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THE PEDAL STUDY: FACTORS ASSOCIATED WITH BICYCLE CRASHES AND INJURY SEVERITY IN THE ACT FINAL REPORT JULY 2011

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EXECUTIVE SUMMARY

Introduction

Over the last decade in many parts of Australia as in other high income countries, there has been a substantial increase in the number of people cycling. The Australian Capital Territory (ACT) has the highest cycling participation rate in Australia and a population rate for serious bicycle crash injuries that is significantly above the national rate, which may be due to higher exposure.

This report summarises the findings of a study which examined the characteristics of bicycle crashes in different cycling environments in the ACT and investigated the type and severity of injuries associated with the type of clothing worn. The objective was to inform strategies to reduce bicycle crashes and the severity of the associated injury.

Methods

A cross sectional survey of adults (aged 17-70 years) who were injured in cycling crashes and presented to hospital Emergency Departments in the ACT over the six months from November 21, 2009 to May 21, 2010. All cyclists involved in crashes on public roads or publically accessible areas within the ACT were eligible for inclusion. Recruitment was restricted to residents of the ACT or the adjacent New South Wales (NSW) border region of Queanbeyan. Cyclists with severe trauma were excluded from the study as they were considered to be medically unfit or otherwise unable to provide informed consent. Riding environments were defined as either off-road or transport related. Off-road includes recreational environments such as mountain bike trails and skate parks. Transport related includes on road in traffic, in bicycle lanes, on shared paths and on footpaths (including other pedestrian areas).

Results

Of the 372 eligible cyclists presenting to Emergency Departments during the study period, 84.1% (n=313) participated in the study, with an overall response rate of 93.4%. Participants included 111 (35.5%) who were riding off-road such as on mountain bike trails or skate parks and 202 who crashed in transport related environments. The latter included 79 (25.2%) riding in traffic, 16 (5.1%) in bicycle lanes, 73 (23.3%) on shared paths and 34 (10.9%) on footpaths or other pedestrian areas.

Nearly three quarters of participants were males with a mean age of 37.5 years. A higher proportion of young cyclists (17-25 year) crashed off-road (44.9% versus 27.0%), compared to older cyclists (40 years or more). A higher proportion of older cyclists compared to young cyclists crashed on shared paths (36.5% versus 10.1%).

The majority of participants had been wearing a helmet when they crashed (88.8%). This included a lower proportion of those riding in bicycle lanes (68.8%) or on footpaths (70.6%) than those riding in traffic or on shared paths.

The majority of cyclists (65.2%) fell without the involvement of any other road user, but this varied by riding environment. Slightly over half of those riding in traffic (51.9%) were involved in a collision with another road user and a further 11.4% crashed while taking action to avoid a collision. Those riding on shared paths had a higher proportion of falls (56.2%) most of which were due to running out of control (58.2%) without the involvement of either other road users or objects. However 16.4% of crashes on shared paths involved pedestrians and almost a quarter involved other cyclists (23.3%).

While the most common purpose given for the ride that resulted in the crash was recreation (42.8%), over half (52%) of crashes in transport environments occurred while commuting. The majority (62.6%) rode in excess of 100 kilometres per week on average but were not members of bicycle clubs or ride groups. Almost one third (30.0%) had undertaken some bicycle skills training in recent years.

Participants were asked to estimate how much the crash had cost them personally including out-of-pocket costs for health services, loss of income and property damage. Based on those who provided this information, the average cost for each cyclist was $1,003.25.

Three quarters of cyclist crashes in transport environments occurred during weekdays and nearly half occurred in the early morning (25%, 6-8.00am) and late afternoon (20%, 4.00-6.00pm).

Almost two thirds (60.4%) of crashes that occurred in transport environments involved a single cyclist, often losing control on straight sections of the road (49.2%)or falling as a result of an impact with objects on the path(20.0%). Road surface conditions that may have contributed to these crashes included wet surface, slippery surface, loose gravel or rocks, broken, cracked or potholed surface and raised edge or lip to sealed surface. Equipment failure such as flat tyres, dropped chains and problems disengaging shoe cleats, also played an important role contributing to one in four single cyclist crashes. Excessive speed and alcohol were also identified as contributing factors.

The majority of crashes where another vehicle was involved, occurred in traffic (58.8%), 22.5% on shared paths and 12.5% in bicycle lanes. The other vehicle was almost equally as likely to be another bicycle as a motor vehicle (47.5% versus 52.5%). Motor vehicles were most likely to be involved in intersection crashes involving vehicles from adjacent directions or manoeuvring which include where either the motorist or cyclist emerged into the traffic stream from a driveway or pathways.

The estimated average travelling speed of cyclists prior to a multi-vehicle crashes was 25.3km/h. Average reported speeds were highest for cyclists in traffic (28.7km/h) and bicycle lanes and lowest on footpaths (10.9km/h). The average speed on shared paths was 20.9km/h with a maximum of 43km/h.

The majority of cyclists included in the study (58.4%) sustained minor injuries but more than a third had injuries rated moderately or very severe. Crashes that occurred in bicycle lanes were less severe than those that occurred in other riding environments. The mean severity score was highest for cyclists who crashed on shared paths (4.36) and in traffic (4.04).The majority of cyclists sustained soft tissue injuries including abrasions (74.8%), bruises (67.3%) and cuts and lacerations (35.6%). with a relatively high proportion sustaining fractures (42.6%). The most common body locations of injury were upper and lower limbs, particularly shoulders and knees, with almost one in four sustaining injuries to the head.

The study also identified a significantly reduced risk of injury to upper and lower limbs associated with clothing that fully covered the skin, such as long sleeved tops and full length pants, regardless of the materials used. After adjusting for all clothing types, age, gender, riding environment, number of vehicle involved, speed zone, collision source, bicycle type and journey purpose, those wearing any type of short sleeved tops were more likely to sustain an injury to the upper limbs compared to those wearing long sleeves (Adj. OR=2.06, 95% CI: 1.02-4.18, P=0.05). Those wearing short sleeve tops were particularly more likely to sustain cuts or abrasion injuries to their upper body than those wearing long sleeved clothing (Adj. OR=2.69, 95% CI: 1.31-5.52, P=0.01).

After adjusting for similar characteristics, cyclists wearing short pants or skirts were over three times more likely to sustain injuries to their lower body (Adj. OR = 3.37, 95%CI: 1.42-7.96, P=0.01). They were over twice as likely to have cuts or abrasion injuries (Adj. OR=2.25, 95%CI: 1.04-4.86, P=0.04).

Only 11.2% of all crashes (17.3% of crashes in transport environments) were reported to the police with crashes involving motor vehicles most likely to be reported (71.4%), whereas none of the pedestrian crashes, only 5.3% of crashes involving other cyclists and 2.9% of single vehicle crashes were reported.

LIMITATIONS

The recruitment methodology limited participants to those cyclists who attended a hospital Emergency Department in the ACT. The exclusion of the most severely injured riders biases the findings and may underestimate the severity of cyclists' injuries in the ACT. The total number of bicycle crash related injuries is also underestimated as the study did not include those who sought treatment from other medical services or pharmacies. In addition, no data is available as to the number and severity of pedestrians and other road users injured in crashes with a cyclist, except those circumstances where the cyclist also required hospital treatment.

The cross sectional design also limits the findings regarding factors associated with crash and injury risks due to the lack of information on the behaviour and riding experiences of controls, that is cyclists who did not crash or were not injured. In addition, information on traffic crash rates for various routes needs to be treated with caution because of the small number of crashes on each route but also due to the incompleteness of information on exposure.

CONCLUSIONS

This study confirms the value of on-road lanes reserved exclusively for cyclists as a means of reducing their crash and injury rates but raises questions as to the safety of cycling on shared paths and pedestrian areas.

The number of crashes involving pedestrians and the relatively high speeds of some of the cyclists on shared paths and footpaths suggests that the regulation of cycling in shared areas should be reviewed, formally recognized as a part of the road reserve and appropriate speed limits applied. Such measures would be in the interests of cyclists and pedestrians, as cyclists who crashed on shared paths sustained higher average injury severity scores than those injured in any other road environment.

The high proportion of crashes between cyclists is also a matter of concern as almost half of all multi-vehicle crashes were between bicycles. Whereas better traffic management such as centre lines and warning signs on shared paths should reduce such conflicts, it is apparent that behavioural factors such as speed and riding in close packed groups should also be addressed. Other cyclist dependent factors associated with crashes included alcohol, usage of shoe cleats, carrying unbalanced loads such as back packs and shopping bags and poor bicycle maintenance.

The study found that full body coverage including gloves, shoes, long sleeved tops and full length pants, regardless of the materials used, provided a significant benefit in preventing or reducing injuries.

Consideration should be given to undertaking a large population study (i.e. Case control study) to examine risk factors of cyclist crashes in the ACT in order to identify appropriate countermeasures. The study would provide an opportunity to further examine the incidence of conflicts with pedestrians and the impact of factors such as alcohol use, helmet use, road infrastructure, protective and conspicuous clothing on cyclist crash and injury risk.

INTRODUCTION

Cycling is often promoted as an energy efficient, sustainable travel mode with many advantages over motorized transport including personal and public health benefits (TAMS 2000, City of Sydney 2007). However cycling is also relatively risky compared to other forms of transport, due to the fragility of the unprotected human body. In the US the risk of fatal injury per 100 million person trips is estimated to double (21.0 versus 9.2) when travelling by bicycle compared to a passenger vehicle (Bhatia and Wier 2011). In Australia cyclists represent almost 15% of all seriously injured road crash casualties compared to motorcyclists (22%) and pedestrians (9%) (AIWA 2009). There is cause for concern that as an increasing number of Australians take up cycling, so the number injured will also increase (Sikic et al. 2009). In fact, the number of Australians cycling, increased by 36% between 2000-2008 (Australian Sports Commission 2008) and over the same period (2000 -2007) there was a 47% increase in age standardised serious injury for pedal cyclists (AIWA 2009).

The serious injury rate for cyclists in the Australian Capital Territory (ACT) is significantly above the national rate (31 versus 23) per 100,000 population (AIWA 2009). This may be due to higher exposure as the ACT has the highest cycling participation rate[1] in Australia, with 18.2% of the population compared to 13.8% in Victoria and 9.9% in NSW (Australian Sports Commission 2008). The ACT has a well established and extensive network of linked on-road and off-road cycling routes. The network includes cycling environments with a range of degrees of segregation from motorised traffic including road-side bicycle lanes, shared pedestrian/cycle paths and footpaths (TAMS 2000).

The extent to which the higher participation in ACT compared to other states is a function of the available cycling infrastructure or of the more suitable geographic environment for riding (flat terrain, short distances) has not been established. Risk rates for cyclists are difficult to estimate and they vary considerably amongst countries due to factors including under reporting and lack of exposure data (Wegman *et al.* 2010). There is some evidence that countries with a lot of bicycle traffic have a relative low fatality rate compared to those with less bicycle usage, leading to theories about safety in numbers, arguing that increasing numbers of cyclists create safer riding environments (Jacobsen 2003, Elvik 2009). However these countries are the exception to the rule and there are more examples of countries where bicycle travel distances, trip numbers and fatality rates are low. These findings suggest that exposure is not the only factor and caution should be applied in assuming the principles of

[1] Participation rate is the number of persons who participated in the activity at least once in the preceding 12 months expressed as a percentage of the population.

safety in numbers in transportation policy and planning (Wegman *et al.* 2010, Bhatia and Wier 2011).

Strategies designed to increase the safety of cyclists can be classified as concerned either with primary or secondary safety. Primary safety programs are aimed at reducing crash risk whereas secondary safety programs are aimed at reducing the risk and severity of injuries when crashes do occur.

Primary safety strategies include bicycle designed traffic facilities such as segregated bicycle lanes, advanced stop lines and shared paths. There is a growing body of literature relating to road environment factors and bicycle crashes, but limited evidence of their effectiveness in reducing crash risk in high standard evaluations published in peer-reviewed literature (Wegman *et al.* 2010). The provision of segregated bicycle facilities is also often cited as critical to encourage more people to take up cycling (Wilson and Bailey 2006) although research suggests that separated bicycle paths do not necessarily increase cycling safety (Pasanen 1999, Forester 2001). Studies from the US and Europe have identified roundabouts as relatively high risk intersection configurations for cyclists (Bared *et al.* 1997, Hels and Orozova-Bekkevold 2007, Daniel *et al.* 2009). There is evidence that sidewalks and multi-use trails pose the highest risk and that major and high speed roads are more hazardous than minor roads (Aultman-Hall and Adams Jr 1998, Reynolds *et al.* 2009). Conversely the presence of bicycle facilities (e.g. on-road bike routes, on-road marked bike lanes, and off-road bike paths) have been associated with the lowest risk (Petritsch *et al.* 2006, Reynolds *et al.* 2009, Koorey and Mangundu 2010). Despite such findings, scientific evaluation of different styles and configurations of cycling environments has been difficult due to the complexities of establishing true comparisons between different sites. This is due to the array of different bicycle path treatments, traffic volumes and other factors. Reviews of the literature also tend to prove inconclusive as many reported evaluations do not specifically define the types of bicycle facilities being studied (Hallett *et al.* 2006).

Bicycle helmets are commonly identified as key secondary safety measures for reducing the risk and severity of injury in crashes (WHO 2004). While there seems little doubt that helmets do reduce the risk of brain injury (Thompson *et al.* 2009, Elvik 2011, Otte *et al.* 2011), it is only recently that some authors have drawn attention to the potential value of other forms of protective clothing for cyclists (Abu-Kishk *et al.* 2010). Earlier references to protective clothing for cyclists relate to conspicuity and crash prevention rather than injury reduction (Beers and Burg 1978, Kwan and Mapstone 2006, Hagel *et al.* 2007, Thornley *et al.* 2008, Miller *et al.* 2010).

This study was funded by the NRMA ACT Road Safety Trust to identify the factors associated with bicycle crashes in different cycling environments and to investigate the type and severity of injuries associated with the clothing worn. The objective was to inform strategies to reduce bicycle crashes and the severity of injury. Secondary aims were to obtain information about the cyclists who crash, including demographic details and the extent and type of their riding.

METHODS

The study was a cross sectional survey of adults who presented to Emergency Departments at Canberra or Calvary Hospitals in the ACT due to an injury caused in a cycling crash. The study was conducted over the six months from November 21, 2009 to May 21, 2010. All cyclists involved in crashes on public roads or publically accessible areas within the ACT were eligible for inclusion. Recruitment was restricted to residents of the ACT or the adjacent NSW border region of Queanbeyan, who were aged seventeen years or over. The age cut off of seventeen was selected as it is the minimum age for independent driver and motorcycle licences in the ACT and NSW. Cyclists were excluded if they had severe head (AIS3+) or spinal injuries (AIS4+) as rated on the Abbreviated Injury Scale (AAAM 2005); had post traumatic amnesia for 24 hours or more; rated less than thirteen on the Glasgow Coma Scale (Teasdale and Jennett 1974) or were considered to be medically unfit or otherwise unable to provide informed consent.

Promotional information about the study was provided through posters and brochures throughout the bicycle community, retail outlets and in waiting areas in each hospital. Potential participants were identified from Emergency Department presentation records and sent letters and then telephoned to request their participation in the study. Participants were offered a payment of $25 in compensation for their time in taking part in the study. Those who agreed to participate were interviewed either in hospital or at home by telephone.

The interview followed a structured questionnaire format with questions relating to the crash circumstances, specific location, type of bicycle, what they had been wearing and the extent of injuries, in addition to background information about their riding experience and the cost to them of the crash. Injury details were recorded at interview and each injury from the self-reports was independently scored by a trained assessor on the Abbreviated Injury Scale (AIS), (AAAM 2005). The medical records of those participants who attended The Canberra Hospital (n=190, 60.7%) were used to corroborate interview reports on injury and admissions details but this was not available for those who had attended Calvary Hospital (n=123, 39.3%).

Cycling environments were classified as either transport-related, including those occurring on public roads, bicycle lanes, shared paths and footpaths, or non-transport related, such as mountain bike trails and BMX parks. Data on bicycle usage counts on selected roads and bicycle lanes for 2009 and shared paths in 2008 were obtained from ACT roads authority (ACT Roads 2010). If average weekly usage counts were available for crash locations, they were used to estimate total usage over six months as a base to calculate crash rates per 10,000 cyclists per route. Age was categorised into identified crash risk age groups 17-25, 26-39 and 40 years or older (ATSB 2004). Crashes were also defined by number of vehicles involved (single/multi-vehicle) and by type of incident, defined as falls (without contribution from other road users), collisions with other road users (including other vehicles, pedestrians and animals) and conflicts (where the cyclists crashed while avoiding a collision). Crashes involving pedestrians were by convention classified as single vehicle crashes. The key outcomes reported were the AIS score of the most serious injury sustained (Maximum-AIS), the combined injury severity score (ISS), the number of days away from work or normal daily duties, types of injury sustained and clothing worn.

Injuries were classified by part of the body and type of injury. For the purposes of the analysis, the body was divided into six zones corresponding to types of clothing. The body zones were: head, upper limbs (arms and elbows), torso (including shoulders), hands/wrists, lower limbs (legs and knees) and feet/ankles. Injuries were recorded according to types: bruises, cuts/lacerations, abrasions, fractures, sprains, dislocations and internal injuries and body zone. The main injury outcomes were coded for each part of the body: 1 – any injury and 2: any open wound injuries (cuts/ lacerations or abrasions). The latter represents a subset of soft tissue injuries, but specifically excludes injuries caused by high impact forces (e.g. bruises, sprains, dislocations or internal injuries) in order to determine any association between injuries and clothing worn. Clothing worn was classified according to whether it provided full or partial cover (e.g. long pants or shorts), whether it was purpose designed for cycling and the type of material (cotton, Lycra, leather or other).

Chi-squared tests were used, when appropriate, to examine differences in proportions between groups examined. Logistic regression analyses were undertaken to examine the association between various types of clothing worn by cyclists and the risk of injury to the relevant body part. The regression models were used to determine odd ratios (OR) and 95% confidence intervals (CI) for injury. Potential confounding variables (demographic, behavioural and crash characteristics) were included in the multivariate regression models if they were associated with the outcome measure in bi-variate regression models ($p<0.2$ as the conventional level to screen independent variables for multivariate modelling). Backward elimination was used to determine confounders adjusted for in the final models. The analyses were conducted in SAS 9.1 (SAS 2008).

RESULTS

Over the study period 723 injured cyclists were identified including 372 who were eligible for the study and 351 who were ineligible. Of the 372 eligible cyclists, 84.1% (n=313) participated, 9.9% (n=37) were not contactable and 5.9% (n=22) declined to take part. The overall response rate was 93.4% of eligible participants contacted. Of the 351 ineligible cyclists, 61.0% (n=227) were excluded due to being aged under seventeen years, 19.6% (n=73) were not local residents and 1.1% (n=4) were excluded on medical grounds. A further 13.4% had either been miss-classified as having a cycling crash (n=25) or had crashed outside the study areas (n=16) or time period (n=6).

Participants included 111 (35.5%) who were riding off-road in non-transport related environments such as mountain bike trails and skate parks and 202 who crashed in transport related environments. The latter included 79 (25.2%) riding in traffic, 16 (5.1%) in bicycle lanes, 73 (23.3%) on shared paths and 34 (10.9%) on footpaths or other pedestrian areas. Over a third of those who crashed on shared paths (34.2%), described their riding environment as a ‘bike’ or ‘cycle’ path. The following section provided demographic details and key factors associated with injury severity and the consequences of crashing according to riding environment for the whole sample. Subsequent sections will focus primarily on crashes that occurred in transport related environments.

CHARACTERISTICS OF CYCLISTS BY ALL CRASH ENVIRONMENT

The characteristics of the sample by riding environment are summarised in Table 1. Almost three quarters of the bicycle casualties were male (73.8%, n=231). The average age of casualties was 37.5 years with a median age of 36. Just over half (52.4%) lived with a partner and 3.1% had dependent children. The majority worked full-time and seventy percent earned $50,000 or more in the past year including 22% over $100,000 per year.

Almost all (96.4%) had a driver licence and 15% were licensed motorcycle riders. Those with driver licences included 84.0% with a full licence, 5.1% probationary and 4.5% learners. A small proportion (4.2%) had never held a drivers licence and 1.6% (n=5) had lost their licence (cancelled or disqualified). A total of 35 casualties (11.2%) had incurred road traffic infringements in the past twelve months. These included 31 speeding offences, one unlawful blood alcohol and two unspecified. All infringements were in relation to driving; there were no infringements relating to either bicycle or motorcycle riding.

A high proportion of males had crashed off-road (40.3%) compared to female cyclists (22.0%). There was little difference in the proportion of male casualties who crashed in-traffic (22.5%) compared to shared paths (22.9%), but only 5.6% crashed in bicycle lanes and 8.7% on footpaths. A higher proportion of female than male casualties crashed in-traffic (32.9%), on shared paths (24.4%) and while riding on a footpath (17.1%).

A higher proportion of young cyclists (17-25 year) crashed off-road (44.9% versus 27.0%), compared to older cyclists (40 years or more). A higher proportion of older cyclists compared to young cyclists crashed on shared bicycle paths (36.5% versus 10.1%).

Table 1 Characteristics of sample by riding environment

	In traffic n=79 %	Cycle lane n=16 %	Shared path n=73 %	Footpath n=34 %	Off-road n=111 %	Total N=313
Sex						
Male	52 (22.5)	13 (5.6)	53 (22.9)	20 (8.7)	93 (40.3)	231
Female	27 (32.9)	3 (3.7)	20 (24.4)	14 (17.1)	18 (22.0)	82
Age group						
17-25	17 (24.6)	5 (7.2)	7 (10.1)	9 (13.0)	31 (44.9)	69
26-39	32 (27.1)	6 (5.1)	20 (16.9)	14 (11.9)	46 (39.0)	118
40+	30 (23.8)	5 (4.0)	46 (36.5)	11 (8.7)	34 (27.0)	126
Relationship Status						
Single	30 (23.1)	6 (4.6)	24 (18.5)	16 (12.3)	54 (41.5)	130
Live-in relationship	47 (28.7)	8 (4.9)	43 (26.2)	15 (9.1)	51 (31.1)	164
Separated	2 (11.8)	2 (11.8)	6 (35.3)	3 (17.6)	4 (23.5)	17
Employment status						
Full time work	53 (25.5)	10 (4.8)	50 (24.0)	18 (8.7)	77 (37.0)	208
Part time work	6 (22.2)	3 (11.1)	3 (11.1)	4 (14.8)	11 (40.7)	27
Self employed	5 (23.8)	1 (4.8)	7 (33.3)	1 (4.8)	7 (33.3)	21
Keeping house	1 (20.0)	1 (20.0)	2 (40.0)	1 (20.0)	0 (0.0)	5
Student	7 (28.0)	1 (4.0)	2 (8.0)	4 (16.0)	11 (44.0)	25
Retired	5 (45.5)	0 (0.0)	4 (36.4)	1 (9.1)	1 (9.1)	11
Unemployed	0 (0.0)	0 (0.0)	0 (0.0)	3 (100.0)	0 (0.0)	3
Other	2 (15.4)	0 (0.0)	5 (38.5)	2 (15.4)	4 (30.8)	13
Income						
Under $10,000	7 (22.6)	1 (3.2)	5 (16.1)	4 (12.9)	14 (45.2)	31
$10,001 -$25,000	5 (29.4)	2 (11.8)	3 (17.6)	4 (23.5)	3 (17.6)	17
$25,001-$50,000	9 (22.0)	3 (7.3)	11 (26.8)	5 (12.2)	13 (31.7)	41
$50,001-$75,000	21 (24.4)	3 (3.5)	17 (19.8)	10 (11.6)	35 (40.7)	86
$75,001-$100,000	20 (30.8)	2 (3.1)	16 (24.6)	7 (10.8)	20 (30.8)	65
$100,001-$125,000	11 (37.9)	1 (3.4)	7 (24.1)	1 (3.4)	9 (31.0)	29
$125,001+	5 (12.8)	4 (10.3)	12 (30.8)	3 (7.7)	15 (38.5)	39
Not stated	1 (20.0)	0 (0.0)	2 (40.0)	0 (0.0)	2 (40.0)	5

Table 2 presents cycling factors associated with the crash by different riding environments. The majority of participants had been wearing a helmet when they crashed (88.8%). This included a lower proportion of those riding in bicycle lanes (68.8%) or on footpaths (70.6%)

than those riding in traffic or on shared paths. Overall most cyclists (65.2%) fell without the involvement of any other road user, but this varied by riding environment. Over half of those riding in traffic (51.9%) were involved in a collision with another road user and a further 11.4% crashed while taking action to avoid a collision. Those riding on shared paths had a higher proportion of falls (56.2%), but almost one quarter (24.7) was involved in collisions and while 19.2% did not actually collide, they crashed as a result of a conflict with either pedestrians or other cyclists.

Over half were riding alone when they crashed (56.9%) but 24.1% (n=28) of all in-traffic crashes involved other cyclists and 12.7% (n=10) of these multi-cycle on-road crashes occurred when riding in a group of 11 or more cyclists.

Over half the participants (n=164) went directly to hospital with 11.2% admitted (n=35) and 41.2% treated in the Emergency Department and discharged (n=129). Almost a quarter (n=75) were able to ride home and a further 21.1% (n=66) were driven home before going to hospital. Only 11.2% (n=35) said that they had reported the crash to the Police.

The most common purpose given for the ride that resulted in the crash was recreation (42.8%), closely followed by commuting (36.7%) with competition or training accounting for 11.8%. A higher proportion of males had been riding off-road (e.g. mountain biking). When off-road riding was excluded, a higher proportion of journeys (63.4% versus 36.1%) had transport purposes (i.e. commuting, visiting, shopping or work related) than non-transport (i.e. recreational, competition or training). Over half (52%) of crashes in transport environments occurred while commuting.

A high proportion (59.7%, n=187) of participants had crashed before and almost all (n=181) had been injured previously. These included 31.6% (n=59) seriously injured (e.g. broken bones/stitches/hospitalization) and 17.6% (33) who had sustained moderate injuries. The majority (62.6%) rode in excess of 100 kilometres per week on average but were not members of bicycle clubs or ride groups. Less than one third, (30.0%) had undertaken any bicycle skills training in recent years.

Table 2 Cycling factors associate with crash by riding environment

	In traffic n=79(%)	**Cycle lane n=16(%)**	**Shared path n=73 (%)**	**Footpath n=34(%)**	**Off-road n=111(%)**	**Total N=313(%)**
Helmet worn						
No helmet	4 (5.1)	5 (31.3)	4 (5.5)	10 (29.4)	12 (10.8)	35 (11.2)
Helmet	75 (94.9)	11 (68.8)	69 (94.5)	24 (70.6)	99 (89.2)	278 (88.8)
Type of crash						
Fall	29 (36.7)	5 (31.3)	41 (56.2)	26 (76.5)	103 (92.8)	204 (65.2)
Collision	41 (51.9)	7 (43.8)	18 (24.7)	4 (11.8)	7 (6.3)	77 (24.6)
Avoid collision	9 (11.4)	4 (25.0)	14 (19.2)	4 (11.8)	1 (0.9)	32 (10.2)

(Continued over)

Table 2 (cont.)

	In traffic n=79(%)	Cycle lane n=16(%)	Shared path n=73 (%)	Footpath n=34(%)	Off-road n=111(%)	Total N=313(%)
Reported to Police						
Yes	24 (30.4)	4 (25.0)	5 (6.8)	2 (5.9)	- -	35 (11.2)
No	53 (67.1)	12 (75.0)	68 (93.2)	32 (94.1)	111 (100)	276 (88.2)
Unknown	1 (1.3)	- -	- -	- -	- -	1 (0.3)
Assistance required after crash						
None	- -	- -	- -	- -	3 (2.7)	3 (1.0)
Injured rode home	16 (20.3)	6 (37.5)	19 (26.0)	13 (38.2)	21 (18.9)	75 (24.0)
Car/taxi home	14 (17.7)	3 (18.8)	11 (15.1)	5 (14.7)	33 (29.7)	66 (21.1)
Ambulance at scene	3 (3.8)	- -	- -	1 (2.9)	- -	4 (1.3)
Treated in Ed only	32 (40.5)	7 (43.8)	35 (47.9)	13 (38.2)	42 (37.8)	129 (41.2)
Admitted to hospital	14 (17.7)	0 (0.0)	8 (11.0)	1 (2.9)	12 (10.8)	35 (11.2)
Unknown	- -	- -	1 (2.9)	- -	- -	1 (0.3)
Purpose of ride						
Not stated	1 (1.3)	- -	- -	- -	- -	1 (0.3)
Recreational ride	18 (22.8)	3 (18.8)	23 (31.5)	9 (26.5)	81 (73.0)	134 (42.8)
Commuting	38 (48.1)	9 (56.3)	40 (54.8)	19 (55.9)	9 (8.1)	115 (36.7)
Racing/training	16 (20.3)	2 (12.5)	1 (1.4)	1 (2.9)	17 (15.3)	37 (11.8)
Social/ visiting	3 (3.8)	1 (6.3)	3 (4.1)	4 (11.8)	2 (1.8)	13 (4.2)
Shopping/ errands	1 (1.3)	1 (6.3)	4 (5.5)	1 (2.9)	- -	7 (2.2)
Work related	2 (2.5)	- -	2 (2.7)	- -	2 (1.8)	6 (1.9)
Riding with other cyclists						
Riding alone	52 (65.8)	12 (75.0)	58 (79.5)	24 (70.6)	32 (28.8)	178 (56.9)
1 other cyclist	7 (8.9)	2 (12.5)	10 (13.7)	8 (23.5)	29 (26.1)	56 (17.9)
2-5 other cyclists	6 (7.6)	1 (6.3)	3 (4.1)	1 (2.9)	30 (27.0)	41 (13.1)
6-10 other cyclists	4 (5.1)	- -	1 (1.4)	- -	7 (6.3)	12 (3.8)
11 or more cyclists	10 (12.7)	- -	- -	- -	13 (11.7)	23 (7.3)
Ever crashed before						
Yes	41 (51.9)	11 (68.8)	37 (50.7)	18 (52.9)	80 (72.1)	187 (59.7)
No	38 (48.1)	5 (31.3)	36 (49.3)	16 (47.1)	30 (27.0)	125 (39.9)
Average distance ridden per week						
Less than 10 kms	2 (2.5)	- -	2 (2.7)	1 (2.9)	1 (0.9)	6 (1.9)
10-20 kms	2 (2.5)	- -	3 (4.1)	3 (8.8)	2 (1.8)	10 (3.2)
21-100 kms	22 (27.8)	4 (25.0)	25 (34.2)	15 (44.1)	35 (31.5	101 (32.3)
101-200 kms	26 (32.9)	6 (37.5)	33 (45.2)	7 (20.6)	33 (29.7)	105 (33.5)
Over 200 kms	24 (30.4)	4 (25.0)	9 (12.3)	6 (17.6)	38 (34.2)	81 (25.9)
Other	3 (3.8)	2 (12.5)	1 (1.4)	2 (5.9)	2 (1.8)	10 (3.2)

(Continued over)

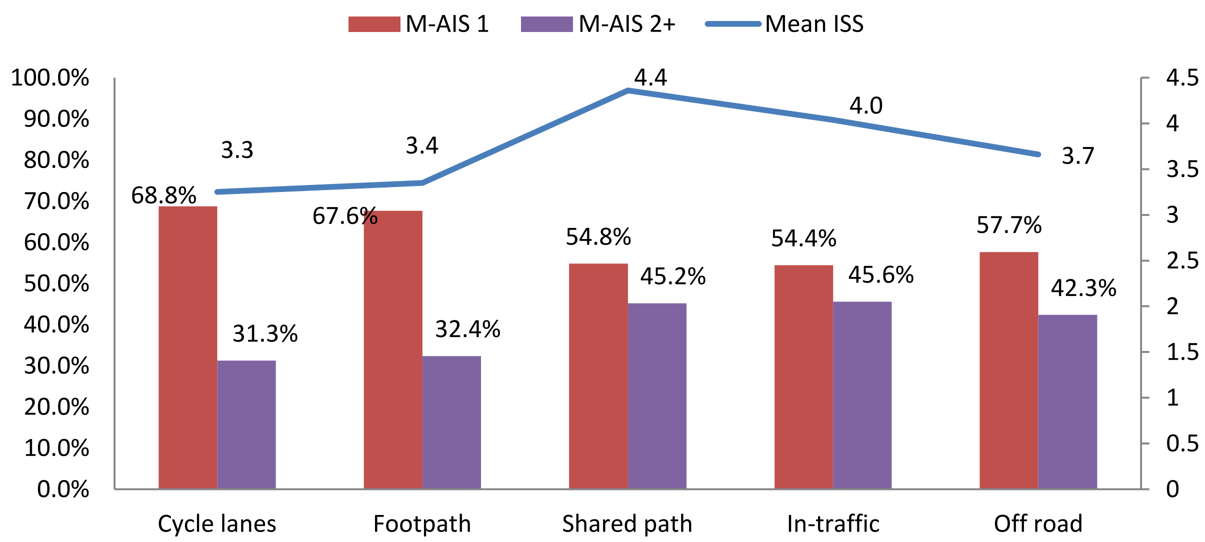
Table 2 (cont.)

	In traffic n=79(%)	Cycle lane n=16(%)	Shared path n=73 (%)	Footpath n=34(%)	Off-road n=111(%)	Total N=313(%)
Member of bicycle club or ride group						
No	48 (60.8)	13 (81.3)	55 (75.3)	30 (88.2)	70 (63.1)	216 (69.0)
Yes	31 (39.2)	3 (18.8)	18 (24.7)	4 (11.8)	41 (36.9)	97 (31.0)
Cycle skills training						
No	51 (64.6)	7 (43.8)	54 (74.0)	28 (82.4)	66 (59.5)	206 (65.8)
Yes	23 (29.1)	9 (56.3)	17 (23.3)	5 (14.7)	40 (36.0)	94 (30.0)
Other	5 (6.3)	- -	2 (2.7)	1 (2.9)	5 (4.5)	13 (4.2)

INJURY SEVERITY BY ALL CRASH ENVIRONMENTS

The mean ISS was higher for cyclists who crashed in traffic (4.0) and on shared paths (4.4) than for those who crashed off-road (3.7) or footpaths (3.4) and lowest for crashes in bicycle lanes (3.3). See Figure 1.

Figure 1. Maximum injury severity (AIS) by riding environment

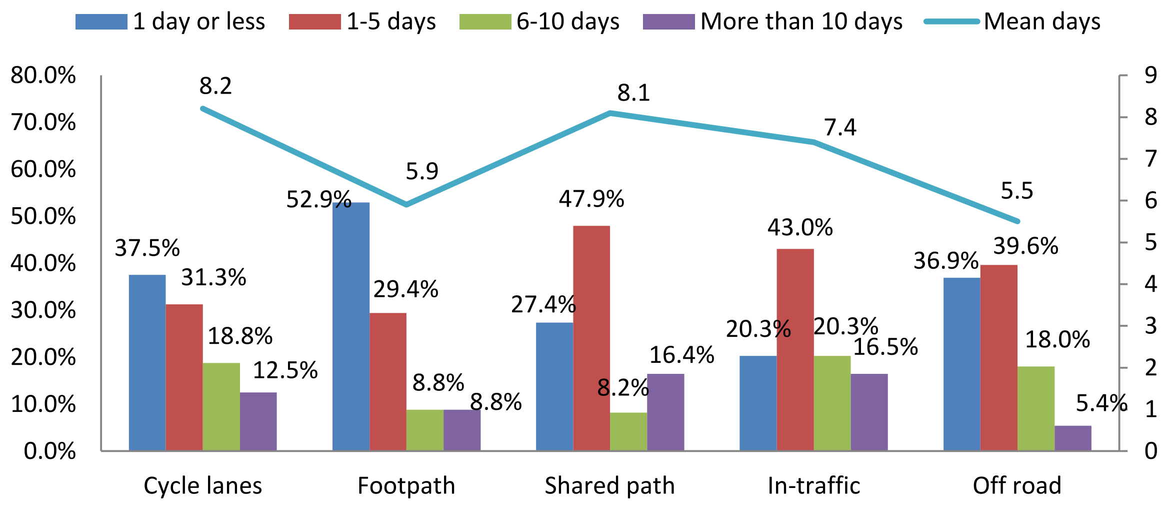


Over two thirds of the cyclists (71.2%, n=226) required time away from their work or normal daily duties as a result of their injuries.

A higher proportion of cyclists who crashed in-traffic (82.3%), in bicycle lanes (75%), or shared paths (72.6%) required time off work compared to those who crashed off-road (66.7%) or on footpaths and pedestrian areas (55.9%). (X^2 = 8.6, df=3; p=0.03) The average amount of time off was 6.9 days (Median =5 days). Those who crashed in-traffic or on shared paths were more likely to take 10 or more days off work (16.5% & 16.4%) compared to those who crashed in bicycle lanes (12.5%), footpaths (8.8%) or off-road (5.4%), however the difference was not significant (X^2 = 7.96, df=4; p=0.1). See Figure 2.

While the majority were eventually able to return to their previous work role, a small number were permanently disabled including 3% of those riding on shared paths and 1% of those who crashed riding off-road.

Figure 2. Number of days off work by riding environment



COST OF CRASHES BY ALL CRASH ENVIRONMENTS

Participants were asked to estimate how much the crash had cost them personally. For those cyclists (n=259) who were able to provide costs at the time of the interview, their combined estimated out-of-pocket costs were $64,057 for health services, $85,274 for loss of income and $110,511 for property damage. The total out of pocket costs were $259,841 with an average cost of $1,003.25 for each cyclist. Costs varied by riding environment with the highest average costs to those riding in bicycle lanes (n=67, $1,359) or in-traffic (n=13, $1,250) with lower costs for those riding on shared paths (n=62, $942), off-road (n=89, $928) and footpaths (n=28, $622).

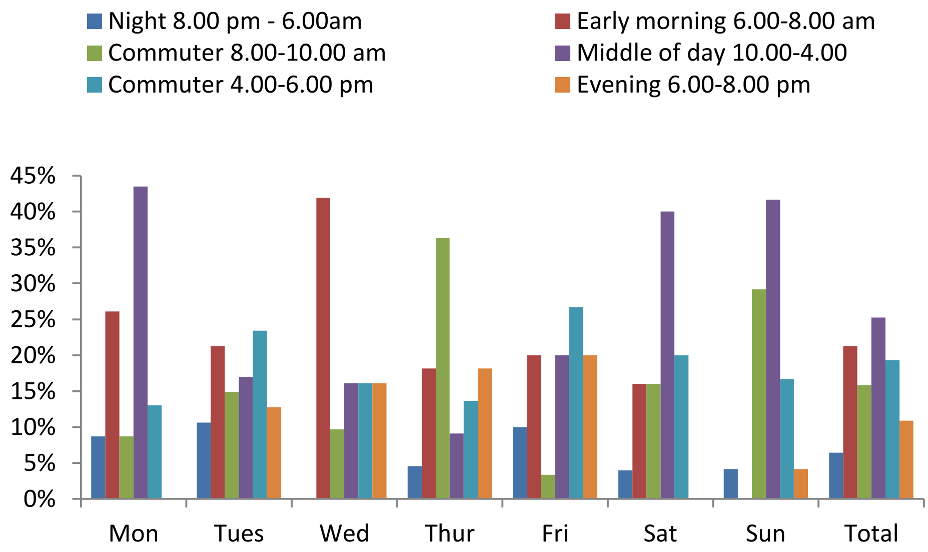
CRASHES IN TRANSPORT RELATED ENVIRONMENTS

The following section describes those cyclists injured in crashes (n=202) which occurred in transport related environments including in-traffic (39.1%), bicycle lanes (7.9%) , shared paths (36.1%) and footpaths (16.8%).

DAY AND TIME OF CRASH

Almost a quarter (23.3%) of all crashes took place on a Tuesday. Across all week days, there was a peak of crashes in the early morning (25%, 6-8.00am) and late afternoon (20%, 4.00-6.00pm). See Figure 4.

Figure 3. Distribution of crashes by time and day of week



The pattern on weekends differed, with crashes evenly distributed across the day from 8.00 am through to 6.00 pm. See Table 3.

Table 3 Day and time of crashes

Time period	Weekdays (%)		Weekend (%)		All week (%)	
Night 8.00 pm-6.00 am	11	(7)	2	(4)	13	(6)
Early morning 6.00-8.00 am	39	(25)	4	(8)	43	(21)
Commuter 8.00-10.00 am	21	(14)	11	(22)	32	(16)
Middle of day 10.00-4.00	31	(20)	20	(41)	51	(25)
Commuter 4.00-6.00 pm	30	(20)	9	(18)	39	(19)
Evening 6.00-8.00 pm	21	(14)	1	(2)	22	(11)
Missing	0	(0)	2	(4)	2	(1)
Total	153	(100)	49	(100)	202	(100)

CRASHES AND CRASH RATES

Table 4 shows the number of crashes and weekly traffic counts for those cycling routes in the ACT for which exposure data on the average number of cyclists per week was available.

Injury crash rates for those routes have also been calculated based on traffic volumes for the six months of the study extrapolated from the average weekly counts. For example, the injury crash rate for cyclists riding in traffic on Northbourne Avenue was 3.81 per 10,000 cyclists compared to 3.41 in the bicycle lane. While these rates are of interest, the number of crashes per route is too small to be used as reliable indicators of crash risk.

The routes with the highest overall number of crashes during the study period were Lady Denman Drive (n=8), Ginninderra Drive (n=8), Northbourne Avenue (n=7) and Alexandria Drive (n=5). Lady Denman Drive is a shared path with a high number (n=8) and high injury crash rate per 10,000 cyclists (5.04). Other routes with relatively high crash rates in traffic were Flynn Drive (6.31), Barry Drive (5.79), Adelaide Avenue, Northbourne Avenue (3.81) and Gunghalin Drive Extension (2.57). Bicycle lanes for which usage rates were available included Belconnen Way (4.30) and Northbourne Avenue (3.41).

Table 4 Crash rate per 10,000 cyclists over 6 months per route by environment

Address	Suburb	Riding environment	Total Crashes	Weekly average	Traffic volume 6 months	Crash rate
Adelaide Ave	Deakin	In traffic	3	294	7056	4.25
Alexandria Drive	Yarralumla	In traffic	1	NA		
Alexandria Drive	Yarralumla	Cycle lane	1	NA		
Alexandria Drive	Yarralumla	Shared path	3	NA		
Athllon Drive	Wanniassa	Shared path	2	367	8808	2.27
Barry Drive	Civic	In traffic	1	72	1728	5.79
Barry Drive	Turner	Shared path	1	447	10728	0.93
Belconnen Way	Bruce	Cycle lane	1	97	2328	4.30
Belconnen Way	Belconnen	Shared path	1	120	2880	3.47
Benjamin Way	Belconnen	Shared path	1	107	2568	3.89
Bike Path	Curtin	Shared path	1	421	10104	0.99
Bike Path	Barton	Shared path	1	859	20616	0.49
Carruthers Street	Curtin	Shared path	1	498	11952	0.84
Clunnies Ross St	Parkes	Shared path	1	743	17832	0.56
Cotter Rd	Curtin	Shared path	1	281	6744	1.48
Flynn Drive	Yarralumla	In traffic	3	198	4752	6.31
Flynn Drive	Parkes	Shared path	1	468	11232	0.89
Ginninderra Drive	McKellar	Shared path	1	72	1728	5.79
Ginninderra Drive	McKellar	In traffic	6	NA		
Ginninderra Drive	McKellar	Footpath	1	NA		
Gunghalin Drive Extension	Mitchell	In traffic	1	162	3888	2.57
Lady Denman Drive	Yarralumla	Shared path	8	662	15888	5.04
Northbourne Ave	Lyneham	In traffic	3	328	7872	3.81
Northbourne Ave	Civic	Cycle lane	3	367	8808	3.41
Northbourne Ave	Civic	Footpath	1	NA		
Parkes Place	Parkes	Shared path	1	945	22680	0.44

Figure 4 shows the location of bicycle crashes that occurred on-road in-traffic by crash type (Red = single vehicle, Orange = collision with pedestrian, Yellow = collision with other cyclist, Green = collision with motor vehicle). Lines show the direct distance from Home address. These riders are frequently found a long way from home in no obvious pattern, and they frequently cross the lake, regarded as the north-south dividing line in Canberra. Many appear to be partaking of serious exercise rather than commuting.

Figure 4. Bicycle crashes in-traffic by type of crash

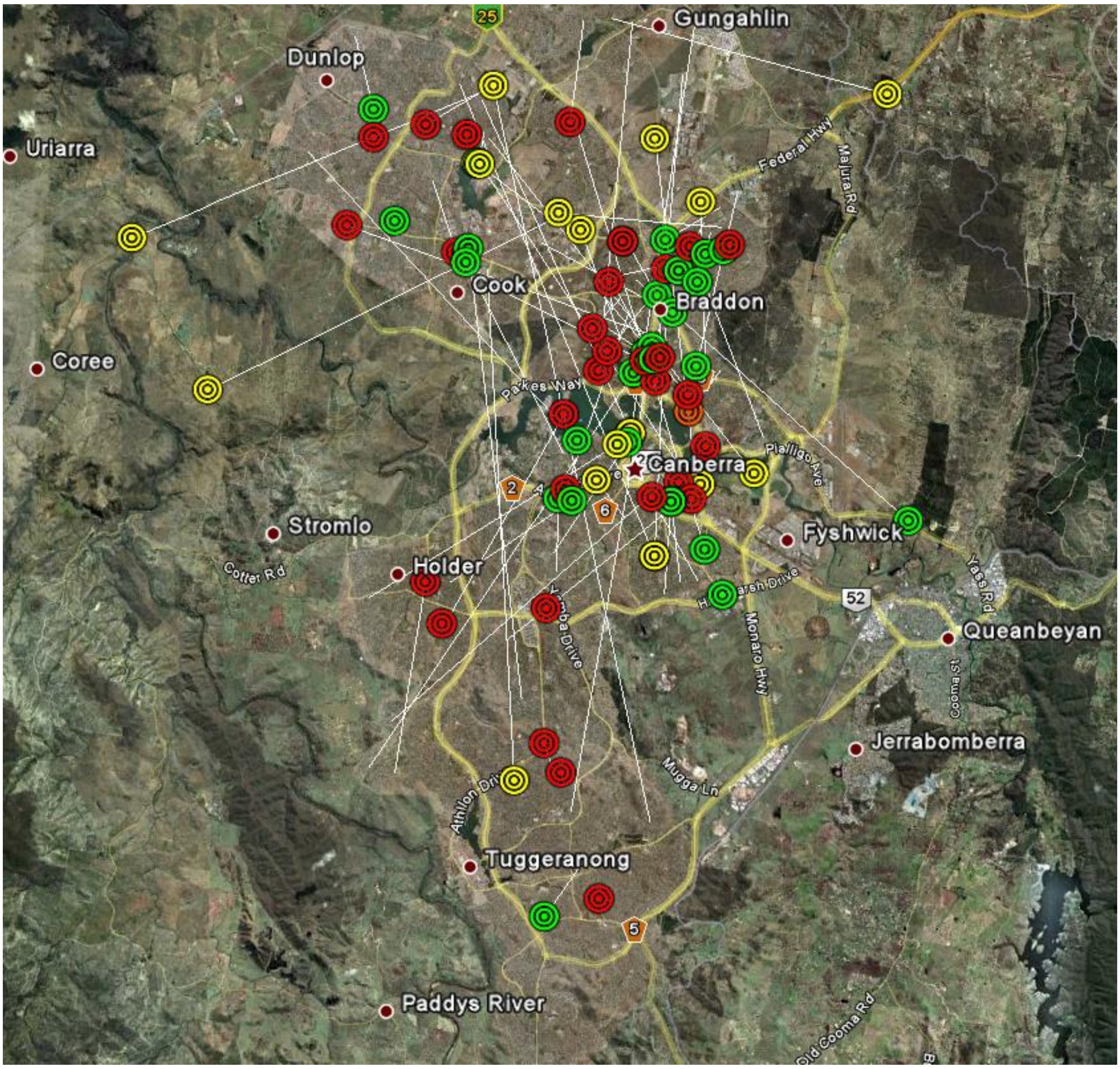


Figure 5 shows the location of bicycle crashes for those injured on road whilst in bicycle lanes by the type of crash (Red = Single Vehicle, Yellow = Collision with other Cyclist, Green = Collision with Motor vehicle). Lines show the direct distance from Home address. The pattern is similar to injuries in Traffic but restricted to areas with bicycle lanes.

Figure 5. Bicycle crashes on road in bicycle lanes by type of crash

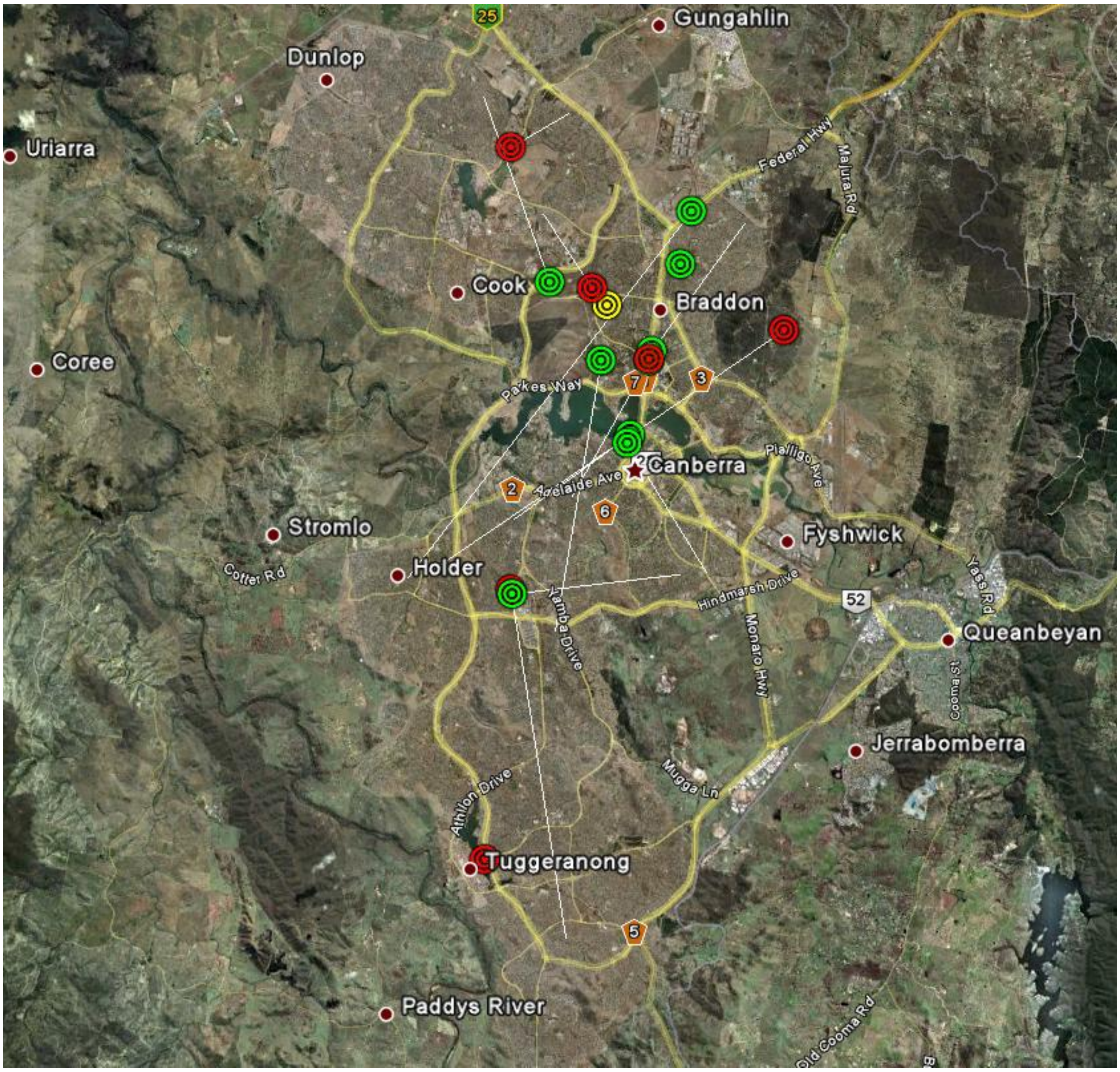


Figure 6 shows the location of bicycle crashes for those injured on shared paths by type of crash (Red = Single Vehicle, Orange = Collision with Pedestrian, Yellow = Collision with other Cyclist, Green = Collision with Motor vehicle, Blue = Collision with Animal). Lines show the direct distance from Home address. This group is visibly different from Figs 4&5: they tend to be in a centripetal direction from home (towards the centre of the city) and rarely cross the lake, or, if they do, crash near the lake. This is a commuter and social exercise pattern of bicycle usage.

Figure 6. Bicycle crashes on shared paths by type of crash

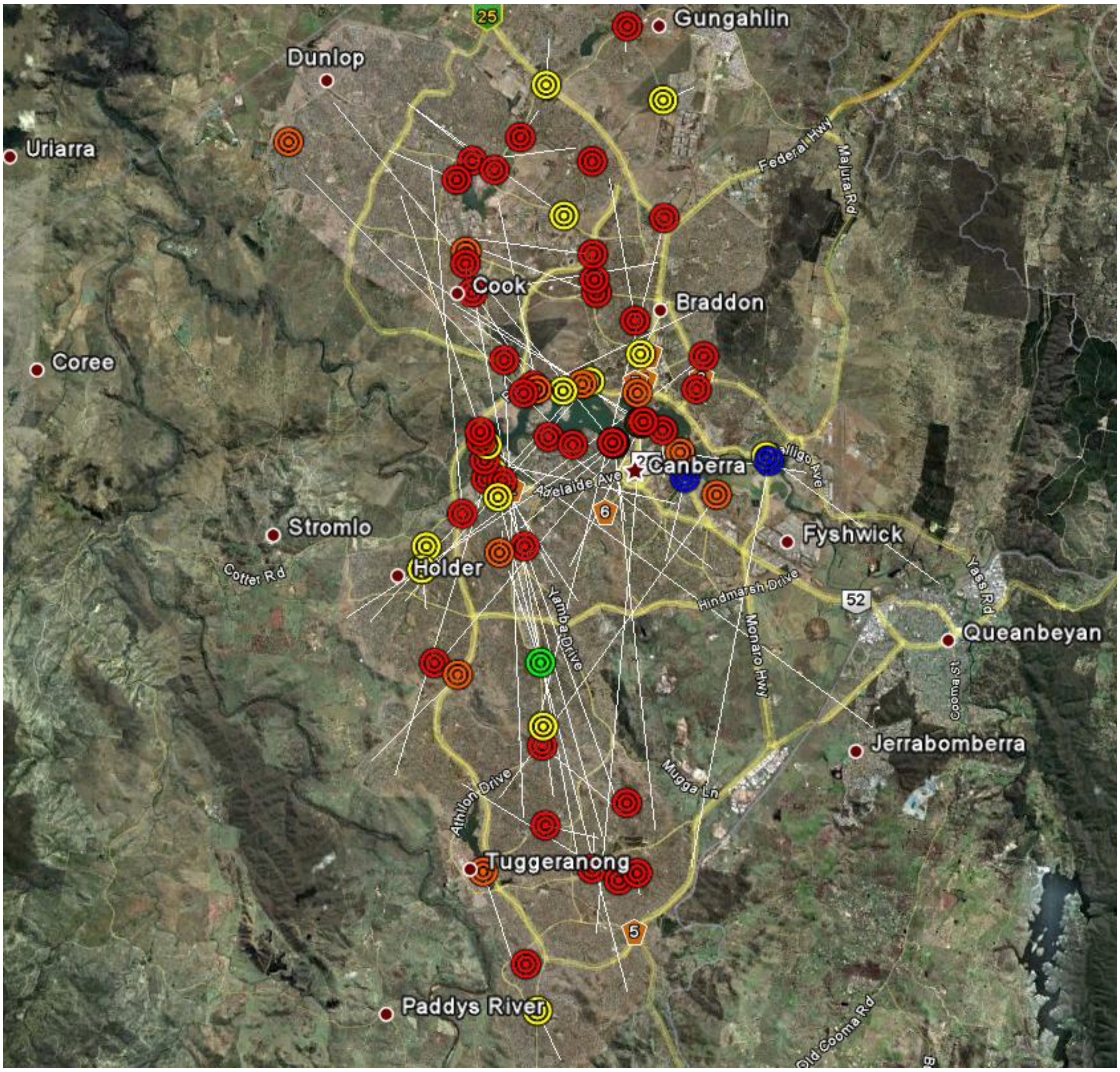


Figure 7 shows the location of bicycle crashes for those injured on footpaths and paved areas by type of crash (Red = Single Vehicle, Orange = Collision with Pedestrian, Yellow = Collision with other Cyclist, Green = Collision with Motor vehicle, Blue = Collision with Animal). Lines show the direct distance from Home address. On average this group are injured closer to home. They are concentrated in the older part of the city (Civic and suburbs north) where there are limited shared paths and traffic is considerable on the few roads with bicycle lanes.

Figure 7. Bicycle crashes on footpaths and paved areas by type of crash

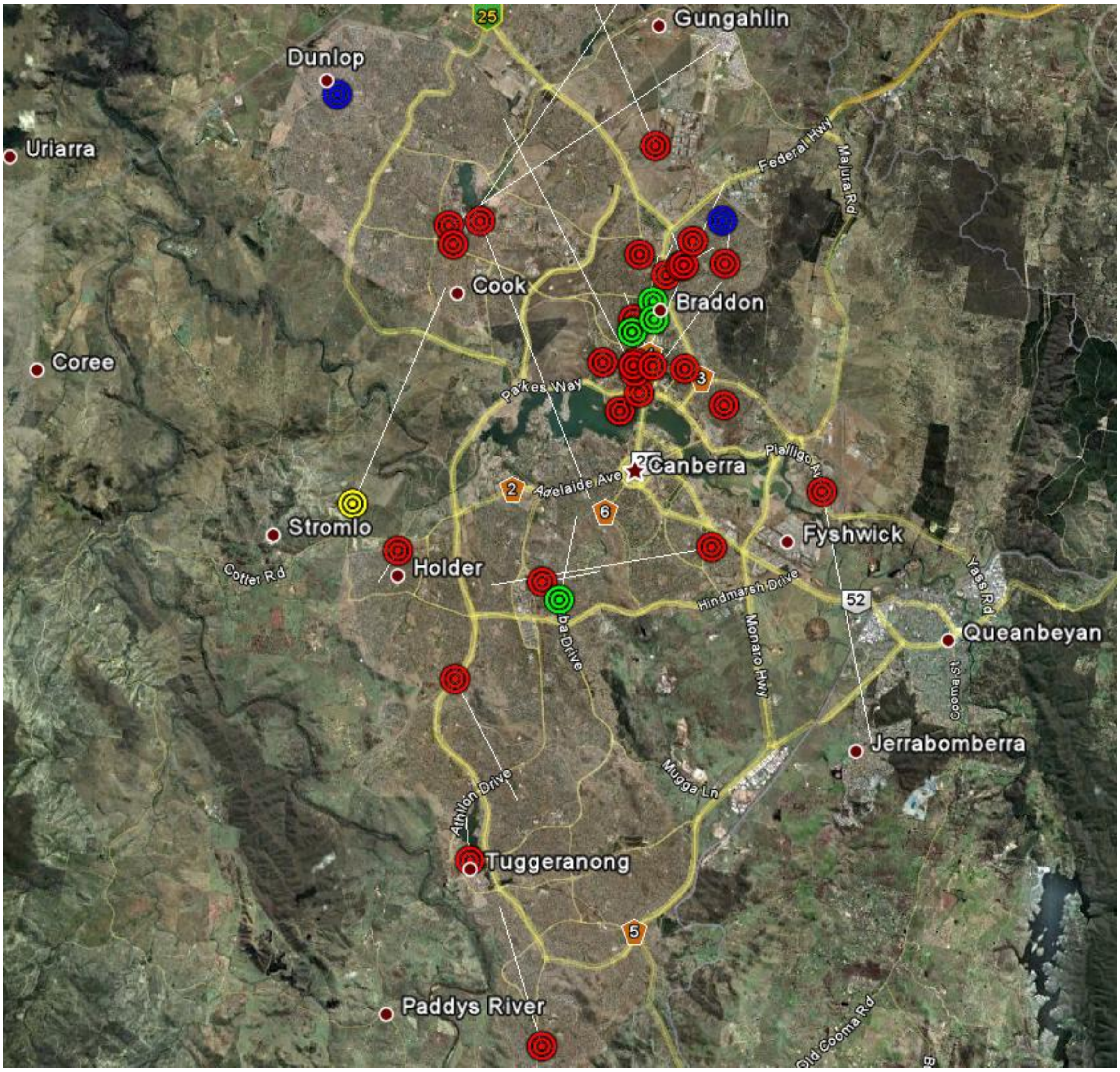
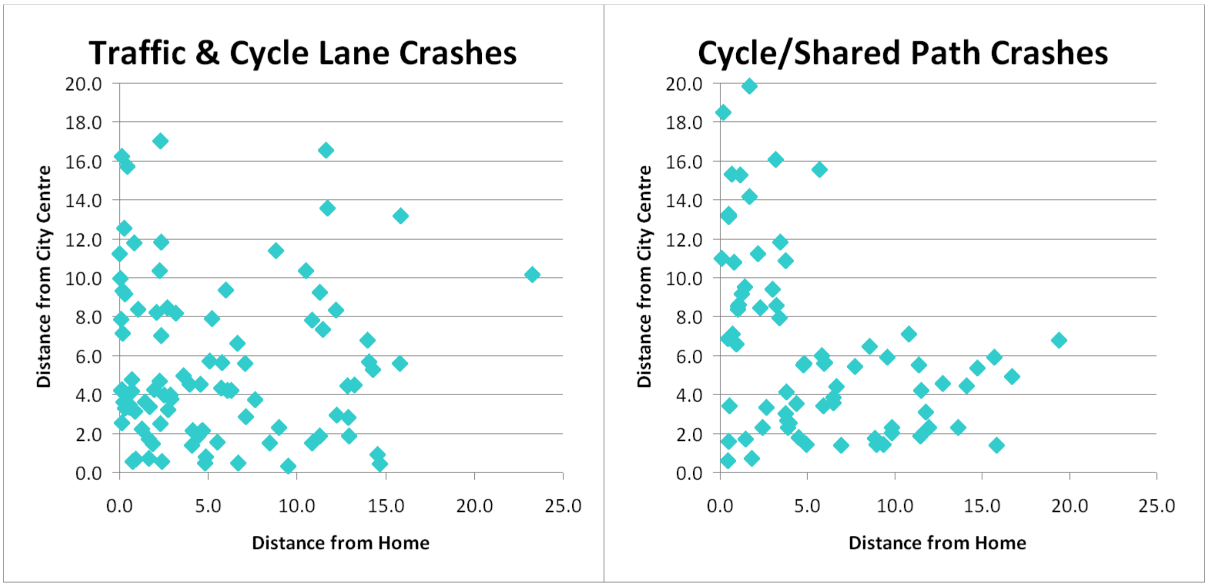


Figure 8 shows the relationship between crash distance from home and crash distance from city centre for the two major types of crash - traffic (including bicycle lanes) and shared paths. Although the mean distance from home is the same (5.4km traffic, 5.2km bicycle lanes, 5.6km shared paths) there are marked differences in distribution. Riders in traffic were much more likely to be injured with 300m of their own home (14/94, 15%) than riders on shared paths (2/73, 2%) (P<0.02, Fisher's exact test). Riders in traffic were often far from home and far from the city, but riders on shared paths showed an inverse relationship between these values. Partly this reflects the distribution of paths in Canberra - riders from distant suburbs who choose to ride on paths will find the majority of their options lie between their home and the city. However, it appears that the traffic riders represent a different group - those who ride long distances for exercise/training.

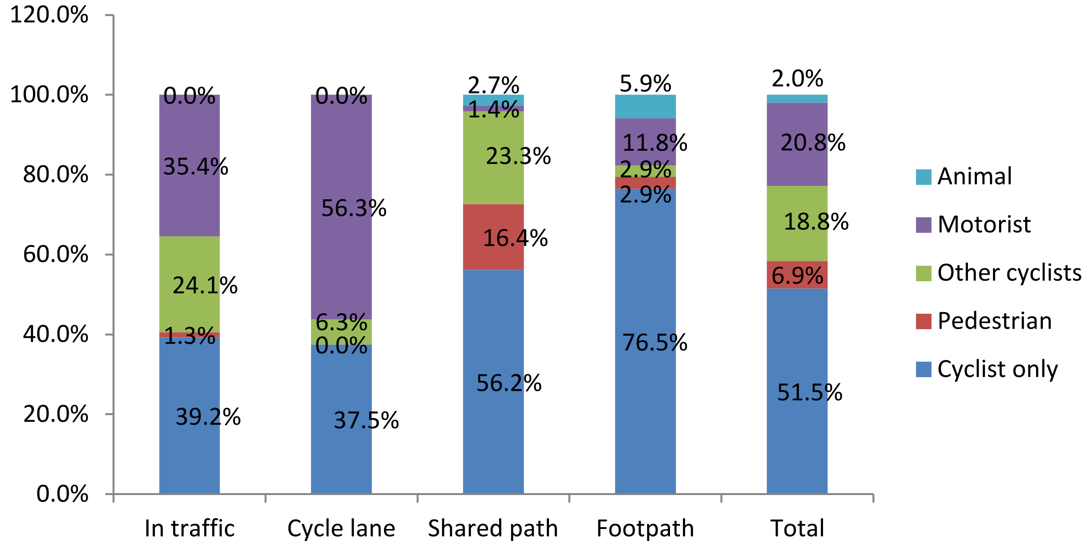
Figure 8. Comparison of crash distance from home and city centre by riding environment.



THE ROLE OF OTHER ROAD USERS

Half of the cyclists were injured in crashes that did not involve any other road user. This includes 76.5% of those who crashed on footpaths and other pedestrian areas and 56.2% of those on shared paths. Where crashes involved other road users, 20.8% involved motor vehicles, 18.8% involved other bicycles, 6.4% involved pedestrians and 2.0% involved animals. Half of those involved in crashes with other cyclists had completed bicycle safety training programs. Of the twelve crashes involving pedestrians on shared paths, half were actual collisions with a pedestrian, the remainder occurred when the cyclist crashed trying to avoid a collision with a pedestrian.

Figure 9. Proportion of other road users involved in crashes by riding environment



FACTORS ASSOCIATED WITH SINGLE VEHICLE CRASHES

Table 5 shows the characteristics of single vehicle crashes. Loss of control crashes on straight sections of road accounted for 49.2% of all single vehicle bicycle casualties compared to loss of control on curves (14.3%) and impacts with objects on the path (30.4.). Excessive speed was associated with 14.6% of all single vehicle crashes, with the highest proportion occurring on shared paths (27.7%). Ten percent (10.5%) of all single vehicle crashes involved pedestrians of which the majority (84.6%) occurred on shared paths.

The majority of crashes that occurred in poor light conditions were single vehicle crashes (half-light (n=6/12) and dark (n=17/23). Road surface conditions that may have contributed to crashes included: wet surface (6%), slippery surface (3%), loose gravel or rocks (6%), broken, cracked or pot hold surface (8%) and raised edge or lip to sealed surface (2%).

Table 5 Characteristics of single vehicle crashes

	In traffic		Cycle lane		Shared path		Footpath		Total	
Out of control off straight	19	59.4%	4	66.7%	21	38.2%	17	58.6%	61	49.2%
Collision with object on path	7	21.9%	2	33.3%	11	20.0%	7	24.1%	27	30.4%
Out of control off curve	4	12.5%	-	-	11	20.0%	1	3.4%	16	14.3%
Pedestrian	1	3.1%	-	-	11	20.0%	1	3.4%	13	10.5%
Manoeuvre/Other	1	3.1%	-	-	1	1.8%	3	10.3%	5	4.1%
Total	32		6		55		29		122	

Table 6 shows estimated travel speed prior to single vehicle crashes. Cyclists were asked to estimate their travelling speed before the crash. The average estimated speed for single vehicle crashes was 19.1 km/h, with a range of 0- 70 km/h. The majority of cyclists (61.3%) estimated travel speeds of 20km/h or less (n=76). A smaller proportion (n=20, 14.8%) were riding at much higher speeds, including 9 cyclists who reported riding at over 30 km/h on shared paths.

Table 6 Cyclists' estimation of travel speed prior to single vehicle crash by riding environment

	In traffic	Cycle lane	Shared path	Foot path	Total
Cyclists Speed					
Contributing factor	4 11.1%	1 12.5%	13 27.7%	- -	18 14.6%
Travelling speed					
Mean speed (km/h)	23.3	22.5	20.9	10.6	19.1
Median speed (km/h)	20	20	20	10	15
Range	70	30	43	27.5	70
Distribution of travelling speed					
20km/h or less	17 53.1%	3 50.0%	31 56.4%	25 86.2%	76 61.3%
21-30 km/h	7 21.9%	2 33.3%	12 21.8%	4 13.8%	25 20.2%
31-40 km/h	6 18.8%	1 16.7%	8 14.5%	0 0.0%	17 12.3%
Over 40 km/h	2 6.3%	0 0.0%	1 1.8%	0 0.0%	3 2.5%
Unknown	0 0.0%	0 0.0%	3 5.5%	0 0.0%	3 2.5%
Total	32	6	55	29	122

When asked, most of those riding in-traffic (97.9%) or bicycle lanes (100.0%) were able to give the speed limit that applied in the area where they crashed. By contrast 12.3% of those who had crashed on shared paths and 23.5% of those who crashed on footpaths, believed that no speed limits applied. Of those who crashed on shared paths, 67.1% thought the speed limit was 50km/h, 4.1% said 60 km/h and 15.1% nominated speeds between 70-100 km/h. Of those who crashed on footpaths 44.1% thought the speed limit was 50Km/h, 14.7% nominated 60km/h and a further 14.7% nominated 80km/h.

Equipment failure accounted for 24.0% of single vehicle crashes including bicycle maintenance problems such as flat tyres and dropped chains (n=16, 13.1%) and problems disengaging shoe cleats or toe clips (n=9, 7.4%). Impacts with objects on the path included 18 impacts with road furniture such as guard rail, kerbs and bollards. There were also three collisions into parked cars and two into vehicle doors. Debris such as leaf litter or mud on the path (n=4) and road surface damage (n=10) was a contributing factor in 11.5% of single vehicle crashes.

Cyclists were also asked whether they were carrying anything that may have contributed to the crash by affecting their balance, over half of all cyclists (54.5%, n=110) said they were carrying some additional weight. The average weight carried was 4.4 kg, with 8% carrying between 10-20 kg and were mostly backpacks but three were carrying shopping bags which caught in the wheels. The proportions were similar for single and multi-vehicle crashes. Other contributing factors identified included alcohol (n=9), riding with dogs on a leash (n=3) and wearing ear phones (n=2).

MULTI-VEHICLE CRASHES

The majority (58.8%) of crashes involving another vehicle occurred in traffic, 22.53% on shared paths and 12.5% in bicycle lanes. See Table 7.

Table 7 Road user movement of multi-vehicle crashes by riding environment

	In traffic		Cycle lane		Shared path		Foot path		Total	
Adjacent direction	12	25.5%	2	20.0%	4	22.2%	1	20.0%	19	23.8%
Opposing direction	4	8.5%	1	10.0%	4	22.2%	-	-	9	11.3%
Same Direction	24	51.1%	5	50.0%	5	27.8%	-	-	34	42.5%
Collision with object on path	3	6.4%	1	10.0%	3	16.7%	-	-	7	8.8%
Manoeuvre	2	4.3%	1	10.0%	-	-	4	80.0%	7	8.8%
Overtaking	0	0.0%	0	0.0%	1	6.7%	-	-	1	1.3%
Other	2	4.3%	-	-	1	5.6%	-	-	3	3.8%
Total	47		10		18		5		80	

The other vehicle in a multi-vehicle crash was almost equally as likely to be another bicycle (47.5%) as a motor vehicle (52.5%). The most common type of crash (42.5%) involved vehicles moving in the same direction and were more likely to involve other cyclists than motorists (67.6% versus 32.4%). Crashes between bicycles were less frequent in bicycle lanes than in other riding environments. Another bicycle was the other vehicle in 94.4% of crashes on shared paths, 40.4% in traffic, 20% on footpaths and 10% in bicycle lanes.

Motor vehicles were most likely to be involved in intersection crashes involving vehicles from adjacent directions (78.9%) or in manoeuvring (100%). The intersection crashes included failure to give way at stop or give way signs (n=8), left turn overtaking across a bike lane (n=6), turning right across traffic (n=5) and entering roundabouts (n=3). There were also six crashes where a cyclist emerged from a footpath or shared path to cross a road and two crashes where cars emerged from driveways. See Table 8.

Table 8 Other vehicles involved in multi-vehicle bicycle crashes

	Other bicycle		Motor vehicle		Total	
Same Direction	23	67.6%	11	32.4%	34	42.5%
Adjacent direction	4	21.1%	15	78.9%	19	23.8%
Opposing direction	5	55.6%	4	44.4%	9	11.3%
Impact object on path	4	57.1%	3	42.9%	7	8.8%
Manoeuvre	-	-	7	100.0%	7	8.8%
Other	1	33.3%	2	66.7%	3	3.8%
Overtaking	1	100.0%	-	-	1	1.3%
Total	38	47.5%	42	52.5%	80	100.0%

The estimated average travelling speed of cyclists prior to a multi-vehicle crashes was 25.3km/h with a maximum of 50km/h. Average reported speeds were highest for cyclists in traffic (28.7km/h) and bicycle lanes and lowest on footpaths. The average speed on shared paths was 20.9km/h with a range of 40km/h. See Table 9.

Table 9 Cyclists' estimation of travel speed prior to multi-vehicle crash by riding environment

	In traffic		Cycle lane		Shared path		Foot path		Total	
Mean travel speed	28.7		26.7		20.9		7.8		25.3	
Median travel speed	27.5		30		20		5		25	
Range	47.5		45		40		18		50	
Travelling speed										
20 km/h and less	16	34.0%	4	40.0%	10	55.6%	5	100.0%	35	43.8%
21-30	10	21.3%	2	20.0%	6	33.3%	-	-	18	22.5%
31-40	12	25.5%	3	30.0%	1	5.6%	-	-	16	20.0%
More than 40 km/h	8	17.0%	1	10.0%	1	5.6%	-	-	10	12.5%
Total	46		10	18		5		79		

Ten of the twelve cyclists involved in multi-vehicle crashes in half light or in dark conditions were operating lights on the bike or helmet at the time of the crash. See Table 10.

Table 10 Natural lighting conditions in multi-vehicle crashes by riding environment

n (%)	In traffic		Cycle lane		Shared path		Foot path		Total	
Good light/ day light	37	(78.7)	7	(70.0)	17	(94.4)	5	(100)	66	(82.5)
Glary/ low sun	2	(4.3)	-	- -	-	-	-	2	(2.5)	
Half light dawn or dusk	3	(6.4)	2	(20.0)	1	(5.6)	-	-	6	(7.5)
Dark	5	(10.6)	1	(10.0)	-	-	-	-	6	(7.5)

Crashes reported to police

Only 11.2% of all crashes (17.3% of crashes in transport environments) were reported to the police. These included 30.4% of crashes that occurred in-traffic, 25.0% in bicycle lanes and 6.8% in shared paths and 5.9% on foot paths. Crashes involving motor vehicles were most likely to be reported (71.4%), whereas only 5.3% of crashes involving other cyclists and 2.9% of single vehicle crashes were reported. None of the crashes involving pedestrians (n=13) or animals (n=5) and only one of the nine involving alcohol was reported to the police. In two multi-vehicle crashes, the cyclist had not reported the crash but was uncertain whether it may have been reported by others. See Table 11.

Table 11 Other road users involved in bicycle crashes

n (%)	Self only	Pedestrian	Other bicycle	Motor vehicle	Animal	Total
Yes	3 (2.9)	- -	2 (5.3)	30 (71.4)	- -	35 (17.3)
No	102 (97.1)	13 (100.0)	35 (92.1)	11 (26.2)	4 (100)	165 (81.7)
Unknown	- -	- -	1 (2.6)	1 (2.4)	- -	2 (1.0)
Total	105	13	38	42	4	202

INJURIES SUSTAINED

The majority of cyclists (58.4%) sustained minor injuries but more than a third (36.1%) had injuries rated moderately severe (AIS 2) and 5.4% (n=11) were seriously injured (AIS 3 or more). There did not appear to be a pattern to the location of the most serious injuries, which included the head and face, chest, spine, arms and legs. See Table 12.

Table 12 Maximum Injury severity (AIS) by part of the body

%	No injury	AIS 1	AIS 2	AIS 3-5
Head	159 (78.7)	23 (11.4)	18 (8.9)	2 (1.0)
Face	148 (73.3)	51 (25.2)	2 (1.0)	1 (0.5)
Arm	44 (21.8)	111 (55.0)	45 (22.3)	2 (1.0)
Hand	99 (49.0)	93 (46.0)	10 (5.0)	- -
Chest	163 (80.7)	35 (17.3)	1 (0.5)	- -
Spine	173 (85.6)	24 (11.9)	3 (1.5)	3 (1.5)
Legs	90 (44.6)	109 (54.0)	2 (1.0)	2 (1.0)
Knee	107 (53.0)	94 (46.5)	1 (0.5)	1 (0.5)
Foot	166 (82.2)	33(16.3)	3 (1.5)	- -

Table 13 shows the distribution of the mean ISS and proportion of casualties by the maximum injury severity of the worst single injury by other road users involved. Those involved in crashes with pedestrians had the highest mean ISS (4.8), whereas crashes involving other cyclists and motor vehicles had equivalent mean ISS (4.0) compared to single vehicle (3.9) and animal (2.5) crashes.

Single vehicle crashes accounted for just over half (50.7%) of those with moderately severe injuries (AIS 2), other cyclists and motor vehicles accounting for equal proportions (17.8% each) and pedestrian crashes for 12.3%. Single vehicle crashes also accounted for the highest proportion (45.5%) of those who were seriously injured (AIS 3 or more), followed by motor vehicles (36.4%) and other cyclists (18.8%).

Table 13 Cyclists injury severity by type of crash (other road users involved)

(%)	**ISS Mean (std)**	**Max_AIS 1**	**Max_AIS 2**	**Max_AIS 3 - 5**	**All severity**
No other	3.9 (3.3)	63 (53.4)	37 (50.7)	5 (45.5)	105 (52.0)
Pedestrian	4.8 (2.5)	4 (3.4)	9 (12.3)	0 (0.0)	13 (6.4)
Other cyclists	4.0 (4.4)	23 (19.5)	13 (17.8)	2 (18.2)	38 (18.8)
Motor vehicle	4.0 (3.0)	25 (21.2)	13 (17.8)	4 (36.4)	42 (20.8)
Animal	2.5 (1.7)	3 (2.5)	1 (1.4)	0 (0.0)	4 (2.0)
Total	4.0 (3.4)	118 (100)	73 (100)	11 (100)	202 (100)

Almost one in four sustained a head injury and slightly more had facial injuries. The most common injuries were to the shoulders (51.2%) and knees (46.8%). The majority of cyclists sustained soft tissue injuries including abrasions (74.8%), bruises (67.3%) and cuts and lacerations (35.6%). A relatively high proportion sustained fractures (42.6%) most commonly to the shoulders (n=23), hands (n=20) and chest (n=21). Over half had sprains (55.9%) most commonly involving neck (n=23), shoulders (n=41) and hands/wrists (n=46). A smaller proportion suffering dislocations (8.4%) mostly to shoulders (n=9). Over one in five (22.8%) had internal injuries mostly to the head (n=40). See Table 14.

Table 14 Proportion of cyclists with each type of injury by part of the body

	Bruises	Cuts	Abrasions	Fractures	Sprains	Dislocation	Internal	Any
	n %	n %	n %	n %	n %	n %	n %	n %
Head	9(4.5)	6(3.0)	9(4.5)	1(0.5)	3(1.5)	- -	40(19.8)	48(23.4)
Eye	16(7.9)	10(5.0)	13(6.4)	2(1.0)	3(1.5)	- -	- -	24(11.7)
Face	17(8.4)	19(9.4)	38(18.8)	10(5.0)	6(3.0)	- -	- -	52(25.4)
Neck	3(1.5)	1(0.5)	3(1.5)	1(0.5)	23(11.4)	- -	- -	-26(12.7)
Shoulder	38(18.8)	3(1.5)	48(23.8)	23(11.4)	41(20.3)	9(4.5)	2(1.0)	105(51.2)
Arm	11(5.4)	7(3.5)	22(10.9)	5(2.5)	6(3.0)	- -	- -	47(22.9)
Elbow	18(8.9)	13(6.4)	41(20.3)	14(6.9)	8(4.0)	4(2.0)	- -	90(43.9)
Hand	27(13.4)	8(4.0)	42(20.8)	20(9.9)	25(12.4)	2(1.0)	- -	82(40.0)
Wrist	6(3.0)	- -	11(5.4)	6(3.0)	21(10.4)	1(0.5)	- -	37(18.1)
Chest	16(7.9)	1(0.5)	16(7.9)	21(10.4)	15(7.4)	- -	2(1.0)	45(21.9)
Spine	11(5.4)	2(1.0)	11(5.4)	5(2.5)	16(7.9)	- -	- -	33(16.1)
Abdomen	6(3.0)	1(0.5)	6(3.0)	- -	5(2.5)	- -	2(1.0)	14(6.8)
Pelvis	1(0.5)	- -	1(0.5)	- -	1(0.5)	- -	- -	2(1.0)
Buttocks	8(4.0)	- -	5(2.5)	- -	4(2.0)	- -	- -	11(5.4)
Hip	41(20.3)	2(1.0)	28(13.9)	3(1.5)	6(3.0)	- -	- -	59(28.8)
Upper leg	27(13.4)	2(1.0)	21(10.4)	- -	2(1.0)	- -	- -	37(18.1)
Knee	33(16.3)	15(7.4)	64(31.7)	1(0.5)	3(1.5)	- -	- -	96(46.8)
Lower leg	31(15.3)	8(4.0)	31(15.3)	1(0.5)	4(2.0)	- -	- -	54(26.3)
Ankle	15(7.4)	5(2.5)	18(8.9)	2(1.0)	13(6.4)	1(0.5)	1(0.5)	33(16.1)
Foot	6(3.0)	2(1.0)	5(2.5)	2(1.0)	3(1.5)	- -	1(0.5)	9 (1.4)

CYCLISTS CLOTHING AND INJURY RISK

The majority of cyclists had been wearing a helmet (88.6%) and 42.1% reported that their helmet had been damaged in the crash (n=85). In addition over a third (36.6%) were wearing conspicuity aids including Fluro/high visibility vests (n=27), bright colours (n=42) and reflectors (n=4). See Table 15.

Table 15 Conspicuity aids worn by riding environment

	In traffic	Cycle lane	Shared path	Foot path	Total
Fluoro vest	18 (22.8)	1 (6.3)	6 (8.2)	2 (5.9)	27 (13.4)
Bright clothing	20 (25.3)	2 (12.5)	16 (21.9)	4 (11.8)	42 (20.8)
Reflectors	3 (3.8)	- -	- -	- -	3 (1.5)
Total cyclist with conspicuity aids	39 (49.4)	5 (31.3)	23 (31.5)	7 (20.6)	74 (36.6)

The majority were also wearing footwear that fully covered their feet (93.1%), however few wore any other form of protection. A high proportion wore short sleeves (55.9%) and either short pants or skirts (65.3%). Less than half wore gloves (47.5%, n=96), which were more likely to be fingerless (33.2%, n=67) than providing full coverage (14.4%, n=29). See Table 16.

Table 16 Clothing worn by type and coverage provided

	Full cover	Partial cover	Cycle specific	Lycra/ synthetic	Cotton/ natural fiber	Leather
Upper body clothing	86 (42.6)	113 (55.9)	78 (38.6)	71 (35.1)	108 (53.5)	- -
Lower body clothing	67 (33.2)	132 (65.3)	80 (39.6)	69 (34.2)	78 (38.6)	- -
Gloves	29 (14.4)	67 (33.2)	9 (4.5)	4 (2.0)	- -	9 (4.5)
Shoes	188 (93.1)	10 (5.0)	4 (2.0)	18 (8.9)	- -	42 (20.8)

Cyclist wearing bicycle designed or Lycra tops appeared to be more likely to sustain injuries than were those wearing cotton or natural fibre materials. However, these differences were not significant when length of sleeves and other factors were taking into account. After adjusting for all clothing types, age, gender, riding environment, number of vehicle involved, speed zone, collision source, bicycle type and journey purpose, those wearing any type of short sleeved tops were more likely to sustain an injury to the upper limbs compared to those wearing long sleeves (Adj. OR=2.06, 95% CI:1.02-4.18, P=0.05).

Those wearing short sleeve tops were particularly more likely to sustain cuts or abrasion injuries to their upper body than those wearing long sleeved clothing (Adj. OR=2.69, 95% CI: 1.31-5.52, P=0.01). See Table 17.

Table 17 Odds Ratios (OR) for risk of any injury to the upper limbs associated with upper body clothing.

Clothing worn	Injuries Yes	No	Unadj. OR	95% Confidence Interval	P	Adj. OR*	95% Confidence Interval	P
ANY INJURIES SUSTAINED?								
Upper body –sleeve length								
Long sleeves	43	46						
Short sleeves	70	43	1.74	0.99-3.06	0.05	2.06	1.02-4.18	0.05
Upper clothing -cycle specific								
Not bicycle designed	58	66						
Cycle designed	55	23	2.72	1.49-5.00	0.001	2.04	0.52-8.06	0.31
Upper clothing –fabric Lycra								
Non- Lycra	64	67						
Lycra	49	22	2.33	1.27-4.28	0.01	1.03	0.26-3.65	0.97
Upper clothing – fabric cotton								
Non-cotton	62	32						
Cotton	51	57	0.46	0.26-0.82	0.01	0.67	0.19-2.34	0.53
ANY CUTS OR ABRASION INJURIES								
Upper clothing –sleeve length								
Long sleeves	28	61						
Short sleeves	57	56	2.22	1.24-3.96	0.01	2.69	1.31-5.52	0.01
Upper clothing -cycle specific								
Not bicycle designed	43	81						
Cycle designed	42	36	2.20	1.23-3.92	0.01	1.33	0.35-5.07	0.68
Upper clothing –fabric								
Non- Lycra	47	84						
Lycra	38	33	2.058	1.14-3.70	0.02	1.06	0.27-3.22	0.90
Upper clothing – fabric								
Non cotton	48	46						
Cotton top	37	71	0.499	0.28-0.88	0.02	0.62	0.17-2.26	0.46

*Adjusted for all clothing characteristics, age, gender, riding environment, number of vehicle involved, speed zone, collision source, bicycle type and journey purpose.

Cyclists wearing skirts or shorts including bicycle-designed and Lycra clothing were more likely to have injuries, than were those wearing long and cotton fabric pants; however, as with the upper body, the salient factor was exposed skin. Cyclists wearing short pants or skirts were over 3 times more likely to sustain injuries to their lower limbs (Adj. OR = 3.37, 95%CI: 1.42-7.96, P=0.01). They were over twice as likely to have cuts or abrasion injuries (Adj. OR=2.25, 95%CI: 1.04-4.86, P=0.04). See Table 18.

Table 18 Odds Ratios (OR) for risk of any injuries to the lower limbs associated with lower body clothing.

Clothing worn	Injuries Yes	No	Unadj. OR	95% Confidence Interval	P	Adj. OR*	95% Confidence Interval	P
ANY INJURIES								
Lower body-pants length								
Long pants	38	32						
Shorts/ skirt	92	40	1.94	1.06-3.53	0.03	3.37	1.42-7.96	0.01
Lower body -cycle designed								
Not bicycle designed	77	45						
Cycle designed	53	27	1.15	0.64-2.07	0.65	0.93	0.28-3.08	0.90
Lower body –fabric								
Non- Lycra	83	50						
Lycra	47	22	1.29	0.70-2.38	0.42	0.74	0.24-2.26	0.6
Lower body –fabric								
Non cotton	83	41						
Cotton	47	31	0.75	0.42-1.35	0.34	0.66	0.22-1.95	0.45
ANY CUTS OR ABRASION INJURIES								
Lower body-coverage								
Long pants	24	46						
Shorts/ skirt	74	58	2.45	1.34-4.46	0.01	2.25	1.04-4.86	0.04
Lower body – clothing bicycle designed								
Not bicycle designed	55	67						
Cycle designed	43	37	1.42	0.80-2.49	0.23	1.57	0.54-4.58	0.41
Lower body –clothing type of fabric								
Non- Lycra	62	71						
Lycra	36	33	1.25	0.70-2.24	0.45	0.56	0.20-1.57	0.27
Non cotton	63	61						
Cotton top	35	43	0.79	0.45-1.39	0.41	0.78	0.30-2.05	0.62

*Adjusted for all clothing characteristics, age, gender, riding environment, number of vehicle involved, speed zone, collision source, bicycle type and journey purpose.

Cyclists who were not wearing gloves were no more likely to have no hand injuries than those wearing gloves, but, they were significantly more likely to have cuts, lacerations or abrasion injuries to their hands (Adj. OR=3.51, 95%CI: 1.48-6.7, P=0.003). In addition, those without gloves or wearing fingerless bicycling glove compared to full gloves had almost 4 times the risk of sustaining cuts and abrasion injuries compared to those wearing full coverage gloves (Adj. OR=3.6., 95%CI: 1.08-13.54, P=0.05).

Table 19 Odds Ratios (OR) for risk of any injuries to the hands or wrists associated with usage of gloves.

Clothing worn	Injuries		Unadj.	95% Confidence		Adj.	95% Confidence	
	Yes	No	OR	Interval	P	OR*	Interval	P
ANY INJURIES TO HANDS OR WRISTS								
Gloves worn	43	53						
No gloves worn	58	48	1.49	0.86-2.59	0.16	1.46	0.77-2.76	0.23
ANY CUTS, LACERATIONS OR ABRASION INJURIES								
Gloves worn	15	81						
No gloves worn	42	64	3.54	1.81-6.96	0.0002	3.51	1.48-6.7	0.003
Full cover gloves worn	3	26						
Fingerless/no gloves	54	119	3.93	1.14-13.55	0.03	3.63	1.08-13.54	0.05

*Adjusted for age, gender, collision source and crash type.

While, as noted earlier, the majority of cyclists wore footwear that fully enclosed their feet (93.1%), those few who had been wearing sandals or other open footwear were more than 5 times more likely to sustain injuries to their feet and ankles (Adj. OR=5.36, 95%CI: 1.34-21.53, P=0.02) and almost 5 times as likely to sustain cuts, lacerations or abrasion injuries (Adj. OR=4.97, 95%CI: 1.01-24.6, P=0.05).

Table 20 Odds Ratios (OR) for risk of any injuries to the feet or ankles associated with foot wear.

Clothing worn	Injuries		Unadj.	95% Confidence		Adj.	95% Confidence	
	Yes	No	OR	Interval	P	OR*	Interval	P
ANY INJURIES TO FEET OR ANKLES								
Footwear – coverage								
Full enclosed	33	159						
Not fully enclosed	5	5	4.82	1.32-17.59	0.02	5.36	1.34-21.53	0.02
ANY CUTS, LACERATIONS OR ABRASION INJURIES								
Footwear – coverage								
Fully enclosed	18	174						
Not fully enclosed	3	7	4.15	0.99-17.44	0.05	4.97	1.01-24.6	0.05

*Adjusted for age, gender, number of vehicles involved and crash type.

DISCUSSION

This report describes the characteristics of bicycle crashes in the ACT over a six month period and highlights some of the key areas of risk for cyclists. The major focus of this report and the discussion of its findings is on the almost two thirds who crashed in transport-related environments including on the road in traffic or bicycle lanes and on shared paths or footpaths. The remaining injured cyclists presenting to hospitals had been riding off-road in non-transport related areas such as mountain bike trails or skate parks, and are not the main focus of this report.

Nearly three quarters of participants were males with a mean age of 37.5 years. The gender and age characteristics were consistent with the experience of other Australian States and countries where the proportion of male cyclists varied between 70 and 80% and the mean age between 31 and 40 years (De Lapparent 2005, Knowles *et al.* 2009, Sikic *et al.* 2009, Boufous *et al.* 2011b). More than half of crashes in transport-related environments occurred while commuting, highlighting the rising popularity of cycling as a mode of transport in Australia. This rise has been attributed to various factors including high petrol prices, issues of climate change, concerns around community health and fitness and the promotion of cycling by state governments concerned with reducing road congestion and providing healthy and environmentally sustainable transport options (Australian Bicycle Council 2010).

The majority of cyclists involved in crashes had been wearing a helmet when they crashed (88.8%) although helmet use varied according to the riding environment. Lower helmet usage was reported among those injured while riding in bicycle lanes (68.8%) and on footpaths (70.6%) compared to in-traffic (94.9%), shared paths (94.5%) or off-road (89.2). Non-usage of helmets has been consistently shown to be associated with increased risk of serious injury in cyclists (Povey *et al.* 1999, Hansen *et al.* 2003, Richter *et al.* 2007).

Only a small proportion of the transport-related crashes occurred in dedicated bicycle lanes (less than one in 12) with the majority occurring in-traffic and on shared paths. While these findings might simply reflect the difference in the number of cyclists that ride in various road environments, this study also indicates that crashes that occurred in bicycle lanes were less severe than those that occurred in other riding environments. This confirms the findings of other studies that show high risks associated with shared or multi-use paths for both cyclists and other users (Aultman-Hall and LaMondia 2005, Reynolds *et al.* 2009, Chong *et al.* 2010, Lusk *et al.* 2011), and provide support for the mounting evidence about the effectiveness of segregated purpose-built bicycle- facilities to prevent crashes and injuries among cyclists and other road users.

A recent review of the literature found that on-road bicycle lanes, marked with painted lines or a coloured surface to designate that they were reserved exclusively for cyclists, had a positive safety effect, consistently reducing injury rates, collision frequencies or crash rates by about 50% compared to unmodified roads (Reynolds *et al.* 2009). It has been suggested that cycling facilities that are most likely to reduce the risk of crashes to cyclists are those that are marked for cyclists, do not share the space with parked cars and are designed to reduce the potential for conflict between cyclists and motorists at intersections. The latter can be achieved by the provision of facilities such as advanced green lights for cyclists and cyclist activated traffic signals at key intersections (Pucher J and L. 2003, Pucher *et al.* 2010)

This study found that crashes resulting from a conflict between cyclists and motor vehicles were most likely to occur at intersections, indicating the need for effective interventions to reduce this risk, particularly through improving the road environment. A recent review of the literature on the most effective intersection treatments designed to improve bicycle access and safety found that bike boxes, also known as advanced stop lines, that allow cyclists to move in front of vehicles when stopped at a signalised intersection reduced the potential for conflicts with vehicle turning movements on green signal (Weigand 2008). The review also found that separate signal phases for cyclists at intersections, which stop all vehicular traffic while permitting cyclists to proceed through the intersection in designated directions similar to vehicular traffic, reduce conflict with vehicle turning movements and have the potential to improve safety for cyclists. Other intersection treatments highlighted by the review as potentially beneficial in term of reducing conflict between cyclists and motorists included coloured bicycle lane markings through intersections and coloured cyclist crossings at the intersection approach (where only a small portion of the bicycle lane approaching the intersection is coloured).

A number of improvements to roundabout design to ensure safe access for pedestrians and cyclists has also been proposed to reduce conflict between motorists and vulnerable road users at intersections. These include the design of exit legs to ensure proper sight lines and low motor vehicle speeds and the addition of traffic control measures such as off-carriageway routes, with signal control across the entry and exit of multi-lane roundabouts (Harkey and Carter 2006). It is important to note however that none of these proposed measures has been evaluated in terms of their impact on cyclists' crash risk.

The present study also revealed that more than half of the crashes in transport-related environments involved a single cyclist, often losing control on straight sections of the road or falling as a result of an impact with objects on the path. Road surface conditions that may have contributed to these crashes included wet surface, slippery surface, loose gravel or rocks, broken, cracked or pot hold surface and raised edge or lip to sealed surface. Equipment failure such as flat tyres, dropped chains and problems disengaging shoe cleats, also played an important role contributing to one in four single cyclist crashes. In addition over half of the injured cyclists were carrying additional weight (average 4.4kg), mostly backpacks, which may have contributed to the crash by affecting their balance at critical times. The role of improvement in road surface condition as well as of cyclist training in reading the road environment, safe cycling practice and bicycle maintenance as measures for reducing these types of crashes needs further investigation.

Also of particular concern is the study's finding regarding the relatively high proportion of crashes between cyclists both on-road and shared paths, with the other vehicle being a bicycle in almost half of all multi-vehicle crashes. Few studies have explored this issue, although there is some evidence to indicate that conflict between cyclists on shared paths can be reduced by introducing simple traffic controls such as painted centre lines and arrows to indicate direction of travel, as well as warnings of crossings, blind curves and driveways (Jordan and Leso, 2000).

The contribution of cyclist behaviour including excessive speed and alcohol indicates potential areas for education and regulation. The relatively high speeds of some of the cyclists on shared paths and footpaths suggests that speed management should be reviewed to ensure that appropriate speed limits are applied. This is particularly important in areas shared with pedestrians such as shared paths where over 16% of crashes involved pedestrians. It was apparent that many study participants were unaware of speed limits applying to cyclists, with a substantial proportion believing either that no speed limits applied or nominating 60km/h or higher on shared paths or footpaths. It is also relevant to note that a high proportion of participants referred to shared paths as 'bike' or 'cycle' paths, which suggests an expectation of priority usage above the usage rights of others such as pedestrians. Similar unrealistic expectations have been reported by other researchers in relation to cyclists assumptions about the distance within which drivers can see and recognize their presence (Wood *et al.* 2009).

This study also showed that cyclists who were injured while riding on shared paths had the highest average injury severity score compared to cyclists injured while riding in other road environments. These findings are also consistent with an earlier retrospective study of hospital admissions in the ACT, which found that the average number of hospital bed days reported for cyclists known to have been riding on bicycle paths was higher (1.64) compared to those known to have been riding on road (1.06) (Richardson and Paini 2006).

Over half of the cyclists involved in a transport-related crash in this study sustained minor injuries, more than a third had injuries rated moderately severe and a small proportion were seriously injured. The majority of cyclists sustained soft tissue injuries including abrasions, bruises, and cuts and lacerations with a relatively high proportion sustaining fractures. The most common body locations of injury were upper and lower limbs, particularly shoulders and knees, with almost one in four sustaining injuries to the head. Comparable results have been found in other Australian states (Sikic *et al.* 2009, Boufous *et al.* 2011a).

This study is the first to investigate the role of clothing in protecting cyclists from injury in crashes. It identified a significantly reduced risk of injury to upper and lower limbs associated with clothing that fully covered the skin, such as long sleeved tops and full length pants, regardless of the materials used. Whereas other studies have reported on conspicuous clothing as a crash countermeasure and some have mentioned cyclist protective clothing as an injury reduction measure (Lind and Wollin 1986, Rivara and Thompson 2001, Abu-Kishk *et al.* 2010, Otte *et al.* 2011), this appears to be the first to study to examine the association between clothing and injury protection for cyclists. The findings point to the potential benefit to cyclists wearing clothing that fully covers their skin including usage of full coverage gloves. Although in the Australian climate heat is likely to play a role in choice of clothing, development of light weight full length cycling clothes may provide some benefits. The role of protective clothing in reducing injury to cyclists in Australia warrants further investigation using large population based studies.

The study also indicates that none of the crashes involving pedestrians and only 1 in 10 of all cyclist crashes were reported to police, with this proportion increasing to about one third for crashes that occurred in traffic. The findings highlight the limitations of police data, with previous studies from Australia and other countries indicating significant under-reporting of bicycle crashes to police (Langley *et al.* 2003, Meuleners *et al.* 2007, Lujic *et al.* 2008). The findings also highlight the importance of survey-based studies in complementing information from administrative data sources and providing a comprehensive picture of circumstances and outcomes of cyclist crashes.

LIMITATIONS

The recruitment methodology limited participants to those cyclists who attended a hospital Emergency Department in the ACT. The exclusion of the most severely injured riders biases the findings and may underestimate the severity of cyclists' injuries in the ACT. The total number of bicycle crash related injuries is also underestimated as the study did not include those who sought treatment from other medical services or pharmacies. In addition, no data is available as to the number and severity of pedestrians and other road users injured in crashes with a cyclist, except those circumstances where the cyclist also required hospital treatment.

In addition, information on traffic crash rates for various routes needs to be treated with caution because of the small number of crashes on each route but also due to the incompleteness of information on exposure.

CONCLUSIONS

This study confirms the value of on-road lanes reserved exclusively for cyclists as a means of reducing their crash and injury rates but raises questions as to the safety of cycling on shared paths and pedestrian areas.

The number of crashes involving pedestrians and the relatively high speeds of some of the cyclists on shared paths and footpaths suggests that the regulation of cycling in shared areas should be reviewed, formally recognized as a part of the road reserve and appropriate speed limits applied. Such measures would be in the interests of cyclists and pedestrians, as cyclists who crashed on shared paths sustained higher average injury severity scores than those injured in any other road environment.

The high proportion of crashes between cyclists is also a matter of concern as almost half of all multi-vehicle crashes were between bicycles. Whereas better traffic management such as centre lines and warning signs on shared paths should reduce such conflicts, it is apparent that behavioural factors such as speed and riding in close packed groups should also be addressed. Other cyclist dependent factors associated with crashes included alcohol, usage of shoe cleats, carrying unbalanced loads such as back packs and shopping bags and poor bicycle maintenance.

The study found that full body coverage including gloves, shoes, long sleeved tops and full length pants, regardless of the materials used, provided a significant benefit in preventing or reducing injuries.

Consideration should be given to undertaking a large population study (i.e. Case control study) to examine risk factors of cyclist crashes in the ACT in order to identify appropriate countermeasures. The study would provide an opportunity to further examine the impact of factors such as alcohol use, helmet use, road infrastructure, protective and conspicuous clothing on cyclist crash and injury risk.

RECOMMENDATIONS

The following recommendations are provided for consideration.

- On-road marked bicycle lanes should be reserved exclusively for cyclists, and not share the space with parked cars.
- Cycle friendly facilities should be considered at intersections including continued marked bicycle lanes, to reduce the risk of conflict between cyclists and other vehicles.
- Road surface should be maintained in areas with high cycling volumes as poor roads and paths surface contribute to a significant number of cycling crashes, particularly single vehicle crashes.
- The status of shared paths should be reviewed and recognised as a part of the road reserve and therefore subject to traffic regulation and crash reporting requirements.
- Traffic controls should be introduced to reduce conflict on shared paths through measures such as speed limits, painted centre lines and arrows to indicate direction of travel, as well as warnings of crossings, blind curves and driveways.
- The conditions of usage of shared paths and other pedestrian areas should be reviewed to ensure right of way and warnings systems (e.g. bells) to reduce the risk of collisions with pedestrians.

- The findings indicate that many injuries to cyclists can be prevented by wearing clothing that fully covers the skin, particularly of upper and lower limbs.
- Consideration should be given to developing and fully evaluating training and information programs for cyclists in order to reduce the risk of crashes and injuries.
- Community education programs should be conducted to raise awareness of:
    - The legal requirement to report to the police all cyclist crashes involving an injury including those involving non-motorised road users
    - Legal requirements applying to cyclists in relation to alcohol usage and speed
    - The high risk of crashes between cyclists, due to riding too close or unsafe overtaking practices
    - The high risk of crashes between cyclists and non-motorised road users in shared zones
    - The importance of equipment maintenance and the risks associated with carrying heavy or unbalanced loads, use of foot straps, clips and cleats.

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