THE RELATIONSHIP BETWEEN BLOOD ALCOHOL CONTENT AND HARM FOR NON-DRIVERS: A SYSTEMATIC REVIEW

Leading responses to alcohol and drug issues
THE RELATIONSHIP BETWEEN BLOOD ALCOHOL CONTENT AND HARM FOR NON-DRIVERS: A SYSTEMATIC REVIEW

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# TABLE OF CONTENTS

Executive summary ................................................................. 6

Introduction ............................................................................. 9

Method .................................................................................. 16

Results .................................................................................. 20

Discussion ............................................................................. 28

Conclusion ............................................................................. 40

References ............................................................................. 47
LIST OF FIGURES AND TABLES

Figure 1. Literature search and screening process ..............................................................18

Figure 2. Dose-response curve for the amount of alcohol consumed 3 hours prior to injury and the odds ratio of (non-motor vehicle) injury, from Taylor et al. ........................................35

Table 1. Evidence Table from the Systematic Review – Study Characteristics .................21

Table 2. Evidence Table from the Systematic Review – Findings ..............................23

Table 3. Summary table of the relative risk of injury by BAC where odds ratios are presented, sorted by risk ........................................................................................................30

Table 4. Summary table of the relative risk of injury by BAC where significant differences are presented, sorted by risk .................................................................33
EXECUTIVE SUMMARY

Aims: This report provides a systematic review of evidence concerning the relationship between blood alcohol content (BAC) and non-drink driving related harms. It is intended to identify whether there is a level of BAC where non-drink driving alcohol related harm rises appreciably. This evidence would support the identification of a BAC threshold where licensees and their staff might reasonably be required to refuse alcohol service to patrons.

Method: We designed a systematic literature search to identify previous systematic reviews, case control and case crossover studies examining a relationship between BAC and non-driving-related acute health outcomes. Included studies were published in English during 1980 to December 2011. Studies that examine associations between self-reported number of standard drinks consumed prior to the injury occurring were excluded as they did not address our specific research question, as were those with inadequate controls. The initial search identified 10503 references. After three screening phases only three studies remained that were adequately controlled and that explored the link the between BAC and harm. Each of these utilised a case control method.

Findings: Of the three included studies, two indicate respectively that a BAC of around .155-.16 exposes people to a 73 times greater than normal risk of falls and a significantly increased rate of injury, findings that must be considered in light of each study’s limitations. The third found a relationship between BAC and poorer hospital outcomes but did not further analyse a relationship between harm and BAC of over .03.

Conclusions: That harm rises in proportion to the number of drinks consumed by an individual on any one occasion is well established, although risk for an individual from any drinking occasion varies by a range of factors including alcohol dependence, pre-existing...
medical conditions, the length of time over which alcohol is consumed, alcohol metabolism capacity and the social context where drinking occurs.

While a BAC of .16 or over appears to be correlated with the highest recorded relative risk of injury amongst studies included in our systematic review, we found no evidence to enable us to identify of a point of inflection where the relationship of risk of adverse acute outcomes intensifies. This was because included studies provided information on risk in relation only to specific BAC ranges, making it impossible to accurately graph risk.

Our findings should be considered in conjunction in with Taylor et al.’s (1) meta-analysis of the dose-response relationship of alcohol to injury which, unlike our review, was not limited to studies specifically measuring BAC. Importantly, Taylor et al.’s meta-analysis shows a smooth risk curve for acute non-driving related harms from alcohol consumption, providing persuasive evidence that there is no point where harm could be said to rise appreciably. Taylor et al. (1) found that consuming 100 grams of alcohol is associated with around ten times the risk of non-motor vehicle-related injury, and consuming 140 grams is linked with almost 25 times this risk. Unfortunately a likely BAC after consuming this amount of alcohol cannot be calculated using an established method for converting the number of drinks to BAC (2), which is only likely to be accurate up to seven standard drinks. A rigorous case control and crossover study (3, 4) identified odds ratios for risk of injury after 5 or 6 drinks as being between 9.5 and 13.5, with 7 plus standard drinks giving an odds ratio of 17. Although all these studies all show rising relative risk with increasing alcohol consumption, we are unable, on the basis of the available evidence, to identify a compelling argument that any of these levels of alcohol consumption (or a point in between them) is preferable as a threshold where alcohol sales should be refused.
When no point of inflection can be detected, identifying an appropriate risk threshold becomes particularly fraught. In formulating the current Australian Guidelines to Reduce Health Risks from Drinking (5), an expert committee decided to set a risk threshold at the level of one in 100 lifetime absolute risk of mortality. Studies of acute events such as drinking to intoxication (as discussed here) entail comparison of the risk of an adverse event after drinking specified levels of alcohol against the likelihood of the same outcome for the same or similar people when they have not drunk alcohol. Thus they calculate relative, rather than absolute risk. Further work is required to calculate absolute risk of lifetime injury from these risk ratios before any absolute risk threshold can be identified. This is outside the scope of the current review.

**Implications:** Further case crossover and case control studies of alcohol and injury with robust methodological designs are required to identify risk curves for alcohol associated acute non-driving related injury. Future research should control for demographics, type of injury, cultural differences, type of alcohol consumed before the injury and drinking environment. Studies should measure self-reported number of standard drinks as well as specific BAC levels at gradations before and after seven standard drinks to clarify the relationship between these two factors and should test body weight and record the period of time over which alcohol was consumed to enable accurate calculation of BAC when acute harm occurs.

Finally, identifying a BAC at which people are exposed to excessive harm will always involve a judgement as to how (as either relative or absolute risk) and where (at what level of risk of injury or mortality) to set thresholds where risk becomes considered unacceptable.
INTRODUCTION

Alcohol-related problems are a major cause of harm and social disorder in Australia. Alcohol is the fourteenth leading cause of disease, responsible for 3.2% of the total burden (6). The estimated cost of alcohol to the Australian community is $15 billion per annum, including crime, violence, treatment, loss of productivity and premature death (7). In particular, problems associated with the night-time economies of inner-urban entertainment precincts cause significant community concern and constitute a substantial drain on police, community and health resources (8-10).

While population levels of alcohol consumption in Australia have remained at relatively stable levels over the past twenty years (11), harms related to alcohol as seen in ambulance and hospital presentations have increased significantly over the same time period (12, 13). This is likely to be related to an increase in levels of ‘risky drinking’, also known as ‘heavy episodic drinking’ (11, 14, 15). In Australia, one in four young people reported consuming alcohol at levels associated with short-term harm on a weekly to monthly basis in the past year and over 40% of young Victorians reported having consumed more than 20 standard drinks on a single occasion (14, 16). This is concerning, given that up to 47% of alcohol-related deaths can be attributed to single sessions of heavy episodic drinking (17). The primary immediate harms and injuries that arise from risky drinking include: drink driving, assault, unwanted and risky sexual behaviour, alcohol poisoning/overdose, accidents (such as falls and pedestrian accidents) and social harms (such as regret, embarrassment, stigma and shame) (18).

It is widely believed that alcohol consumption is associated with cumulative increased risk of injury (19, 20). For example, a systematic review of 21 studies of the relationship between alcohol intake and unintentional injury conducted since 2004 showed that greater levels of
alcohol consumption were positively associated with risk of unintentional injury (21). Two studies have found that injury increases proportionately to levels of BAC (19, 20), with a third finding support for the theory that even at low levels of consumption, there is a positive dose-outcome relationship between alcohol consumption and injury (22).

Research conducted in hospital emergency rooms provide valuable insight into the association between intoxication and accidents or violence. For example, US research has shown that of 68,000 patients presenting to an Emergency Department (ED), approximately 45% (31,000) were positive for alcohol, and patients with alcohol in their system required more invasive procedures, more diagnostic tests, stayed longer in the ED, were more likely to require hospital or intensive care admission and their hospital charges were higher (23). Similarly, of the 100,000 patients in the US hospitalised each year for burn injury, approximately 50% have significant levels of alcohol in their blood at the time of injury and intoxication has been linked to more severe injury, more difficult resuscitation and longer hospitalisation (24).

In Australia, the drink-driving limit is set at .05mg/100mL to minimise the risk of injury from driving; however, as yet, no BAC limit has been set for refusing entry or service to patrons in licensed venues in an effort to minimise alcohol-related harm. Setting a threshold BAC for alcohol service is likely to be complex, as evidenced by a recent meta-analysis drawing on 28 studies of alcohol consumption and injury (1). This study shows that risk of non-driving related injury increases as a smooth curve by the amount of alcohol consumed. In other words, the meta-analysis shows no point of inflection or point where risk rises appreciably. We will return to consider the implications of this finding in the discussion section of this report.
This report addresses the following research questions:

1. What evidence exists of the nature of the relationship between level of BAC and the risk of a drinker causing short-term harm to him/herself and/or others (other than through drink driving)?

2. On the basis of available evidence, is there a BAC level above which the risk of a drinker causing such harm rises appreciably (or, to put the same question in more applied terms, is there a level above which a plausible case could be made for legally prohibiting the serving of alcohol to the drinker on licensed premises?).

3. If so, what is that level of BAC?

Alcohol policy context and problems with behavioural measurement of intoxication

Across Australia state and territory licensing laws prohibit the sale of alcohol to people who are intoxicated. For example, Section 102 of the Northern Territory Liquor Act stipulates that:

A licensee or a person employed by a licensee shall not sell or supply liquor to a person unless the person to whom it is sold or supplied is not intoxicated at the time (the onus of proof of which lies with the defendant) (25).

Section 121(1) of the NT Liquor Act requires a licensee or employee of the licensee to ‘exclude or remove a person, not being a bona fide resident of the licensee’s licensed premises, from the licensed premises if the person is intoxicated, violent, quarrelsome, disorderly or incapable of controlling his behaviour’. However, neither the NT Liquor Act nor the NT Liquor Regulations defines intoxication.

The situation is similar in other Australian jurisdictions. The National Alcohol Strategy 2006-2009 noted that at present in Australia there is no ‘consistent or formally agreed definition of
intoxication’ (26). Assessing intoxication is therefore a complex interpretive exercise (27). For example, one UK study (28) entailed analysis of subjective assessments of intoxication by trained surveyors, comparing these with BAC levels from the same observed individuals using a breathalyser. The study found that trained surveyors were able to identify individuals who were highly intoxicated (BAC of .15 or higher) by identifying staggering gait, glazed eyes and slurred speech. However, women displayed these behaviours at a lower BAC than men and the authors acknowledged that such behaviours are difficult to accurately identify in a crowded venue where music is loud and lighting is low, and when BAC levels are lower than .15.

Reliance on behavioural measures of intoxication leaves licensees and their employees with no objective measure to use in determining whether a patron should be served alcohol. Setting a maximum BAC level for legal service of alcohol to patrons, to be ascertained by breath testing, would offer a greater level of certainty that a patron could indeed be deemed intoxicated. Thus it is useful to identify a BAC where harm rises appreciably and where alcohol sales to intoxicated customers may reasonably be prohibited.

**Blood and breath testing of alcohol content**

Blood alcohol content is widely considered the most accurate measure of intoxication levels when urinalysis is not possible. While BAC is most rigorously measured through blood samples, it is most often estimated through the use of breathalysers, which calculate approximate blood alcohol content from breath alcohol content. In setting a maximum BAC for alcohol service in licensed venues it is important to consider limitations in the accuracy of breathalyser testing. One review of the literature (29) found that breathalyser obtained BAC estimations vary across exhalation, leading to the possibility of inaccurate readings. However, another study (30) comparing breath tests with blood samples found good
correlation ($r=0.96$). It should be noted that products for BAC estimation have improved in accuracy during the past decades.

BAC was used as the measure of intoxication in this study because the purpose of this review is to identify a BAC level at which a plausible case could be made for legally prohibiting the serving of alcohol to a drinker on a licensed premises. As we shall discuss below, a further reason for our focus on studies that specifically measure BAC was that calculating a likely BAC from studies that measure grams of alcohol consumed is problematic after consumption of seven standard drinks (2). However, in the studies we have focused on in the review, each of which was conducted at least in part in emergency departments, a period of time has elapsed between the occurrence of the injury and BAC measurement at the hospital. It is likely that alcohol has been metabolised by the body during this period, giving lower readings than would have been the case at the time of injury. Due to this concern, some emergency department studies (i.e. 31), which entail measurements of BAC as well as numbers of standard drinks consumed, report on number of standard drinks consumed. Given the likely delay in BAC measurement, the studies described in our systematic review should be considered as conservative estimates of BAC at which harm occurs.

**Measuring intoxication through number of standard drinks consumed**

In Australia, the National Health and Medical Research Council (NHMRC) guidelines (5) define ‘risky drinking’ as an episode of drinking where five or more standard drinks are consumed. This threshold was derived from re-analysis of three emergency department studies examining the role of alcohol consumption in injury morbidity and mortality (32-34).
Evidently, setting a number of standard drinks at which patrons should be refused alcohol sales would be unlikely to be an effective strategy given that patrons may not be truthful with licensees who are attempting to ascertain intoxication in order to refuse sale of alcohol. Additionally there is some question as to the accuracy of people’s assessments of their own drinking. For example, in the analysis conducted to support the development of the NHMRC drinking guidelines, concern was noted over likely under-reporting of number of drinks consumed after four drinks by injury patients (5). Further, the time period over which standard drinks are consumed will influence any individual’s level of intoxication.

Many studies use self-reported number of drinks consumed prior to the injury occurring to identify associations between alcohol consumption and harm, rather than BAC and harm. We did not include these studies in our systematic review, however we summarise findings from relevant research on numbers of standard drinks associated with harm in the discussion section of this report. Bond et al. (2) use the Widmark equation to provide estimations of BAC levels per number of standard drinks (defined as 12g of ethanol) in samples of injury patients in emergency departments, with the caveat that these calculations are approximations (the equation used by Bond et al. does not account for differences in body weight or time periods over which alcohol is consumed). Using the original Widmark equation was not possible in this review as it relies on availability of information about body weight and drinking duration for each individual included in studies. Bond et al.’s equivalency table becomes markedly less accurate after seven drinks, which probably reflects an increasing mis-estimation by participants of numbers of drinks consumed after this point. Thus in this review we only use this formula to offer approximate BAC equivalents for self-reported consumption of up to seven drinks. In the discussion section to this report we use this equivalency table to provide approximate comparisons between studies showing links between numbers of drinks and risk of injury and studies measuring BAC and risk of injury.
Search parameters

We searched for studies identifying a relationship between measured BAC and acute alcohol related harm. It has been suggested that study design is largely responsible for the variation in results between BAC and injury (35). As such, a decision was made to only include systematic reviews and studies with an appropriate control group (case control and case crossover studies) due to significant problems in other methodological approaches. A critique of methodological approaches and problems in research into alcohol-related accidents and injuries by Rehm (36) highlighted significant bias in using cross-sectional research, cohort studies and analysis of secondary data to analyse the relationship between alcohol and injury. In particular, the results of cross-sectional studies might be a reflection of the drinking habits or demographics of those more likely to get injured, rather than the effect of alcohol on injury. Given that experimental designs such as randomised controlled trials could not plausibly be used to address this research question, Rehm argues that case control and case crossover studies are the next best approach to disentangle causal relationships.
METHOD

The study team developed a systematic review protocol. Our initial search included studies that were available in English, published or produced between 1980 (to ensure currency of BAC measurement techniques) and December 2011 and that provided empirical evidence of a relationship between BAC and harm. Studies were excluded if they concerned alcohol-impaired drivers, as BAC levels for driving after consuming alcohol have been established in all Australian jurisdictions and in most other countries. Studies concerning harm sustained while engaged in an activity that we considered to be unlikely for people leaving a licensed venue (for example scuba diving) were also excluded, as were harms for specific population groups (for example, pregnant women).

Databases Web of Science, Embase, Psycinfo, Scopus and Medline were selected for their breadth and relevance to the subject. Grey literature was accessed through searching Google and research databases held by the Lindesmith Library, Cochrane Collaboration, World Health Organisation and the National Technical Information Service (US) databases.

Three sets of search terms were developed:

1. alcohol

2. breathaly* OR blood alcohol* OR breath alcohol* OR BAL OR BAC OR BRAC

3. hospital OR emergency OR assault OR police OR accident OR ambulance OR paramedic OR injury OR violence OR domestic violence OR overdose OR alcohol poisoning OR neglect OR incident OR harm OR death OR fatality OR mortal* OR morbid* OR psychosis OR anger OR crime OR offence OR theft OR burglary OR arson OR larceny OR drowning OR falls OR acute pancreatitis OR fire OR mental health OR hangover OR dehydration OR aggressi* OR fight OR argument OR sexual assault OR risky sexual* OR rape OR homicide OR verbal abuse OR child neglect OR child abuse OR child maltreatment OR risky behavio* OR suicid* OR self-harm OR self harm OR self-injury OR self injury OR regret*. 
Three reviewers conducted a search of 1 + 2 + 3 (limiting to human studies and English language), which produced 10,437 results from the databases and 66 through grey literature for a total of 10,503 (see Figure 1). After removing duplicates and deleting non-relevant citations (n=6409) we were left with 4094 citations for thorough screening. Figure 1 details the literature search and screening process.

The second stage of screening involved three reviewers carefully reading the abstracts of all included articles. Non-relevant citations were excluded, as were references where no information was provided on harms associated with a BAC (i.e. studies that used self-reported number of drinks instead of BAC). In view of the research brief we also excluded studies specifically concerned with measuring harm from drink driving. This led to an exclusion of 4050 abstracts, leaving us with 44 studies. Three reviewers then read the full-text articles of these 44 studies and made the decision to limit the review to case crossover or case control studies due to the significant methodological problems noted in these 44 articles. Twenty-nine studies were excluded, leaving us with 15 case control and case crossover studies.
Figure 1: Literature search and screening process

Citations screened: 10503

First Screen
Number of duplicates and non-relevant citations removed: 4094

Second Screen
Number of articles and studies assessed for eligibility: 44

Third Screen
Number of studies grouped by intervention: 15

Number of studies included in review: 3

Number of citations (records) identified through database searching: 10437

Number of citations (records) identified through other sources: 66

Number of duplicates removed and non-relevant citations excluded: 6409

Number of citations excluded: 4050

Number of articles/studies excluded: 29

Number of studies excluded: 12
Data extraction sheets and quality assessment tools were developed to support the review of each included study. Two reviewers reviewed each reference and inter-rater reliability was managed with a coding framework developed during screening. Following review of these 15 papers, all three reviewers met to cross-check their extraction sheets and determine the final included articles. Of 15 case control and case crossover studies, a further 12 were excluded on the basis that the control group was not adequately matched on factors such as age and gender, or due to a specific BAC level not being identified. All papers that discussed a relationship between numbers of standard drinks consumed and harm, as well as those excluded due to inadequate controls, were retained in a separate database so they could be analysed as part of the discussion section of this report.

The reference lists of the fifteen case control and case crossover papers were hand-searched, as well as six key reviews in the area. This hand searching elicited three new papers that were later deemed irrelevant (due to inadequate controls) after retrieval. The scarcity of high quality studies introduced analytic limitations. No two studies were sufficiently homogenous in design to support meta-analysis.
RESULTS

In this section we describe the findings of the three articles included in our systematic review. First we present two studies that identify a relationship between particular levels of BAC and likelihood of injury and next we discuss the third study, which reports on BAC and hospital outcomes. Evidence tables for the three included studies are provided in Table 1, below.

The first included study was by Honkanen et al. (37). This was a matched case control study that considered the role of alcohol in accidental falls in Helsinki, Finland. A sample of 313 adults aged 15 and over who had accidental falls between 3-11pm over two five-week periods were recruited to the study. These cases were each matched to two randomly selected adults of their gender who were at the site of the accident a week after it occurred, and who agreed to participate in a control group (although some were approached at other times). A blood sample was taken from the cases and a breath sample from the controls, with both analysed to determine BAC.

The study found that alcohol is a powerful causal factor in accidental falls and that risk of accidental fall increases at slightly higher BAC than does the risk of traffic accidents, but then rises more steeply. After controlling for confounding factors (slipperiness of the road, disease, age, use of psychotropic drugs, shoe sole type and social class) they found a relative risk of 1 for .55 BAC, rising to 8.5 for .55-.154 BAC and 73 for .155 BAC or more.
### Table 1. Evidence Table from the Systematic Review – Study Characteristics

<table>
<thead>
<tr>
<th>Reference: (author/s, year, aim, country)</th>
<th>Study design, evidence level and study quality (i.e. response rates, treatment of missing data)</th>
<th>Population: (n, age range, gender, setting)</th>
<th>Comparison group</th>
<th>Blood alcohol or breath measures</th>
<th>Harms measured and measures</th>
<th>Time b/w BAC and observed harm</th>
</tr>
</thead>
</table>
| Reference: Honkanen et al. 1983 (37)    | Study design: matched case-control study with a fixed 1:2 ratio  
Evidence level: Level III (2)  
Study quality: moderate – 74% completion rate for cases and 95% completion rate for controls | Number: 313 people over the age of 15 who presented to emergency because of external injuries caused by falls in public places  
Demographics: 56% male, mean age 44.9 years. | The control group (n=626) was formed by visiting each accident site exactly one week after the accident and interviewing two randomly selected adult pedestrians of the same sex. (Seventeen controls were selected two weeks and one was selected three weeks after the accident – same day and time. Twelve were selected on a different day).  
* Controls not matched on age, however time, date and location were carefully controlled.  
* 27 controls did not give a breath sample | Blood sample and gas chromatography | Injury was classified according to 8th revision of the International Classification of Diseases | Following completion of interview schedule in the emergency department – exact time not specified |
| Country: Finland                         | Study design: a paired case-controlled study (and an unpaired cohort study, the results of which are not included)  
Evidence level: Level III (2)  
Study quality: moderate – only two controls refused but no information on how many cases refused. Individuals who were too intoxicated or too injured were excluded. | Number: 51 adults over age of 18 who presented to emergency as the victim of assault; 49 provided a BAC  
Demographics: male only, mean 22.7 years. | Controls (n=51). All male, mean age 23.75, no, significant difference with controls, were individually matched from their own peer group, a person who was drinking with them and attended the A&E department with them.  
* No significant difference between groups on age, employment status, social class, weekly alcohol consumption, weekend alcohol consumption, consumption in the five days preceding the incident, types of relationships formed with peers or sexual partners, major life events or minor stressors in the period prior to injury.  
* Cases drank significantly more alcohol during a typical weekend session (0.008). | Blood alcohol content using an ‘alcometer’ | Injury severity Score, Revised Injury Severity Score, Assault Trauma Score, Glasgow Coma Score, Holmes and Rahlle Life Style Score | Following completion of interview schedule in the emergency department – exact time not specified |
| Reference: Shepherd and Brickley 1996 (38) | Aim: To investigate the relationship between alcohol consumption, intoxication, stressors, injury and urban violence  
Country: Wales | Study design: a paired case-controlled study (and an unpaired cohort study, the results of which are not included)  
Evidence level: Level III (2)  
Study quality: moderate – only two controls refused but no information on how many cases refused. Individuals who were too intoxicated or too injured were excluded. | Controls (n=51). All male, mean age 23.75, no, significant difference with controls, were individually matched from their own peer group, a person who was drinking with them and attended the A&E department with them.  
* No significant difference between groups on age, employment status, social class, weekly alcohol consumption, weekend alcohol consumption, consumption in the five days preceding the incident, types of relationships formed with peers or sexual partners, major life events or minor stressors in the period prior to injury.  
* Cases drank significantly more alcohol during a typical weekend session (0.008). | Blood alcohol content using an ‘alcometer’ | Injury severity Score, Revised Injury Severity Score, Assault Trauma Score, Glasgow Coma Score, Holmes and Rahlle Life Style Score | Following completion of interview schedule in the emergency department – exact time not specified |
Table 1 (continued). Evidence Table from Systematic Review – Study Characteristics

<table>
<thead>
<tr>
<th>Reference: (author/s, year, aim, country)</th>
<th>Study design, evidence level and study quality; (response rates, treatment of missing data)</th>
<th>Population: (n, age range, gender, setting)</th>
<th>Comparison group</th>
<th>Blood alcohol or breath measures</th>
<th>Harms measured and measures</th>
<th>Time b/w BAC and observed harm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver et al 2008 (24)</td>
<td>Study design: matched case control study (one to one)</td>
<td>Number: 24 BAC+, 24 BAC-</td>
<td>33 BAC+ burn victims identified with TBSA between 15 and 75. Six excluded as (BAC &lt; .03), two had no matches and one had complicating liver disease. Remaining 24 were matched on the following: age, sex, Total Body Surface Area (TBSA), Inhalation injury, type of burn, baux score (age+TBSA). Matching was done blinded to patient outcomes. BAC+ group: 38.3 years, 83% male, 29.17 TBSA, 42% inhalation, 96% flame, 4% scald, 67.4 Baux score</td>
<td>BAC upon admission (hospital policy for all non-paediatric burns victims so this was automatic)</td>
<td><strong>Short Term:</strong> Mechanical ventilation, Apache III, Highest A-a gradient, lowest PaO2: FiO2 ratio, worst base deficit, fluid requirements <strong>Long Term:</strong> Ventilator days, total blood transfusions, burn ICU days, hospital length of stay, hospital charges, mortality</td>
<td>Short term: 24 hours Long term: Length of stay</td>
</tr>
<tr>
<td>Aim: To examine the effects of BAC on outcomes among burn injury patients</td>
<td>Evidence level: Level III (2)</td>
<td>Demographics: Overall for both groups: 87% Male, 37.7 years 42% inhalation injury</td>
<td>BAC- group: 37.1 years, 92% male, 29.3 TBSA, 42% inhalation, 96% flame, 4% scald, 66.4 Baux score</td>
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</tr>
<tr>
<td>Country: U.S.A</td>
<td>Study quality: moderate - no information on missing data before 33 BAC+ patients were selected, but good information provided as to why the next 9 were excluded (n=24) but controls were excellently matched. Comprehensive outcomes also measured</td>
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<tr>
<td>Reference: (author/s, year)</td>
<td>Alcohol Level</td>
<td>Harm Outcome</td>
<td>Effect Size</td>
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<tr>
<td>Reference: Honkanen et al. 1983 (37)</td>
<td>Range 0-155+mg/100ml for both cases and controls</td>
<td>With comprehensive situational controls the ORs per BAC range are as follows: 0-.054 - 1.0; .055-.154 - 8.5; .155+ - 73.0</td>
<td>Please refer to the Odds Ratios.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Reference: Shepherd and Brickley 1996 (38) | Cases: range 0-340mg/100 ml, mean = 141 mg/100ml  
Controls: range 0-300mg/100 ml, mean 133 mg/100ml | No significant difference between cases and control on mean alcohol level (p=0.16). However, more cases had a very high BAC than controls. Cases with over 160mg/100ml had significantly higher chance of injury than controls (p=0.01) | For the non-significant difference between groups on overall BAC the effect size is r~0.06. Effect size could not be calculated for the significant results no mean, SD or df was provided. |
| Reference: Silver et al. 2008 (24) | BAC+ ≥ .03  
BAC- = 0  
Patients with BAC 0.001-0.03 were excluded | BAC+ short term had significantly  
- Higher Apache II score  
- Higher worst base deficit  
- Higher 24 hour fluids  
BAC+ long term had significantly  
- Higher ventilator days  
- Burn ICU days  
- Length of Stay  
- Hospital Charges | Cannot compute effect sizes without mean and SD or t and df (only means and p values provided). |
While the method was rigorous and the completion rate for controls was good, some elements of analysis in the paper are problematic. Even in a case control study correlation does not mean causation. However the authors argue that the ‘strength of association, existence of dose-response relationship and concordance with existing knowledge indicate that causality can be considered certain’ (p. 242).

The second included study by Shepherd and Brickley (38), combined a case control and a cohort study in order to investigate the relationship between alcohol consumption, intoxication and injury in urban violence. The cohort study aspect of the paper is not of interest in the current study, so all the results discussed below, and those presented in the evidence table, stem from the case control study. All study participants were male and there was no significant difference between subjects and controls in age, removing two of the biggest confounding factors in unmatched studies. Fifty-one patients with injury were compared to those who accompanied them to the ED who were present at the time of injury and not injured themselves. One of the primary advantages of this particular type of case control is that it could be assumed that the accompanying control stopped drinking around the same time that the injured party did, so although it is difficult to control the amount of time between the injury and arrival in the emergency room, this time would have been very similar within each pair. In addition, the participant is likely to have a lot in common with the person who they are attending the hospital with, and it could be argued that those who accompanied the injured person to the ED and was there at the time at the accident had a higher risk of being injured than a more neutrally selected control.

In this study no significant difference was found in BAC between the 49 cases who consented to the breathalyser (mean BAC = .141) and their controls (mean BAC = .132). A relationship between BAC and injury was only found when cases with a BAC over .16 were
compared to their controls. Below this level, there was no significant difference. This is an important finding; however, there is no mention of how many participants were in this subgroup and no mention of whether controls with a BAC of .16 or more whose cases had a lower BAC were included in this analysis. Without a theoretical justification provided in the paper for the specific cut-point put forward, this type of selection also increases the chance of finding a false positive result.

The final included study also used a matched case control design. Silver et al. (24) investigated the role of BAC on clinical outcomes among burn injury patients. They reviewed burn intensive care unit admission records over a five year period (September 2001-September 2006). Included records involve patients between 16-75 years of age with burns ranging between 15 and 75% of their body. Records were separated into BAC positive (a minimum level of .03) and BAC negative groups (no detectable alcohol), with reviewers blinded to both BAC and outcomes. BAC positive cases were matched with BAC negative controls on age, sex, burn size, presence of inhalation injury and mechanism of burn injury. Twenty four matched cases were included in analysis.

On early clinical outcomes, BAC positive patients had significantly higher severity of disease scores (p<0.05; measured using the Apache II), worse base deficit (p<0.05) and needed more fluids (p<0.05). Analysis of later clinical outcomes showed that BAC positive patients had on average more ventilator days (p<0.05), more time in the burn intensive care unit (p<0.05), a longer length of hospital stay (p<0.05) and higher hospital charges (p<0.05).

This study was methodologically rigorous, looking at records over a five year period, reviewer’s blind to BAC and outcomes and BAC taken at the time of admission. However, the results are limited to burn injury patients, meaning they cannot be generalised to other patients given the potential for a particular physiological interaction between blood alcohol
content and fire. Further, the cut-off point set by the authors was .03 and particular harms were not reported as rising appreciably at different levels of BAC.

Summary

The first study by Honkanen et al. (37) showed that, after controlling for confounding factors the relative risk of accidental falls is 8.5 times more than normal when BAC is between 0.055-.154 and 73 times more than normal when BAC is .155 or more. The second study by Shepherd and Brickley (38) showed a significant relationship between alcohol and injury among cases who had a BAC of .16 or more. Nonetheless, neither allows us to identify a point where harm rises appreciably as both indicate likelihood harm only at set data points. Honkanen et al (37) which provides odds ratios for risk at more than one data point appears to show a smooth risk curve.

The studies have other limitations. For example, in the Honkanen et al. study (37), the risk of accidental falls at BAC of zero has not been quantified, and as such the absolute risk that stems from this higher relative risk cannot be calculated. In the Shepherd and Brickley study (38) no justification for the cut-point of .16 was given, there is no mention of how many participants were in this secondary analysis and no mention of whether controls with a BAC of .16 or more whose cases had a lower BAC were included in this analysis. This type of selection increases the potential for a false positive finding.

The final study, by Silver et al. (24), showed that treatment outcomes among burn victims were significantly worse for those who had consumed alcohol. Once in hospital even a BAC of .03 or higher resulted in increased chance of complication. This is important to note because it has implications for hospitals and the resources needed to treat burn patients who have consumed alcohol prior to their injury. It also indicates that the risk of complications
once in hospital indicating might rise at quite low BACs. This suggests to us that these two
types of investigations (studies of patients admitted to EDs and studies of outcomes for
people who are hospitalised with a measured BAC) may need to be examined separately.
DISCUSSION

BAC was used as the measure of intoxication in this study because the purpose of this review is to identify a BAC level at which a plausible case could be made for legally prohibiting the serving of alcohol to a drinker on a licensed premises and due to difficulties translating volume of alcohol consumed to BAC after seven standard drinks.

Numerous case crossover and case control studies of alcohol consumption and harm were excluded from the systematic review. There were two primary reasons for this. Firstly, some studies were excluded because they measured self-reported number of drinks rather than BAC. Some of these studies measured BAC, but chose to structure their analysis based on self-estimated number of drinks due to the time lag between the injury occurring and BAC measurement being undertaken. Second, studies were excluded that did not adequately control for demographic differences between those who drank or got injured and those that did not. Not controlling for demographics means that the results of these studies might reflect the drinking habits of those more likely to get injured, rather than the effect of alcohol on injury (39). For example, a time-series analysis found that the presentation of patients to hospital with alcohol-related codes and the number of assaults reported to the police were positively related, however similar to previous studies of this type the predominance of young males in both samples may have confounded results (40). An Australian meta-analysis of studies of injured pedestrians shows that 80-90% of those with a BAC over .15 were male (41).

Nonetheless, research conducted in hospital emergency rooms provide valuable insight into the prevalence of intoxication in accident and violence, with studies repeatedly finding a positive dose-outcome relationship between alcohol consumption and injury, even at low levels of consumption (22, 42, 43).
In this section we discuss studies that were excluded from our systematic review because they did not describe BAC levels, but which provide additional information on the incremental relationship between alcohol and harm that is of relevance to the research question. Table 3 summarises studies that provide an odds ratio of relative risk for acute alcohol-related harm. Table 4 summarises studies that describe a statistically significant relationship between alcohol consumption and injury. For each study we provide indicative BAC levels derived from numbers of standard drinks, calculated using equivalences provided by Bond et al. (2). In reading Tables 3 and 4 it is important to bear in mind that some of these BAC ranges are extremely wide, for instance more than 0, while some are more specific, for instance .1-.149. It should also be remembered that Bond et al. define standard drinks as 12g of alcohol, against the Australian definition of 10g.

Our tables are structured so that the studies which showed the strongest relationship between alcohol and injury are presented first. The three studies identified in the systematic review are also included in the table. As can be seen in Table 3, the Honkanen et al. (37) study, which was included in our systematic review, and was reasonably methodologically rigorous, identified the strongest relationship between alcohol and the chance of accidental falls, with a relative risk of 73 at a BAC of .155 or more. The Shepherd and Brickley (38) study, which is identified in Table 3, showed significant likelihood of injury at BAC levels of .16 or more; however, a relative risk was not provided in this study and thus this study cannot be placed in the context of a scale of risk like the other studies.
Table 3. Summary table of the relative risk of injury by BAC where odds ratios are presented, sorted by risk

<table>
<thead>
<tr>
<th>Paper</th>
<th>Measure</th>
<th>Equivalent BAC*</th>
<th>Relative Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honkanen et al. 1983 (37)</td>
<td>.155+</td>
<td>.155+</td>
<td>Odds ratio of 73 for risk of accidental fall when compared to BAC of 0-.054</td>
</tr>
<tr>
<td>Taylor et al. 2010 (1)</td>
<td>140g</td>
<td>No equivalent</td>
<td>Odds ratio of 24.2 for risk of non-motor vehicle injury compared to BAC of 0</td>
</tr>
<tr>
<td>Vinson et al. 2003 (3)</td>
<td>7+ drinks</td>
<td>.098+</td>
<td>Odds ratio of 17 for risk of injury compared to BAC of 0 (case crossover)</td>
</tr>
<tr>
<td>Vinson et al. 2003 (3)</td>
<td>5-6 drinks</td>
<td>.086+</td>
<td>Odds ratio of 13.5 for risk of injury compared to BAC of 0 (case control)</td>
</tr>
<tr>
<td>Borges et al. 2006 (44)</td>
<td>6+ drinks</td>
<td>.086+</td>
<td>Odds ratio of 10.1 for risk of injury compared to BAC of 0</td>
</tr>
<tr>
<td>Vinson et al. 2003 (3)</td>
<td>5-6 drinks</td>
<td>.086+</td>
<td>Odds ratio of 9.5 for risk of injury compared to BAC of 0 (case crossover)</td>
</tr>
<tr>
<td>Humphrey et al. 2003 (45)</td>
<td>246 ml</td>
<td>No equivalent</td>
<td>Odds ratio of 9.34 for risk of injury compared to BAC of 0</td>
</tr>
<tr>
<td>Savola et al. 2005 (46)</td>
<td>.2+</td>
<td>.2+</td>
<td>Odds ratio of 9.23 for risk of head injury when compared to BAC of 0</td>
</tr>
<tr>
<td>Vinson et al. 2003 (3)</td>
<td>7+ drinks</td>
<td>.098+</td>
<td>Odds ratio of 8.8 for risk of injury compared to BAC of 0 (case control)</td>
</tr>
<tr>
<td>Honkanen et al. 1983 (37)</td>
<td>.055-.154</td>
<td>.055-.154</td>
<td>Odds ratio of 8.5 for risk of accidental fall when compared to BAC of 0-0.54</td>
</tr>
<tr>
<td>Study</td>
<td>Drinking Level</td>
<td>BAC</td>
<td>Odds Ratio</td>
</tr>
<tr>
<td>------------------------</td>
<td>----------------</td>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td>Borges et al. 2004 (47)</td>
<td>.01+</td>
<td>.01+</td>
<td>6.81</td>
</tr>
<tr>
<td>Borges et al. 2006 (44)</td>
<td>4-5 drinks</td>
<td>.062+</td>
<td>6.5</td>
</tr>
<tr>
<td>Vinson et al. 2003 (3)</td>
<td>3-4 drinks</td>
<td>.062+</td>
<td>6.2</td>
</tr>
<tr>
<td>McLeod et al. 1999 (48)</td>
<td>90g</td>
<td>.098+</td>
<td>5</td>
</tr>
<tr>
<td>Borges et al. 2004 (47)</td>
<td>Any drink</td>
<td>0+</td>
<td>4.33</td>
</tr>
<tr>
<td>Borges et al. 2006 (44)</td>
<td>2-3 drinks</td>
<td>.039+</td>
<td>3.9</td>
</tr>
<tr>
<td>Vinson et al. 2003 (3)</td>
<td>3-4 drinks</td>
<td>.062+</td>
<td>3.7</td>
</tr>
<tr>
<td>McLeod et al. 1999 (48)</td>
<td>60g</td>
<td>.086+</td>
<td>3.4</td>
</tr>
<tr>
<td>Borges et al. 2006 (44)</td>
<td>1 drink</td>
<td>.039+</td>
<td>3.3</td>
</tr>
<tr>
<td>Savola et al. 2005 (46)</td>
<td>.15-.199</td>
<td>.15-.199</td>
<td>3.2</td>
</tr>
<tr>
<td>Peden et al. 1996 (49)</td>
<td>&gt;0</td>
<td>0+</td>
<td>2.6</td>
</tr>
<tr>
<td>Vinson et al. 2003 (3)</td>
<td>1-2 drinks</td>
<td>.039+</td>
<td>1.8</td>
</tr>
<tr>
<td>Study</td>
<td>Alcoholic Intake</td>
<td>BAC Range</td>
<td>Odds Ratio</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------------------</td>
<td>-----------</td>
<td>-------------</td>
</tr>
<tr>
<td>Savola et al. 2005 (46)</td>
<td>0.1149 - 0.149</td>
<td>0.1 - 0.149</td>
<td>1.64 for risk of head injury when compared to BAC of 0</td>
</tr>
<tr>
<td>Vinson et al. 2003 (3)</td>
<td>1-2 drinks</td>
<td>0.039+</td>
<td>1.5 for risk of injury compared to BAC of 0 (case control)</td>
</tr>
<tr>
<td>Humphrey et al. 2003 (45)</td>
<td>per 30ml</td>
<td>0.039+</td>
<td>1.4 for risk of injury per 30 ml of alcohol consumed compared to BAC of 0</td>
</tr>
<tr>
<td>Savola et al. 2005 (46)</td>
<td>0.001-0.099</td>
<td>0.001-0.099</td>
<td>1.24 for risk of head injury when compared to BAC of 0</td>
</tr>
</tbody>
</table>

*Equivalent BAC is taken using the equivalency tables from Bond and colleagues (2), where an equivalent BAC is given for different numbers of standard drinks (defined as 12g in this paper compared to 10g for Australian standard drinks). The most conservative BAC for a given number of drinks, grams or mls of alcohol was selected.*
Table 4. Summary table of the relative risk of injury by BAC where significant differences are presented, sorted by risk

<table>
<thead>
<tr>
<th>Paper</th>
<th>BAC measure in paper</th>
<th>Significance (p&lt;0.05 or less)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shepherd &amp; Brickley 1996</td>
<td>.16+</td>
<td>Significantly more likely to be injured through when BAC was .16 or more</td>
</tr>
<tr>
<td>Macdonald et al. 2006</td>
<td>.08+</td>
<td>Significantly more severe injuries such as head injuries than those with 0 or low BAC</td>
</tr>
<tr>
<td>Silver et al. 2008 (24)</td>
<td>.03+</td>
<td>Significantly more time in the burn ICU when compared to matched burn victim with BAC of 0-0.03</td>
</tr>
<tr>
<td>Silver et al. 2008 (24)</td>
<td>.03+</td>
<td>Significantly more ventilator days when compared to matched burn victim with BAC of 0-0.03</td>
</tr>
<tr>
<td>Silver et al. 2008 (24)</td>
<td>.03+</td>
<td>Significantly more fluids required when compared to matched burn victim with BAC of 0-0.03</td>
</tr>
<tr>
<td>Silver et al. 2008 (24)</td>
<td>.03+</td>
<td>Significantly longer length of hospital stay when compared to matched burn victim with BAC of 0-0.03</td>
</tr>
<tr>
<td>Silver et al. 2008 (24)</td>
<td>.03+</td>
<td>Significantly higher worse base deficit scores when compared to matched burn</td>
</tr>
</tbody>
</table>
BLOOD ALCOHOL CONTENT AND INTOXICATION
Turning Point Alcohol and Drug Centre

<table>
<thead>
<tr>
<th>Reference</th>
<th>BAC</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver et al. 2008 (24)</td>
<td>.03+</td>
<td>Significantly higher severity of disease scores when compared to matched burn victim with BAC of 0-0.03</td>
</tr>
<tr>
<td>Silver et al. 2008 (24)</td>
<td>.03+</td>
<td>Significantly higher hospital charges when compared to matched burn victim with BAC of 0-0.03</td>
</tr>
<tr>
<td>Pories et al. 1992 (51)</td>
<td>.1+</td>
<td>No significant difference in injury severity between .1+ and less than .1</td>
</tr>
</tbody>
</table>
Also as shown in Table 3, the study which showed the second greatest odds ratio predicting injury with BAC was a methodologically robust meta-analysis drawing on 28 case control or case crossover studies of alcohol consumption and injury, conducted by Taylor et al. (1). This study was not included in the review because it reported on volume of alcohol consumed as opposed to BAC. However, the findings of this review should be given significant weight, given it was a meta-analysis of 28 case control and case crossover studies of alcohol and injury. The authors found that for non-motor vehicle injury, the odds ratio increases by approximately 1.3 per standard drink, up to an odds ratio of 24.2 at 140 grams of alcohol. We cannot use Bond et al.’s equivalency table (2) for this finding because it is only accurate up to seven standard drinks and 140 grams of alcohol is approximately twice this amount. However, 140 grams of alcohol is approximately twice Bond et al.’s estimate for BAC at seven standard drinks (indicating it may be somewhere in the vicinity of twice .098 BAC).

Importantly, Taylor et al.’s meta-analysis shows a smooth risk curve for acute non-driving related harms from alcohol consumption up to 140 grams, such that it is impossible to identify a level of alcohol consumption where harm could be said to rise appreciably (see Figure 2 below).

**Figure 2. Dose-response curve for the amount of alcohol consumed 3 hours prior to injury and the odds ratio of (non-motor vehicle) injury, from Taylor et al. (1)**
An emergency department study by Vinson et al. (and reported on in two papers (3, 4)) showed the third highest odds ratio predicting injury with BAC. This study involved both a case crossover methodology and a case control methodology (matched community controls accessed via random digit dialling). It showed that after 1 or 2 drinks the odds ratios for risk was 1.8, after 3 or 4 drinks odds ratios were between 3.7 and 6.2, after 5 or 6 drinks odds ratios were between 9.5 and 13.5, and after seven or more drinks the odds ratios were between 8.8 and 17. This was a well designed study with three different types of controls for each case, and was only excluded from the systematic review as BAC was not measured (i.e., it relied on self-reported number of drinks). As can be seen in Table 3, using Bond and colleagues’ equivalency table (2), 5-6 standard drinks is equivalent to a BAC of .098.

Using a case crossover design, Borges et al. (44) also found an odds ratio of 10 for patients who had consumed six or more drinks prior to their injury. This study drew on data from 10 emergency departments around the world. It showed that of 4320 patients who were interviewed about the six hour time period prior to their accident and the six hour time period one week before (to act as the case crossover arm), the risk of injury increased with a single drink (odds ratio of 3.3) and there was a ten-fold increase for patients who had consumed six or more drinks, translated to a BAC of .098 using Bond et al.’s equivalencies (2). This paper was excluded from the review because it relied on self-reported number of drinks rather than measured BAC.

A study of attendees at a New Zealand emergency department by Humphrey et al. (45) found a 1.14 increased cumulative risk for each 30mls of absolute alcohol for people who reported alcohol consumption prior to the injury (OR =1.4, 95% CI: 1.003-1.300). This relationship was stronger at higher levels, with drinking 246ml of absolute alcohol associated with 9.34 times the risk of injury. Again Bond et al.’s equivalency table (2) cannot be used to
measure this in BAC as it is only accurate up to seven standard drinks and 246ml is likely to be more than fifteen standard drinks. This paper was not included in the systematic review as there was no control for demographic differences between the two groups and it relied on self-reported number of drinks.

A case crossover study by Borges et al. (47) of 961 emergency department patients in California and Mexico used each individual’s self reported alcohol consumption during the last 12 months as a control to estimate the relative risk of injury in the hour after alcohol consumption, compared with no alcohol consumption during this hour. Relative risks varied by race, alcohol dependence and frequency of drunkenness, with increased risk of injury concentrated in the hour after alcohol consumption ceased. This study also identified the relative risk for injury for patients with positive BACs (defined as BAC of .01 or higher) as 6.81 (5.61-19.31). Using self-report data, the relative risk of any injury in the hour after alcohol consumption compared with no alcohol consumption during that time was 4.33 (3.55-5.27). This study wasn’t included in the systematic review because the cut off point set by the authors was .01, a level where intoxication is unlikely, and harms were not measured at higher levels of BAC.

An Australian study conducted by McLeod et al. (48) involved interviewing 797 emergency consecutive ED presentations where an injury was present and 797 non-matched controls who were randomly selected members of the local community interviewed at home within eight days of the case’s injury. Logistic regression produced an odds ratio of 3.4 for the risk of injury after consuming more than 60g of alcohol in a six hour period (using Bond et al.’s equivalencies (2), 5-6 standard drinks is equivalent to a BAC of .098) and those who consumed more than 90g of alcohol were five times more likely to sustain an injury, after
controlling for demographics (using Bond et al. this is equivalent to a BAC of well over .098). Controls for this study were only matched on suburb of residence.

The NHMRC (5) re-analysed data from three emergency department datasets to assess the impact of alcohol on injury in single-drink increments (these data sets are reported on in 32, 33, 34). They found a similar risk curve in each, with greater risk after four standard drinks on a single occasion (approximately .062 BAC), more than doubling the relative risk of an injury in the six subsequent hours and rising more rapidly for additional drinks.

Finally, McDonald et al. (50) reviewed data collected from patients at 30 emergency rooms in six countries. They concluded that the odds ratios of violent versus accidental injury for a BAC over .08 were significant for each country. Odds ratios ranged from 2.77 for Mexico to 9.45 for Canada. This finding is of limited utility as the baseline for these odds ratios was accidental injury, rather than no injury. The findings do, however, underline the general finding in emergency room studies of a higher association between alcohol and injury when the injury results from assault rather than accident (for example, see also 45, 52, 53).

**Severity of injury**

We turn now to consider the smaller number of studies concerned with tracking a relationship between BAC and severity of injury type, as in the Silver et al. (24) paper included in the systematic review above. Measures include worse hospital outcomes, more severe injuries or greater likelihood of death.

Based on analysis of 385 consecutive trauma admission patients (of which 51% had a positive BAC), Savola et al. (46) found that BAC positive patients were significantly more likely to have experienced a head injury, with risk increasing sharply with BAC (.1-.99 OR = 1.24; .1-.149 OR = 1.64; .15-.199 OR = 3.2; .2+ OR = 9.23); however this study was not
included in the systematic review as there was no control groups controlling for the demographic differences between the groups of participants split on the basis of BAC.

Peden et al. (49) found that 62% of 321 injured pedestrians seen at a trauma hospital in South Africa were BAC positive, with a mean of .19. BAC positive pedestrians were 2.6 times more likely to have a head injury (p=0.00009), sustained more severe injuries, more frequently required admission to ICU, had longer hospital admissions and were more likely to die of their injuries. An Australian meta-analysis by Holubowycz found that 20-30% of pedestrian accidents occur to people with a BAC over .15 (41).

Analysis of 1398 patients admitted to an Australian trauma centre with injuries by Pories et al. (51) showed that BAC positive patients had significantly higher injury severity and a 13.3% death rate as opposed to 2.3% in the non-alcohol group. In this study, there was no statistically significant difference in injury severity between patients with a BAC under .1 and over .1.

Finally, Haum et al. (54) found that having a positive BAC for patients admitted to hospital for serious burn injuries was associated with a significantly higher fatality rate than for patients with a negative BAC. They found that a BAC over .06 was correlated with increased risk of fatality.
CONCLUSION

There has been much discussion about how to identify a point at which the risk of injury becomes too high (55, 56). In many areas of public policy risk assessment in (such as in relation to risks from radioactive contamination or from food additives) thresholds are set at absolute risk levels. Absolute risk is an individual’s risk of an outcome over a period of time, based on population data (and often measured as lifetime absolute risk). Often for such public policy issues, appropriate risk is considered to be very small, i.e. 1 in 10,000. In formulating the current NHMRC guidelines to Reduce Health Risks from Drinking (5) a committee of experts made a collective decision to set thresholds at the level of 1 in 100 lifetime absolute risk of mortality from alcohol (56), but did not make a recommendation about an absolute threshold for acute risks from alcohol. According to Room and Rehm (56), the reason the risk of lifetime mortality from alcohol was set as higher than in other public health matters was because ‘the hazards of drinking are a matter of foreknowledge and choice’ (pg. 138). Relative risk, on the other hand, involves comparing risks for two different groups of people. Room and Rehm note that assessing risk from acute events such as from single drinking occasions (as in this review) ‘is commonly expressed in terms of the relative risk of injury from an amount of drinking on a particular occasion compared with the risk of no drinking in the same time period’ (p. 138).

In this final section of our report we consider issues involved in identifying either relative or absolute risk as a measure for setting a threshold for alcohol service at a given BAC level. We conclude with a brief discussion of implications of this study for future research in this area.
Setting a BAC threshold on the basis of relative risk

It is well established that harm rises in proportion to the number of drinks consumed by an individual on any one occasion, although risk for any individual varies greatly by a range of factors including alcohol dependence, pre-existing medical conditions, body weight and alcohol metabolism capacity. While there are some methodological limitations evident in all studies reviewed here, Tables 3 and 4 clearly show that odds ratios for injury increase as BAC increases, although the variation within this pattern is considerable. This might be attributed in part to the different types of injuries being measured, for example pedestrian accidents versus falls.

We identified only two studies examining a relationship between particular levels of BAC and likelihood of injury that used a case control design and were well controlled. In both of these a BAC of .16 or over appears to be correlated with the highest recorded relative risk of injury amongst studies included in our systematic review. Honkanen et al. (37) showed that, after controlling for confounding factors, the relative risk of accidental falls is 73 times more than normal when BAC is .155 or more. Shepherd and Brickley (38) showed a significant relationship between alcohol and injury among cases who had a BAC of .16 or more. However, as already noted, it is very important that the limitations of both studies are considered. Moreover, we were able to identify increasing likelihood of harm associated with alcohol consumption only at specific reported levels. While the limited results obtained from included studies do seem to suggest a curve with odds ratios increasing at a very high rate once BAC levels rise over .1, there were insufficient data points available to determine whether an inflection point exists within the curve, or what happens to the curve after recorded BAC level data points. Future studies should where possible provide risk curves for harm, rather than just odds ratios for harm at set BAC levels.
Two studies that were excluded from our systematic review because they reported on total volume of alcohol consumed or standard drinks are important in the context of this review. The first of these is Taylor et al.'s (1) meta-analysis that addressed the same research questions as ours but was not limited to studies specifically measuring BAC. As already noted, this study shows a smooth risk curve for acute non-driving related harms from alcohol consumption up to 140 grams, such that it is impossible to identify a level of alcohol consumption where harm could be said to rise appreciably (see Figure 2 on page 35).

The second methodologically rigorous study that was excluded from our systematic review on the basis that it used self-reported number of drinks as opposed to BAC was by Vinson et al. (3, 4). The study utilised both a case crossover methodology and a case control methodology, both of which showed that after 1 or 2 drinks the odds ratios for risk was 1.8, after 3 or 4 drinks odds ratios were between 3.7 and 6.2 and after 5 or 6 drinks odds ratios were between 9.5 and 13.5, with 7 plus standard drinks giving an odds ratio of 17. Using the equivalencies provided by Bond and colleagues (2), 7 or more standard drinks is equivalent to a BAC of more than .098. The study does not provide specific odds ratios for harm after 7 plus standard drinks; were it to do so it may indicate higher harms at greater levels of alcohol consumption.

Although all these studies point to rising relative risk with increasing alcohol consumption, we are unable on the basis of available evidence to identify a compelling argument that any level of alcohol consumption is preferable as a threshold where alcohol sales should be refused.

One option for setting a BAC threshold would be after consumption of five or six standard drinks, or the approximate BAC equivalent of this, .086. This is consistent with the NHMRC’s (5) decision to identify five or more drinks as increasing risk for a single occasion of drinking, and Livingston’s recent work (57) where he identifies that thresholds of seven or fewer drinks
(an estimated BAC of around .1 or less) provided the best balance between sensitivity and specificity. This would, however, be a level of alcohol consumption at which many people would not consider themselves to be particularly intoxicated.

Setting risk thresholds on the basis absolute risk

Using a level of absolute risk (for instance, one in 100 lifetime risk of mortality) to identify a BAC threshold at which alcohol should not be sold on licensed premises would align this policy with the methods used to formulate existing alcohol consumption guidelines (5). Additionally, thresholds based on absolute risk can, as Stockwell et al. (58) point out, be counter intuitive. For example, such an approach would support advice to women that they could drink greater quantities of alcohol than men, on the basis that men have higher risk of a range of injuries with or without consuming alcohol.

It is a complex task to translate the risk ratios identified in the studies included in this report to a measure of absolute risk. Prevalence rates within the general population of harms measured in our included studies were not provided, meaning that we could not calculate absolute lifetime risk for any of the alcohol-related acute events described. As Room and Rehm (56) describe, ‘specifying lifetime risk estimates [from risk ratios] involved not only arriving at risks for drinking at a given level on a single drinking occasion, but also aggregating results for such a level per occasion across specified frequencies of such drinking occasions in a lifetime of drinking’ (p. 138). Further work is required to calculate absolute risk of lifetime injury from reported risk ratios before any absolute risk threshold can be identified. This task is outside the scope of our systematic review.
Limitations and directions for future research

The purpose of this research is to identify a BAC level where service to intoxicated patrons might be refused. One of the biggest hurdles in addressing this research question is the limitations of existing research. In particular, most studies focus on self-reported number of drinks which has significant limitations such as recall bias (especially when under the influence of alcohol). It is unfortunate that a BAC cannot be calculated with confidence from research identifying numbers of standard drinks consumed prior to injury, particularly over seven standard drinks, making it problematic to use these studies in determining a BAC which indicates intoxication. As Vinson et al. conclude: ‘further work is needed to define more precisely the threshold at which risk begins to increase and to examine risks for different subgroups, different injury patterns and more severe injuries’ (59).

In addition, much of the research drawn on in this review involved alcohol and ‘injury’ rather than specific types of injuries. For example, some ED studies find a higher rate of alcohol involvement in assaults than other injuries (45, 52, 53). Controlling for types of injury received may provide more insight into the specific types of risks that those with high BAC are exposed to. For example, the connection between alcohol and accidental injury is most often related to impaired motor control judgement; however, assault is likely to also be influenced by the disinhibiting effects of alcohol and perhaps also predisposition to aggression. Further to this, the social context in which drinking occurs is also likely to be important in understanding harm. For example, accidental falls might be more likely at home where there are stairs but assault might be more likely at licensed venues where there are other factors such as crowd, noise and lighting influencing the context. Such variables must be controlled for in any future studies of the link between alcohol and injury.
While alcohol consumption is linked strongly to violence, based on analysis of individual and population level data across European countries, Room and Rossow (60) show that there are cultural differences in the proportion of violent episodes involving drinking and clear variations between different drinking cultures in the fraction of violence attributable to drinking. As we have noted, alcohol has been found to have a relationship with injury in ED samples and community controls across different countries, however the strength of this relationship appears to vary across cultures (61). Thus, future research should be sensitive to cultural differences across countries and also within countries; for example, exploring differences for regional and rural areas.

A further consideration in identifying a BAC where patrons may be considered intoxicated is that different alcoholic drinks appear to be associated with different risks of injury. For example, it has been suggested that the higher alcohol content of spirits allows for faster intake and higher BAC levels than lower-strength products such as beer and wine. A quicker rise in BAC from spirits is likely to have different cognitive effects on the drinker including increased aggression (62). The question as to whether spirits are associated with more harm than other types of alcohol is unclear. In one study, Room et al. (63) looked at harms by beverage type across nineteen societies and found that people who drink wine generally have fewer negative consequences from drinking than those who drink other beverages per drink consumed. Controlling for age and gender, the authors found that wine was still associated with the least harm (although this study only included two ‘wine cultures’ and the authors point out that the social context within which wine is often consumed may explain this trend), but there was no overall trend across cultures in comparing trouble associated with beer and spirits. However, two recent studies have shown a link between the consumption of spirits and harm. A study, analysing consumption data and suicide data between the years 1963-2007 showed that the consumption of distilled spirits in Japan was
significantly associated with male suicide rates (64), while analysis from Russian sales and homicide data between 1970 and 2005 showed that total alcohol consumption and total vodka consumption were significantly associated with both male and female homicide rates (65).

Well-designed case crossover and case control studies of alcohol and injury are required to identify with confidence a point where acute injuries become appreciably more likely after drinking alcohol. Future research should control for demographics, cultural differences, types of injury, type of alcohol consumed before the injury and drinking environment. Studies should measure self-reported number of standard drinks as well as specific BAC levels to clarify the relationship between these two factors, and should test body weight and record the period of time over which alcohol was consumed to enable accurate calculation of BAC. Most importantly, future research should provide sufficient data points so as to enable the potential determination of an inflection point within the risk curve, rather than just odds ratios for harm at set BAC levels.

Despite the need for more research, identifying a BAC at which people are exposed to excessive harm will always involve making a judgement as to how (as either relative or absolute risk) and where (at what level of risk of injury or mortality) to set thresholds where risk becomes considered to be unacceptable.
REFERENCES


