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Alcohol, illicit drugs and prescription medications used by severely injured drivers, riders and pedestrians before and after the crash

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ABSTRACT

This project was concerned with examining substance use both before and following involvement in road crashes causing serious injury. It was comprised of two data analysis studies, one on fatal crashes and one on hospital admission cases, a literature review on substance use by those with injury types included within the Lifetime Support Scheme (LSS), and a discussion of potential studies to look at post-injury substance use among seriously injured road users in South Australia. Substance use was found to be involved in a large proportion of hospital admission and fatal injury crashes. A direct contribution to fatal crashes of substance use was found in 36% of cases. An illegal BAC and illicit drug use were found in similar proportions of cases, while combinations of multiple substance types were common. The literature review revealed that post-injury substance use often replicated pre-injury substance use and often results in worse outcomes. Management of pain is a critical issue post-injury for the injury types within the LSS. Opioids are frequently prescribed to treat chronic pain but alternative therapies need to be explored to avoid some of the negative effects of long term opioid use.

KEYWORDS

Serious injury, crash, drug, alcohol, medication, burn, spinal injury, amputation, brain injury

Summary

This project was concerned with examining substance use both before and following involvement in road crashes causing serious injury. It was comprised of two data analysis studies, one on fatal crashes and one on hospital admission cases, a literature review on substance use by those with injury types included within the Lifetime Support Scheme (LSS), and a discussion of potential studies to look at post-injury substance use among seriously injured road users in South Australia.

The choice of an analysis of fatal crashes and crashes resulting in hospital admission was made on the basis that LSS participants are likely to represent an 'average' between these two groups. In any case, the findings of the fatal and hospital admission-based analyses revealed a number of similarities between these groups in terms of pre-crash substance use, that are therefore likely to be generalisable to LSS participants. These similar findings include:

- Around half of both fatal and hospital admission cases were positive to at least one substance
- Illicit drugs and an illegal BAC appeared in similar proportions, with combinations of different substance types being common
- Substance use was associated with higher levels of injury severity or with a higher likelihood of being fatally injured in the crash
- Illicit drugs were used more by younger people while medication use was more common among older road users
- Males were over-represented among fatalities and serious injuries
- Substance use was associated with single vehicle crashes, especially those that involved striking a fixed roadside object.

The literature review included sections on trauma related to road crashes as well as on trauma in general but chiefly focused on specific injury types relevant to the Lifetime Support Authority (LSA): traumatic brain injury (TBI), spinal cord injury (SCI), burns and amputations. Although different injury types are associated with their own specific issues (see Sections 4.7.2 to 4.7.5), some general findings also emerged from the review:

- Traumatic injuries frequently occur when people are impaired by substances. Substance use at the time of the injury is linked to worse outcomes.
- Following serious injury, substance use tends to decline initially, often due to the functional incapacity of the patient, but typically reverts to pre-injury usage levels once the patient has recovered from the acute phase of the injury. Post-injury substance use is often linked to worse outcomes.
- Traumatic injury is often associated with chronic pain and mental health conditions. Substance use, either licit or illicit, is often related to these issues.
- Opioids are frequently prescribed to treat chronic pain. Opioids pose the risk of various negative outcomes. Alternative therapies should be sought where possible.
- Similarly, many traumatic injuries represent complex problems for which a number of different medications are prescribed. Care is needed to avoid the dangers of polypharmacy among patients in this situation.

Although the literature provides a wealth of information in relation to substance use after various types of traumatic injury, there are limitations to which the findings may be generalisable to LSS participants. This notwithstanding, it is clear that post-injury substance use often replicates pre-injury use and, given that seriously injured road users exhibit high rates of substance use and that there are clear risks

identified in the literature from post-injury substance use, a study of post-injury substance use among a sample of seriously injured road users in South Australia would be beneficial to examine this issue in a local context. Ideally, such a study would be based on interviews with the LSS participants themselves, with findings compared to the risks identified in the literature. However, it is understood that such a study may not be possible. Other potential methodologies to investigate post-injury substance use have been proposed, based on interviewing crash participants from CASR's in-depth crash investigation program, or interviewing injured road users admitted to the RAH. The latter is likely to provide a greater likelihood of recruiting a sufficiently large sample.

Contents

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1 Introduction

1.1 Aim of the project

This project is concerned with substance use by those seriously injured in road crashes. Substance use here refers to use of alcohol, illicit drugs or medications, with a focus on use of substances at the time of the crash as well as post-crash.

Use of substances at the time of the crash is of interest because it is important to understand the factors contributing to road crashes and consequent trauma. This aids in allocation of resources to preventative countermeasures.

Use of substances post-crash is of interest because this can have both direct and indirect effects on recovery from trauma. Substance use post-crash can again include illicit drugs, as a continuation of past behaviour or as a means of self-medication, as well as medications taken to assist with pain management or other conditions arising from the crash.

1.2 Lifetime Support Authority

The Lifetime Support Authority (LSA) delivers the Lifetime Support Scheme (LSS), which provides high quality treatment, care and support for people who have been seriously injured in road crashes in South Australia. The injury types covered by the LSS are head injuries, spinal injuries, burns, amputations and blindness. Thresholds of injury severity are defined for each of these injury types to manage entry into the LSS.

The LSA's interest in substance use is two-fold. Understanding of the contribution of different substances to road crashes is important for developing countermeasures to reduce road trauma and hopefully prevent people from needing the LSS. Understanding of post-injury substance use is important for identifying any behaviours or factors having a negative effect on recovery from injury and other associated outcomes. The LSA, then, wishes to reduce road trauma and wants those who have been injured to recover as well as possible.

1.3 Structure of the report

This report has four main sections. Two are concerned with substance use related to road crashes and two are concerned with substance use post-injury.

A chief aim of the sections on substance use at the time of the crash was to ascertain the substance use patterns likely to contribute to the crashes leading to injured people needing the LSS. In other words, the aim was to look at substance use contributing to crashes causing severe injuries. CASR has taken two approaches to this. First, Section 2 describes substance use involved in fatal crashes, based on analysis of Coroner's files. This is likely to be relevant to the LSA as many of the severe injury crashes that LSS participants were involved in are likely to be similar in nature to fatal crashes, except that the LSS participants survived them. Section 3 looks at substance use among road users admitted to hospital with injuries serious enough to be classified as major trauma. This group would include some people injured seriously enough to qualify for the LSS along with some people whose injuries were still serious but not serious enough that they require ongoing support. So, Section 2 considers crashes typically more severe than those leading to participation in the LSS and Section 3 considers crashes typically less severe than LSS participant crashes. It is likely that comparison of the findings from the two analyses will allow an estimate of the likely role of substance use in crashes leading to the high severity injuries covered by the LSS.

The capacity to examine substance use at the time of the crash is due to CASR having developed databases of road crashes leading to fatalities and hospital admissions. CASR do not have ready access, however, to databases recording post-crash substance use. To examine this required a different approach.

Section 4 is a literature review concerned with substance use post-injury for those with injury types covered by the LSA: head injuries, spinal injuries, burns and amputations (blindness was not included as there was little relevant recent literature on that topic). The review considers use of alcohol and illicit drug use, as well as medications taken to treat conditions arising from the injury. Implications for recovery and other outcomes are also discussed.

In recognition that South Australia data would be of great interest to the LSA, Section 5 discusses potential studies that could be done to collect data on post-crash substance use. The feasibility of different approaches are assessed and a broad estimate of a budget is provided.

2 Analysis of fatal road crashes

2.1 Introduction

This section investigates the prevalence of alcohol and drugs, including prescription medication, by road users prior to involvement in a fatal crash. The fatal crashes are examined to provide insights as to who is most likely to use substances prior to the crash, the substances they use and the types of crashes that result from substance use. The findings can be used to inform the direction of future preventative measures to reduce substance use related road trauma.

2.2 Method

2.2.1 Coroner's files

Deaths resulting from road crashes in South Australia are legally required to be reported to the State Coroner for investigation. Through this investigation, the Coroner is provided with comprehensive and detailed information about the circumstances surrounding a fatal crash, including information on the people and vehicles involved. A Coroner's file for a fatal crash typically consists of reports compiled by investigating police officers (usually the Major Crash investigator), a forensic autopsy report detailing injuries, a forensic toxicology report (i.e., alcohol and drugs), and a summary of the Coroner's findings relating to the cause of death. The police investigation report included in the file yields information regarding collision dynamics, photographs and a map of the scene, mechanical examination of vehicles involved, detailed statements from other crash participants and witnesses, and any other relevant information (e.g., interviews with family members, general practitioners). The systematic examination of contributing factors means that Coroner's case files are one of very few data sources that can provide comprehensive information regarding the circumstances surrounding a crash. Note that while most files contain this information the quality and extent of information can vary from case to case.

In South Australia a fatal crash is defined as a death attributable to the movement of a road user (motor vehicles, pedestrians, cyclists, etc.). A crash is considered fatal if an injured party dies as a result of their injuries within 30 days of the crash occurring. Cases included in the present study were fatalities arising from crashes occurring on public roads or road-related areas (e.g., footpaths). Cases were excluded if they were determined to occur on private property, if the crash was judged to be intentional (i.e., suicide/homicide), or if the fatality arose from natural causes (e.g., a pre-existing medical condition such as a myocardial infarction). To be included in the study, cases were also completed or 'closed' files that were no longer under investigation.

2.2.2 Procedure

This study involved examination of all motor vehicle crashes reported to the State Coroner resulting in at least one fatality (i.e., vehicle occupants, motorcycle riders, cyclists, pedestrians) from 2014 to 2015. Individual crashes were independently reviewed by road safety experts with many years of experience in crash investigation to determine the factors contributing to the crash, including the contribution of alcohol and drugs (licit and illicit). For each crash, routinely recorded information included time of day, day of week, crash type, speed limit, road features, environmental conditions and a crash description. The location of the crash was defined according to the Australian Statistical Geography Standard (ASGS) - Remoteness Area framework. In some cases, vehicle speeds were determined using computer aided reconstructions of the crashes or from data downloaded from the vehicle's Event Data Recorder (EDR). Detailed data were also collected on the crash participants (driver and deceased)

including age, sex, location of residence (metropolitan/regional/remote), seat belt use, BAC level, the presence of drugs (licit and illicit) and injuries.

The BAC level and presence of drugs for a deceased road user involved in a fatal crash are routinely recorded in a forensic toxicology report. The report contains the outcomes of toxicological tests of blood samples to detect alcohol and drugs, with interpretation of the findings in terms of likely impairment and, in the case of licit drugs (i.e., medications), whether the concentration of the drug detected is within the therapeutic range for that specific drug. The forensic testing covers a wide range of licit and illicit drugs and is conducted by Forensic Sciences SA. In addition, crash-involved drivers, riders, vehicle occupants and pedestrians over the age of 10 years who present to a hospital in South Australia are required to undergo mandatory testing for blood alcohol concentration (BAC) and screening for three prescribed drugs: Methamphetamine, Delta-9-Tetrahydrocannabinol (THC) and 3,4-Methylenedioxymethamphetamine (MDMA). This legislation requires a blood sample to be taken by hospital personnel within eight hours of being involved in the collision, with most occurring within the first one to two hours following the crash. The samples are sent to, and tested by, Forensic Sciences SA.

In South Australia, driving with a BAC of 0.05 g/100ml or greater (apart from some drivers for whom a zero BAC is required, i.e., taxi, heavy vehicle, provisional drivers), or when positive for the three prescribed drugs, is an offence. Some road users in the fatal crash sample recorded a positive BAC below the legal level: these legal BACs were not included as cases of drink driving within this study. The active component of the three prescribed illicit drugs needed to be present for a case to be recorded as involving substance use. Note that metabolites of these drugs may be detected in the toxicology screen, and this indicates that the drug has been ingested previously but not recently enough prior to driving for the driver to have been impaired.

Licit drugs or medications were categorised into the following broad groups: anti-depressants, antihistamines, anti-hypertensives, stimulants, anaesthetics, anti-psychotics, benzodiazepines, narcotic analgesics, anti-convulsants, anti-inflammatories, anti-diabetics, and analgesics. In some cases, it was specified by the pathologist that licit drugs detected in the toxicology report (e.g., ketamine, fentanyl, morphine) were consistent with medical intervention provided following the crash. These substances were excluded as medications because they were not used by the road user prior to the crash. In other cases, these substances were detected but it was not explicitly stated that they were the result of medical intervention at the crash scene. Where medical intervention was administered at the crash scene and medication consistent with such intervention was detected at therapeutic levels, these medications were not included. It is acknowledged that these drugs can also be used recreationally. We cannot be certain if they were used recreationally in these cases; however, they were all within a therapeutic range consistent with medical treatment.

While the presence of licit drugs or medications was noted, researchers also determined whether the substances may have impacted on road user performance and whether they were likely to have contributed to crash causation. With respect to their effect of road user performance, the side effects of each licit drug and any associated driving-related warnings were reviewed. In particular, side effects associated with dizziness, drowsiness, reduced alertness and impaired vision were considered potentially impairing. Interactions with alcohol and other drugs present was also considered. Medications taken by the deceased or other drivers involved in a fatal crash are not required to be reported but, in many instances, general practitioners or family members reported medical or mental health issues, prescribed medication and any side effects. This information was also considered when assessing the potential effects of medications on driving. The likely effects of licit drugs on driving were rated as ‘definite’, ‘possible’, ‘unlikely’, ‘none’.

Researchers also reviewed the context of all circumstances associated with the crash and determined if substance use was a contributing factor. Some judgement was required, and the response categories reflect this: 'yes', 'possible', 'unlikely', 'no'. Responsibility or culpability for a crash was determined by researchers when reviewing the case, taking police-deemed culpability into consideration.

In the interests of crash prevention, only the substance use of vehicle controllers (i.e., drivers and riders) and active road users (cyclists, pedestrians) involved in the fatal crash was considered (i.e., not passengers). For example, an intoxicated pedestrian was classified as an alcohol-related crash.

A series of chi-square tests for independence were undertaken to compare substance use status for crash and road user related variables.

2.2.3 Sample

Of the 180 closed Coroner's files obtained for the years 2014 and 2015, 21 cases did not meet the study inclusion criteria. The final sample analysed included 159 fatal crashes of which 48 (30%) occurred in the Adelaide metropolitan area, 88 (55%) in regional areas and 23 (15%) in remote areas. The 159 fatal crashes resulted in 175 fatalities, of whom 86 were drivers (49%), 19 were motorcyclists (11%), 21 were pedestrians (12%), 7 were cyclists (4%) and 42 were passengers in a vehicle (24%).

There were 259 road users aged 17 to 97 years (M=45.7, SD= 19.8) actively involved in the fatal crashes, of whom 189 (73%) were male and 70 (27%) were female. The active road users consisted of 202 drivers (78%), 21 motorcyclists (8%), 29 pedestrians (11%) and 7 cyclists (3%). As this analysis is concerned with substance use that contributes to road crashes, the analysis focuses on these active road users and excludes vehicle passengers who may have been impaired at the time of the crash.

2.3 Results

2.3.1 Substance use in fatal crashes

The prevalence of alcohol, illicit and licit drugs (medication) in fatal crashes in South Australia for the years 2014 and 2015 can be seen in Table 2.1. Overall, 54.7% of fatal crashes involved substance use. Almost 24% of crashes involved an illicit drug and 20.1% of crashes involved an illegal BAC. In 35.2% of crashes, a road user had medication in their system prior to the crash. In 20.1% of crashes, more than one substance was present, with a combination of an illegal BAC and/or illicit drugs and/or medication. Note that the categories in Table 2.1 are not mutually exclusive (i.e., the 'combination' row will include cases from the previous three rows), so the total will exceed the number of crashes (N=159).

Table 2.1
Prevalence of substances in fatal crashes in South Australia, 2014-2015

Substance use	Crashes (number)	% of crashes (N=159)
Illegal BAC	32	20.1
Illicit drug	38	23.9
Medication	56	35.2
Combination (alcohol, drug or medication)	32	20.1
None (includes unknown)	72	45.3

The previous table showed the *presence* of substance use in fatal crashes, but it does not indicate whether the substance use contributed to the crash outcome. This distinction is particularly relevant to medications, as not all prescription medication has an impact on driving performance.

Substance use contributing to fatal crashes is presented in Table 2.2. The proportions remain relatively similar to Table 2.1 with the exception of medication. Of the 56 crashes in which the presence of medication was detected, there were 20 crashes (12.6% of all crashes) in which the medication was deemed as 'contributing' or 'possibly contributing' to the crash. Note that the categories in columns 2 and 3 in Table 2.2 are not mutually exclusive (i.e., the 'combination' row will include cases from the previous three rows), so the total will exceed the number of crashes (N=159).

In columns 4 and 5, crashes are categorised into mutually exclusive groups based on substance use: illegal BAC only (8.2% of crashes), illicit drugs only (9.4%), medication only (2.5%) and a combination of two or more different substances (15.7%). In all crashes involving a combination of substances, it was a single road user who was likely to have been impaired. Overall, 35.8% of crashes (n=57) involved substance use that likely contributed to the crash occurring.

Table 2.2
Substance use contributing to fatal crashes in South Australia, 2014-2015

Substance use	Crashes (N)	% of crashes	Mutually exclusive crashes (N)	Mutually exclusive crashes (%)
Illegal BAC	32	20.1	13	8.2
Illicit drug	36	22.6	15	9.4
Medication	20	12.6	4	2.5
Combination (alcohol, drug or medication)	25	15.7	25	15.7
None (includes unknown)	102	64.2	102	64.2
Total (N)			159	100.0

The combinations of illegal BACs, illicit drugs and medication (*n*=57) deemed to have contributed to the fatal crashes are depicted in a Venn diagram (see Figure 2.1). Illicit drugs alone were the most prevalent substance, followed by an illegal BAC alone. Notably, 25 crashes involved combinations of substances with illegal BACs and illicit drugs the most common combination. In six crashes, all three substance types were involved.

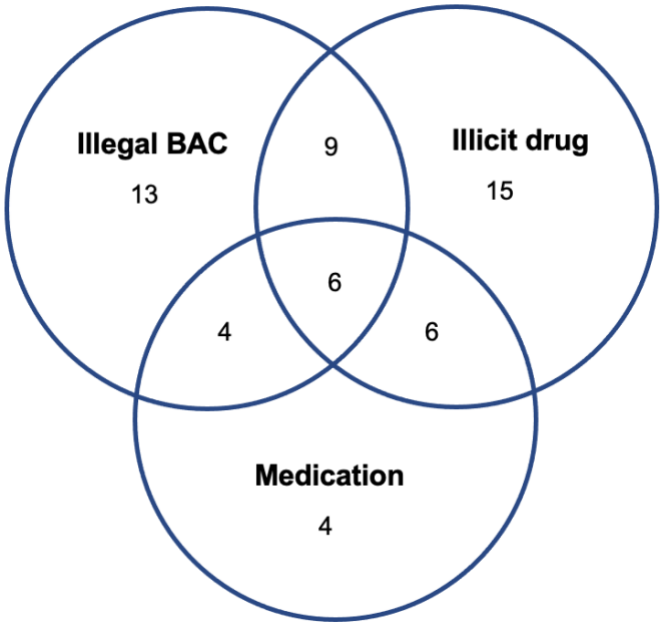

Figure 2.1
Venn diagram of substance use contributing to fatal crashes in South Australia, 2014-2015

2.3.2 Alcohol in fatal crashes

Overall, of the 259 active participants involved in a fatal crash, 205 recorded a zero BAC, 39 recorded a positive BAC and 15 road users had an unknown BAC due to not being tested or the blood sample being denatured. The BAC levels for the road users who recorded a positive BAC are presented in Figure 2.2. There were seven road users who recorded a BAC under the legal limit of 0.05. One of these is considered illegal as the driver was on a provisional licence which requires a zero BAC. As a result, there were 33 road users who were involved in 32 alcohol-related crashes. One of these crashes involved two pedestrians who recorded an illegal BAC, one of whom was not deemed culpable for the crash. All other road users with an illegal BAC were deemed culpable for the crash.

When considering those culpable for a fatal crash with an illegal BAC (*n*=32), the majority 62.5% (*n*=20) had a very high BAC over 0.150. Of the culpable road users with an illegal BAC, 22 were drivers, five were pedestrians, four were motorcycle riders, and one was a cyclist.

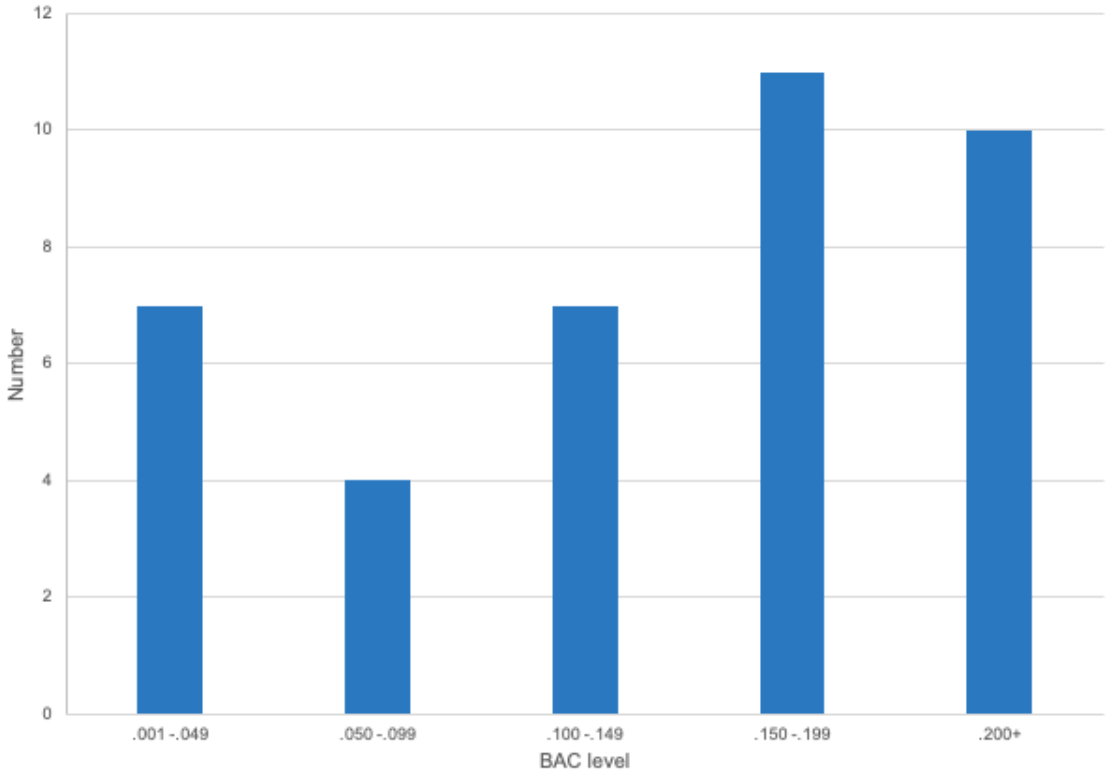

Figure 2.2
BAC levels in alcohol-related fatal crashes in South Australia, 2014-2015

2.3.3 Illicit drugs in fatal crashes

Of the 259 road users involved in a fatal crash, 201 tested negative for illicit drugs, 39 road users tested positive to one or more illicit drugs and for 19 road users drug test results were unknown. In three crashes in which road users were positive for illicit drugs (2 THC, 1 methamphetamine), the substance use did not contribute to the crash occurring (i.e., not culpable for the crash).

The types of drugs and combinations found in road users who contributed to fatal crash causation (*n*=36) are presented in Table 2.3. THC was the most common illicit drug (*n*=26) followed by methamphetamine (*n*=14). Five road users tested positive for both substances and one of these also tested positive for trifluoromethylphenylpiperazine, a synthetic recreational drug similar to MDMA. Of the culpable road users testing positive for illicit drugs, 27 were drivers, three were pedestrians, five were motorcycle riders, and one was a cyclist.

Table 2.3
Drug toxicology for road users culpable for fatal crashes in South Australia, 2014-2015

Illicit drug types	Number	%
THC only	20	55.6
Methamphetamine only	9	25.0
THC & Methamphetamine	4	11.1
THC, Methamphetamine, trifluoromethylphenylpiperazine	1	2.8
MDMA positive & THC	1	2.8
Cocaine	1	2.8
Total	36	100.0

2.3.4 Medication in fatal crashes

The different types of medications that were present in the toxicology screen for road users involved in a fatal crash are presented in Table 2.4. There were 64 road users who were detected with medications in the toxicology screening, 176 tested negative and results were unknown for 19. Many road users (48.4%) were positive for more than one medication (2 medications *n*=19, 3+ medications *n*=12). Anti-depressants (51.6%) were the most common medication followed by narcotic analgesics (e.g., opioids) (26.6%) and benzodiazepines (25%).

Table 2.4
Medications present in toxicology for road users in fatal crashes in South Australia, 2014-2015

Medication type	Number	%
Anti-depressants	33	51.6
Narcotic analgesics	17	26.6
Benzodiazepines	16	25.0
Anti-hypertensives	12	18.8
Antihistamines	5	7.8
Anti-convulsants	5	7.8
Anti-psychotics	4	6.3
Analgesics	4	6.3
Anti-inflammatories	3	4.7
Other disease-modifying anti-rheumatics	3	4.7
Stimulants	2	3.1
Cholinesterase inhibitors	2	3.1
Anti-diabetics	2	3.1
Anaesthetics	1	1.6
Adamantanes	1	1.6
Anti-coagulants	1	1.6
Beta-blockers	1	1.6
Other	1	1.6
Total	113	100.0

However, the presence of a medication does not indicate that it contributed to the crash occurring. For each of the 56 crashes in which the 64 participants were involved, a judgement was made as to whether the medication contributed to the crash (see method for further details). In 11 crashes, medication was not determined as contributing to the crash and, in a further 25 crashes, it was considered unlikely to have contributed to the crash. Medications were considered as possibly contributing to 14 crashes and definitely contributing to six crashes. The types and combinations of medication present in the fatal crashes in which medication was deemed as contributing or possibly contributing are listed in Table 2.5 along with the presence of any illicit drugs and alcohol. Note that where the medication is in plural form, two different medications of this type were present. Multiple medications were frequently detected; in eight crashes, two or more medications were present and in a further six crashes, three or more medications were present. The three most common medications were benzodiazepines (*n*=12), anti-depressants (*n*=11), and narcotic analgesics (*n*=8).

For the six crashes in which medication definitely contributed to the crash, in five crashes the medication was detected at levels above the therapeutic range and narcotic analgesics were the most common type of medication. Where medications were deemed as possibly contributing to the crash, medications were all at therapeutic levels but often combined with other medications and/or illicit drugs and alcohol.

Overall, in ten (50%) of the crashes in which medication contributed or possibly contributed to the crash, illicit drugs were also present. Medications were combined with alcohol in eleven crashes (55%) with

seven of these being a very high BAC at 0.150 and over. Many of these medications (i.e., benzodiazepines, narcotic analgesics and some anti-depressants) have negative interactions with alcohol that can cause very serious side effects which would impair driving. Of the medication crashes, 15 were drivers, three were motorcycle riders and two were pedestrians.

Table 2.5
Combinations of medications contributing or possibly contributing to fatal crashes in South Australia, 2014-2015

Contribute to crash	Type of medication
Definite (n=6)	Anti-convulsants*, benzodiazepines
	Anti-depressant, narcotic analgesic, analgesic
	Anti-depressant*, narcotic analgesics*
	Anti-psychotic* + THC +BAC 0.014
	Narcotic analgesic* + meth +THC
	Narcotic analgesics*, benzodiazepines + meth
Possible (n=14)	Anti-depressant, benzodiazepine +THC + BAC 0.180
	Anti-depressant, benzodiazepine + BAC 0.162
	Anti-depressant, benzodiazepine + BAC 0.253
	Anti-depressant +THC +BAC 0.247
	Anti-depressant +BAC 0.267
	Benzodiazepine +THC + BAC 0.146
	Benzodiazepines +meth
	Anti-depressant, antihistamine + BAC 0.184
	Anti-depressant, anti-psychotic + BAC 0.67
	Benzodiazepines, anti-hypertensives
	Narcotic analgesic, anti-malarial + Cocaine
	Narcotic analgesic, local anaesthesia +THC + BAC 0.150
	Anti-depressants, anti-hypertensive + THC + meth
	Stimulant + BAC 0.022
	*Denotes above therapeutic level

2.3.5 Characteristics of fatal crashes by substance use

In order to examine the characteristics of fatal crashes involving substance use, crashes identified as involving substance use that contributed to the crash were compared with crashes in which no substance use contributed to the crash. A summary of findings is presented in Table 2.6. With respect to crash type, substance use crashes predominantly involved hitting a fixed roadside object (43.9%) in comparison to no substance use crashes for which head on (23.5%) and hitting an object (23.5%) were equally the most frequent crash type. For the ten substance use crashes involving pedestrians, in four crashes it was the pedestrian who was impaired by a substance (illegal BAC n=2, illicit drugs/medication, illegal BAC/illicit drugs) and in six crashes the driver.

Examination of the number of vehicles involved in the crash revealed that substance use crashes were statistically significantly more likely to involve a single vehicle (71.9%) compared to no substance use crashes (52%) (X^2=6.03, *df*=1, *p*=.014). There were no other statistically significant differences by substance use for crash configuration, speed limit or location of the crash. However, it is noteworthy that the majority of substance use crashes occurred at midblock locations, in higher speed zones (80-110km/h) and in regional and remote areas.

Table 2.6
Characteristics of fatal crashes by substance use status in South Australia, 2014-2015

		Substance use		No substance use	
Crash characteristic		(N=57)	%	(N=102)	%
Crash type	Hit object	25	43.9	24	23.5
	Pedestrian	10	17.5	16	15.7
	Roll over	9	15.8	15	14.7
	Head on	8	14.0	24	23.5
	Right angle/right turn	4	7.0	18	17.7
	Side swipe	1	1.8	3	2.9
	Rear end	-	-	2	2.0
No. of vehicles*	Single	41	71.9	53	52.0
	Multiple	16	28.1	49	48.0
	X^2=6.033, df=1, p=.014				
Road configuration	Intersection	9	15.8	27	26.5
	Midblock	48	84.2	75	73.5
	X^2=2.382, df=1, p=.123 ns				
Speed limit	50-70km/h	17	29.8	36	35.3
	80-110km/h	40	70.2	66	64.7
	X^2=0.492, df=1, p=.483 ns				
Location	Metropolitan	18	31.6	30	29.4
	Regional/remote	39	68.4	72	70.6
	X^2=0.081, df=1, p=.775 ns				

Note. *p<.05

To examine the crash characteristics associated with different substances, substance use crashes were divided into mutually exclusive groups in which crashes were categorised as illegal BAC only, illicit drugs only, medication only or a combination of two or more substances, as seen in Table 2.7. While the numbers were too small to undertake meaningful statistical analyses (many cells with <5), some trends were noted. Single vehicle crashes were most common among all substance use groups except for illicit drugs. This is consistent with the results for crash type. The most frequent crash type was hit fixed object but, for illicit drugs, crash types involving multiple vehicles were also prevalent, including head on and right angle/right turn crashes. These results are suggestive that fatal crashes involving Illicit drugs only involve different crash types compared to those involving other substances.

For all substance use groups, the majority of fatal crashes occurred at midblock locations (although the medication group was split equally between intersections and midblock), in higher speed limit zones, and in regional and remote areas.

Table 2.7
Characteristics of fatal crashes by substance use group in South Australia, 2014-2015

	Illegal BAC		Illicit drugs		Medication		Combination	
Crash characteristic	N=13	%	N=15	%	N=4	%	N=25	%
Crash type								
Hit object	5	38.5	4	26.7	1	25.0	15	60.0
Pedestrian	3	23.1	2	13.3	1	25.0	4	16.0
Roll over	4	30.8	1	6.7	1	25.0	3	12.0
Head on	1	7.7	4	26.7	-	-	3	12.0
Right angle/(right turn)	-	-	3	20.0	1	25.0	-	-
Side swipe	-	-	1	6.7	-	-	-	-
No. of vehicles								
Single	12	92.3	6	40.0	3	75.0	20	80.0
Multiple	1	7.7	9	60.0	1	25.0	5	20.0
Road configuration								
Intersection	-	-	5	33.3	2	50.0	2	8.0
Midblock	13	100.0	10	66.7	2	50.0	23	92.0
Speed limit								
50-70km/h	4	30.8	4	26.7	1	25.0	8	32.0
80-110km/h	9	69.2	11	73.3	3	75.0	17	68.0
Location								
Metropolitan	5	38.5	6	40.0	1	25.0	6	24.0
Regional/remote	8	61.5	9	60.0	3	75.0	19	76.0

2.3.6 Characteristics of road users by substance use

The characteristics of road users who were likely to have been impaired by a substance which contributed to the fatal crash occurring, were compared to road users for whom no substance use contributed to the crash, as seen in Table 2.8. Substance use was unknown for 13 road users who were excluded from the analysis. (Of interest, seven of the road users with unknown substance use were pedestrians, suggesting that this road user group is less likely to be tested).

Injury severity differed statistically significantly by substance use. Road users impaired by substance use were more likely to be fatally injured (87.7% vs 42.3%) while those not impaired by substance use were more likely to receive minor injuries (30.7% vs 7.0%). Road users impaired by substance use had a statistically significant younger mean age (39.4 years, SD=15.1) than those not impaired by substance use (48.2 years, SD=20.5) ($t_{(379)}$ =-2.94, p=.004). There were no statistically significant differences by substance use for road user type or by sex.

Table 2.8
Characteristics of road users in fatal crashes by substance use status in South Australia, 2014-2015

		Substance use		No substance use	
Road user characteristic		(N=57)	%	(N=189)	%
Road user	Driver	42	73.7	155	82.0
	Motorcyclist	6	10.5	15	7.9
	Pedestrian	7	12.3	15	7.9
	Cyclist	2	3.5	4	2.1
	X^2=2.0, df=3, p=.573				
Sex	Male	44	77.2	137	72.5
	Female	13	22.8	52	27.5
	X^2=0.50, df=1, p=.480				
Age (years)	Mean (SD)	39.4	(15.1)	48.2	(20.5)
	Age range	19-84		17-97	
Injury severity**	Fatal	50	87.7	80	42.3
	Hospital admitted	1	1.8	27	14.3
	Hospital treated	2	3.5	24	12.7
	Minor/no injury	4	7.0	58	30.7
	X^2=35.35, df=3, p<.001				

Note. *p<.05, **p<.001

The characteristics of the road users using substances in each of the fatal crashes identified as having substance use as a contributing factor can be seen in Table 2.9 by substance use group. Numbers were too small for meaningful statistical analysis but some trends can be noted. While all substance use groups were dominated by drivers, pedestrians comprised a notable proportion of the illegal BAC group. Motorcycle riders tended to use a combination of substances. The mean age of road users in the medication group was much older than the other groups with road users all aged over 60 years. Only seven (12%) of the road users impaired by substance use were not fatally injured.

Table 2.9
Characteristics of road users by substance use group in fatal crashes in South Australia, 2014-2015

	Illegal BAC		Illicit drugs		Medication		Combination	
Road user characteristic	N=13	%	N=15	%	N=4	%	N=25	%
Road user								
Driver	8	61.5	12	80.0	4	100.0	18	72.0
Motorcyclist	1	7.7	1	6.7	-		4	16.0
Pedestrian	3	23.1	1	6.7	-		3	12.0
Cyclist	1	7.7	1	6.7	-		-	
Sex								
Male	10	76.9	12	80.0	2	50.0	20	80.0
Female	3	23.1	3	20.0	2	50.0	5	20.0
Age – mean (SD))	42.2	(15.3)	34.0	(9.3)	70.3	(9.2)	36.7	(12.8)
Age range (years)	20-67		19-48		61-84		19-58	
Injury severity								
Fatal	11	84.6	12	80.0	3	75.0	24	96.0
Hospital admitted	-	-	-	-	-	-	1	4.0
Hospital treated	-	-	2	13.3	-	-	-	-
Minor/no injury	2	15.4	1	6.7	1	25.0	-	-

2.4 Summary

2.4.1 Substance use

Findings from this analysis revealed that 36% (n=57) of fatal crashes involved substance use that potentially contributed to the crash occurring. For crashes in which substance use potentially contributed to the crash, illicit drugs were most common (23%), followed by an illegal BAC (20%) and then medication (13%). In 20% of crashes, more than one substance (illegal BAC/illicit drug/medication) was present.

For those responsible for a fatal crash with an illegal BAC, the majority (63%) had a very high BAC of 0.150 and above. THC was the most common illicit drug (n=26) followed by methamphetamines (n=14). Where medication was identified as potentially contributing to the crash, two or more medications were detected in 70% of crashes. Additionally, in 55% of medication crashes, medication was combined with alcohol (the majority being a high BAC of .150 or greater) and in 50% of crashes combined with illicit drugs. The three most common medications were benzodiazepines (*n*=12), anti-depressants (*n*=11), and narcotic analgesics (*n*=8).

2.4.2 Characteristics of fatal crashes with substance use

Fatal crashes involving substance use were more likely to involve a single vehicle (72%) compared to no substance use crashes (52%) and typically involved hitting a fixed roadside object. However, when examining crashes by substance use group, crashes involving illicit drugs alone were different to other groups as they incorporated more multiple vehicle crashes with common crash types also including head-on and right angle/right turn.

The majority of substance use crashes, and fatal crashes generally, occurred in midblock locations, in high-speed zones and in regional and remote areas.

2.4.3 Characteristics of road users by substance use

Road users potentially impaired by substances were significantly younger than those not impaired by substance use. Those using medications alone were more likely to be older (over 60 years) than the other substance use groups suggesting the use of medications might be an issue among older drivers. Substance use, and fatal crash involvement generally, was more prevalent among males.

Substance use was clearly associated with higher injury severity with 88% of road users potentially impaired by substance use being fatally injured.

2.4.4 Final comment

Further discussion of these results is provided in Section 6.

3 Analysis of road crashes resulting in serious injury

3.1 Introduction

This section is concerned with analysis of the pre-crash substance use of road users who were admitted to the Royal Adelaide Hospital following a road crash. The unique database used in this section links data from several official sources, including medical records from the RAH, road user licensing histories, police crash reports, and the results of drug and alcohol testing of injured road users. Hospital medical records were manually matched with the other sources using a number of variables, including crash details (date, time, location) and participant characteristics (age, sex, residential postcode of patient, licence details).

3.2 Method

3.2.1 Medical data

Details of injuries of each participant were obtained from medical records (including medical and treatment notes from the ambulance service and emergency department), with all injuries coded using the Abbreviated Injury Scale (AIS). This injury coding system applies scores to injuries on the basis of threat to life, with individual injury scores ranging one (minor injury) to six (untreatable, fatal injury). These AIS scores can then be converted to an injury severity score (ISS), which provides an indication of the overall severity of the injuries experienced by the patient. The ISS is the sum of squares of the highest coded AIS injury in each of the three most severely injured ISS body regions (head or neck, face, chest, abdomen, extremities, and external). The ISS has been found to be correlated with mortality and morbidity (Paffrath, Lefering, Flohé & the Trauma Register DGU, 2014). Patients with no codable injuries receive an ISS of zero. For analysis, participants were grouped based on their ISS: No injury (ISS = 0), Moderate injury (ISS1-14), and Serious injury (ISS 15+). Patients who died were excluded to prevent cross-over with the analysis of Coroner's cases in Section 3.

In three cases an ISS could not be calculated due to unspecified injuries resulting in an AIS code ending in "9"; these included traumatic brain injury not further specified, hypoxic brain injury, and non-survivable brain injuries secondary to hypoxia. Two of these cases were fatal while, for the remaining case (with brain injury not further specified), medical notes indicate that the patient was admitted to hospital and then required brain injury rehabilitation after discharge. This patient was counted as a 'serious injury' case and was included in any analyses based on injury group but was excluded from any analyses using numerical values for ISS.

3.2.2 Substance use

The use of illicit substances was determined based on toxicology screening undertaken by Forensic Science SA. As noted in the previous section, by law, in South Australia, all road users above the age of 10 who are involved in a motor vehicle crash must provide a blood sample that is analysed for the presence of alcohol, THC, methamphetamine, and MDMA. In South Australia, driving with a BAC of 0.05 g/100ml or greater, or any amount of the three prescribed drugs is an offence. The use of each substance was coded as present/absent based on a toxicology finding of blood concentrations greater than zero. Two alcohol use groups were used in the analysis: those with a legal BAC (i.e., <.05) and those with an illegal BAC (≥.05). While there is no legal BAC limit for pedestrians, they were included in the latter group as this level of BAC provides some indication of intoxication.

Participants' use of medications was ascertained from medical records with medications grouped into one of the following categories: antiarrhythmics, anticoagulants, anticonvulsants, antihypertensives,

anti-inflammatory drugs, antipsychotics, anxiolytics, barbiturates, benzodiazepines, betablockers, cardiovascular drugs, dopamines, drugs for diabetes control, insulin, non-opiate analgesia, selective serotonin reuptake inhibitors (SSRIs), non-SSRIs, non-steroidal anti-inflammatory drugs (NSAIDs), opiates, oral hypoglycaemics, psychoactive drugs, steroidals, vasodilators, and other medications. Levels of these medications present in the blood were not reported (Forensic Science SA are not required to report the presence of drugs other than alcohol, THC, methamphetamine, and MDMA) so medication use was scored dichotomously as present/absent for each group. A separate variable recording the combined use of illicit drugs (including alcohol) and medication, dichotomously coded present/absent, was also created.

3.2.3 Crash details

Information about the crash was obtained from the Traffic Accident Reporting System (TARS) which is a database pertaining to all crashes that are reported to South Australian Police. All crashes resulting in at least $3,000 property damage or which result in an injury to a road user are required to be reported to police. Data used in this study include road user type (driver, motorcycle rider, cyclist, pedestrian [including wheelchair users, gophers, and small wheeled recreational devices such as skateboards, push/electric scooters, and roller skates]), and crash type (e.g., head on, right angle, hit fixed object, etc.).

3.2.4 Sample

All people involved in a crash on a public road (as defined by ICD-10-AM) in South Australia who were admitted (i.e., received treatment for four hours or more) to the Royal Adelaide Hospital (RAH) over the period 2014 to 2017 were included in the study. The RAH is the major trauma hospital in South Australia which receives the majority of crash participants and also treats serious trauma cases initially taken to other hospitals. Injury details for 2,072 cases were recorded over this period; 48 were excluded due to the person dying, leaving a final sample of 2,024. Participants included in the study were aged 16 to 95 (M=44.79, SD=18.99) and 70% (1,417) were male. Participants were primarily drivers (n=959, 47.4%), followed by motorcyclists (n=463, 22.9%), cyclists (n=416, 20.6%), and pedestrians (n=186, 9.2%).

3.3 Results

3.3.1 Descriptive statistics

Descriptive statistics for participants based on injury grouping are provided in Table 3.1.

Table 3.1
Descriptive statistics for participants based on injury severity

	No injury (n=196)	Moderate injury (n=1,584)	Serious Injury (n=244)
ISS			
Range	-	1-14	16-38
M(SD)	-	5.53(3.94)	21.92(5.75)
Age			
Range	17-95	16-95	16-91
M(SD)	47.37(20.42)	44.35(18.86)	45.57(18.51)
Male	118	1099	200
Female	78	485	44
Driver	167	685	107
Motorcycle rider	13	374	76
Cyclist	8	376	32
Pedestrian	8	149	29

Investigation of differences in injury severity (ISS) between road users was undertaken using analysis of variance (ANOVA). The assumption of homogeneity of variance was violated so the Welch statistics is reported. Results are displayed in Table 3.2. Post-hoc comparisons were conducted using Games-Howell tests. These showed significant differences between drivers and motorcyclists (p<.001) and pedestrians (p<.001), between motorcyclists and cyclists (p<.001), and between pedestrians and cyclists (p=.01). This demonstrates a greater average level of injury severity for motorcyclists and pedestrians, compared to the other groups.

Table 3.2
Analysis of variance of ISS for road users

	N	Range	M	SD	df	*F*
Driver	959	0-38	5.89	6.95	3, 654.83	20.12*
Motorcycle rider	463	0-38	8.83	7.52		
Cyclist	416	0-38	6.61	5.46		
Pedestrian	186	0-38	8.62	7.93		

Note. Welch statistic reported. *p<.001

3.3.2 Substance use and injury severity

In order to investigate the links between substance use and injury severity, participants were grouped based on the types of substances they used (none, medication only, alcohol with a BAC less than .05, BAC greater than .05, illicit drug use, and combination use). It is possible for participants in the medication and illicit drug use groups to have used multiple drugs of that type. Those classed as using a combination of substances were those who used at least one substance from at least two broad types (e.g., medication plus alcohol or medication plus illicit).

The use of any type of substance and severity of injury was assessed using the chi-square test of independence. Legal alcohol use (i.e., a BAC greater than zero but less than .05) was excluded from analysis due to low numbers (n=5). A significant difference was detected: $\chi^2(8)=40.34$, $p<.001$. Examination of Table 3.3 suggests a greater than expected frequency of medication use among the no injury group and correspondingly less than expected in the moderate and serious injury groups. A greater than expected frequency was also observed for illegal alcohol use in the serious injury group, with trends also among this group for greater use of illicit drugs and a combination of one or more types of substances.

Table 3.3
Substance use by injury severity group

	No injury		Moderate Injury		Serios Injury		Total	
Drug use group	N	%	N	%	N	%	N	%
None	80	40.82	819	51.70	115	47.13	1014	50.10
Medication	86	43.88	426	26.89	56	22.95	568	28.06
Alcohol (BAC <.05)[a]	-	-	4	0.25	1	0.41	5	0.25
Alcohol (BAC >.05)	10	5.10	116	7.32	33	13.52	159	7.86
Illicit	9	4.59	91	5.74	17	6.97	117	5.78
Combination	11	5.61	128	8.08	22	9.02	161	7.95
Total	196	100	1584	100	244	100	2024	100

Note. [a]Legal alcohol use was excluded from analysis due to low numbers.

Investigation of differences in injury severity (ISS) associated with the type of substance used was undertaken using one-way ANOVA, with descriptive statistics provided in Table 3.4. The assumption of homogeneity of variance was violated and so the Welch *F*-ratio is reported. There was a significant effect of type of substance used on the severity of injury, $F(4, 43.23),= 4.85$, $p = .001$. Post-hoc comparisons were undertaken using Games-Howell tests as homogeneity between groups could not be assumed. These results showed that ISS was higher among those with an illegal BAC than those who used medications ($p < .05$) or no substances ($p < .05$), and ISS was higher among those who used a combination of substance types than those who used medication ($p < .05$).

Table 3.4
Descriptive statistics for injury severity score of groups based on type of substance used

Type of substance used	N	*M*	*SD*	*Range*
None	1013	6.81	6.65	0-38
Medication	568	6.08	6.32	0-33
Alcohol (BAC <.05)	5	10.60	13.24	1-33
Alcohol (BAC ≥ .05)	159	9.34	9.24	0-38
Illicit drugs	117	7.65	7.92	0-38
Combination	161	8.07	7.59	0-34

Differences between the injury severity groups based on the number of medications, illicit drugs, and total substances used (medication, illicit drugs, and alcohol) were assessed using a one-way ANOVA. Descriptive statistics and results are provided in Table 3.5. For both the number of medication and number of illicit drugs used, the assumption of homogeneity of variance was violated so post-hoc comparisons were undertaken using Games-Howell tests. These showed that the no injury group used a higher number of medications on average than both the moderate ($p<.001$) and serious injury ($p=.001$) groups. The no injury group, however, used a lower number of illicit drugs than the moderate injury

group (p=.035). For total substances used, post-hoc comparisons were undertaken via Bonferroni tests, which found that the no injury group used fewer total substances than the moderate injury group (p=.006).

Table 3.5
Analysis of variance for number of substances by injury group for medication, illicit drugs, and all substances

	Injury group								
	No injury		Moderate injury		Serious injury				
	M	SD	M	SD	M	SD	*F*	df	*p*
Medication	1.58	1.95	1.05	1.73	0.98	1.81	7.05*	2, 350.52	<.001
Illicit drugs	0.07	0.26	0.12	0.4	0.13	0.4	3.27*	2, 405.35	0.039
All substances[a]	1.73	1.95	1.3	1.79	1.32	1.83	4.83	2, 2021	0.008

Note. [a]Total number of substances used including medication, illicit drugs, and alcohol. *Welch statistic reported.

3.3.3 Demographic statistics and substance use

The demographic characteristics of participants from each substance use group are provided in Table 3.6. Comparisons of age for each substance use group was undertaken via ANOVA. The assumption of homogeneity of variance was violated and so the Welch F-ratio is reported. There was a significant difference in age between groups F(5, 43.77)=94.18, p<.001. Post-hoc comparisons were undertaken using the Games-Howell tests as homogeneity between groups could not be assumed. The results of the post-hoc tests revealed the following:

- Those using medication only were older than those who did not use any substances (p<.001).
- Those who did not use any substances were older than those who used illicit drugs only (p=.004).
- Those who used a combination of substance types were older than those with an illegal BAC (p=.005) and those who used illicit drugs only (p<.001).

Table 3.6
Characteristics of participants in each substance use group

	Substance use group					
	None	Medication only	Alcohol (BAC <.05)	Alcohol (BAC >.05)	Illicit drugs	Combination
Age						
Range	16-93	17-95	26-62	16-83	16-61	17-88
M(SD)	39.95(17.31)	57.97(18.47)	43.40(13.67)	37.30(14.25)	33.85(11.82)	44.11(15.43)
Male	713	346	5	132	99	122
Female	301	222	-	27	18	39
Driver	400	335	1	65	69	89
Motorcyclist	266	102	3	27	35	30
Cyclist	284	76	1	33	8	14
Pedestrian	64	55	-	34	5	28

Comparisons of sex between substance use groups, excluding those with a BAC below .05, found significant differences $\chi^2(4)=49.60$, $p<.001$. These differences appear to be associated with greater than expected frequencies of males in the alcohol (BAC >.05), illicit drug, and combination substance use groups and fewer than expected males in the medication only group (again, see Table 3.6).

Participant descriptive characteristics for each of the substances used are provided in Table 3.7. Mean ISS scores typically ranged between 5 and 8 for most specific substance types but, among those substances with large samples, alcohol use with a BAC ≥ .05 and methamphetamine both had average ISS scores higher than the average, suggesting these may be associated with more serious injuries.

The frequency with which the various substances were identified for participants in each injury severity group is provided in Table 3.8. The most frequently used substances were cardiovascular drugs (12.6%), psychoactive drugs (12.1%) antihypertensives (9.3%) and alcohol use with a BAC ≥.05 (9.1%). Among the serious injury group, alcohol with a BAC ≥.05 was the most common substance (16.1%), followed by cardiovascular drugs (13.9%), and psychoactive drugs (10.2%).

The road user characteristics associated with different combinations of substances are shown in Table 3.9. Once the sample has been broken down to these small groups, statistical testing becomes difficult. Nonetheless, some potential trends are apparent. These include:

- Males being heavily represented among road users positive for multiple substance types
- A younger age among those whose combination of substance types included illicit drugs
- A high degree of injury severity for those combining an illegal BAC and illicit drugs
- A high representation of pedestrians among those combining an illegal BAC and medications.

Table 3.7
Substance type frequency and participant characteristics

	Sex		Age		ISS		Road user type			
Substance	Male	Female	Range	*M(SD)*	Range	*M(SD)*	Driver	Motorcyclist	Cyclist	Pedestrian
Antiarrhythmics	11	18	29-95	69.11(14.23)	1-19	7.67(5.38)	7	6	3	2
Anticoagulants	92	36	22-95	69.83(13.08)	0-29	7.45(7.19)	76	21	14	17
Anticonvulsants	36	15	19-73	44.29(16.05)	0-29	4.25(5.37)	34	3	8	6
Antihypertensives	182	90	29-95	64.77(13.81)	0-30	6.61(6.26)	167	39	35	31
Anti-inflammatory drugs	30	23	20-95	57.75(16.71)	0-17	5.02(5.03)	29	11	8	5
Antipsychotics	29	15	19-83	40.95(17.50)	0-29	7.41(8.33)	27	7	3	7
Anxiolytics	10	6	21-86	44.13(19.53)	0-17	6.25(6.69)	10	4	1	1
Benzodiazepines	36	17	19-89	51.32(19.49)	0-34	5.87(7.06)	38	4	7	4
Betablockers	38	16	26-95	65.24(14.53)	0-33	6.52(7.75)	36	7	5	6
Cardiovascular drugs	240	129	22-95	65.22(13.93)	0-33	6.75(6.69)	217	58	48	46
Dopamines	2	1	60-72	64.33(6.66)	5-21	15.67(9.24)	3	-	-	-
Drugs for diabetes control	95	22	20-92	58.22(16.36)	0-24	6.47(6.44)	70	26	10	11
Insulin	38	7	20-89	53.89(16.71)	0-21	6.09(6.30)	28	8	6	3
Non opiate analgesia	23	27	26-93	64.56(17.16)	0-21	4.98(5.11)	41	3	2	4
Non-SSRIs	17	14	19-86	51.00(16.97)	0-33	7.03(8.73)	20	5	1	5
NSAIDs	18	18	20-95	59.97(15.81)	0-17	4.42(4.19)	20	6	6	4
Opiates	43	22	19-90	48.68(17.60)	0-21	5.25(5.42)	45	11	3	6
Oral hypoglycaemics	71	19	20-92	59.78(15.66)	0-24	6.77(6.70)	55	20	7	8
Other medications	117	45	38-95	67.58(12.88)	0-26	6.44(6.17)	106	30	14	12
Psychoactive drugs	215	140	17-93	48.93(18.93)	0-34	6.34(6.61)	223	61	35	36
SSRIs	94	76	17-89	48.72(18.64)	0-33	6.41(5.84)	99	39	20	12
Steroidals	11	8	25-81	52.42(17.52)	0-17	5.68(5.66)	12	5	2	-
Vasodilators	4	2	58-84	71.67(12.23)	0-14	4.17(5.23)	4	-	1	1
BAC <.05	11	5	24-85	44.19(16.64)	1-33	10.38(9.19)	5	5	2	4

Table 3.7 (cont.)
Substance type frequency and participant characteristics

	Sex		Age		ISS		Road user type			
Substance	Male	Female	Range	*M(SD)*	Range	*M(SD)*	Driver	Motorcyclist	Cyclist	Pedestrian
BAC ≤.05	214	51	16-88	40.99(15.65)	0-38	9.09(8.86)	125	39	46	55
THC	85	18	16-58	35.00(12.58)	0-27	6.86(5.84)	51	36	9	7
Methamphetamine	97	24	17-61	35.69(10.47)	0-38	8.71(8.65)	82	25	5	9
MDMA	13	4	18-52	33.54(10.52)	1-17	7.94(5.54)	13	1	2	1

Note. Participants may have used more than one type of substance. SSRIs = Selective Serotonin Reuptake Inhibitors, NSAIDs = Non-steroidal anti-inflammatory drugs

Table 3.8
Frequency of substance use by injury group

	No Injury		Moderate injury		Serious injury		Total	
Substance	N	%	N	%	N	%	N	%
Antiarrhythics	-	-	16	0.77	2	0.62	18	0.61
Anticoagulants	19	5.60	90	4.35	19	5.88	128	4.37
Anticonvulsants	7	2.06	42	2.03	2	0.62	51	1.74
Antihypertensives	30	8.85	212	10.26	30	9.29	272	9.29
Antiinflammatory drugs	11	3.24	39	1.89	3	0.93	53	1.81
Antipsychotics	5	1.47	31	1.50	8	2.48	44	1.50
Anxiolitics	3	0.88	12	0.58	1	0.31	16	0.55
Benzodiazepines	6	1.77	43	2.08	4	1.24	53	1.81
Betablockers	11	3.24	35	1.69	8	2.48	54	1.84
Cardiovascular drugs	49	14.45	275	13.30	45	13.93	369	12.60
Dopamines	-	-	1	0.05	2	0.62	3	0.10
Drugs for diabetes control	21	6.19	80	3.87	16	4.95	117	3.99
Insulin	12	3.54	27	1.31	6	1.86	45	1.54
Non opiate analgesia	9	2.65	38	1.84	3	0.93	50	1.71
Non SSRIs	6	1.77	22	1.06	3	0.93	31	1.06
NSAIDs	6	1.77	29	1.40	1	0.31	36	1.23
Opiates	13	3.83	48	2.32	4	1.24	65	2.22
Oral hypoglycaemics	13	3.83	63	3.05	14	4.33	90	3.07
Other medications	23	6.78	119	5.76	20	6.19	162	5.53
Psychoactive drugs	42	12.39	280	13.55	33	10.22	355	12.12
SSRIs	16	4.72	141	6.82	13	4.02	170	5.80
Steroidals	5	1.47	13	0.63	1	0.31	19	0.65
Vasodilators	2	0.59	4	0.19	-	-	6	0.20
BAC <.05	-	-	14	0.68	2	0.62	16	0.55

Table 3.8 (cont.)
Frequency of substance use by injury group

	No Injury		Moderate injury		Serious injury		Total	
Substance	N	%	N	%	N	%	N	%
BAC ≤.05	16	4.72	197	9.53	52	16.10	265	9.05
THC	3	0.88	91	4.40	9	2.79	103	3.52
Meth	11	3.24	90	4.35	20	6.19	121	4.13
MDMA	-	-	15	0.73	2	0.62	17	0.58
Total	339	100	2067	100	323	100	2929	100

Note. Participants may have used more than one type of substance. SSRIs = Selective Serotonin Reuptake Inhibitors, NSAIDs = Non-steroidal anti-inflammatory drugs

Table 3.9
Descriptive statistics for participants by combination of substance use

	Medication, Illicit drugs & Alcohol (BAC >.05)	Medication & Illicit drugs	Medication & Alcohol (BAC <.05)	Medication & Alcohol (BAC >.05)	Illicit drugs & Alcohol (BAC <.05)	Illicit drugs & Alcohol (BAC >.05)
Sex						
Male	13	34	2	56	4	13
Female	4	10	2	17	3	3
Age						
Range	23-55	17-58	38-85	19-88	24-52	19-54
M(SD)	42.12(9.35)	38.16(11.21)	61(19.31)	50.82(16.17)	35.14(9.84)	31.63(10.57)
ISS						
Range	1-29	0-17	5-14	0-34	1-29	1-34
M(SD)	9.00(7.75)	5.95(5.22)	9.75(3.69)	8.14(8.36)	10.57(9.33)	11.13(8.40)
Injury group						
None	-	5	-	6	-	-
Moderate	15	37	4	54	6	12
Serious	2	2	-	13	1	4
						-
Road user						
Driver	12	25	1	37	3	11
Motorcyclist	2	16	1	8	1	2
Cyclist	2	-	-	11	1	-
Pedestrian	1	3	2	17	2	3

3.3.4 Substance use by crash type

Frequency of crash type by substance use group is shown in Table 3.10. Among participants who had consumed alcohol (BAC ≥.05), illicit drugs, or a combination of drugs, the most frequent crash type was hit fixed object: 28% for alcohol (BAC ≥.05), while illicit drug and combination groups were both 37%. The frequencies of hit fixed object crashes for the no substance use group (13.9%) and medication only group (16.0%) were considerably lower.

Table 3.10
Crash type of participants in each substance use group

	Substance use group													
	None		Medication only		Alcohol only (BAC <.05)		Alcohol only (BAC ≥.05)		Illicit only		Combination		Total	
Crash type	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Head on	60	5.92	29	5.11	-	-	9	5.66	11	9.40	6	3.73	115	5.68
Hit animal	13	1.28	2	0.35	-	-	1	0.63	-	-		0.00	16	0.79
Hit fixed object	141	13.91	91	16.02	-	-	45	28.30	44	37.61	60	37.27	381	18.82
Hit object on road	4	0.39	1	0.18	-	-	2	1.26	1	0.85		0.00	8	0.40
Hit parked vehicle	25	2.47	28	4.93	1	20.00	8	5.03	7	5.98	7	4.35	76	3.75
Hit pedestrian	53	5.23	45	7.92	-	-	20	12.58	5	4.27	16	9.94	139	6.87
Left road out of control	12	1.18	3	0.53	-	-	-	-	3	2.56	1	0.62	19	0.94
Other	4	0.39	3	0.53	-	-	1	0.63		0.00		0.00	8	0.40
Rear end	92	9.07	60	10.56	-	-	1	0.63	9	7.69	7	4.35	169	8.35
Right angle	160	15.78	110	19.37	1	20.00	3.00	1.89	13	11.11	8	4.97	295	14.58
Right turn	112	11.05	59	10.39	1	20.00	6	3.77	6	5.13	3	1.86	187	9.24
Roll over	123	12.13	48	8.45	1	20.00	16	10.06	8	6.84	13	8.07	209	10.33
Side swipe	56	5.52	27	4.75	1	20.00	8	5.03	3	2.56	7	4.35	102	5.04
Unknown/not reported	159	15.68	62	10.92	-	-	39	24.53	7	5.98	33	20.50	300	14.82
Total	1014	100	568	100	5	100	159	100	117	100	161	100	2024	100

3.3.5 Head, spine, burn and amputation injuries

Focusing only on the serious injury group (N=244), a more detailed investigation of AIS injury codes was undertaken to determine the extent to which the injuries sustained are of a nature that may involve substantial impact to quality of life. Of particular interest were injury types that qualify injured road users for the LSS: head, spine, burn, and amputation injuries. No cases of blindness were identified in the current sample.

A total of 153 head injuries were identified in the sample. In 75 cases, a head injury was the most serious injury coded. Of all head injuries, 51.6% involved a loss of consciousness. For cases in which the head injury was the most serious injury, a loss of consciousness was coded in 100% of cases. Around half (52%) of participants with a head injury had used at least one type of substance. Among these, medication was the most commonly used substance (22%) followed by alcohol with a BAC ≥.05 (16%).

A spinal injury was identified in 109 cases (44.6%). The spinal cord was compromised in seven cases, five of which involved some form of paraplegia, which was complete in four cases and incomplete in one. The injury descriptions are provided in Table 3.11. Among these, three cases were found to have no substance use while two had used medication only and two involved alcohol only, with a BAC ≥.05.

Table 3.11
Injury description of spinal injuries in which the spinal cord was compromised

Spinal injury description	N
ASIA A T4 complete T4 paraplegia	1
C4/C5 incomplete quadriplegia	1
Complete cord transection at T6/7	1
Complete T10 paraplegia ASIA 1	1
T12 burst fracture with spinal compromise	1
T4 tetraplegia secondary to C6/C7 fracture/dislocation	1
Unstable L1 fracture with spinal cord involvement	1
Total	7

Three cases of amputations were identified, one of which involved loss of the third finger, one amputation at the shoulder, and the other a near amputation above the knee. In each of these cases no substance use was reported.

Two cases were found to involve burn injuries. One involved full thickness burns to 6% of the body and the other involved burns in total of 38% of skin surface to face, arms, legs and feet. No substance use was recorded in either of these cases.

3.4 Summary

3.4.1 Injury severity

To summarise the results, greater injury severity appears to be more likely for road users with an illegal BAC, with some indication of a greater likelihood also for those testing positive for illicit drugs or positive for a combination of different substance types. When results for individual substances were examined, there appeared to be a higher likelihood of greater injury severity among those with an illegal BAC and those testing positive to methamphetamine.

3.4.2 Demographics

In regard to demographics of those using different substances, those using medications only tended to be older, while those positive for illicit drugs tended to be younger. Males were over-represented among serious injury crashes in general but also specifically among those with an illegal BAC, those testing positive for illicit drugs and those testing positive for a combination of substance types. Closer examination of cases in which substance types were combined suggested that younger people were more likely to combine illicit drugs with other substances, while pedestrians were over-represented among those with an illegal BAC combined with medications.

3.4.3 Crash types

In regard to crash type, hit fixed object crashes were common among those with an illegal BAC, those testing positive to illicit drugs and those testing positive to a combination of substance types. Such crashes are typically associated with the loss of vehicular control.

3.4.4 LSA type injuries

Head injuries and spinal injuries were more numerous than the other types of injuries covered by the LSA program (burns, amputations and blindness). Approximately half of the head injury cases tested positive to at least one substance. The most common of these were medications, followed by an illegal BAC (16%).

3.4.5 Final comment

Further discussion of these results is provided in Section 6.

4 Literature review: use of substances by those with serious injuries

The chief aim of this literature review was to ascertain levels of use of alcohol, illicit drugs and prescription medications ('substance use') following serious traumatic injury caused by road crashes. The nature of the injuries considered in this review incorporate a number of the injury types that qualify someone to receive support through the Lifetime Support Authority: brain injury, spinal injury, burns and amputations. Blindness is not included as there was little recent relevant literature on that topic.

Although the intended topic of the review was injury following road crashes specifically, many studies are, instead, focused on injury types regardless of the nature of the traumatic incident causing them. For this reason, literature was also reviewed for substance use following traumatic brain injury, spinal injury, burns and amputations, regardless of the causal traumatic event. It is apparent, in any case, that many of the injured people included in these injury type-based study samples had been involved in road crashes.

The review commences with a section on findings related to studies on transport related injuries specifically (Section 4.1), followed by a section concerned with recent studies of trauma patients in general (4.2). The remainder of the report is dedicated to separate sections on particular injury types: traumatic brain injury (4.3), spinal injury (4.4), burns (4.5) and amputations (4.6). A final section provides a summary and conclusions of the review, including a discussion on the likely generalisability of the findings to the participants in the LSA program (4.7).

4.1 General findings for transport related injuries

4.1.1 Introduction

Researchers are often interested in the overall outcomes for injured road users. By studying injured road users as a group, it is possible to measure the quantum of trauma caused by road crashes, determine the overall resources required for treatment and management of injured road users, and assess how the characteristics of road users affect outcomes. These characteristics of road users will include a number of factors that are relevant to this review: their prior substance use behaviour, their medication needs for pain management and other aspects of treatment, their mental health, and their substance use post-crash. How well an injured person recovers may be affected by all of these characteristics. Medical professionals therefore need to know the extent of such issues and how they may be treated.

4.1.2 Treating pain and medical conditions

Much of the research has been concerned with management of pain and mental health conditions. In regard to the latter, those seriously injured in road crashes are known to be at greater risk of conditions such as major depressive disorder, post-traumatic stress disorder (PTSD), and substance use disorders (Hruska, Irish, Pacella, Sledjeski & Delahanty, 2014; O'Donnell, Creamer, Pattison & Atkin, 2004), and these conditions are also known frequently to co-occur (Lee, Liverant, Lowmaster, Gradus & Sloane, 2014; Pietrzak, Goldstein, Southwick & Grant, 2011).

Mental health conditions such as those above can have effects on the use of medication. A study by Cody and Beck (2014) of female survivors of road crashes or domestic violence found that PTSD symptoms mediated the relationship between injury severity and the use of both pain medications and psychiatric medications. Among those who had been involved in road crashes (n = 315), approximately 75% were prescribed pain or psychiatric medications, or both (Cody & Beck, 2014).

4.1.3 Opioids

The use of opioids to treat pain has come into focus in recent research given the opioid crisis affecting the USA and, to a lesser extent, other countries such as Australia. One recent Victorian study looked at rates of disabling pain and mental health conditions at 12 months following either a transport or workplace injury (Nguyen et al., 2020). It was found that one third of the sample had disabling pain, one third had at least one mental health condition, and one fifth had both. A higher likelihood of having disabling pain at 12 months post-injury was associated with taking psychotropic medications after the first three months post-injury and taking opioids at 6-12 months. Similarly, a higher likelihood of having a mental health condition at 12 months post-injury was associated with taking opioids at 3-6 months and taking psychotropic medications at 6-12 months. The authors suggest that the findings indicate that medication use beyond the first three months post-injury aids in the identification of those who are more likely to develop disabling pain and poor mental health (Nguyen et al., 2020).

4.1.4 Anti-depressants

Another recent study examined the use of anti-depressants after road traffic injury (Berecki-Gisolf, Collie, Hassani-Mahmooei & McClure, 2015). Using a sample of 734 people with a compensable injury in Victoria, it was found that 17% used anti-depressants after the crash, while 12% had been using them prior to the crash, with 7.7% of the injured cohort commencing anti-depressant use following the crash. It was deduced that 45% of anti-depressant use among the sample could be attributed to the crash, while 55% was a continuation of pre-injury use. The authors argued that the study results highlight the importance of obtaining information about pre-injury health and medication use before interpreting post-injury health and medication use as being an outcome of that injury (Berecki-Gisolf et al., 2015).

4.1.5 Study by Giummarra et al. (2018)

Another recent large-scale study into mental health and pain following a road crash was undertaken in Victoria by Giummarra et al. (2018). This study involved examining the incidence, profile, and healthcare cost implications for people with a mental health condition or persistent pain or both, following a compensable transport injury. The population studied covered the years 2008 to 2013 and incorporated over 70,000 injured road users. Their medication usage and medical treatments, including allied health services, were followed for 24 months post-injury. It was found that 3.3% of injured road users were treated for a mental health condition and 6.3% suffered persistent pain. An interesting aspect of this study was that rates of mental health conditions and persistent pain were determined for different injury types. It was found that the rates of mental health conditions were higher for a number of the injury types covered by the LSA: 7.5% for spinal injuries, 4.3% for burns, 8.5% for amputations, 6.8% for mild acquired brain injury, and 55.6% for severe acquired brain injury. Similarly, rates of persistent pain were higher for a number of these conditions: 15.5% for spinal injuries, 14.9% for amputations, 9.4% for mild acquired brain injury, and 44.9% for severe acquired brain injury (the rate was 2.9% for burns). The authors noted that successful interventions include trauma-focused cognitive behavioural therapy and prolonged exposure therapy, while there are also benefits associated with the use of centralised case management and stepped care procedures, in which higher levels of intervention are provided for cases at risk of adverse outcome (Giummarra et al., 2018). Of particular relevance to this present review, the results of this study suggest that a number of injury types covered by the LSA, by virtue of having greater associations with mental health conditions and persistent pain, could result in greater use of medications and other substances.

4.2 General findings for trauma patients

4.2.1 Introduction

Although road traffic injuries are the focus of the work of the LSA, research findings related to trauma in general are of relevance to this review. Many of the issues faced by those who have suffered traumatic injuries, such as persistent pain, will be the same regardless of the cause of the trauma.

4.2.2 Substance use post-injury

A study by McFarlane, Browne, Bryant, O'Donnell, Silove, Creamer and Horsley (2009) examined the use of alcohol before and after sustaining a traumatic injury and how this related to symptoms of PTSD. Using a sample of 1,045 patients recruited from three hospitals in Australia, the study found that the emergence of alcohol abuse in the three months following the traumatic injury was predicted by PTSD symptoms, suggestive that this group were using alcohol to 'self-medicate'. Although the follow-up period was only three months, the authors noted that the threat posed by alcohol abuse to recovery from injury means that early intervention strategies focused on moderate alcohol use are needed among those with traumatic injuries (McFarlane et al., 2009).

Another study examined opioid abuse and illicit drug use among 500 patients in an interventional pain management practice in the USA (Manchikanti, Cash, Damron, Manchukonda, Pampati & McManus, 2006). Opioid abuse (obtaining opioids from sources other than the prescribing physician at the pain management centre) was found in 9% of patients, while 16% exhibited illicit drug use. Of particular relevance to the present review, opioid abuse (16%) and illicit drug use (24%) were more common among those who had suffered an injury in a road traffic crash. There was also a strong relationship between past substance use and substance use post-injury, with 51% of those who self-reported a past history of illicit drug use being current illicit drug users. The most commonly used non-opioid illicit drug was cannabis (11%), followed by cocaine (5%) and then methamphetamine (2%) (Manchikanti et al., 2006).

4.2.3 Medicinal cannabis

With the increasing availability of medicinal cannabis, especially in North America, a number of researchers have examined use of cannabinoids among those with traumatic injuries, as well as other conditions. Bruce, Brady, Foster and Shattell (2018) found through interviews with patients with a variety of chronic conditions (including spinal cord injury/disease) that medicinal cannabis is used as an alternative to using prescription medications, or as a complementary treatment with prescription medications, or as a means of tapering off prescription medications. Motives for reducing or eliminating prescription medications include concerns regarding toxicity, dependence and tolerance; and perceptions that medicinal cannabis has quicker and longer lasting effects (Bruce et al., 2018).

Despite this preference among some people for medicinal cannabis, Allan et al. (2018), in a review of prescribing guidelines, recommended limiting prescriptions of medicinal cannabis to restricted use only in a small subset of conditions for which there is some evidence of efficacy. Allan et al. (2018) argued that there was insufficient evidence for the use of medicinal cannabis in the treatment of acute pain but that there was some evidence for its value in treating neuropathic pain (pain caused by issues with the nervous system) if prescription analgesics have not produced optimal results.

4.2.4 Benzodiazepines

Another recent study considered the use of benzodiazepines for pain treatment (Wright, 2020). Wright noted that benzodiazepines are often prescribed to treat pain but found that there was limited evidence

for its efficacy beyond only a very small number of conditions. It was also noted that benzodiazepines are often used to treat anxiety disorders, including PTSD, a common condition among injured road users. Wright reported that benzodiazepines are chiefly useful for short term use in treating crisis anxiety.

4.3 Traumatic brain injury (TBI)

4.3.1 Introduction

Traumatic brain injury (TBI) is a leading cause of death and disability worldwide, especially among younger people, and road crashes are one of the most common causes of TBI (West, 2011). TBI is characterised by neurological dysfunction caused by a blow or penetrating injury to the brain. TBI severity ranges from mild (a brief loss of consciousness and transient neurological impairment followed by rapid recovery) to severe (involving an extended period of loss of consciousness) (Weil, Corrigan & Karelina, 2018). The high frequency of TBI, combined with the issue of substance use affecting an already damaged brain, means that TBI has been a major focus of studies on substance use and injuries.

4.3.2 Baseline substance use

One very common finding in the literature is that substance use, especially alcohol and illicit drugs, is commonly linked to the occurrence of TBI (Corrigan, 1995; Parry-Jones, Vaughan & Cox, 2006; Taylor, Kreutzer, Demm & Meade, 2003, Weil et al., 2018; West 2011). Weil et al (2018), in a review of alcohol and TBI, noted that rates of alcohol intoxication at the time of injury typically range between 30 and 50%, with higher rates for road crashes. West (2011) reported that rates of drug abuse predating a TBI range between 21 and 40% and that studies of drug intoxication at the time of the injury-causing incident have found that cannabis, cocaine and methamphetamine are the most common impairing drugs.

Being intoxicated at the time of the incident is known to have negative effects on the outcome of TBIs (Parry-Jones et al., 2006; West, 2011). West (2011) reported that alcohol intoxication at the time of injury is associated with increased injury severity and concomitant complications in the acute phase of the injury. Acute complications include sepsis, pneumonia and organ failure. It was further noted that alcohol and other drug use, abuse, and dependence “are associated with increased length of inpatient stay, increased severity and duration of patient agitation, lower scores on the Glasgow Coma Scale, increased brain tissue atrophy, poorer performance on a variety of neurocognitive assessments,” and “lower cognitive functioning at discharge…” (West, 2011, p4). A review by Corrigan (1995) found that the effects of alcohol intoxication included increased likelihood of intubation, respiratory distress, and development of pneumonia during acute hospitalisation; more neurological impairment at acute hospital discharge; longer acute hospital stays; and prolonged post-traumatic amnesia.

4.3.3 Substance use post-injury

In regard to a central issue for the present review, that of substance use or abuse following injury, the most common finding appears to be that substance use declines initially after injury but frequently increases again over time, often reaching pre-injury levels (Beaulieu-Bonneau, St-Ogne, Blackburn, Banville, Paradis-Giroux & Ouellet, 2018; Bjork & Grant, 2009; Graham & Cardon, 2008; Hawley, Ketchum, Morey, Collins & Charlifue, 2018; Olsen & Corrigan, 2022; Ponsford, Whelan-Goodinson & Bahar-Fuchs, 2007; Taylor et al., 2003;, Weil et al., 2018; West, 2011). For example, Ponsford et al. (2007) followed 121 TBI patients in Victoria, Australia, compared to 133 demographically matched controls. The two groups reported similar levels of drug and alcohol use prior to injury (31% for TBI patients, 29% for controls). Post-injury, substance use declined in the first year but had increased again

by the 2-year mark, with 25% drinking alcohol at hazardous levels. Only 9% of those with a TBI exhibited a drug problem but 24% had returned to drug use (Ponsford et al., 2007). A study in Canada by Beaulieu-Bonneau et al. (2018) of 225 people who had been hospitalised with a TBI found that the percentage of study participants using alcohol or drugs decreased in the first four months post-injury but had increased to pre-injury levels again by the end of the first year. Approximately 11% of the participants met the criteria for substance use disorder (Beaulieu-Bonneau et al., 2018). A study in the USA of 95 adults with TBI found that none of them abused drugs or alcohol in the first two years after being discharged from hospital. After 5 years, 25% of the sample had been found to experience substance abuse problems (Corrigan, Smith-Knapp & Granger, 1998).

One of the reasons postulated for the initial decrease in alcohol and drug use among those with a TBI is that some of the injured are too incapacitated to seek and consume alcohol or drugs, or that they are in institutional settings where access to alcohol and drugs is restricted (Taylor et al., 2003). An example of a study finding a relationship between TBI severity and substance use was that by Kreutzer, Witol, Sander, Cifu, Marwitz & Delmonico (1996), who followed 73 people with TBI in the USA and found that higher scores on the Disability Rating Scale were associated with lower alcohol consumption rates, suggesting that patients with greater levels of impairment were less likely to drink alcohol. In a study using a sample of military personal who had been discharged from the armed forces (Ommaya, Salazar, Dannenberg, Ommaya, Chervinsky & Schwab, 1996), it was found that those with mild TBI were 2.6 times more likely to be discharged for substance use, while those with a moderate TBI were 5.4 times more likely. There was no increase in the rate of discharge for this reason, however, among those with severe TBI. It is likely that this group was unable to use substances due to functional incapacity.

4.3.4 TBI leading to substance use

Although research has established high rates of substance use among those who have suffered a TBI, what is less clear is the extent to which those with TBI who did not previously use alcohol or drugs begin to do so post-injury. One issue is that many studies do not undertake follow-up data collection at a sufficient time post-injury to allow seriously injured patients to recover and begin substance use (Bjork & Grant, 2009). One study that did find evidence that TBI could actually cause substance use was conducted by Hibbard, Uysal, Kepler, Bogdany and Silver (1998). In their sample of 100 TBI patients in the USA, they found that those who had no pre-TBI disorders had elevated rates of major depression and substance use disorders compared to community controls. Studies have also shown that those with a history of TBI, including TBIs in childhood, are more likely to exhibit substance use or abuse (Adams, Corrigan, Ritter, Hagemeyer, Pliskin & Reif, 2021; Chan, Toccalino, Omar, Shah & Colantonio, 2022; Olsen & Corrigan, 2022; West, 2011).

Although the evidence of TBI causing substance use is not as strong as the evidence showing that those who suffer TBIs are more likely to be substance abusers in the first place, there are some possible mechanisms by which a causal link between TBI and the development of substance use could exist. These mechanisms, which are not mutually exclusive, include both psychosocial and neurochemical causes.

In a review of alcohol use and TBI, Weil, Corrigan and Karelina (2016) noted that psychosocial causes of alcohol use post-TBI could include self-medication to cope with a negative affective state, and peer pressure and a desire to relate to social groups via substance use. The negative affective states could include a natural reaction to impairment following injury, through to mental health conditions such as depression and PTSD. Jorge, Sarkstein, Arndt, Moser, Crespo-Facorro and Robinson (2005) noted that the relationship between mood disorders and alcohol abuse can be reciprocal, with alcohol-related brain changes producing dysphoria and mood disturbance which then perpetuate alcohol abuse.

Potential neurochemical causes include damage-associated neuroplasticity, chronic changes in neuroimmune signalling, TBI-associated alterations in brain networks, dysregulation of the dopamine system, and heightened inflammatory responses in the brain (Olsen & Corrigan, 2022; Weil et al., 2016). In regard to inflammation, it is known that it can have a bidirectional relationship with alcohol: alcohol is proinflammatory in the brain and inflammatory states drive alcohol consumption. Therefore, the inflammatory events associated with TBI could lead to increased alcohol intake (Weil et al., 2016).

Of particular relevance to the issue of substance use is the area of the brain damaged in TBI. Very commonly, TBI is associated with damage to the frontal lobes and anterior tips of the temporal lobes, as well as shearing and tearing of axon sheaths and neuron bundles connecting to the frontal lobes. As noted by Jorge et al. (2005, p747)), these structures "form part of the neural circuits that mediate critical aspects of addictive behaviour, such as stimulus salience attribution, reward expectation and response inhibition." Therefore, decision making and executive functioning processes can be disrupted by the brain lesions common in TBI, leading to reduced capacity to recognise the risks of substance use. Furthermore, many of those with a history of substance use (common in the TBI population) have reduced grey matter volumes in the frontal cortex, which also impairs decision making and reward mechanisms. The combination of this pre-existing problem and further damage from TBI increases the risk of substance use relapse in this population (Jorge et al., 2005).

There is also likely interaction between the neurochemical and psychosocial aspects of TBI-related substance use. For example, damage to the frontal lobes can interfere with inhibition of emotions and fear. Therefore, TBI can play a role in mental health conditions including mood disorders and PTSD. Self-medication of these conditions can then involve substance use (Jorge et al., 2005; Weil et al., 2016).

4.3.5 Risk factors for substance use for those with a TBI

A number of studies have looked at risk factors for substance use by those who have sustained a TBI. The most commonly reported risk factor for substance use by those with TBI is substance use prior to the TBI (Beaulieu-Bonneau et al., 2018; Jorge et al., 2005; Merkel, Cannella, Razmpour, Lutton, Raghupathi, Rawls & Ramirez, 2017; Parry-Jones et al., 2006; Ponsford et al., 2007). A study by Ponsford et al. (2007) in Victoria, Australia, for example, looked at pre- and post-injury drinking patterns among 121 TBI patients and 133 controls and found that the best predictors of post-injury alcohol consumption were age and pre-injury alcohol consumption. In an American study, Bombardier, Temkin, Machamer and Dikmen (2003) found that 44% of TBI patients who were heavy drinkers pre-injury returned to these alcohol consumption patterns post-injury, while this behaviour was exhibited by only 4% of pre-injury non-drinkers.

Other risk factors for substance use after TBI include the following:

- having sustained multiple previous TBIs (Merkel et al., 2017),
- intoxication at the time of sustaining the TBI, (Beaulieu-Bonneau et al., 2018, Kreutzer et al., 1996 Parry-Jones et al., 2006)
- being male, (Beaulieu-Bonneau et al., 2018; Bombardier et al., 2003; Ponsford et al., 2007)
- being younger, (Beaulieu-Bonneau et al., 2018; Bombardier et al., 2003; Ponsford et al., 2007)
- being single, (Beaulieu-Bonneau et al., 2018)
- being unemployed (Beaulieu-Bonneau et al., 2018), and
- having less education (Beaulieu-Bonneau et al., 2018; Jorge et al., 2005).

4.3.6 Outcomes

One of the concerns about substance use by those affected by TBI is that the use of substances will impede the person's recovery from the trauma and negatively affect their everyday health and functioning. As noted earlier, studies have shown, first of all, that intoxication at the time of the event causing the TBI often leads to worse outcomes. Use of alcohol and other substances post-injury has also been shown to have negative effects on outcomes. These negative effects of post-TBI substance use include direct effects on the brain as well as broader effects on the injured person's life. In regard to direct effects, West (2011) noted that chronic alcohol use causes brain tissue atrophy that in turn may complicate the existing TBI in terms of both physical impact, functional limitations and psychosocial sequelae. Weil et al. (2016), also discussing alcohol, noted that its use even at 'social levels' produces impairments in neuropsychological indices of executive functioning over and above the deficits of this type detected in TBI patients abstaining from alcohol. Chronic, sustained drinking or binge drinking has been linked to neuroinflammation, loos of neurons, demyelination (degeneration of the protective sheath surrounding nerve fibres in the brain) and significant impairment of cognition. This neurodegeneration also tends to be concentrated in the frontal and limbic structures of the brain that also tend to be already damaged in typical cases of TBI (Weil et al., 2016).

The direct effects of substance use on the damaged brain inevitably have negative effects on broader outcomes. These negative effects include:

- Reduced participation in, and efficacy of, rehabilitation (Weil et al., 2016; West, 2011)
- Increased chances of developing seizures (Taylor et al., 2003; Weil et al., 2016)
- Increased chances of developing mood or anxiety disorders (Jorge et al., 2005; Weil et al., 2016)
- Job loss or unemployment (Jorge et al., 2005; Taylor et al., 2003; Weil et al., 2016; West, 2011)
- Higher risk of arrest, aggressive behaviour, and suicide (West, 2011), and
- Greater likelihood of subsequent TBIs (Corrigan, 1995; Taylor et al., 2003; Weil et al., 2016).

Furthermore, substance use can interact with medications taken to treat residual complications of the TBI. Taylor et al. (2003) report that interactions between alcohol, illicit drugs and medications can lead to fainting, weakness, vision problems, hallucinations and fatigue, while the effectiveness of medications can also be reduced.

4.3.7 Opioids

The latter point regarding medications for TBI is pertinent given that TBI patients are often prescribed opioids to treat pain for headaches and other injuries (Corrigan & Adams, 2019). The addictive nature of opioids combined with the disruption to parts of the brain regulating executive functioning and decision-making processes means that those with TBI are at particular risk of opioid use disorder. In addition to the risk of addiction to opioids, there is a risk of future brain injury with opioid use. Overdoses suppress or stop respiration, leading to denial of oxygen to the brain and subsequent damage. This damage in turn leads to impaired cognitive functioning and emotional dysregulation. Additional TBIs can also occur if the person affected by opioid overdose loses consciousness and falls, leading to an injurious head impact (Corrigan & Adams, 2019).

4.3.8 Polypharmacy

Another issue related to medications and TBI is the risks of polypharmacy, which is the unintended prescription of multiple medications that could potentially have adverse reactions with each other

(Brown-Taylor, Jaramillo, Eapen, Kretzmer, Gavin, Cooper & Pugh, 2021). It is commonly defined as taking five or more prescription medications concurrently (Gupta, McColl, Smith & McColl, 2021). The risk of polypharmacy is particularly high when someone has a combination of TBI, PTSD and pain. Although clinical guidelines exist for treating each of these conditions on their own, that is not the case for the combination of all three. Many of the medications used to treat these conditions affect the functioning of the central nervous system and so the compounding side-effects of multiple medications can prolong recovery or result in adverse events (Brown-Taylor et al., 2021).

4.4 Spinal injury

4.4.1 Introduction

Spinal cord injury (SCI) causes a variety of issues for those afflicted by it, including various functional deficits and chronic pain. These, in turn, can affect quality of life and emotional well-being (Graupensberger, Corey, Turrisi & Evans, 2019). Pain is an especially common issue for those with SCI. A review by Van Gorp, Kessels, Joosten, van Kleef and Patijn (2015) found that the prevalence of SCI-related pain was 61%. The pain can be nociceptive (type of pain caused by damage to body tissue) or neuropathic (caused by damage to nerves). Pain can also be acute (occurring during the injury or immediate recovery period) or chronic (lasting for months or more) (Guan et al., 2021). Many of those with SCI suffer chronic neuropathic pain (Shah, Saklecha, Patel & Divi, 2022). As with TBI, there is research that examines use of substances such as alcohol and illicit drugs by those with SCI but there is also a considerable literature concerned with the use of medications to treat related conditions, especially chronic pain.

4.4.2 Baseline substance use

As with TBI, substance use is commonly reported at the time of the occurrence of the injury. A review by Tetrault and Courtois (2014) stated that 31 to 50% of SCI patients were intoxicated by alcohol at the time of the occurrence of the injury, while 16 to 33% were intoxicated by illicit drugs. They also cite one paper reporting that 26% were intoxicated by a ‘cocktail’ of alcohol and illicit drugs at the time of the injury-causing event (McKinley, Kalakowsky & Kreutzer, 1999).

4.4.3 Substance use post-injury

Also in common with TBI, substance use is commonly reported post-injury among those who have sustained an SCI. One recent study in the US on a sample of 4,577 people with SCI found that 24.1% self-reported use of a non-prescription psychoactive substance. The most common was cannabis (16.4%), followed by sedatives or sleeping pills (8.0%). Those who used cannabis were more likely to be male, younger, less educated, with lower income, and were fewer years post-SCI. Those using medications without prescription, on the other hand, were more likely to be female, older and to be more years post-SCI (DiPiro & Krause, 2022).

Saunders and Krause (2011) studied self-reported data from over 1,500 SCI patients in the US. It was found that 19.3% were heavy drinkers, with another 29.4% drinking at moderate levels. Those with a higher income or education were more likely to be heavy drinkers, as were those who scored higher on measures of impulsive sensation seeking, neuroticism-anxiety and aggression-hostility.

Tate, Forcheimer, Krause, Meade and Bombardier (2004), using self-reported data for over 3,000 SCI patients in the USA found that 17% of SCI patients met the criteria for alcohol abuse and dependence compared to 7.4% of the general population. They also found that 11% used illicit drugs or prescription medications for non-medical purposes. At-risk drinkers and substance users tended to younger, single, male and less educated. Notably, Tate et al. also reported that road crashes were a major cause of the

SCIs reported in their study, especially for those who were found to be at-risk drinkers (over 50% of their SCIs were due to road crashes). It was also found that those with alcohol use problems reported lower life satisfaction, prompting the authors to speculate that alcohol is often used as an avoidance coping mechanism by SCI patients (Tate et al., 2004).

Graupsenberger et al. (2019) compared the health records of a sample of over 6,000 SCI patients with over 1.45 million other patients in the US. It was found that those with SCI were more likely to have an alcohol use disorder (odds ratio 4.2), cannabis use disorder (OR 7.8), and opioid use disorder (OR 8.0). The authors note that those with SCI have greater than average levels of anxiety and depression, often suffer chronic pain and report lower levels of well-being. They suggested, after Saunders and Krause (2011), that greater substance use among SCI patients could be due to anxiety/depression, addiction to medication prescribed for initial treatment, dysfunctional coping methods, or sensation seeking (Graupsenberger et al., 2019).

4.4.4 Outcomes

Substance use has been nominated as a contributing factor to a number of negative outcomes for SCI patients. It has been linked to poor rehabilitation outcomes, longer lengths of hospital stays, decreased life satisfaction, depression, anxiety, impaired self-care, poor ratings of health, increased risk of seizures, pressure ulcers, urinary tract infection and re-injury (Tate et al., 2004). Cao, DiPiro, Li, Roesler and Krause (2020) specifically studied the risk of unintentional injuries among SCI patients across a 12-month period. They found that 23% of SCI patients sustained a non-intentional injury in that time. A greater likelihood of injury was associated with prescription medication use for pain or depression, non-medical medication use and binge drinking (Cao et al., 2020).

As post-injury substance use is often related to pre-injury substance use (e.g., Kolakowsky-Hayner, Gourley, Kreutzer, Marwitz, Meade & Cifu, 2002), there are also risks associated with long term substance use for SCI patients. Risks associated with a history of excessive alcohol use by SCI patients include higher mortality rates, deterioration after injury, brain abnormalities and a greater likelihood of suicide (Tate et al., 2004).

4.4.5 Medication

A major area of research regarding SCI patients is the use of medications to treat the various symptoms of SCI, including pain. Common medication types prescribed for those with SCI include anti-convulsants, anti-spasmodics, anti-depressants, analgesics, antibiotics (for urinary tract infection) and cannabinoids (Canavan, Inoue, McMahon, Doody, Blake & Fullen, 2022; Gupta et al., 2021). Of particular interest among the research community has been the use of opioids by SCI patients but studies have also been undertaken into cannabinoids and polypharmacy.

4.4.6 Opioids

Guan et al. (2021) undertook a study of 934 individuals with SCI in Canada. Analysis of the dispensing records of publicly funded opioids, they found 55% of those with SCI had received one or more opioid prescriptions in the year after their injury. Significant associations with opioid prescriptions included being male, having chronic obstructive pulmonary disease, using prescription opioids prior to the injury, and shorter hospital stays for the initial treatment of the injury.

DiPiro, Murday, Corley, DiPiro and Krause (2021) studied prescription records for over 500 people in the USA with chronic SCI. They found that 53.5% of those with SCI filled at least one opioid prescription during their second or third year after the injury. Of those who filled an opioid prescription, 23% had

high-risk fills (i.e., a high dose) and 38% had concurrent prescriptions for benzodiazepines, sedatives or hypnotics.

Hand, Krause and Simpson (2018) compared the opioid usage patterns of approximately 1,400 individuals with SCI in the USA with matched controls (matched for comorbidities, hospital admissions, age, sex and geographical region). Those with SCI were more likely to be long term users of low-dose, short acting opioids and were also more likely to be taking high doses of long-acting opioids. The latter was particularly the case for those with lumbar/sacral injuries rather than thoracic or cervical injuries.

The prescription of opioids for the treatment of SCI pain is problematic for a number of reasons. Complications or risks associated with opioids include reduced respiratory function (shortness of breath, difficulty coughing and breathing), impeded bowel function (constipation), increased risk of falls, increased risk of lower extremity fractures, impaired mobility, fatigue, potential dependence, and risk of overdose (DiPiro et al., 2021; Guan et al., 2021; Gupta et al., 2021; Hand et al., 2018). Hand et al. (2018) also reported that over 80% of patients with chronic pain misuse opioids, resulting in emergency department utilisation, in-hospital stays and increased health care costs. Furthermore, Krause, Cao and Clark (2017) found a link between opioid medication use and mortality among those with SCI. Based on a sample of approximately 2,500 individuals with SCI in the USA, it was found that those who used pain medication daily were over 50% more likely to have died by the end of the study period, while measures of pain intensity and pain interference were not statistically significant in the model. Possible explanations for this finding include the risk of overdose; that opioids suppress the immune system, leading to infections; harmful interactions with other medications; and respiratory depression among a population already at risk of mortality due to respiratory dysfunction (Krause et al., 2017).

The likelihood of adverse effects from opioids is related to strength of dose, duration of use, and type of opioid prescribed (short-acting or long-acting). Those on higher doses, using for a longer period of time, or using long-acting opioids are more likely demonstrate abuse or dependence, and are more likely have an unintentional overdose (Hand et al., 2018).

Although opioids are commonly prescribed for the pain associated with SCI, there is limited evidence for their efficacy. In fact, opioids are recommended only as a last resort (DiPiro et al., 2021; Gupta et al., 2021). Wong, Alexander, New, Delgado and Bryce (2019) conducted a survey of over 100 spinal cord physicians asking about their prescription of opioids and found that a third of them felt opioids were appropriate for the treatment of chronic SCI pain, and that around half of these did not think there should be an upper limit on the doses that can be prescribed. This contradicts the official guidelines of many countries, including Australia, which nominate an upper daily limit on opioid doses (Wong et al., 2019).

4.4.7 Alternative treatments for pain

Given the marginal efficacy of opioids and the risks associated with their use, it is desirable to find alternative treatments for SCI pain. Hand et al. (2021) noted that alternative approaches to opioid prescription for SCI include physiotherapy, posture/wheelchair adjustments, anti-spasmodics and antibiotics. Canavan et al. (2022), while noting that first line pharmacological treatments for SCI pain are anticonvulsants and antidepressants, additionally suggested cognitive behavioural therapy as a pain treatment. Cognitive behavioural therapy has been shown to improve function and mood, and to reduce pain intensity, pain-related disability and pain catastrophising in those with chronic SCI pain (Canavan et al., 2022). Guan et al. (2021), in noting that later opioid use was associated with a shorter duration of initial hospital stay and that those prescribed opioids participated less in inpatient rehabilitation, suggested that “a more fulsome course of inpatient treatment, or ensuring continuous rehabilitation treatment after discharge may be a better method to address pain and lead to less opioid use” (Guan et al., 2021, p6).

4.4.8 Polypharmacy

Another risk associated with pharmacological treatment of SCI, aside from the risks of opioid use specifically, is the risk of polypharmacy. It has been linked to a number of negative outcomes in SCI patients, including adverse drug events, falls, frailty, mobility issues and medication non-adherence (Gupta et al., 2021). Krause et al. (2017) also raised the possibility that the link they found between use of pain medication and mortality in SCI patients could be due to polypharmacy. A study by DiPiro et al. (2021) of approximately 500 individuals in the USA with SCI and chronic pain found that 38% of the study participants had concurrent prescriptions of opioids and other high-risk medications, such as benzodiazepines, sedatives and hypnotics. Gupta et al. (2021) studied 108 Canadians with SCI and found that 45% of them were prescribed more than five medications concurrently, with 35% of the participants being prescribed a combination of two or more analgesics, including opioids. They also noted that some participants were prescribed muscle relaxants for treatment of muscle spasms and cephalosporins for treatment of urinary tract infection, neither of which are recommended for those with SCI (Gupta et al., 2021). Cadel, Everall, Hitzig, Packer, Patel, Lofters and Guilcher (2019) reported that polypharmacy among those with SCI is associated with older age and higher severity of injury. Gupta et al. (2021) argued that, although multiple medications are frequently needed with complex conditions like SCI, practitioners should seek to avoid polypharmacy where possible through the use of alternative strategies based on physical activity, nutrition and lifestyle management.

4.4.9 Medicinal cannabis

In recent years, changes in legislation and expanding availability have led to increasing use of medicinal cannabis for a range of conditions, including SCI. Medicinal cannabis is reported by users to reduce SCI pain without some of the side-effects of other more traditional medications like opioids (Bourke, Catherwood, Nunnerley, Martin, Levack, Thompson & Acland, 2019; Stillman, Capron, Mallow, Ransom, Gustafson, Bell & Graves, 2019). Users additionally report that cannabis helps with spasms, sleeplessness and anxiety (Stillman et al., 2019). A few studies have examined prevalence of use of medicinal cannabis among those with SCI. A study in the USA by Cardenas and Jensen (2006) of 117 individuals with SCI found that 20% of them were current users of cannabis and reported high levels of pain relief from using it. In another USA study, Drossel, Forchheimer and Meade (2016) interviewed 244 individuals with SCI and neurogenic bowel and bladder, and found that approximately 23% were using cannabis for therapeutic purposes, with relief of pain nominated as a reason by 70% of them and relief of spasticity nominated by nearly half. A study of over 500 individuals with SCI in Denmark by Andresen, Biering-Sorenson, Hagen, Nielsen, Bach and Finnerup (2017) found a smaller percentage of current users of cannabis (9%), again reporting relief from pain and spasticity. Over three quarters of the cannabis users also used the drug prior to the injury and there was some overlap between current recreational and medicinal use.

Use of cannabis could be beneficial if it were to lead to reductions in the use of other pain medication, such as opioids, but research suggests that this tends not to be the case. Drossel et al. (2016), for example, found that 38% of cannabis users had an opioid prescription, compared to just 23% of non-cannabis users. Clark, Cao and Krause (2017), meanwhile, found that cannabis use was associated with an increased likelihood of pain medication abuse in SCI patients.

There has also been insufficient research to establish the clinical benefits of cannabis as a therapeutic tool for treatment of SCI. The optimal dosage, composition of compounds and methods of ingestion remain unknown and longitudinal studies are needed to understand the long-term outcomes of cannabis use by those with SCI (Shah et al., 2022). Drossel et al. (2016) argued that research is complicated by the fact that those who choose to use cannabis are often continuing pre-existing behaviours.

Drossel et al. (2016) also raised concerns that cannabis-using SCI patients may be more at risk of substance use disorders and social isolation. They argued that, given the possibility of adverse events from use of cannabis, clinicians need patients to disclose their patterns of medicinal cannabis use to allow for monitoring of adverse drug or drug interaction effects.

4.4.10 Comparing TBI and SCI

Finally, a small number of studies have compared substance use by those with TBI and SCI. Kolakowsky-Hayner et al. (2002) compared the substance use of 30 TBI patients and 30 age and sex-matched SCI patients in the USA. They found that 43% of those with TBI and 41% of those with SCI were moderate or heavy drinkers, above the general population estimates of 25%. Higher rates of drinking than the population were also evident in the pre-injury period. There were very few light drinkers in either group, however, with the majority abstaining from alcohol. The groups differed in terms of illicit drug use, with approximately one in five SCI patients using drugs in a one-year period compared to fewer than 5% of TBI patients (Kalokowsky-Hayner et al., 2002).

A more recent comparative study was conducted by Hawley et al. (2018), looking at cannabis use in Colorado, USA by 51 individuals with SCI and 65 with moderate to severe TBI. Cannabis was used prior to injury by 67% of SCI patients and 74% of TBI patients, while post-injury usage rates were 53% for SCI and 45% for TBI. The pre-injury usage rates among the sample were higher than the average for Colorado, which the authors attributed to the demographic profile (young, male) of those sustaining these injuries. Among those with SCI, the most common reasons given for cannabis use were reducing spasticity (70%), recreation (63%) and improving sleep (63%). For those with TBI, the reasons were recreational (72%), reducing stress/anxiety (62%) and improving sleep (55%). The authors concluded that SCI patients were more likely to use cannabis for medicinal purposes than the TBI group but cautioned that clinicians should be aware of the high cannabis use rates in both groups so that any effects on medical management of the patients can be monitored (Hawley et al., 2018).

4.5 Burns

4.5.1 Introduction

Burns are known to be one of the most painful forms of trauma (Kim, Pruskowski, Ainsworth, Linsenbardt, Rizzo & Cancio, 2019). Recent advances in treatment also mean that many who used to die from burn trauma now survive but do so with serious injuries accompanied by significant pain (Emery & Eitan, 2020). This means that, similarly to SCI discussed in the previous section, individuals with burns can have issues with analgesic medication like opioids as well as more general substance use.

4.5.2 Baseline substance use

Similar to other forms of trauma, burns are known to be associated with substance use or abuse. For example, a recent study in Spain by Eiroa-Orosa, Giannoni-Pastor, Fidel-Kinori and Arguello (2015) looked at the substance use of 243 burn patients. They were found to be above average compared to the general population in the use of opiates and traquilisers. The users of opiates and tranquilisers had similar profiles, being characterised by unemployment and low socio-economic status (Eiroa-Orosa et al., 2015). A study in Canada of 157 burn patients compared their health care utilisation rates to a group of age and sex-matched controls and found that burn patients had higher rates of both depression and substance use than the controls prior to the burn injury (Logsetty et al., 2016). A study in Sweden by Sveen and Oster (2015) found that 15 out of the 67 burns patients in the sample were impaired by alcohol at the time of the injury, with 10 of these 15 assessed as having an alcohol use disorder.

4.5.3 Complications

Use of substances at the time of the burn has been found to lead to greater complications during the acute care phase. A systematic review and meta-analysis by Klifto, Shetty, Slavin, Gurno, Seal, Asif and Hultman (2020) found substance use of various types to be linked to more operations, graft loss, longer length of ICU and hospital stays, days on a ventilator, intubation, wound infections and mortality.

4.5.4 Post-injury substance use

Many of the studies that have looked at substance use pre-injury have also looked at substance use post-injury. The study by Eiroa-Orosa et al. (2015) specifically examined whether substance use post-injury was related to levels of post-traumatic symptoms and could potentially be a means of self-medication. In a follow-up sample of 183 burn patients, there was some evidence that use of tobacco and use of alcohol were associated with various negative psychological symptoms, while use of cannabis was found to be associated with avoidance, suggesting its use as a coping strategy (Eiroa-Orosa et al., 2015). Logsetty et al. (2016) found that rates of mental health conditions and substance use post-burn injury were not statistically significantly different from pre-injury rates. Compared to controls, rates of substance use disorder were 4.6 times higher among the burn patients but this higher rate was not significantly greater than the relative rate of substance use disorder that already existed pre-burn (2.6) (Logsetty et al., 2016). The study by Sveen and Oster (2015) found that 17 of the 67 burn patients exhibited at-risk drinking behaviours 2-7 years after the burn injury. The best predictor of at-risk drinking was answering yes to the Coping with Burns questionnaire item, “I use alcohol, tobacco or other drugs to be able to handle my problems” (Sveen & Oster, 2015).

4.5.5 Negative outcomes

Substance use has been found to result in negative outcomes for those with burn injuries, although the literature and evidence is not as extensive as for SCI or TBI. Smolle, Hutter and Kamolz (2022) noted that research has shown substance use to result in prolonged and less successful rehabilitation. A review by Spronk, Legemate, Dokter, van Loey, van Baar and Pollinder (2018) of all factors affecting health-related quality of life among burn survivors found that poorer quality of life was predicted by substance use disorders, although not as strongly as by a number of other factors such as burn severity, depression and PTSD.

4.5.6 Opioids for pain management

The most salient issue for burn injuries in regard to substance use is the use of opioids to manage pain. Kim et al. (2019, p983) note that the intense pain that often accompanies burns requires a ‘robust’ analgesic regimen and that the ‘analgesics of choice’ for treating burns are opioids. Emery and Eitan (2020) report that burns patients are frequently prescribed opioids in doses and for durations that are significantly higher and longer than standard analgesic dosing guidelines. Yenikomshian, Curtis, Carrougher, Qiu, Gibran and Mandell (2019) note that, even once a burn wound has ‘healed’, pain treatment remains necessary. These authors conducted a study of 366 burns patients in the USA who were prescribed opioids at discharge from hospital. Most of the patients had ceased using opioid prescriptions by 30 days post-discharge. Longer term use of opioids (up to 90 days) was associated with higher doses prescribed at discharge and self-reported pre-injury alcohol and drug use. However, no predictive factors could be identified for the 10% of patients still being prescribed opioids after a year post-injury (Yenikomshian et al., 2019).

Despite the common use of opioids, many burns patients continue to experience considerable pain. Emery and Eitan (2020) explain that opioids can vary markedly in their effectiveness for treating burns-

related pain and that research is needed to identify the opioids that are most effective for this condition. Long term opioid use can lead to dependence among burn patients (Emery & Eitan, 2020, Duchin et al., 2021) as well as tolerance, hyperalgesia and various side effects such as constipation (Kim et al., 2019), A study by Duchin et al. (2021) based on interviews with burn patients found that inpatients were interested in getting information about the side effects of their pain medication and information about addiction, while a third expressed interest in information about stopping pain medication. Among outpatients, a quarter were interested in alternatives to pain medicines (Duchin et al., 2021).

4.5.7 Non-pharmacological pain treatment

Given all of this, there is a need to identify effective non-pharmacological treatments for burn pain. Kim et al. (2019), partly in response to the USA opioid crisis, reviewed adjunctive therapies for burn pain. The types of pain for which therapies were sought included background pain (therapies included ketamine, methadone, ibuprofen, propranolol, cooling, low frequency ultrasound, music, massage, aromatherapy, extracorporeal shock wave therapy, and hypnosis), neuropathic pain (therapies included gabapentin, pregabalin, transcranial direct current stimulation, electroacupuncture, and laser therapy), and procedural pain (therapies included dexmedetomidine, ketamine, intravenous lidocaine, nitrous oxide, methoxyflurane, music, whole body vibration, jaw relaxation, hypnosis, virtual reality, interactive gaming console, and transcranial direct current stimulation). Interestingly, many of these treatments were found to lead to decreases in reported pain levels. However, only one randomised controlled trial on music therapy for acute background pain showed a reduction in opioid use, while only one cohort study on hypnosis demonstrated reduced opioid use compared to historical controls. The authors attributed the rarity of an effect on opioid use to a number of factors: (a) the common practice of premedicating patients in anticipation of procedural pain, (b) the lack of statistical power to demonstrate a reduction in opioid use, and (c) some investigators may have maintained constant levels of opioid use so that any differences in pain severity could be attributed solely to the effects of the adjunctive therapy (Kim et al., 2019).

4.6 Amputations

4.6.1 Introduction

Traumatic amputations cause a sudden loss of independence in addition to issues related to pain management and psychological trauma. Baby, Chaudhury and Walia (2018) studied 100 soldiers with new amputations and found that 66% had psychiatric disorders, including adjustment disorder, depressive episode and PTSD. Psychiatric morbidity was associated with negative body image, distressing pain and restriction of activities of daily life (Baby et al., 2018). As reported in Section 4.1.5, those sustaining amputations in road crashes have also been found in an Australian study to have higher levels of mental health conditions and persistent pain (Giummarra et al., 2018). It can therefore be expected that amputees are a group who will potentially have issues with substance use as well as having to negotiate the risks of pain medication.

4.6.2 Post-amputation substance use

Yepson, Mazzone, Eskridge, Shannon, Awodele, Farrokhi & Mazzone (2020) conducted a study of 681 US army personnel discharged with lower limp amputation and found that, in the first three months post-injury, the proportion using tobacco increased from 30.0. to 55.7%, while the proportion using alcohol increased from 32.8% to 72.0%. The authors postulated that this substance use was a coping mechanism for many of the amputees. Additionally, it was suggested that tobacco and alcohol use may represent a form of social engagement with peers that is not based around physical activities (Yepson et al., 2020).

4.6.3 Post-amputation medication use

Melcer, Walker, Sazon, Domasing, Perez, Bhatnagar & Garlarneau (2020) also looked at US army personnel (n = 381) who had suffered serious combat injuries, including amputations (n = 123). Based on the first year post-injury, higher counts of individual and multiple medication prescriptions were associated with higher injury severity, limb amputation (especially bilateral amputation), and diagnoses of chronic pain and PTSD. For those with bilateral amputations, greater than average use beyond the first three months post-injury was found for opioids (62% versus an average of 34%), central nervous system medications (56% versus 32%), psychotherapeutic medications (40% versus 24%), nonopioid analgesics (30% versus 14%), and immunologic medications (18% versus 12%). Those with bilateral amputation also had the highest rate among all injury groups of prescriptions for a combination of opioids, CNS medications, and psychotherapeutic medications (32% versus 13%) (Melcer et al., 2020).

Park, Liston, Samuel, Forester and DeGeorge (2022) examined opioid use in 2247 amputees in the USA. It was found that 54.7% used opioids in the perioperative period, with 44.6% exhibiting prolonged opioid use. Predictors of prolonged opioid use included chronic pain, migraines, lower back pain, greater levels of comorbidity, and pre-operative use of benzodiazepines, muscle relaxants, anticonvulsants, and anti-depressants. The average doses of opioids being used by those in the prolonged use period were greater than those in perioperative periods, suggesting reliance on opioids for ongoing pain (Park et al., 2022). As this study was on those with lower limb amputations in general, many of those in the sample had amputations due to conditions like diabetes rather than due to trauma, so the applicability of its findings to the LSA cohort is unclear.

4.7 Summary and conclusions

4.7.1 General findings

The aim of this literature review was to examine the use of substances by those who have sustained traumatic injuries in road crashes, with an emphasis on the types of injuries that qualify people for the LSS. Studies on trauma patients who have been involved in road crashes reveal that medications are often necessary for the treatment of mental health conditions (e.g., PTSD) and persistent pain. Furthermore, it has been reported that mental health conditions and pain are more common among those who have sustained injuries of the types covered by the LSA (e.g., burns). Studies of trauma patients in general, whose injuries did not necessarily occur due to a road crash, reveal that many of those who use substances post-injury previously used those substances pre-injury, so the post-injury substance use is a continuation of pre-existing patterns of behaviour. Research also shows that trauma patients are often prescribed medications for conditions for which the medications are not effective.

The bulk of the research that has been undertaken in this area has not been on trauma patients in general but has focused on particular injury types. Below is a brief summary of findings for various types of injuries that qualify injured road users for the LSS. Note that the studies on which the review was based often covered a range of severity within the injury type and not necessarily the more serious end, which the LSS covers. Caution is therefore necessary in generalising these findings to participants in the LSS.

4.7.2 Traumatic brain injury

Traumatic brain injury (TBI) is a leading cause of death and disability worldwide, especially among younger people, and road crashes are one of the most common causes of TBI. The high frequency of TBI, combined with the issue of substance use affecting an already damaged brain, means that TBI has

been a major focus of studies on substance use and injuries. Some of the main findings of the review were as follows:

- The occurrence of TBI is often linked to alcohol and drug intoxication. Intoxication at the time of sustaining the TBI is often linked to poor outcomes.
- Levels of substance use initially decline post-injury but tend to return to pre-injury levels over time. The initial reduction in substance use is due to functional incapacity and/or inability to access alcohol or drugs.
- Those with a history of TBI are more likely to use substances.
- Whilst the evidence that substance users sustain TBIs is stronger than the evidence for TBIs leading to substance use, there are mechanisms by which this could occur. These include psychosocial causes (self-medication, relating to social groups) and neurochemical causes (e.g., inflammatory responses in the brain to TBI driving alcohol consumption). Damage to the frontal and temporal lobes (common with TBI) also affects decision making and reward mechanisms, which could lead to substance use
- There are a number of risk factors for post-injury substance use; the major one is pre-injury substance use.
- Substance use post-TBI has a negative effect on outcomes. These include direct effects (further damage to the brain) and indirect effects (e.g., reduced participation in rehabilitation; mood and anxiety disorders).
- Opioids are frequently prescribed to treat those with TBI. This can lead to the development of opioid use disorders, especially for those with a damaged frontal lobe. Opioids also pose a risk of additional TBIs.
- There is also a risk of polypharmacy among those with TBI (the prescription of multiple medications which can have adverse reactions with each other), especially for those who also have PTSD and persistent pain.

4.7.3 Spinal cord injury

Spinal cord injury, like TBI, has been the subject of much research in regard to substance use. A particular focus has been on the management of chronic neuropathic pain, with opioids commonly prescribed to treat this. Some of the main findings of the review were as follows:

- Similar to TBI, substance use is a common contributor to the event causing the injury.
- Substance use post-injury is common, often as a means of self-medication.
- Substance use post-injury often leads to negative outcomes.
- SCI is treated with a variety of prescription medications, including opioids. Opioids pose a number of risks for SCI patients and their use has been linked to greater mortality. Greater risks are associated with large doses of opioids, a longer duration of use, and with certain types of opioids (long-acting). Opioids actually have a low level of efficacy for SCI pain and there are various alternative therapies that are available.
- Polypharmacy is common with SCI and comes with a variety of risks.
- Some SCI patients use medicinal cannabis. Its effectiveness is unclear and it does not lead to a reduction in opioid use.
- Comparisons between those with TBI and those with SCI have revealed that, while both groups are associated with high levels of alcohol use pre- and post-injury, illicit drug use is higher among

SCI patients. Among those who use cannabis, SCI patients report using it for medicinal reasons more than TBI patients do.

4.7.4 Burns

Burns are known to be one of the most painful forms of trauma and so, again, pain medication is a key issue for treatment. This, again, frequently involves opioids. Some of the main findings of the review were as follows:

- As with both TBI and SCI, substance use at the time of sustaining the injury is common. Being intoxicated at the time of the burn is associated with worse outcomes.
- Post-burn substance use, for some, is a coping strategy.
- Substance use post-injury is linked to worse outcomes, although this has not been studied as much as TBI or SCI.
- Opioids are a common medication used for treatment, although long term use has various risks, including dependence.
- A review of adjunctive therapies found that many of them were effective for reducing pain but there was little evidence of a reduction in opioid use.

4.7.5 Amputations

Amputations often involve a loss of independence in addition to pain and psychological trauma, so there is a clear risk of substance use disorders developing for this group. There has been comparatively little recent research on amputations and substance use in recent years. Much of what has been done has been focused on military personnel. Nonetheless, findings indicate that substance use can be a coping strategy for those with amputations, as well as a means of social engagement that does not require physical activity. Those with amputations are frequently prescribed a large number of medications, especially those with bilateral amputations, who had the highest rates of drug prescriptions among the those with combat injuries.

4.7.6 Limitations of the literature

Some limitations of the literature summarised in this review need to be pointed out. These are as follows:

A majority of the literature was based on studies in the US. The US has a very different health system to Australia and a different profile of substance use in general. Much of the recent US research has been focused on opioid use by those with ongoing pain following their injury, which is an important topic of study, but which has also been prompted by the opioid crisis that has caused huge numbers of deaths in the US over the past decade. There is likely to be some limitation in the extent to which US studies can be generalisable to Australia, although opioid deaths are also an issue here, with an average of over 1,000 opioid-related deaths per annum from 2001 to 2018 (National Coronial Information System, 2021).

The studies often involved examination of prescription databases. Databases of prescriptions will not detect use of over-the-counter medications or medications obtained outside of legitimate medical channels. They will also not detect use of illicit substances. Furthermore, just because someone is prescribed a drug, does not mean that they necessarily take it. Many studies, particularly those concerned with illicit drug use, were based on self-reported data. These data can be affected by a number of biases that may affect the accuracy of the results.

Finally, the severity of injuries would have varied considerably, not only from study to study, but also within studies. The injury severity levels of the LSS participants are at the higher end and so generalising from the various findings of this review to LSS participants may be problematic.

4.7.7 Overall summary

The limitations notwithstanding, there are some general conclusions that can be drawn from the literature in regard to substance use and serious injury. These are as follows:

- Injuries such as those covered by the LSA are frequently sustained while people are intoxicated. This applies to road crashes as well as other injury-causing incidents. Intoxication at the time of the injury is linked to worse outcomes. Pre-injury substance use is also predictive of post-injury substance use, and the latter is also linked to worse outcomes. These findings are likely to apply to LSS participants.
- Substance use, beyond prescribed medication, reduces for a period after a serious injury is sustained but tends to increase again to pre-injury levels as the injured person regains functional capability and independence. This is likely the case among LSS participants to the extent that such recovery has occurred. Substance use, post-injury, is often linked to worse outcomes.
- A major issue for many of the injury types covered by the LSA is pain management. Opioids are frequently prescribed to treat pain, including chronic pain. This can lead to opioid dependence and other negative outcomes. For many types of pain (e.g., neuropathic pain associated with SCI), other medication types are likely to be more effective than opioids. Various adjunctive therapies are also available that have been shown to reduce pain but evidence is needed that they can also lead to reductions in the use of opioids.
- Medicinal cannabis is used by many people to treat various symptoms that follow traumatic injury. There is currently insufficient evidence of its clinical benefits and of its long-term effects. Furthermore, the evidence suggests it does not lead to a reduction in use of prescription opioids among those with chronic pain and that many who use it are continuing with pre-injury patterns of substance use. Clinicians need patients to disclose their patterns of medicinal cannabis use to allow for monitoring of adverse drug or drug interaction effects.
- Those with complex issues such as those with the injury types covered by the LSA are often prescribed a number of different medications. This leads to the potential for polypharmacy - the unintended prescription of multiple medications that could have adverse reactions with each other. Although multiple medications are frequently needed with complex conditions, practitioners should seek to avoid polypharmacy where possible through the use of alternative strategies based on physical activity, nutrition and lifestyle management.

Finally, for various reasons, there are potential limits to the generalisability of the literature to participants in the LSS. For a clearer picture on post-injury substance use among those seriously injured in road crashes, a study of the participants in the LSS would be ideal. If this is not possible, other potential studies can be done to give some indication of likely substance abuse and the factors associated with it. The next section describes a couple of these potential studies.

5 Potential studies of post-injury substance use among seriously injured South Australian road users

There is currently a knowledge gap in regard to the use of substances by injured road users who are participants in the LSS. The preceding literature review (Section 4) provides some indication of the possible substance use issues that may be affecting this group but only a study of the LSS participants themselves will provide definitive evidence. As this may not be possible, another means of investigating this issue among seriously injured road users in South Australia is desirable. This section provides a brief description of two potential methods for examining post-injury substance use and the factors associated with it among samples of injured South Australian road users.

The two potential methodologies both involve interviews with injured road users but with samples recruited from different sources. One involves interviewing crash participants involved in road crashes that have been investigated as part of CASR's in-depth at-scene crash investigation study. The other involves interviewing crash participants who have been admitted to the Royal Adelaide Hospital. These two potential studies are described below, along with an assessment of their feasibility, in Sections 5.3 and 5.4. Prior to that, Section 5.1 discusses the topics to be covered in interviews, Section 5.2 outlines the ideal timing of interviews in relation to the road crash, and Section 5.3 provides a discussion of the issue of injury severity and its implications for recruiting samples of injured road users who are representative of the LSS participants.

5.1 Interview topics

As noted above, each of the proposed methodologies involve interviewing individuals who have sustained serious injuries following involvement in a road crash on the South Australian road network. Whichever methodology is chosen, a similar set of research questions will be used to explore themes related to substance use that will include, but not be limited to, the following:

- Type of substances used pre- and post-crash (alcohol, illicit drugs and prescription medications)
  - Quantification of substance use through a standardised measure
  - Purpose of substance use (recreational, pain relief, trauma, aid to sleep, anti-anxiety, GP prescribed etc)
  - Time of first use – pre- or post-crash/exacerbated by crash
  - Self-perceptions regarding aiding or inhibiting recovery from injuries sustained in crash
  - Professional involvement/support regarding substance use; desire for such support
  - Ever having been told that they have a substance use problem; beliefs/perceptions related to this
- Status of injury/prognosis
- Experiences of pain and pain management
- Therapeutic/professional care pre/post-crash
- Driving behaviours/adjustments to driving post-crash – substance or injury-related
- Views on licensing decisions (if revoked or conditions on licence); alternative support for mobility/transport
- Legal involvement/compensation status (research indicates that this can impact recovery)
- Assess for confounding variables which may account for changes in substance use:

- Any adverse life events since crash, such as exposure to trauma, employment changes, financial problems, significant relationship difficulties, self-perceived loneliness, social supports
- medical conditions (mental and physical); pre/post mental health status
- physical activity status

5.2 Timing of interviews

An important consideration for interviewing those involved in road crashes to assess levels of substance use is the choice of timelines for the interviews. Although the logistics of organising interviews introduces variability in the extent to which desired timelines can be followed, there are certain time points when it is ideal to speak to road users about their substance use.

5.2.1 Baseline

Currently, as part of the in-depth crash investigation (see Section 5.4 below), researchers aim to undertake a first interview with participants approximately five weeks post-crash but, in practice, it can take a lot longer to contact participants and to organise a mutually suitable time. To gain a comprehensive understanding of post-crash substance use related to potential changes following involvement in a crash, it would be ideal to compare pre-crash functioning and substance use at some point before it becomes harder for participants to recall. This would enhance insight related to any trends in exacerbation or commencement of substance use on account of involvement in a road crash. This interview would be undertaken as soon as practicable post-crash, to determine functioning and substance use just prior to the crash (specifically asking the participant to recall the two weeks leading up to the crash, but before the crash happened), and any immediate changes to this since the crash. Importantly, this needs to be carefully balanced by the seriously injured individuals' capacity to voluntarily engage with the interview process; this, for some, may not be possible until the three-month interview.

5.2.2 Three months post-crash

An interview conducted three months post-crash would form an important point of contact to monitor any immediate changes to substance use following the crash (as noted in Section 4, substance use often declines or stops after sustaining a serious injury and will then later revert to pre-injury usage levels). This interview would be used to determine if substance use is the same or different to pre-crash use, or whether it has developed or been exacerbated post-injury. If participants were unable to be contacted or participate in the five-week baseline interview, the three-month interview would be used to establish baseline measures for future interviews.

5.2.3 24 months post-crash

The advantage of a 24-month post-crash interview is that is gives an indication of substance use once the acute phase of any injuries sustained in the crash have passed. It is also sufficient time for participants to return to baseline levels of substance use should this be going to happen. One issue with interviewing people after a two-year time period is the possibility of loss of contact. In an attempt to combat natural attrition resulting from people relocating, at the initial point of contact the information sheet would advise potential participants how to update their contact details should they relocate prior to the study follow-up, which may secure CASR contact with those interested in continuing the study. Memory degradation is not likely to be a major issue, as participants will be asked to discuss their current substance use, and to reflect on their perceptions as to whether this has changed over the past 24 months only. CASR researchers have previously successfully contacted an older population (70 years

+) of active crash participants at a point 3-5 years after their crash involvement and hospitalisation, with a 57% response rate (Baldock, Thompson, Dutschke, Kloeden, Lindsay & Woolley, 2016). Hence, if the LSA were interested in a longer follow-up period, this could be extended further, dependent on the scope of interest.

Ideally the interviewer at follow-up interviews would be blind to baseline interview responses and as such would not be aware of the substance use profile of participants so as not to bias interview questions and data gathering.

5.3 Injury severity

Another important consideration for any study looking at injured road users for the LSA is the degree to which the results could be generalised to those qualifying for the LSS. The key issue here is the severity of the injuries of the group being studied. The LSS participants have necessarily sustained severe injuries and so, for a study sample to be generalisable to the LSS participants, their average injury severity also needs to be at the more serious end of the distribution.

Injury severity has been defined in multiple ways in the research literature, with one of the most common means being use of the Abbreviated Injury Scale (AIS), which was developed by the Association for the Advancement of Automotive Medicine and last updated in 2015. As noted in Section 3, AIS scores, which are applied to various body regions, can be converted to Injury Severity Scores (ISS), which provide an indication of overall injury severity. An ISS score of 15 or greater is typically taken as an indicator of 'major trauma' (Palmer, 2007). If this were chosen as the basis for sample selection, this would have an impact on the rate of study participant recruitment, as such major trauma is a small percentage of all road crash injury cases.

Another option for study participant selection is to set the minimum injury criterion as 'admitted to hospital'. For those road users who were admitted to hospital you would expect a greater likelihood of a serious injury, but the majority of these will not meet the eligibility criteria of LSS participants. Ideally an ISS of 15 or greater would be the gold standard for recruitment of the intended population.

5.4 In-depth crash investigation interviews

CASR runs a program of in-depth at-scene crash investigation, which involves specialist teams attending the scenes of South Australian road crashes and collecting detailed information about the circumstances of the crash, including details about the vehicles, the road and environment, and the people involved in the crash. Approximately 50 crashes are investigated in this way each year. The criterion for a crash to be included in the study is the transport to hospital of at least one individual, who may have been active (e.g., driver) or non-active (e.g., passenger) in the crash. Follow-up work includes collection of police reports, Coroners files if fatal, licensing records, results of drug and alcohol tests, and medical notes for anyone attending a hospital. This information can all be collected without having to obtain consent from the crash participants as CASR is listed as an authorised research group in the *SA Health Care Act 2008*. In addition to this information, CASR invites all active participants (riders, drivers and pedestrians, including those who are not injured) to be interviewed to obtain their account of the crash and detailed background information (e.g., questions about health, licensing history etc). As part of this, crash participants are asked about substance use pre- and post-crash. Currently, these interviews usually take place within a few months of the crash but without any longer-term follow-up. The proposed study would capitalise on this dataset with ethics approval sought to recontact interview participants at proposed follow-up points to further explore substance use in this population.

In the current interviewing process, potential interview participants receive an introductory letter with an information sheet and consent form in the post approximately four weeks after the crash, informing them

about the interview component of the study and notifying them that they will receive a follow-up phone call to seek their decision regarding interview participation. Potential interview participants for whom CASR does not have a phone number are sent a letter inviting them to contact CASR if they would like to be involved. Letters are also sent to participants who have been involved in crashes in which a road user has been fatally injured, seeking their willingness to contact CASR should they like to participate in an interview. Approximately 47% of active participants agree to an interview (with many of the non-interviewed participants unable to be contacted, i.e., not answering the phone).

With regard to recruitment time required for participants of interest to the LSA, Table 1 presents the data for injury severity differentiated by both injury severity score (ISS) and hospital attendance status. Analysis of injury severity data collected by CASR's in-depth program to date indicates that a significant amount of time would be required to recruit even a very small sample of participants who were seriously injured with an ISS of 15 or greater. For instance, Table 1 reveals that, of the 608 participants (aged between 15 years and 97 years) involved in road crashes and investigated by CASR over the 5-year period between 2015 and 2019, only 10 individuals had an ISS of 15 or over (14 individuals with an ISS greater than 15 were fatally injured and thus excluded from the analysis). Given CASR's approximate 47% response rate for interviews with active participants, we could expect almost half of the participants invited not to consent to participate, or to be unable to contacted at follow-up.

Therefore, to undertake a study of post-crash substance use with individuals with an ISS of 15 or greater, it would take approximately 5 years to obtain interviews with approximately 5 participants. It is possible that this is an underrepresentation and that individuals with an ISS in the 1-14 range could meet eligibility criteria for the LSS but this is an unknown quantity.

Table 5.1
Prevalence and type of injuries sustained by drivers, riders, passengers and pedestrians in South Australian road crashes investigated at the scene by CASR, by year of crash

Injury severity	2015 (N=107)		2016 (N=107)		2017 (N=118)		2018 (N=138)		2019 (N=138)		Total* (N=608)	
	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%
ISS score												
ISS = 0	11	10.3%	15	14.0%	19	16.1%	17	12.3%	20	14.5%	82	13.5%
ISS = 1-14	23	21.5%	25	23.4%	27	22.9%	34	24.6%	22	15.9%	131	21.5%
ISS = 15+	3	2.8%	2	1.9%	1	0.8%	2	1.4%	2	1.4%	10	1.6%
No ISS (minor/no injury)	48	44.9%	43	40.2%	62	52.5%	69	50.0%	70	50.7%	292	48.0%
Unknown ISS	22	20.6%	22	20.6%	9	7.6%	16	11.6%	24	17.4%	93	15.3%
Hospital status												
Admitted	24	22.4%	19	17.8%	16	13.6%	27	19.6%	20	14.5%	106	17.4%
Treated	34	31.8%	42	39.3%	40	33.9%	37	26.8%	45	32.6%	198	32.6%
Minor Injury	2	1.9%	3	2.8%	6	5.1%	5	3.6%	3	2.2%	19	3.1%
Non injury	46	43.0%	42	39.3%	55	46.6%	66	47.8%	54	39.1%	263	43.3%
Unknown	1	0.9%	1	0.9%	1	0.8%	3	2.2%	16	11.6%	22	3.6%

*Excludes 23 fatally injured road users

A potential way of capturing a larger number of participants is to base the study sample on road users who have been admitted to hospital. Examining Table 5.1, it can be seen that a total of 17.4% (N=106) of participants were admitted to hospital (aged between 16-93 years; mean age = 46 years, SD = 20 years) over the same five-year period. In this sample, inactive participants (passengers) who were admitted for their injuries are included. Using the same approximate interview response rate (47%), we could expect to recruit approximately 10 participants per year. However, the relevance of the injury severity to the LSA may be less than desired, and again the sample size is not large.

While CASR do not currently interview injured non-active participants (vehicle passengers) as a part of the current crash investigation project, ethics approval could be amended to include follow-up with seriously injured non-active participants for the LSA component of investigation and data collection. CASR have the means to continue this prospective approach to data collection, interviewing both active and non-active road users who are seriously injured, although the prospective data collection would be slow and many years would be required to obtain a sample size amenable to statistical analyses to gain an understanding of trends in substance use. Notably, from 2020 onwards, consent for future contact has already been approved by the SA Health Human Research Ethics Committee and CASR are therefore building up a sample of individuals consenting to follow-up contact from CASR. Importantly, CASR already have a database of these participants' baseline functioning, including their substance use, and could undertake follow-up interviews to assess their level of functioning, including any changes in their substance use over the years since the crash.

To increase the relevant sample size and to achieve a longer follow-up period immediately, CASR have the opportunity to undertake retrospective analysis of past crash participants who have been injured in previous years by recontacting them for a follow-up interview. This would require CASR to seek ethics approval to recontact participants who CASR have already interviewed between 2015 and 2019 (as described above).

The retrospective approach to data collection would increase the sample size at a faster rate than prospective data collection alone. Across the years 2015-2019, CASR have interviewed 42 participants who were hospital admitted active participants (with another 42 not interviewed, for numerous reasons including being unable to contact them or an unwillingness to participate). Assuming a 47% participation rate again, we could expect to re-recruit 20 participants who had been previously interviewed and thus obtain longitudinal data (currently 3-7 years post-crash). However, again these injuries may not best represent those participants in the LSS. It would also be likely that there has been some natural attrition in this sample.

5.5 Interviews with hospital admitted road users

Another methodology that may yield a greater number of participants representing the injury levels of those in the LSS is use of the Royal Adelaide Hospital (RAH) data set. This data set has been described and analysed in detail earlier in this report (Section 3). Covering the time period of 2014 to 2017, this database comprises information pertaining to 2,072 participants admitted to hospital following their active involvement in a road crash (driver, rider, pedestrian). CASR have access to the medical notes of these injured road users but they have not been interviewed. As stated in Section 3 of this report, 12.1% (N=244) of the 2,072 active road users sustained an ISS of 15 or greater. This analysis excludes fatally injured participants. This database therefore provides a larger sample of individuals who have sustained injuries at the higher levels of severity than does the in-depth crash investigation methodology discussed above.

To determine recruitment rates with the hospital population of seriously injured road users of interest to the LSA, using a cut-off of an ISS of 15 or greater coupled with CASR's interview response rate of 47%, we could expect to recruit approximately 115 participants with an injury severity of 15 or greater over 3.5 years. This is equivalent to recruitment of 33 participants each year. In addition, if a greater level of participant recruitment were desired, CASR could seek to extend the SA Health ethics application to include data collection for non-active road users, (i.e., include passengers of vehicles). Ultimately, the greater the sample size, the greater the ability to undertake statistical analyses and identify meaningful relationships between variables. Furthermore, the larger the sample is to begin with, the less impacted it will be by natural attrition rates (e.g., drop out due to deaths in the sample, withdrawal of consent, inability to re-contact at follow-up, etc.).

The RAH data collection is currently in a hiatus as CASR seek a new data collector, potentially embedded within the RAH or the broader Central Adelaide Local Health Network (CALHN). Once this has been established, CASR will return to collecting data for all road crash-related admissions to the RAH. CASR also have the opportunity to retrospectively invite the injured road users for whom data has already been collected throughout 2014-2017 to be involved in the study. This would provide an instant measure of long-term substance use post-crash, some five to eight years after the injury was incurred. While baseline interview data would not previously have been obtained, there would be considerable information available in the medical notes and the results of Forensics SA alcohol and drug tests which could be analysed for relationships with long term substance use and other outcomes.

For the prospective data collection, a letter of invitation would be posted to prospective participants approximately five weeks following their crash involvement (as with the in-depth crash investigation protocol), including an information sheet relating to the details and purpose of the study. A CASR researcher trained in sensitive and respectful interviewing and many years of experience with in-depth interviewing would follow-up this letter with a phone call approximately one week later to invite their participation. As with in-depth crash investigation, a suitable location for the interviews would be arranged in liaison with the participant. The protocol for retrospective data collection would be similar, except letters could be sent to all participants matching the study criteria, immediately, with a follow-up process similar to the prospective study.

5.6 Budget considerations

Given the different options for methodologies outlined above, it is difficult to estimate a budget for a project looking at post-crash substance use by injured road users. Nonetheless, some component costings are provided here to give an indication of the budgetary implications of choosing different methodological approaches. The budget items necessary for the potential studies are: interview design, ethics application, recruitment, interviews, data entry and analysis, report writing, and administration. Note that there is no cost for in-depth crash investigation as this is an ongoing activity that is funded through CASR's Deed of Agreement with the State Government. There is also no cost listed here for data collection for injured road users admitted to the RAH. This activity has been funded in the past but is not currently active. CASR is seeking a new data collector for that work and is looking at funding options. Therefore, prospective collection of hospital cases would require re-commencement of the broader RAH-based data collection activity.

5.6.1 Interview design

Questions relevant to substance use are already being used in CASR's in-depth crash investigation study. Therefore, these can be adapted to be suitable for an LSA project looking at post-injury substance use, including adaptation for the various follow-up periods.

Time estimate: 3 hrs

Cost estimate: $750

5.6.2 Ethics application

Ethical approval will be needed from the University of Adelaide Human Research Ethics Committee and from the SA Health Human Research Ethics Committee. This requires ethics applications, plus production of introductory participant letters, information sheets and consent forms.

Time estimate: 20 hrs

Cost estimate: $5,000

5.6.3 Recruitment

This requires preparation and sending of introductory letters, plus follow-up phone calls to establish participation and agree a location for interviews. For some people, multiple phone calls are necessary and extra time is needed for budgeting purposes for multiple unsuccessful attempts to contact participants.

Average time per participant: 30 mins.

Average cost per participant: $125

5.6.4 Interviews

Interview costs include the time to conduct an interview, travel time for face-to-face interviews, and time for a second researcher to attend for occupational health and safety reasons. Interviews can be conducted by phone but face-to-face interviews are preferable for establishing rapport, especially for those who may have sustained significant trauma. An associated cost for interviews is data entry.

Average time per interview: 45 mins

Average cost per interview: $188

Average cost for three interviews (baseline, 3 months, 2 years): $563

For face-to-face interviews, there are additional costs for travel and for another researcher to accompany the interviewer. The presence of the additional person doubles the interview costs:

Average cost per interview (two researchers attending): $375

Average cost for three interviews (two researchers attending): $1,125

Travel time for each interview: 1 hour

Average travel time cost (for two researchers): $500

Average time for data entry for an interview: 1 hour

Average cost for data entry per interview: $250

5.6.5 Data analysis and report writing

Finally, there are costs associated with analysing data and preparing reports summarising the outcomes.

Data analysis time estimate: 35 hrs

Data analysis cost estimate: $8,750

Report writing time estimate: 70 hrs

Report writing cost estimate: $17,500

5.6.6 Administration

Administration costs include those associated with project management and quality management. Project management costs increase with the length of time the project takes, so will therefore increase if the recruitment of participants takes longer and if longer follow-up periods are used for interviews. Quality management involves a senior researcher checking the draft report before submission to the LSA and is a set cost.

Project management time per annum: 20 hrs

Project management cost per annum: $5,000

Quality management: 5 hrs

Quality management cost: $1,750

5.6.7 An example budget

On the basis of the numbers above, an example budget can be given for a project measuring substance use among injured road users in SA. For illustration purposes, the following study options have been chosen: Face-to-face interviews at the interviewee's residence for injured road users admitted to the RAH with an ISS of 15 or more, covering a two-year period of study participant recruitment. This results in a four-year study. The assumed sample size, based on Section 5.5, is 66 participants (33 recruited in each of two years). No allowance has been made for attrition. The estimated budget is $177,500, excluding GST.

Lower costs could be achieved if fewer (or no) interviews were done at the study participant's residence (either at CASR or by phone) and if the sample were smaller (lower number recruited and/or attrition for later interviews). However, no allowance has been made for the possibility of providing monetary compensation to the participants, which would add to the cost, and salary costs are likely to increase with inflation in later years. The likely budget for a project of this nature is therefore somewhere between $150,000 and $200,000.

Table 5.2
Example budget for a study of the substance use of crash-involved road users with ISS of at least 15

Budget item	Calculation	Cost ($, ex-GST)
Interview design		750
Ethics		5000
Interviews, including travel time and data entry	66 x (1125 + 500 +250)	123,750
Data analysis		8750
Report writing		17500
Project management	4 x 5000	20000
Quality management		1750
Total		177500

6 Discussion

This project was concerned with examining substance use both before and following involvement in road crashes causing serious injury. It was comprised of two data analysis studies, one on fatal crashes and one on hospital admission cases, a literature review on substance use by those with injury types included within the LSS, and a discussion of potential studies to look at post-injury substance use among seriously injured road users in South Australia.

The choice of an analysis of fatal crashes and crashes resulting in hospital admission was made on the basis that LSS participants are likely to represent an 'average' between these two groups. In any case, the findings of the fatal and hospital admission-based analyses revealed a number of similarities between these groups in terms of pre-crash substance use, that are therefore likely to be generalisable to LSS participants. These similar findings include:

- Around half of both fatal and hospital admission cases were positive to at least one substance
- Illicit drugs and an illegal BAC appeared in similar proportions, with combinations of different substance types being common
- Substance use was associated with higher levels of injury severity or with a higher likelihood of being fatally injured in the crash
- Illicit drugs were used more by younger people while medication use was more common among older road users
- Males were over-represented among fatalities and serious injuries
- Substance use was associated with single vehicle crashes, especially those that involved striking a fixed roadside object.

The considerable involvement of alcohol in the two sets of crashes is consistent with the well-established finding that drink driving markedly increases the risk of crash involvement (e.g., Lacey et al., 2016). Elvik (2013) conducted a meta-analysis of studies into use of drugs and road crash involvement. Elvik argued that illicit drug use did not increase risk to the same extent as alcohol but did report the relative risk of a crash after amphetamine use to be 5 to 8 times higher, depending on the level of injury severity of the crashes used in the analysis. The risks associated with cannabis were more modest, with the increased risk found to be approximately 25%. The medication type with the most reliable estimate of increased risk was benzodiazepines, for which fatal crash risk was 2.3 relative to controls (Elvik, 2013).

The finding of a higher proportion of hit fixed object crashes among the drivers using substances suggests that the crashes were caused by loss of vehicular control. The higher likelihood of loss of vehicular control among substance using drivers could be related to the direct effects of impairment and also possibly the outcome of greater levels of risk taking behaviour (e.g. speeding) (e.g. National Center for Statistics and Analysis, 2019).

Other findings of note from the fatal crash sample which may be of interest include the following:

- 36% of fatal crashes were adjudged to have resulted, at least in part, from road user substance use. In 16%, this was a combination of different substance types.
- The majority of those with an illegal BAC involved in fatal crashes had a BAC in excess of 0.15 g/100ml.
- The medication type most implicated in contributing to fatal crashes was benzodiazepines, followed by anti-depressants and narcotic analgesics. Medications were often combined with high levels of alcohol.

- Many of the fatally injured pedestrians had a BAC above the legal driving limit.
- Fatal crashes tended to occur in rural locations with high speed limits.

The findings in regard to medications need to be considered in light of the medical conditions they treat. Benzodiazepines and anti-depressants are often used to treat anxiety, insomnia and depression. Prevalence rates in the South Australian community indicated that in 2018, 19.9% of people had a mental or behavioural condition, similar to the previous census at 18.3% (Australian Bureau of Statistics, 2018). Anxiety-related conditions were reported for 12.8% of South-Australians and depressive symptomatology in 10.2%. While the 2015 census indicated no gender differences in prevalence of mental and behavioural conditions, in 2018 mental and behavioural conditions were more commonly reported by females than males (22.6% compared to 17.1%, respectively). Females experienced more anxiety-related conditions (15.2% up from 11.8%) and depressive symptomatology (12.3% current) compared to males (10.3% and 8.2% respectively) (ABS, 2018). Consistent with this, medication use among the crash-involved samples in these studies was proportionally higher among female than male road users. Notably, however, males appeared to combined medication with other substances more than females.

The finding that fatal crashes tend to occur in rural locations with high speed limits underscores the importance of considering the broader context in which crashes occur, aside from the characteristics or behaviour of the road user. Rural locations with high speed limits are more likely to be associated with fatal outcome when a road user makes a mistake, regardless of the reason for the mistake. There is a recent report by Austroads which examines the challenges of regional and remote road safety (Wundersitz, Palamara, Brameld, Rafery, Govorko & Thompson, 2019).

The literature review included sections on trauma related to road crashes as well as on trauma in general but chiefly focused on specific injury types relevant to the LSA: TBI, SCI, burns and amputations. Although different injury types are associated with their own specific issues (see Sections 4.7.2 to 4.7.5), some general findings also emerged from the review:

- Injuries such as those covered by the LSA are frequently sustained while people are intoxicated. This applies to road crashes as well as other injury-causing incidents. Intoxication at the time of the injury is linked to worse outcomes. Pre-injury substance use is also predictive of post-injury substance use, and the latter is also linked to worse outcomes. These findings are likely to apply to LSS participants.
- Substance use, beyond prescribed medication, reduces for a period after a serious injury is sustained but tends to increase again to pre-injury levels as the injured person regains functional capability and independence. This is likely the case among LSS participants to the extent that such recovery has occurred. Substance use, post-injury, is often linked to worse outcomes.
- A major issue for many of the injury types covered by the LSA is pain management. Opioids are frequently prescribed to treat pain, including chronic pain. This can lead to opioid dependence and other negative outcomes. For many types of pain (e.g., neuropathic pain associated with SCI), other medication types are likely to be more effective than opioids. Various adjunctive therapies are also available that have been shown to reduce pain but evidence is needed that they can also lead to reductions in the use of opioids.
- Medicinal cannabis is used by many people to treat various symptoms that follow traumatic injury. There is currently insufficient evidence of its clinical benefits and of its long-term effects. Furthermore, the evidence suggests it does not lead to a reduction in use of prescription opioids among those with chronic pain and that many who use it are continuing with pre-injury patterns of substance use. Clinicians need patients to disclose their patterns of medicinal cannabis use to allow for monitoring of adverse drug or drug interaction effects.

- Those with complex issues such as those with the injury types covered by the LSA are often prescribed a number of different medications. This leads to the potential for polypharmacy - the unintended prescription of multiple medications that could have adverse reactions with each other. Although multiple medications are frequently needed with complex conditions, practitioners should seek to avoid polypharmacy where possible through the use of alternative strategies based on physical activity, nutrition and lifestyle management.

Although the literature provides a wealth of information in relation to substance use after various types of traumatic injury, there are limitations to which the findings may be generalisable to LSS participants. This notwithstanding, it is clear that post-injury substance use often replicates pre-injury use and, given that seriously injured road users exhibit high rates of substance use and that there are clear risks identified in the literature from post-injury substance use, a study of post-injury substance use among a sample of seriously injured road users in South Australia would be beneficial to examine this issue in a local context. Ideally, such a study would be based on interviews with the LSS participants themselves, with findings compared to the risks identified in the literature. However, it is understood that such a study may not be possible. Other potential methodologies to investigate post-injury substance use have been proposed, based on interviewing crash participants from CASR's in-depth crash investigation program, or interviewing injured road users admitted to the RAH. The latter is likely to provide a greater likelihood of recruiting a sufficiently large sample. An initial estimate of a likely budget is between $150,000 to $200,000 for a four-year study. Various methodological choices could reduce or increase this budget.

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