Hospital Site Participant Information Sheet and Consent Form

This authorisation is based on the approval from the Royal Perth Hospital Human Research Ethics Committee and the review from the Research Governance Office. This authorisation is valid subject to the ongoing approval from the HREC, and on the basis of compliance with the 'Conditions of Site Authorisation to Conduct a Research Project' (attached) and with the compliance of all reports as required by the Research Governance Office and approving HREC. Noncompliance with these requirements could result in the authorisation be withdrawn.

The responsibility for the conduct of this project remains with you as the Principal Investigator at the site.

~~Yours~~ sincerely

Paul Mark

Dr Paul Mark
A/EXECUTIVE DIRECTOR

19 August 2015

APPENDIX 9: ONLINE SURVEY (PHASE 2: NATURALISTIC STUDY)

Safer Cycling and the Urban Road Environment

Thank you for taking the time to participate in this study.

Curtin and Monash Universities are conducting an Australian-first bicycle study looking at the relationship between urban road design and cyclist safety. The study will inform new road designs aimed at improving cyclist safety. It will also examine safety behaviours and attitudes and collect new information on group riding safety.

The survey is expected to take approximately 20 minutes to complete.

All information provided in this survey will be kept confidential according to the Curtin University privacy regulations.

1. You need to be over 18 years of age to answer this survey. *
   Mark only one oval.

   - Yes, I confirm that I am over 18 years of age
   - No, I am not over 18 years of age *Stop filling out this form.*

Explanatory Statement

This research is being conducted by the Curtin-Monash Accident Research Centre (C-MARC), Curtin University as part of an Australian Research Council funded project studying the role of urban road design and its relationship to cyclist safety. A sub-study will also specifically investigate the safety issues affecting group riders on Perth roads

The survey includes questions about your cycling experience, behaviours, attitudes, participation in group riding and asks for your views on different types of cycling infrastructure and safety. By completing this questionnaire, you will be contributing to our understanding of cycling experiences in the urban road environment. You will also be informing the development of new road designs aimed at improving the urban cycling experience.

The answers you provide will be completely de-identified and used for research purposes only. Where findings are presented (e.g. an article in a journal), no individual results will be reported.

Participation in this survey is voluntary, and it is your right to not continue with the survey at any stage. If you would like to contact the researchers about any aspect of this study, or to receive feedback on the results, please contact our research staff. Contact details can be found at c-marc.curtin.edu.au/safercycling

This study has been approved by Curtin University Human Research Ethics Committee (Approval number HR 189/2013)

Recruitment details

2. How did you hear about the 'Safer Cycling' study? *
   Mark only one oval.

   - I was approached by Curtin University road side recruiters and was given a slapband *Skip to question 3.*
   - I am a group rider and saw the study advertised/ promoted *Skip to question 7.*
   - Other: ________ *Skip to question 7.*

3. Where were you recruited? *
   Please enter details regarding the location where you were given the study slapband (Street Name, Suburb etc.)

   ____

4. If you have your slapband, please enter the number on the sticker

   ____

5. Approximately what time of day were you recruited?
   Mark only one oval.

   - Midnight - 6am
   - 6am - 9am
   - 9am - noon
   - noon - 3pm
   - 3pm - 6pm
   - 6pm - 9pm
   - 9pm - midnight

Further participation? (Safer Cycling Study)

After you complete the online survey to follow, you may be invited to participate further by recording your bicycle rides for up to two weeks using video cameras supplied by Curtin University. Those who record a group ride during the two weeks may also be invited to take part in a telephone interview. This will allow us to investigate the role of road design and other factors in cyclist crashes that occur individually and in groups. Please note that you WILL NOT BE IDENTIFIED in any report, publication or presentation. The details you provide below are for contact purposes only, and will not be used at any other stage during the study. If you have any questions or concerns please contact our research staff. Contact details can be found at c-marc.curtin.edu.au/safercycling

6. Are you interested in being contacted to participate further in this study? *
   Mark only one oval.

   ◯ Yes *Skip to question 8.*
   ◯ No *Skip to question 12.*

Further participation? (Group riding study)

After you complete the online survey to follow, you may be invited to record up to six hours of your group rides for up to two weeks, using video cameras supplied by Curtin University. You will also be invited to take part in a telephone interview about your group riding experience. This will allow us to investigate the safety issues specifically affecting group riders on Perth roads. Please note that you WILL NOT BE IDENTIFIED in any report, publication or presentation. The details you provide below are for contact purposes only, and will not be used at any other stage during the study. If you have any questions or concerns please contact our research staff. Contact details can be found at c-marc.curtin.edu.au/safercycling

7. Are you interested in being contacted to participate further in this study? *
   Mark only one oval.

   ◯ Yes
   ◯ No *Skip to question 12.*

Please enter your contact details

8. First Name *

   ____

9. Last Name *

   ____

10. Email Address *

    ____

11. Phone Number *

    ____

Tell us about yourself

12. What is your gender?
    Mark only one oval.

    ◯ Male
    ◯ Female

13. What is your age?

    ____

14. What is your nationality?
    Mark only one oval.

    ◯ Australian *Skip to question 16.*
    ◯ Other: ______________________

15. How long have you been in Australia?

    ____

16. What is your postcode?

...

17. Do you have a current driver's licence? *
Mark only one oval.

- ( ) Yes *Skip to question 19.*
- ( ) No *Skip to question 18.*

18. Why do you not have a driver's licence?
Mark only one oval.

- ( ) Voluntarily choose not to drive *Skip to question 20.*
- ( ) Lost license due to infringement *Skip to question 20.*
- ( ) Lost license due to medical reasons *Skip to question 20.*
- ( ) Other: ... *Skip to question 20.*

19. What type of licence do you have?
Mark only one oval.

- ( ) Full licence
- ( ) Probationary red
- ( ) Probationary green
- ( ) Learners permit

20. What is your current employment status?
Mark only one oval.

- ( ) Full-time work
- ( ) Part-time work
- ( ) Volunteer work
- ( ) Casual work
- ( ) Keeping house
- ( ) Currently unemployed
- ( ) Retired
- ( ) Other:

21. What is your current study status?
Mark only one oval.

- ( ) Not studying
- ( ) Full-time University/TAFE
- ( ) Part-time University/TAFE
- ( ) Secondary school
- ( ) Other:

22. What is the highest level of education you have completed?
Mark only one oval.

- ( ) Primary School
- ( ) Secondary School
- ( ) Technical School/TAFE
- ( ) University Degree
- ( ) Higher Degree
- ( ) Other: ...

Tell us about your cycling habits

The following questions relate to your current cycling participation and habits

23. How many years have you been riding a bicycle?
    Enter figure in years

    ....

24. How would you describe your level of confidence when riding on-road?
    Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Not very confident	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Very confident

25. Over the last month, on average, how many days per week did you ride a bicycle? *

    ....

26. Over the last month, on average, how many kilometres have you usually ridden a bicycle each week?
    Mark only one oval.

    ◯ Less than 10km
    ◯ 10 - 30km
    ◯ 31 - 50km
    ◯ 51 - 100km
    ◯ 101 - 200km
    ◯ More than 200km
    ◯ Not applicable

27. What days of the week do you usually ride?
    Choose as many as apply

    ☐ Monday
    ☐ Tuesday
    ☐ Wednesday
    ☐ Thursday
    ☐ Friday
    ☐ Saturday
    ☐ Sunday

28. What times of the day do you usually ride?
    Choose as many as apply

    ☐ Midnight - 3am
    ☐ 3am - 6am
    ☐ 6am - 9am
    ☐ 9am- Noon
    ☐ Noon - 3pm
    ☐ 3pm- 6pm
    ☐ 6pm-9pm
    ☐ 9pm - Midnight

29. What is the purpose of the majority of your riding?
Please select one response

- ⬭ Recreation riding
- ⬭ Commuting to work or school
- ⬭ Utilitarian, e.g. shopping
- ⬭ Fitness
- ⬭ Work related travel
- ⬭ Social
- ⬭ Club/ group cycling
- ⬭ Other: ....

30. Over the last month, did you ride for any other purposes?
Mark only one oval.

- ⬭ Yes
- ⬭ No *Skip to question 32.*

31. What were the other purposes for your riding?
Select all responses that apply

- ☐ Recreation riding
- ☐ Commuting to work or school
- ☐ Utilitarian e.g. shopping
- ☐ Fitness
- ☐ Work related travel
- ☐ Social
- ☐ Club/ group cycling
- ☐ Other: ....

32. Over the last year, what percentage of your cycling took place on roads?
Please enter % below

33. Over the last month, approximately how many days per week did you cycle alone (solo cycling)?

....

34. Over the last year, on average, what percentage of your cycling took place with at least one other cyclist?
Mark only one oval.

- ⬭ None *Skip to question 45.*
- ⬭ Other: ....

35. Over the last month, how many cyclists were in each group you rode with (including yourself)?
Answer as many as apply

- ☐ 2
- ☐ 3-4
- ☐ 5-10
- ☐ 11-20
- ☐ 21-30
- ☐ Over 30

36. Over the last month who did you ride in a group with?
Answer as many as apply

- ☐ Family (adults)
- ☐ Family (children)
- ☐ Friends
- ☐ Spouse/ partner
- ☐ Workmates
- ☐ Cycling group/ club
- ☐ Other: ....

37. What was the main purpose of your cycling when you rode in a group of each size listed below?
Mark only one oval per row.

	Recreation	Commuting	Domestic e.g. shopping	Fitness	Work-related travel	To/ from social venue	To/ from sport	Social e.g. visiting friends	Training	Not applicable
2 cyclists	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
3-4 cyclists	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
5-10 cyclists	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
11-20 cyclists	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
21-30 cyclists	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Over 30 cyclists	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

38. Over the last month, approximately how many days per week did you ride in a group of each size listed below
Mark only one oval per row.

2 cyclists ____
3-4 cyclists ____
5-10 cyclists ____
11-20 cyclists ____
21-30 cyclists ____
Over 30 cyclists ____

39. Do you participate in group riding with 5 or more cyclists (including yourself)? *
Mark only one oval.

- ◯ Yes
- ◯ No *Skip to question 41*
- ◯ Other:

40. Over the last month, what percentage of your cycling was in a group of 5 or more (including yourself)? *
Enter % below

....

41. Do you belong to a cycling club? *
Mark only one oval.

- ◯ Yes
- ◯ No *Skip to question 43*

42. Please specify the type of club or group

....

....

43. What would be your main reasons for cycling in a group?

44. What, if anything would stop you from cycling in a group?

....
....
....
....
....

Skip to question 47.

45. What would be your main reasons for not cycling in a group?

....
....
....
....
....

46. What, if anything would encourage you to try group cycling?

....
....
....
....
....

47. To what extent would you agree, or disagree that:

Mark only one oval per row.

	Disagree strongly	Disagree somewhat	Don't know	Agree somewhat	Agree strongly
Riding in a group is safer than riding alone	⬭	⬭	⬭	⬭	⬭
Riding in a group would increase my chance of being involved in a crash with a motor vehicle, compared to riding alone	⬭	⬭	⬭	⬭	⬭
Roads in Perth are well suited to group riding	⬭	⬭	⬭	⬭	⬭
Riding alone would decrease my chance of being involved in a single bicycle crash, compared to riding in a group	⬭	⬭	⬭	⬭	⬭
I am less likely to experience aggression from drivers when riding alone than in a group	⬭	⬭	⬭	⬭	⬭
Riding in a group would increase my chance of being involved in a crash with another cyclist, compared to riding alone	⬭	⬭	⬭	⬭	⬭

48. How often do you answer your mobile phone if it rings while you are cycling? *
(Includes being stopped at traffic lights but not when pulled over in a safe spot) *Mark only one oval.*

- Always
- Very often
- Fairly often
- Just occasionally
- Rarely
- Never *Skip to question 52.*
- Declined

49. When you answer calls while cycling, how often do you use a hands-free device?
(Includes being stopped at traffic lights but not when pulled over in a safe spot)
Mark only one oval.

- Always
- Very often
- Fairly often
- Just occasionally
- Rarely
- Never
- Declined

50. Do you ever answer your mobile phone if it rings while riding in a group of 5 or more? *Mark only one oval.*
(Includes being stopped at traffic lights but not when pulled over in a safe spot)

- Yes
- No
- Not applicable
- Declined

51. Do you ever answer your mobile phone if it rings while non-group riding? *Mark only one oval.*
(Includes being stopped at traffic lights but not when pulled over in a safe spot)

- Yes
- No
- Not applicable
- Declined

52. How often do you make calls on your mobile phone while you are cycling? * *Mark only one oval.*
(Includes being stopped at traffic lights but not when pulled over in a safe spot)

- Always
- Very often
- Fairly often
- Just occasionally
- Rarely
- Never *Skip to question 56.*
- Declined

53. When you make calls while cycling, how often do you use a hands-free device? *Mark only one oval*
(Includes being stopped at traffic lights but not when pulled over in a safe spot)

- Always
- Very often
- Fairly often
- Just occasionally
- Rarely

- Never
- Declined

54. Do you ever make calls on your mobile phone while riding in a group of 5 or more?
(Includes being stopped at traffic lights but not when pulled over in a safe spot) *Mark only one oval.*

- Yes
- No
- Not applicable
- Declined

55. Do you ever make calls on your mobile phone while non-group riding??
(Includes being stopped at traffic lights but not when pulled over in a safe spot) *Mark only one oval.*

- Yes
- No
- Not applicable
- Declined

56. How often do you read text messages or emails on your mobile phone while you are cycling? *
(Includes being stopped at traffic lights but not when pulled over in a safe spot) *Mark only one oval.*

- Always
- Very often
- Fairly often
- Just occasionally
- Rarely
- Never
- Declined

57. How often do you send text messages or emails on your mobile phone while you are cycling? *
(Includes being stopped at traffic lights but not when pulled over in a safe spot) *Mark only one oval.*

- Always
- Very often
- Fairly often
- Just occasionally
- Rarely
- Never
- Declined

58. Do you ever read or send text messages or emails while riding in a group of 5 or more? (select all that apply) *
(Includes being stopped at traffic lights but not when pulled over in a safe spot) *Tick all that apply.*

- ☐ Yes - read
- ☐ Yes - send
- ☐ No
- ☐ Declined

59. Do you ever read or send text messages or emails while non-group riding? (select all that apply) *
(Includes being stopped at traffic lights but not when pulled over in a safe spot) *Tick all that apply.*

- ☐ Yes - read
- ☐ Yes - send
- ☐ No
- ☐ Declined

60. How often do you use portable audio equipment (including audio on your mobile phone) while you are cycling? *
(Includes being stopped at traffic lights but not when pulled over in a safe spot) *Mark only one oval.*

- ◯ Always
- ◯ Very often
- ◯ Fairly often
- ◯ Just occasionally
- ◯ Rarely
- ◯ Never *Skip to question 64.*
- ◯ Declined

61. Do you have a device in your ears while listening to portable audio equipment?
(Includes being stopped at traffic lights but not when pulled over in a safe spot) *Mark only one oval.*

- ◯ Yes
- ◯ No
- ◯ Declined

62. Do you ever use portable audio equipment while riding in a group of 5 or more?
(Includes being stopped at traffic lights but not when pulled over in a safe spot) *Tick all that apply.*

- ☐ Yes
- ☐ No
- ☐ Not applicable
- ☐ Declined

63. Do you ever use portable audio equipment while non-group riding?
(Includes being stopped at traffic lights but not when pulled over in a safe spot) *Tick all that apply.*

- ☐ Yes
- ☐ No
- ☐ Not applicable
- ☐ Declined

64. Do you use your phone for any other purpose while cycling? *
(Includes being stopped at traffic lights but not when pulled over in a safe spot) *Mark only one oval.*

- ◯ Yes
- ◯ No *Skip to question 66.*
- ◯ Declined *Skip to question 66.*

65. What is the purpose?

....

....

....

....

....

66. In the past 12 months, how likely is it that you may have cycled when over the legal blood alcohol limit? *
(includes cycling on road or path) *Mark only one oval.*

- ◯ Very likely
- ◯ Fairly likely
- ◯ Fairly unlikely *Skip to question 70.*
- ◯ Very unlikely *Skip to question 70.*

- Definitely not — *Skip to question 70.*
- Declined — *Skip to question 70.*

67. In the past 12 months, on how many occasions did you cycle when you may have been over the legal blood alcohol limit?
(enter number below)

68. Were any of these occasions while riding in a group of 5 or more?
Mark only one oval.

- Yes
- No
- Declined

69. Were any of these occasions while non-group riding?
Mark only one oval.

- Yes
- No
- Declined

70. In the past 12 months, how likely is it that you may have cycled while under the influence of an illicit drug? *
(includes cycling on road or path) *Mark only one oval.*

- Very likely
- Fairly likely
- Fairly unlikely — *Skip to question 75.*
- Very unlikely — *Skip to question 75.*
- Definitely not — *Skip to question 75.*
- Declined — *Skip to question 75.*

71. In the past 12 months, on how many occasions did you cycle when you may have been under the influence of an illicit drug?
(enter number below)

72. Please specify which drugs
(enter text below)

73. Were any of these occasions while riding in a group of 5 or more?
Mark only one oval.

- Yes
- No
- Declined

74. Were any of these occasions while non-group riding?
Mark only one oval.

- Yes
- No
- Declined

Previous crashes

The following questions relate to crashes you have been involved in as a cyclist

75. How many crashes as a cyclist have you been involved in within the last 3 years?
    Enter number in box *Mark only one oval.*

    - ⬭ None *Skip to question 80.*
    - ⬭ Other: ....

76. What was the primary cause of your most recent crash?
    Mark only one oval.

    - ⬭ A pedestrian
    - ⬭ Another cyclist
    - ⬭ A moving vehicle
    - ⬭ A parked vehicle
    - ⬭ Another object (street furniture, pot hole, kerb)
    - ⬭ Mechanical failure
    - ⬭ Other: ....

77. In the last 3 years, have you been involved in any crashes as a bicycle rider on the road or path, resulting in injury requiring medical treatment?
    Mark only one oval.

    - ⬭ Yes
    - ⬭ No *Skip to question 80.*

78. In the last three years, how many crashes have you been involved in as a bicycle rider on the road that resulted in an ED visit or hospital admission?
    Mark only one oval.

    - ⬭ None *Skip to question 80.*
    - ⬭ 1 crash
    - ⬭ 2 crashes
    - ⬭ 3 crashes
    - ⬭ 4 crashes
    - ⬭ 5 crashes
    - ⬭ 6 crashes

79. How many cyclists were you riding with at the time of each of the crashes resulting in ED or hospital admission?
    Mark only one oval per row.

	Riding alone	2 cyclists (including self)	3-4 cyclists (including self)	5-10 cyclists (including self)	11-20 cyclists (including self)	21-30 cyclists (including self)	Over 30 cyclists (including self)	Not applicable
Crash 1	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Crash 2	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Crash 3	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Crash 4	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Crash 5	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Crash 6	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭

Bicycle Infrastructure

The following questions relate to bicycle infrastructure

80. Where do you typically ride?

Mark only one oval per row.

	Never	Rarely	About half of the time	Usually	Always.
On-Road in motor vehicle lane					
On-Road in bicycle lanes					
Shared path					
Footpaths					

81. When riding on different facilities, how safe do you feel?

Mark only one oval per row.

	Very unsafe	Somewhat unsafe	Neither safe nor unsafe	Somewhat safe	Very safe	Do not use
On-Road in motor vehicle lane						
On-Road in bicycle lanes						
Shared path						
Separated bicycle path						
Footpaths						

82. How safe do you consider the following factors regarding riding on the road?

Mark only one oval per row.

	Very unsafe	Somewhat unsafe	Neither dangerous or safe	Somewhat safe	Very safe	Unsure
Interaction with cars						
Interaction with other cyclists						
Interaction with trucks and buses						
Vehicle speeds over 60km/h						
Vehicle speeds between 40km/h and 60km/h						
Vehicle speeds below 40km/h						
Lack of bicycle facilities						
Inadequate lighting						
Narrow kerbside traffic lane						
Pavement surface condition						
Debris on road						
Roundabouts						
Signalised Intersections						
Unsignalised Intersections						

83. When riding on-road what is the number one improvement that could be made to improve cyclist safety?

Mark only one oval.

- Lower vehicle speeds
- Create more bicycle lanes
- Create separated bicycle facilities (Copenhagen lanes)
- Legislation to improve cyclists road rights (e.g. 1 metre minimum passing distance)
- Better bicycle lane maintenance
- Allow cyclists on footpaths
- Other: ....

84. When at intersections what is the number one improvement that could be made to improve cyclist safety?
Mark only one oval.

- Bicycle head start box
- Bicycle signal phases
- Bicycle lanes on approach to intersection
- Bicycle lanes on departure side of intersection
- Other: ....

85. Do you have any other comments regarding on-road bicycle infrastructure

....
....
....
....
....

86. Do you have any other general comments regarding cycling

....
....
....
....
....

APPENDIX 10: PARTICIPANT INFORMATION SHEET AND CONSENT FORM (PHASE 2: NATURALISTIC STUDY)

Curtin University

MONASH University
Accident Research Centre

Curtin University

PARTICIPANT INFORMATION SHEET

SAFER CYCLING AND THE URBAN ROAD ENVRONMENT
Group riding sub-study
Video camera and interview components

Invitation
You are invited to participate in research aimed at improving the safety of group/ bunch riders on Perth roads. This research is part of a larger study being conducted by Professor Lynn Meuleners, Curtin-Monash Accident Research Centre, Curtin University examining cycling safety in the urban road environment. The larger study is funded by an Australian Research Council Linkage grant and is part of a national collaborative study co-ordinated by Monash University in Melbourne. You are invited to take part in a sub-study being undertaken by a Curtin University PhD student specifically examining safety for group/ bunch riders.

Before you decide whether or not you wish to participate in this study, it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully and discuss it with others if you wish.

If you wish to discuss any details of this study or if you have any questions relating to your participation in this research, you may contact Michelle Fraser at Curtin University on 04- - --- --- or m.fraser@curtin.edu.au or Professor Lynn Meuleners on telephone 08 9266 4636, email: l.meuleners@curtin.edu.au at any time.

If you agree to participate in this study, you will be asked to sign the attached Participant Consent Form.

1. 'What is the purpose of this study?'

The purpose of this sub-study is to investigate the safety issues specifically affecting group/ bunch riders on Perth roads using bicycle mounted video cameras and interviews. We aim to determine what type of roads and infrastructure are used by group/ bunch riders in Perth and how road infrastructure, motorist and cyclist-related factors influence their safety.

2. 'What does this study involve?'

Video camera component:
You have been invited to record up to six hours of your usual group/ bunch riding experience using two action video cameras attached to your bicycle. One camera will be facing in the direction you travel and the other in a rearward direction. One camera will include a GPS logger that will record your position while cycling (e.g. latitude, longitude and speed). Both cameras include a lithium ion rechargeable battery that allows you to record approximately 2 hours of video without interruption.

You will be required to attach and detach both video cameras each time you cycle, and may be required to recharge the cameras via USB (to a computer or power-point) after each ride.

You will also be asked to:

- Attend a private induction session (at a time and location convenient to you), at which you will be briefed on the set-up and operation of the cameras. This should take approximately 30 minutes.
- Meet with a researcher at the end of your 6 hours of recording, at an agreed time and location to hand over the cameras and complete a short semi-structured questionnaire about the use of the cameras.
- Contact the researchers if you experience any technical problems with the cameras.

Interview component
You will also be invited to undertake an interview about your group/ bunch riding experience. The interview will be conducted by a Curtin University researcher, either in person or by phone. The interview will be recorded if your permission is given. The interview will address your group/ bunch riding exposure, experience, riding behaviours and your thoughts on safety issues affecting group/ bunch riders. The interview will take approximately 30 minutes.

3. 'Why have I been invited to participate in this study?'

You have been invited to participate in this study because you are aged 18 years or older and you regularly participate in group/ bunch cycling in Perth.

4. 'What if I don't want to take part in this study or if I want to withdraw later?'

Participation in this study is voluntary. It is completely up to you whether or not you participate. If you wish to withdraw from the study once it has started, you can do so at any time without having to give a reason.

5. 'How is this study funded?'

The study is being sponsored by the Australian Research Council Linkage grant and industry partners including: Main Roads Western Australia, VicRoads, Transport Accident Commission, Amy Gillett Foundation, Cycling Promotion Fund and Portland State University.

6. 'Are there risks to me in taking part in this study?'

Although there are minimal risks associated with taking part in the study as you will only be asked to attach cameras to your bike and record your travel during your normal group/ bunch riding routine, you might experience some inconvenience as you;

- May be required to recharge the cameras after each ride;
- Will be asked to protect the cameras from theft or loss. For example, removing them from your bike and carrying them with you after you finish riding (e.g. into a café, workplace); and
- May attract attention from other road users (e.g. motorists).

In the event a video camera is lost or stolen, researchers may be required to cease your contribution to the study. If a video camera is lost or stolen under unexpected circumstances and a replacement camera is available, researchers may invite you to continue with the study.

If the video camera is lost or stolen under avoidable circumstances (e.g. left on the bicycle when parked on the street), you will be asked to cover the cost of purchasing an additional video camera of the same make and model to the amounts detailed below.

- Contour+2 camera = $332.00
- Contour Roam2 camera = $179.30

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Accident Research Centre

7. 'Will I benefit from the study?'

By participating in this research, you are contributing to our understanding of safety issues affecting group/ bunch riders in Perth and this may improve the safety and experience of group/ bunch riders in the urban environment. Participating in this study however, will not directly benefit you.

8. Will taking part in this study cost me anything?

Participation in this study will not cost you anything. You will not be paid for participating.

9. 'How will my confidentiality be protected?'

The information we collect is for research purposes only and will be treated in the strictest confidence. No identifying information will be reported or published. Any faces or other unique identifiers that are captured in the footage will be blurred, if any footage is reported.

Only research staff and students directly involved in the research will have access to the data, which will be stored securely for a period of seven years after study completion and then destroyed in accordance with Curtin University regulations. Other parties will not be able to identify the individuals participating in the study because responses will be de-identified.

No information from the online questionnaire or bicycle cameras will be provided to a third party unless subpoenaed by a court of law.

10. 'What happens with the results?'

In the event of any publication regarding this study, your identity will remain confidential. A summary of the study results will be made available to you upon request at the conclusion of the study.

11. 'What should I do if I want to discuss this study further before I decide?'

When you have read this information, the researcher will discuss it with you and any queries you may have. If you would like to know more at any stage, please do not hesitate to contact:

Ms Michelle Fraser
Curtin-Monash Accident Research Centre
Phone: 04-- --- ---
Email: m.fraser@curtin.edu.au

Professor Lynn Meuleners
Curtin-Monash Accident Research Centre
Phone: (08) 9266 4636
Email: l.meuleners@curtin.edu.au

12. 'Who should I contact if I have concerns about the conduct of this study?'

This study has been approved by Curtin University Human Research Ethics Committee (Approval number HR 189/2013). The committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. If needed, verification of approval can be obtained by either writing to the Human Research Ethics Committee, C/O Office of Research and Development, Curtin University, GPO Box U1987, Perth, 6845 or by telephoning 9266 9223 or emailing hrec@curtin.edu.au.

Thank you for taking the time to consider this study.
If you wish to take part in it, please sign the attached consent form.
This information sheet is for you to keep.

Curtin University

MONASH University
Accident Research Centre

Curtin University

CONSENT FORM

SAFER CYCLING AND THE URBAN ROAD ENVRONMENT
Group riding sub-study
Video camera and interview component

I have been asked to take part in the Curtin University research project specified above and hereby consent to participate in this project.

I consent to the following: ***(tick each statement below)***	
Attaching 2 action video cameras to my bicycle for the purpose of recording my group/ bunch riding for up to 6 hours	☐
Participating in an interview after completing the filming	☐
Attending an induction and handover meeting	☐
Covering the cost of any video cameras lost or stolen under avoidable circumstances (e.g. leaving video camera on bicycle parked on the street)	☐

1. I acknowledge that I have read and understood the Participant Information Sheet, which explains why I have been selected, the aims of the study and the nature and possible risks of participating.
2. Before signing this consent form, I have been given the opportunity to ask any questions relating to any possible physical and mental harm I might suffer as a result of my participation and I have received satisfactory answers.
3. I understand that my participation is voluntary, that I can choose not participate in part or all of the research, and that I can withdraw at any stage without being penalised or disadvantaged in any way.
4. I agree that research data gathered from the results of the study may be published, provided that I cannot be identified.
5. I understand that if I have any questions relating to my participation in this research, I may contact the Curtin University researchers: Michelle Fraser on 04-- --- --- or m.fraser@curtin.edu.au or Professor Lynn Meuleners on (08) 9266 4636 or l.meuleners@curtin.edu.au who will be happy to answer them.
6. I acknowledge receipt of a copy of this Consent Form and the Participant Information Sheet.

Complaints may be directed to the Curtin University Human Research Ethics Committee on (08) 9266 9223 or at hrec@curtin.edu.au

Signature of participant	**Please PRINT name**	**Date**
______________________	______________________	__________
Signature of investigator	**Please PRINT name**	**Date**
______________________	______________________	__________

Consent form group riding sub-study version 1, 01/02/15

APPENDIX 11: RESEARCHER-ADMINISTERED QUESTIONNAIRE (PHASE 2: NATURALISTIC STUDY)

Curtin University

Curtin University

SAFER CYCLING AND THE URBAN ROAD ENVRONMENT
Group riding sub-study semi-structured interview

ID ______________ Date ________________

Section 1: Rider characteristics

1.1 How long have you been group riding for?
1.2 How would you rate your group riding level?
1.3 What are the main purposes of group riding for you? (e.g. training, social, racing)
1.4 How did you become involved in group riding?
1.5 Have you undertaken any sort of group training? Please describe

Section 2: Group characteristics

2.1 How many different groups did you ride with while using the cameras?
For the first group, can you tell me:
2.2 How often do you ride with this group?
2.3 What is the approximate size of the group?
2.4 How would you describe the level of this group?
2.5 Can you describe the main purpose/s of this group? (e.g. training, social, racing)
2.6 What approximate distance would you travel on a ride with this group?
2.7 What would be the average speed of this group?
2.8 Can you tell me about how this group is organised?
2.9 Does this group have a committee?
2.10 Is this group run by a registered business?
2.11 Does it cost to ride with this group? Please describe
2.12 Who can join this group? Is it open or closed membership? Please describe
2.13 Do you wear uniforms? Are they compulsory/ optional?
2.14 Can you tell me about the leadership structure on the ride?
2.15 Can you tell me how the group communicates on a ride?
2.16 Does this group have sprint points on the rides? Please describe
2.17 Does this group drop riders (leave riders behind) on the ride?
2.18 Are there any safety rules, guidelines or codes of conduct for this group?

- What do they cover?
- Are they written down?
- How do riders in the group learn of these rules?
- Do riders ever breach these rules?
- What happens in the event of a breach?

(Repeat questions for each group the cyclist rode with while using cameras)

Section 3: Motivations and safety issues

3.1 Are there any negative aspects to participation?
3.2 How safe do you feel when riding in a group?
3.3 What are your main safety concerns when riding in a group?

- Interaction with motorists
- Road infrastructure
- Group characteristics or behaviour

3.4 In your opinion, what could be done to improve safety for group riders in Perth
3.5 Is there anything else you would like to comment on regarding group riding?

Naturalistic study semi-structured interview 01/02/15

APPENDIX 12: BIKE CAMERA INSTRUCTION SHEET (PHASE 2: NATURALISTIC STUDY)

Curtin University

MONASH University

Safer cycling and the urban road environment: Group riding sub-study Bicycle camera instructions

1. Mounting the cameras

- The grey camera (Countour+2) goes on the back of your bike
- The black camera (ContourRoam2 or 3) goes on the front
- Make sure the camera lenses are facing out
- Rotate so 0° or dot is at top

2. Recording

- Please wait until you are outside to turn on the cameras
- Unlock the record slider
- Slide forward to record
- Lock the record slider
- Your cameras will power on, beep once and the record light will turn red, indicating the camera is now recording
- Slide back to stop recording and lock
- Please note – cameras record sound

3. Indicator lights on cameras

Battery light	Memory card light	GPS light
• Changes from green to yellow to red as battery is used up • When the battery light flashes red, battery is almost used up • Please recharge	• Changes from green to yellow to red as memory card fills up • If light flashes and there is beeping, the card is full. • Please contact the researcher to collect cameras	• The grey camera has a GPS receiver • GPS light will flash green when recorder slider is switched on • Turns solid green when GPS position fix obtained • Wait for solid green before moving

If you have any queries please contact Michelle Fraser on 04-- — — or m.fraser@curtin.edu.au

Curtin University MONASH University

4. Recharging the camera batteries

- The camera batteries can record 2-2.5 hours of footage, then need to be recharged
- Charging from empty takes around 4 hours
- Cameras lose charge when not being used, please charge regularly

- Connect your cameras to a computer or wall charger using the supplied USB cables

- Slide the camera door up to open

- The battery light indicates the charge level of the battery
- Charge is fully complete when the battery light turns green

5. Status button

- When you press the status button, the camera will beep and show you the current battery and memory card status (also GPS status on grey camera)
- If you press this button accidently, don't do anything, the camera will power off automatically after 15 seconds

6. Wet weather case

- The grey camera requires a case if it is raining or you think it will get wet.
- Open cover latch and place camera in.
- Close latch to lock tight
- Start and stop recording with slider on top of case (you do not need to turn the slider on the camera on before placing in the case)

If you have any queries please contact Michelle Fraser on 04-- — — or m.fraser@curtin.edu.au

APPENDIX 13: DATA DICTIONARY FOR UNSAFE EVENT, RIDER AND MOTORIST-RELATED VARIABLES (PHASE 2: NATURALISTIC STUDY)

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
Event-related					
Conflict begin [a]	The point in the video when the sequence of events defining the occurrence of the unsafe event begins. For controls this is the beginning of the control time period [a]	Video timestamp [a]	✓	✓	✓
Conflict end [a]	The timestamp in the video, when the sequence of events defining the occurrence of the unsafe event ends. For controls this is the end of the control time period [a]	Video timestamp [a]	✓	✓	✓
Precipitating event [a]	The state of environment or action that began the unsafe event sequence under analysis [a]	Subject rider/s lost control: poor road conditions [a]	✓	✓	
		Subject rider/s lost control: unknown cause [a]			
		Subject rider/s over right lane line [a]			
		Subject rider/s over left edge of road [a]			
		Subject rider/s in intersection: turning left [a]			
		Subject rider/s in intersection: turning right [a]			

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
		Subject rider/s in intersection: passing through [a]			
		Subject rider/s lane change: right behind vehicle [a]			
		Subject rider/s lane change: left in front of vehicle [a]			
		Subject rider/s lane change: right in front of vehicle[a]			
		Subject rider/s lane change right: sideswipe threat [a]			
		Subject rider/s attempt to overtake other road user [b]			
		Other road user lost control [a]			
		Other road user ahead: stopped on roadway [a]			
		Other road user ahead: decelerating [a]			
		Other road user lane change: right in front of subject rider/s [a]			
		Other road user oncoming: over right line [a]			
		Other road user entering intersection: turning same direction [a]			
		Other road user from driveway/ parking lot: turning into same direction [a]			
		Other road user attempt to overtake subject rider/s [b]			
		Object in roadway [a]			
Event nature [a]	Identifies the other object(s) of conflict (e.g., lead road user, following road	Conflict with a lead road user [a]	✓	✓	
		Conflict with oncoming road user [a]			

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
	user) for the unsafe event that occurred [a]	Conflict with road user in adjacent lane [a]			
		Conflict with road user turning across another road user path: same direction [a]			
		Conflict with road user turning across another road user path: opposite direction [a]			
		Conflict with road user turning into another road user path: same direction [a]			
		Conflict with road user turning into another road user path: opposite direction [a]			
		Conflict with road user moving across another road user path: through intersection [a]			
		Conflict with parked vehicle [a]			
		Conflict with obstacle/ object in roadway [a]			
		Single rider conflict [a]			
		Conflict with road user overtaking/ passing [b]			
Event severity [a]	General term describing the outcome of the unsafe event listed [a]	Crash: Any contact that the subject rider/s has with an object, either moving or fixed, at any speed. This also includes any contact between the ground and the bike (other than tires) or ground and rider (other than foot) [a]	✓	✓	

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
		Near crash: Any circumstance that requires a rapid evasive manoeuvre by the subject rider/s or any other vehicle, pedestrian, rider, or animal to avoid a crash[a]			
		Crash relevant: Any circumstance that requires an evasive manoeuvre on the part of the subject rider/s or any other vehicle, pedestrian, rider, or animal that is less urgent than a rapid evasive manoeuvre, but greater in urgency than a normal manoeuvre to avoid a crash [a]			
		Close passing only: An incident where a motor vehicle passes at least one group rider at an unsafe distance [b]			
Traffic density [a]	The level of motor vehicle traffic density at the start of the Precipitating Event or at the control time point [a]	Free flow, no lead traffic [a]	✓	✓	✓
		Free flow, leading traffic present [a]			
		Flow with some restrictions [a]			
		Stable flow, manoeuvrability and speed are more restricted [a]			
		Unstable flow – temporary restrictions substantially slow driver [a]			

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
		Flow is unstable, vehicles are unable to pass, temporary stoppages [a]			
		Forced traffic flow condition with low speeds and traffic volumes that are below capacity [a]			
Fault [a]	Indicates which rider/s or motorist (if any) committed an error that led to the event [a]	Subject rider/s [a]	✓		
		Motorist [a]			
		Other rider/s [a]			
		Shared fault [a]			
		No fault [a]			
		Unable to determine [a]			
Group rider-related					
Trip number [a]	Unique identifier for trip [a]	Trip ID [a]	✓	✓	✓
Rider reaction start [a]	The timestamp, after the start of the file, when the rider/s is first seen to recognise and begin to react to the unsafe events occurring [a]	Video timestamp [a]	✓	✓	
Rider pre-incident manoeuvre [a]	This represents the last type of action or manoeuvre that the subject rider/s engaged in or was engaged in just prior to or at the time of the Precipitating	Going straight, constant speed [a]	✓	✓	✓
		Going straight but with unintentional drifting within lane or across lanes [a]			
		Going straight, accelerating [a]			

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
	Event, beginning anywhere up to 5 seconds before the Precipitating Event. For controls, this is the manoeuvre riders were engaged in immediately (up to 5 seconds before) the control time period [a]	Going straight, decelerating [a]			
		Starting in traffic lane [a]			
		Passing or overtaking another vehicle [a]			
		Turning right [a]			
		Turning left [a]			
		Negotiating a curve [a]			
		Changing lanes [a]			
		Merging [a]			
		Manoeuvring to avoid an object [a]			
		Rolling [b]			
Rider evasive manoeuvre [a]	The subject rider/s reaction or avoidance manoeuvre (if any) in response to the unsafe event [a]	No reaction [a]	✓	✓	
		Braked only [a]			
		Steered to left [a]			
		Steered to right [a]			
		Braked and steered left [a]			
		Braked and steered right [a]			
		Accelerated [a]			
		Other actions [a]			
Rider post-manoeuvre control [a]	Ability of subject rider/s to maintain control of the bicycle during evasive	Control maintained [a]	✓	✓	
		Wobble [a]			

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
	manoeuvre(s), if any [a]	Capsize: bike fell over [a]			
Rider behaviour [a]	Group rider/s behaviours (those that either occurred within seconds prior to the Precipitating Event or those resulting from the context of the riding environment) that include what the rider/s did to cause or contribute to the unsafe event. For controls, this was group rider/s behaviour in the seconds before the control point [a]	None [a]	✓	✓	✓
		Distracted [a]			
		Lane drifting [a]			
		Passing on left [a]			
		Other improper or unsafe passing [a]			
		Cutting in, too close in front of other road user [a]			
		Cutting in at safe distance but then decelerated, causing conflict [a]			
		Did not see other road user during lane change or merge [a]			
		Other improper or unsafe lane change [a]			
		Aggressive riding, specific, directed menacing actions [a]			
		Wrong side of road, not overtaking [a]			
		Following too closely [a]			
		Making turn from wrong lane [a]			
		Improper backing [a]			
		Signal violation, intentionally disregarded signal [a]			

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
		Stop sign violation, intentionally ran stop sign at speed [a]			
		Stop sign violation, "rolling stop" [a]			
		Other sign (e.g. give way) violation, intentionally disregarded [a]			
		Right-of-way error in relation to other road user or person, apparent decision failure [a]			
		Right-of-way error in relation to other road user or person, other or unknown cause [a]			
		Sudden or improper braking [a]			
		Avoiding other road user [a]			
		Avoiding object [a]			
		Riding three abreast [b]			
Riding tasks [a]	An indication of whether the subject rider/s engaged in any riding-related tasks, beginning at any point during the 5 seconds prior to the Precipitating Event time through the end of the event (or throughout the control time period) [a]	None [a]	✓	✓	✓
		Checking behind [b]			
		Hand signalling [b]			

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
Rider count [b]	Number of riders in group during unsafe event or control time period [b]	Count [b]	✓	✓	✓
Rider speed [b]	Rider speed seconds prior to the Precipitating Event or seconds prior to the control time point, as recorded by GPS [b]	Km/h [b]	✓	✓	✓
Rider proximity [b]	Distance the subject rider/s were from the rider in front seconds prior to the Precipitating Event or seconds prior to the control time point [b]	Close proximity: < 3 metres distance from the rider in front [b]	✓	✓	✓
		Staggered: ≥ 3 metres distance from the rider in front [b]			
Rolling manoeuvre [b]	Whether the subject rider/s were undertaking a rolling manoeuvre seconds prior to the Precipitating Event or seconds prior to the control time point [b]	No: no rotation of the lead [b]	✓	✓	✓
		Yes: constant rotation of the lead riders in an anti-clockwise direction in a rolling formation [b]			
Group position on road [b]	The position of the group on the road seconds prior to the Precipitating Event or seconds prior to the control time point [b]	Single file in traffic lane [b]	✓	✓	✓
		Two abreast in traffic lane [b]			
		Two abreast in bike and traffic lane [b]			
		All riders in bike lane [b]			
Rider violation [b]		No [b]			

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
	Whether the subject rider/s committed a traffic violation seconds prior to the Precipitating Event or seconds prior to the control time point [b]	Yes [b]	✓	✓	✓
Rider aggression [b]	Whether the subject rider/s displayed obvious aggressive behaviour towards a motorist during the during unsafe event time period [b]	None [b]	✓		
		Yelling [b]			
		Swearing [b]			
		Hand gestures [b]			
		Other [b]			
Rider reckless behaviour [b]	Whether the subject rider/s displayed deliberate, careless or aggressive behaviour seconds prior to the Precipitating Event or seconds prior to the control time point [b]	No [b]	✓	✓	✓
		Yes [b]			
Motorist-related					
Motorist type [a]	Specification of motor vehicle that is involved in the event [a]	Automobile: light vehicle designed primarily to transport passengers [a]	✓		
		Utility vehicle [a]			
		Van (minivan or standard) [a]			
		Light vehicle pulling trailer [a]			

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
		Bus [a]			
		Motorcycle [a]			
		Truck [a]			
Motorist location [a]	Position of motor vehicle that is involved in the event at the start of the Precipitating Event [a]	In front of subject rider/s [a]	✓		
		In front and to the immediate right of the subject rider/s [a]			
		On the right side of the subject rider/s [a]			
		Behind and to the immediate right of the subject rider/s [a]			
		Behind the subject rider/s [a]			
		Behind and to the immediate left of the subject rider/s [a]			
		On the left side of the subject rider/s [a]			
		In front and to the immediate left of the subject rider/s [a]			
Motorist pre-incident manoeuvre [a]	Ongoing actions of the motorist immediately prior to the start of the Precipitating Event [a]	Going straight, constant speed [a]	✓		
		Going straight but with unintentional drifting within lane or across lanes [a]			
		Going straight, accelerating [a]			
		Going straight, decelerating [a]			

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
		Starting in traffic lane [a]			
		Stopped in traffic lane [a]			
		Passing or overtaking rider/s [a]			
		Entering a parking position [a]			
		Leaving a parking position [a]			
		Turning right [a]			
		Turning left [a]			
		Negotiating a curve [a]			
		Changing lanes [a]			
		Merging [a]			
		Manoeuvring to avoid an object [a]			
Motorist evasive manoeuvre [a]	The motorist's reaction or avoidance manoeuvre (if any) in response to the Precipitating Event [a]	No reaction [a]	✓		
		Braked only [a]			
		Steered to left [a]			
		Steered to right [a]			
		Braked and steered left [a]			
		Braked and steered right [a]			
		Accelerated [a]			
		Other actions [a]			
Motorist behaviour [a]	Motorist behaviours (those that either	None [a]			

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
	occurred within seconds prior to the Precipitating Event or those resulting from the context of the driving environment) that include what the motorist did to cause or contribute to the unsafe event [a]	Distracted [a]	✓		
		Lane drifting [a]			
		Passing on left [a]			
		Other improper or unsafe passing [a]			
		Cutting in, too close in front of rider/s [a]			
		Cutting in at safe distance but then decelerated, causing conflict [a]			
		Did not see rider/s during lane change or merge [a]			
		Other improper or unsafe lane change [a]			
		Aggressive driving, specific, directed menacing actions [a]			
		Wrong side of road, not overtaking [a]			
		Following too closely [a]			
		Making turn from wrong lane [a]			
		Improper backing [a]			
		Signal violation, intentionally disregarded signal [a]			
		Stop sign violation, intentionally ran stop sign at speed [a]			
		Stop sign violation, 'rolling stop' [a]			

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
		Other sign (e.g. give way) violation, intentionally disregarded [a]			
		Right-of-way error in relation to rider/s or person, apparent decision failure [a]			
		Right-of-way error in relation to rider/s or person, other or unknown cause [a]			
		Sudden or improper braking [a]			
		Avoiding other road user [a]			
		Avoiding object [a]			
Motorist violation [b]	Whether the motorist committed a traffic violation seconds prior to the Precipitating Event [b]	No [b]	✓		
		Yes [b]			
Motorist aggression [b]	Whether the motorist displayed obvious aggressive behaviour towards rider/s during the during the unsafe event time period [b]	None	✓		
		Repeating beeping			
		Passing closer than necessary			
		Yelling			
		Revving of engine			
Motorist reckless behaviour [b]	Whether the motorist displayed deliberate, careless or aggressive	No [b]	✓		
		Yes [b]			

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
	behaviour seconds prior to the Precipitating Event [b]				
Other-rider (non-subject)- related					
Other rider location [a]	Position of non-subject rider that is involved in the event [a]	In front of subject rider/s [a]		✓	
		In front and to the immediate right of the subject rider/s [a]			
		On the right side of the subject rider/s [a]			
		Behind and to the immediate right of the subject rider/s [a]			
		Behind the subject rider/s [a]			
		Behind and to the immediate left of the subject rider/s [a]			
		On the left side of the subject rider/s [a]			
		In front and to the immediate left of the subject rider/s [a]			
Other rider pre-incident manoeuvre [a]	Ongoing actions of the other non-subject rider immediately prior to the start of the Precipitating Event [a]	Going straight, constant speed [a]		✓	
		Going straight but with unintentional drifting within lane or across lanes [a]			
		Going straight, accelerating [a]			
		Going straight, decelerating [a]			

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
		Starting in traffic lane [a]			
		Passing or overtaking another vehicle [a]			
		Turning right [a]			
		Turning left [a]			
		Negotiating a curve [a]			
		Changing lanes [a]			
		Merging [a]			
		Manoeuvring to avoid an object [a]			
		Rolling [b]			
Other rider evasive manoeuvre [a]	The other non-subject rider's reaction or avoidance manoeuvre (if any) in response to the Precipitating Event [a]	No reaction [a]		✓	
		Braked only [a]			
		Steered to left [a]			
		Steered to right [a]			
		Braked and steered left [a]			
		Braked and steered right [a]			
		Accelerated [a]			
		Other actions [a]			
Other rider behaviour [a]	Other non-subject rider's behaviours (those that either occurred within seconds prior to the Precipitating Event	None [a]		✓	
		Distracted [a]			
		Lane drifting [a]			

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
	or those resulting from the context of the riding environment) that include what the other rider did to cause or contribute to the unsafe event [a]	Passing on left [a]			
		Other improper or unsafe passing [a]			
		Cutting in, too close in front of rider/s [a]			
		Cutting in at safe distance but then decelerated, causing conflict [a]			
		Did not see rider/s during lane change or merge [a]			
		Other improper or unsafe lane change [a]			
		Aggressive riding, specific, directed menacing actions [a]			
		Wrong side of road, not overtaking [a]			
		Following too closely [a]			
		Making turn from wrong lane [a]			
		Improper backing [a]			
		Signal violation, intentionally disregarded signal [a]			
		Stop sign violation, intentionally ran stop sign at speed [a]			
		Stop sign violation, 'rolling stop' [a]			
		Other sign (e.g. give way) violation, intentionally disregarded [a]			

Variable	Variable Description	Variable categories	Motor vehicle event (case)	Non-motor vehicle event (case)	Control
		Right-of-way error in relation to rider/s or person, apparent decision failure [a]			
		Right-of-way error in relation to rider/s or person, other or unknown cause [a]			
		Sudden or improper braking [a]			
		Avoiding other road user [a]			
		Avoiding object [a]			
		Riding three abreast [b]			

[a] Variable, description or categories taken/ modified from the SHRP 2 Naturalistic Driving Study (Virginia Tech Transportation Institute, 2015)
[b] Variable, description or categories added for this study
✓ Indicates whether the variable was included for Part A: Unsafe events involving a motor vehicle, Part B: Unsafe events not involving a motor vehicle and/or for control time periods

APPENDIX 14: REGULATIONS FROM THE WA ROAD TRAFFIC CODE (2000) USED TO DEFINE RIDER VIOLATIONS (PHASE 2: NATURALISTIC STUDY)

Part	Division	Regulation
RED LIGHT VIOLATION		
Part 6: Traffic control signals	Division 1: Obeying traffic-control signals (traffic lights)	**40. Stopping for a circular red signal or red arrow** (1) If a traffic-control signal facing a driver displays a circular red signal — (a) subject to regulation 43, the driver shall not proceed beyond the stop line associated with the signal; (2) If a traffic-control signal facing a driver displays a red arrow signal — (a) subject to regulation 43, the driver shall not proceed beyond the stop line associated with the signal;
STOP SIGN VIOLATION		
Part 7: Giving way	Division 1: Places with a stop sign, stop line, give way sign or give way line applying to the driver	**50. Stopping and giving way at a stop sign or stop line at an intersection without traffic-control signals** (2) A driver approaching or at an intersection with a "stop" sign or stop line shall - (a) stop at the stop line; or (b) if there is no stop line, stop as near as practicable to, but before entering, the intersection.
WRONG SIDE OF ROAD VIOLATION		
Part 9: Roundabouts	N/A	**96. Driving through a roundabout** (1) A driver passing through a traffic roundabout shall drive to the left of the central traffic island, unless subregulation (2) or (3) applies to the driver

Part	Division	Regulation
Part 11: Keeping left, overtaking and other driving provisions	Division 2: Keeping to the left	**116. Keeping left of continuous dividing lines** Where a carriageway is marked with a dividing line comprising — (a) 2 continuous lines; (b) a continuous line on the left of a broken or dotted line; or (c) a continuous line, a driver shall not permit any portion of the vehicle to travel on, over, or to the right of, the dividing line except for the purpose of making a right turn or a U turn, where permissible. **117. Keeping to the left of a median strip** Where a road is divided by a median strip, a driver shall not drive upon the median strip, or the carriageway to the right of the median strip, unless the driver is — (a) entering or driving in a median strip parking area; (b) required to drive to the right of the median strip by a “keep right” sign; or (c) using a special purpose lane as permitted by information on the sign applicable to that lane. **120. Avoiding obstructions on a carriageway** (1) A driver on a two-way carriageway without a dividing line or median strip may drive to the right of the carriageway or into the other carriageway to avoid an obstruction if — (a) the driver has a clear view of any approaching traffic; (b) it is necessary and reasonable, in all the circumstances, for the driver to drive in that manner to avoid the obstruction; and (a) the driver can do so safely. (2) A driver on a two-way carriageway with a dividing line may drive to the right of the dividing line to avoid an obstruction if —

Part	Division	Regulation
		(a) the driver has a clear view of any approaching traffic; (b) it is necessary and reasonable, in all the circumstances, for the driver to drive to the right of the dividing line to avoid the obstruction; and (c) the driver can do so safely.
RIDING MORE THAN 2 ABREAST VIOLATION		
Part 11: Keeping left, overtaking and other driving provision	Division 4: Driving in marked lanes or lines of traffic	**130. Riding a 2-wheeled vehicle alongside more than one other rider** (1) The rider of a motor cycle, moped, power-assisted pedal cycle or bicycle shall not ride on a carriageway that is not a multi-laned carriageway alongside more than one other rider, unless the rider is overtaking the other riders (2) The rider of a motor cycle, moped, power-assisted pedal cycle or bicycle shall not ride in a marked lane on a carriageway alongside more than one other rider, unless the rider is overtaking the other riders
RIGHT OF WAY VIOLATION AT INTERSECTION		
Part 7: Giving way	Division 1: Places with a stop sign, stop line, give way sign or give way line applying to the driver	**50. Stopping and giving way at a stop sign or stop line at an intersection without traffic-control signals** (3) A driver approaching or at an intersection with a “stop” sign or stop line shall give way to a vehicle in, entering or approaching the intersection except- (a) an oncoming vehicle turning right at the intersection, if a “stop” sign, stop line, “give way” sign or give way line applies to the driver of the oncoming vehicle; (b) a vehicle turning left at the intersection using a slip lane; or (c) a vehicle making a U turn **52. Giving way at a give way sign or give way line at an intersection** (1) A driver at an intersection with a ‘give way’ sign or give way line shall give way to a vehicle in, entering or approaching the intersection except –

Part	Division	Regulation
		(a) an oncoming vehicle turning right at the intersection, if a “stop” sign, stop line, “give way” sign or give way line applies to the driver of the oncoming vehicle; (b) a vehicle turning left at the intersection using a slip lane; or (c) a vehicle making a U turn
	Division 2: Giving way at an intersection without traffic control signals or a stop sign, stop line, give way sign or give way line applying to the driver	**55. Giving way at an intersection (except a T-intersection or roundabout)** (2) If a driver at an intersection is going straight ahead, the driver shall give way to any vehicle approaching from the right, unless a “stop” sign, stop line, “give way” sign or give way line applies to the driver of the approaching vehicle. (3) If a driver at an intersection is turning left (except if the driver is using a slip lane), the driver shall give way to – (a) any vehicle approaching from the right, unless a ‘stop’ sign, stop line, ‘give way’ sign or give way line applies to the driver of the approaching vehicle (6) If a driver at an intersection is turning right, the driver shall give way to- (a) any vehicle approaching from the right unless a ‘stop’ sign, stop line, “give way” sign or give way line applies to the driver of the approaching vehicle; (b) any oncoming vehicle that is going straight ahead or turning left at the intersection unless (i) a ‘stop’ sign, stop line, ‘give way’ sign or give way line applies to the driver of the approaching vehicle (ii) the oncoming vehicle is turning left using a slip lane
		56. Giving way at a T-intersection (2) If a driver at a T-intersection is turning left (except if the driver is using a slip lane), or right, from the terminating road into the continuing road, the driver shall give way to – (a) any vehicle travelling on the continuing road

Part	Division	Regulation
		(6) If a driver at a T-intersection is turning right from the continuing road into the terminating road, the driver shall give way to- (a) any oncoming vehicle that is travelling through the intersection on the continuing road or turning left at the intersection
	Division 3: Entering or leaving land abutting a carriageway or road	**57. Giving way when entering a carriageway from land abutting a carriageway or road** (1) A driver entering a carriageway from land abutting the carriageway, without a traffic-control signal or a “stop” sign, stop line, “give way” sign or give way line, shall give way to – (a) any vehicle travelling on the carriageway or turning into the carriageway (except a vehicle turning right into the carriageway from land abutting the carriageway); (b) any pedestrian on the carriageway; and (c) any vehicle or pedestrian on any land abutting the carriageway (including a path) that the driver crosses to enter the carriageway.
		58. Giving way when entering land abutting a carriageway or road from a carriageway (1) A driver entering land abutting a carriageway or road from a place on a carriageway without a traffic-control signal or a “stop” sign, stop line, “give way” sign or give way line, shall give way to – (a) any pedestrian on the carriageway; (b) any vehicle or pedestrian on any land abutting the carriageway that the driver crosses or enters; (c) if the driver is turning right from the carriageway — any oncoming vehicle on the carriageway that is going straight ahead or turning left; and

Part	Division	Regulation
		(d) if the carriageway the driver is leaving ends at a T-intersection opposite the land abutting the carriageway and the driver is crossing the continuing road — any vehicle on the continuing road.
Part 9: Roundabouts	N/A	**95 Right of way in a roundabout** A driver entering a roundabout shall give way to a vehicle that is within the roundabout
ONE WAY VIOLATION		
Part 8: Traffic signs and road markings	Division 2: Traffic signs and road markings generally	**80 One-way signs** (1) A driver shall not drive on a carriageway to which a 'one-way' sign applies, except in the direction indication by the arrow on the sign

("Western Australia Road Traffic Code," 2000)