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Alcohol use, aquatic injury, and unintentional drowning: A systematic literature review

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Abstract

Background: Drowning is a global public health issue, and there is a strong association between alcohol and risk of drowning. No previous systematic review known to date has identified factors associated with alcohol use and engagement in aquatic activities resulting in injury or drowning (fatal and non-fatal).

Methods: Literature published from inception until 31 January 2017 was reviewed. Included articles were divided into three categories: (1) prevalence and/or risk factors associated with alcohol-related fatal and non-fatal drowning and aquatic injury, (2) understanding alcohol use and engagement in aquatic activities, and (3) prevention strategies. Methodological quality of studies was assessed against the National Health and Medical Research Council (NHMRC). Levels of Evidence and risk of bias was assessed using the Newcastle-Ottawa Quality Assessment Scales.

Results: In total, 73 studies were included (57 on prevalence and/or risk factors, 14 on understanding alcohol use, and two on prevention strategies). Prevalence rates for alcohol involvement in fatal and non-fatal drowning varied greatly. Males, boating, not wearing lifejackets, and swimming alone (at night, and at locations without lifeguards) were risk factors for alcohol-related drowning. No specific age groups were consistently identified as being at risk. Study quality was consistently low, and risk of bias was consistently high across studies. Only two studies evaluated prevention strategies.

Conclusion: On average, 49.46% and 34.88% of fatal and non-fatal drownings, respectively, involved alcohol, with large variations among studies observed. There is a need for higher quality studies and behavioural basic and applied research to better understand this risky behaviour.

Keywords: Alcohol, Drowning, Injury, Water Safety, Systematic Review

What is already known on this subject?
Reports indicate a strong association between alcohol consumption and drowning risk, with alcohol estimated to be a contributory factor in approximately 20% of all drowning deaths. Previous research has shown alcohol to significantly increase the risk of drowning when engaging in recreational aquatic activities, and a lack of research and practice on policies and water safety initiatives around alcohol. No systematic review has identified factors associated with alcohol-use and engagement in aquatic activities where injury or drowning (fatal or non-fatal) has occurred.

What this study adds?
Current findings showed that the prevalence rates for alcohol involvement in fatal drowning ranged from 4.46% to 72.22%, with a similar range identified in non-fatal drowning. Risk factors included males, boating, not wearing lifejackets and swimming alone, at night and at locations without lifeguards. No specific age groups were consistently identified as being at increased risk of alcohol-related drowning. This study also highlights the urgent need for high quality intervention research aimed at reducing alcohol-related drowning.

Policy implications?
The findings of this systematic review identify the need for the use of consistent study methodology to allow comparison of studies. Future research should also focus on the implementation and evaluation of prevention strategies to reduce further loss of life due to alcohol-related drowning.

Introduction

Drowning accounts for 7% of all injury-related deaths making it the third leading cause of unintentional death worldwide [1]. Detailed examination of the correlates of drowning indicates a strong association between alcohol consumption and drowning risk [2], with studies reporting that alcohol is a contributing factor in approximately 20% of all drowning deaths [3]. This increases to 30% [4] and 41% [5] of all deaths related to recreational aquatic activity and river drownings, respectively, and to almost half in certain age groups [5]. The true extent of alcohol-related drowning is likely to be higher as alcohol is not routinely ascertained as an autopsy outcome [6].

Although previous research has examined the role of alcohol use and fatal drownings [7] and the attitudes and beliefs underpinning alcohol consumption and aquatic activities [8, 9], to the authors' knowledge, to date there has been no systematic review of empirical evidence identifying factors associated with alcohol use and engagement in aquatic activities where injury or drowning (fatal and non-fatal) has occurred. Gaining this knowledge is important as currently there is a lack of national and international research and practice in the area of alcohol-related water policies and water safety initiatives concerning alcohol use around aquatic areas [8]. This systematic review aimed to summarise the evidence of studies reporting on unintentional drowning deaths and injury occurring as a result of alcohol use while engaging in aquatic activities.

Method

This study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [10].

Eligibility criteria

Observational study designs including prospective and retrospective cohort studies, case-control studies, cross-sectional studies, and case series were included. Inclusion criteria were

based upon meeting the pre-determined (PECO) population, exposure, comparator, and outcome criteria. *Population*: people engaged in recreational aquatic activities. *Exposure*: Alcohol use prior to or during activity. BAC measured, estimated, or other evidence for intoxication. BAC estimated to be greater than zero. *Comparator*: Those engaged in recreational aquatic activities who did not use alcohol. *Outcome*: Unintentional fatal or non-fatal drowning death or injury; or, studies aimed at understanding behaviour or evaluating interventions.

Studies were published in English language, and in the peer-reviewed literature. Where more than one study reported on the same data set, only the study reporting the most information on alcohol involvement was included. Additionally, studies reporting drowning statistics that included intentional (i.e. suicide or homicide) drownings were excluded, as were studies examining alcohol-related drownings outside of the scope of this study (i.e. non-recreational drownings including occupational drownings and drownings that occurred while attempting to perform a rescue, and injury or drownings where alcohol was a factor but the victim was BAC negative).

Search strategy and study selection

Scopus, PubMed, PsycINFO, SPORTDiscus, and CINAHL were searched up to 31 January 2017 using search terms (see Appendix A supplementary material). Reference lists of reviews and obtained articles were also screened, identifying no additional articles. Endnote X7 citation management software was used, and duplicates removed. Author JK carried out initial title and abstract screening (to exclude ineligible articles). Where information was not available in title and abstract, the full text was retrieved and screened to assess eligibility. Detailed full-text screening of remaining articles was carried out by authors JK and KH (Figure 1). Any disagreements between reviewers were resolved through discussion and consultation with AEP.

Data extraction and quality assessment

Data synthesis was performed by dividing the articles into three categories (1) prevalence and/or risk factors associated with alcohol-related fatal and non-fatal drowning and aquatic injury, (2) understanding alcohol use and engagement in aquatic activities, and (3) prevention strategies. Methodological quality of all included studies was assessed using the National Health and Medical Research Council (NHMRC). Levels of Evidence [11] and risk of bias was assessed using the Newcastle-Ottawa Quality Assessment Scale [12]. Studies were assigned 'star' ratings according to each quality criterion. Case series and case control studies could attain a maximum of nine stars, case-control studies could attain a maximum of six, and cross-sectional studies could attain a maximum of 10 stars. Information regarding population, data source, prevalence, activity prior to drowning, and associated risk factors was extracted for the studies in the prevalence and/or risk factors category. Information regarding the methodological quality, population and setting, and results were extracted from the studies on understanding alcohol use during recreational aquatic activities. In studies evaluating prevention strategies, information regarding location, prevention strategy, and results of the evaluation were extracted. The final search generated 74 studies to be included in the qualitative synthesis. NVivo 11 was used to facilitate coding. Overall mean alcohol involvement in fatal and non-fatal drowning and means clustered by country were calculated to summarise prevalence data.

Results and Discussion

Summaries of included studies on prevalence and/or associated risk factors are presented in Tables 1-3, studies in understanding alcohol use and aquatic activities are presented in Table 4, and studies on prevention strategies are presented in Table 5. Assessment of risk of bias among the included studies [12] revealed that only six studies in each of the three areas achieved a star rating of 4- or 5-, with the 23.6% of studies attaining a 3-star rating, 34.7%

attaining a 2-star rating, and 23.3% attaining 1- or 0- star rating. This indicated generally high risk of bias of the studies in all domains. A quality assessment [11] of the included studies indicated that most studies attained the lowest possible rating (a grade of IV) with only a small number of studies holding a grade of III.

Prevalence and/or associated risk factors

Fatal drowning. Forty-eight studies reported on fatal drowning (Table 1). Prevalence rates of alcohol involvement in fatal drowning ranged from 4.46% to 72.22% (*M* = 28.10%, *SD* = 17.03%, 95% CI [3.15%, 53.06%]), with five studies [3, 13-16] identifying prevalence of both drug and alcohol use ranged from 2.8% to 23.8% of fatal drowning victims. Twelve studies [13, 15, 17-26] found a higher proportion of male drownings compared to female drownings were alcohol-related. One study [21] found non-white male drowning victims in the USA were more likely to have a BAC ≥ 100mg/dl compared to white drowning victims and female drowning victims, while another study [5] found alcohol involvement to be more likely in fatal drownings among Australian Indigenous people compared with non-indigenous Australians. In contrast, one study [27] found no significant gender or ethnic difference in the prevalence of alcohol-related drowning.

Eleven studies [13, 17, 21, 25, 27-33] identified age-related trends in prevalence of alcohol involvement in fatal drowning; however, these varied considerably, and a conclusion could not reliably be drawn as to the existence of an overall trend. One study [34] found alcohol-related drownings, as a result of falls and boating incidents, were more common in those older than 35 years. Two studies [35, 36] identified beaches and two studies [21, 37] identified rivers as locations where alcohol-related drownings were most prevalent. Risk-taking behaviours including deliberately jumping into a river, violating safety rules, and swimming in unauthorised areas were also identified as being more likely to precede alcohol-related drownings in two studies [5, 38]. Another study found alcohol involvement in

drowning deaths among off-duty UK Army personnel to be at a higher rate than the general population [39]. A single study [40] reported a decrease in alcohol-related drowning deaths, with an 81% decrease in the 21-year period until 1995 in King County, Washington State. This decrease was partially explained by an overall reduction in severe submersion episodes and less alcohol use around water; however, about half of the decrease was unexplained. Another study [41] found 53% of drownings deaths in Alaska that occurred while the victim was alone were alcohol-related, compared to 26% of cases where there were witnesses.

Three studies found alcohol-related drowning to be more prevalent in watercraft/boat users compared to swimmers [42-44]. Another study [45] showed the risk of boating incidents increases as BAC increases, with the risk being 10 times higher at 1.0% and 20 times higher at 1.5% BAC. Two studies [43] found that fall-related drownings were also more likely to be alcohol-related (and involve higher BAC levels) than swimming-related drownings. A study [46] examining alcohol-related recreational boating incidents found alcohol-related fatalities were most prevalent in canal boats (54%), followed by motor boats (32%). A case-control study [44] found recreational boating passengers were more likely to be BAC positive in the fatality group (68% vs. 48%) and that the risk of death increases as BAC increases; OR=1.3 at 10mg/dl (95% CI [1.2, 1.4]), 3.7 at 50mg/dl (95% CI [2.8, 4.7]), 10.4 at 100mg/dl (95% CI [6.9, 15.7]) and 52.4 at 250 mg/dl (95% CI [25.9, 106.1]). The control group was a stratified random sample of boaters matched by location to the fatality subjects. Four studies [23, 30, 38, 47] identified alcohol-related deaths may have been prevented if lifejackets were worn; or, that death was more likely when safety equipment or lifeguards were not present. One study [30] examining fatal drowning identified proportionally more instances of lifejackets being available but not used and proportionally less instances of lifejacket use when alcohol was involved compared with drownings not involving alcohol.

Non-fatal drowning. Seven studies reported on non-fatal drowning (Table 2). Prevalence rates of alcohol involvement in non-fatal drowning ranged from 21.25% to 74.14% (*M* = 34.87%, *SD* = 16.37%, 95% CI [7.56%, 62.17%]). Three [48-50] of the studies conducted further analyses of the factors associated with these alcohol-related incidents. A case-control study [48] found alcohol use during the most recent aquatic activity was four times more likely in those who sustained a spinal injury than the non-injured controls (OR = 4.0, 90% Cl [1.1, 15.0]). A study [49] examining Barbados hospital records found alcohol to be involved in 13 visitor and five resident non-fatal drownings; however, the difference was not statistically significant. A study [50] examining surf lifesaving resuscitations found 89% of incidents involving alcohol were related to immersion; involvement of alcohol was not significantly different between gender and did not significantly reduce the likelihood of resuscitation (79% success rate when alcohol involved; 64% success rate when alcohol not involved).

Combined fatal and non-fatal drowning. Two studies [51, 52] compared alcohol involvement in fatal and non-fatal submersion cases (Table 3). One study [52] found fatal cases were significantly more likely to have alcohol involved than non-fatal cases (OR 2.35). Fatal and non-fatal submersions were most likely to have alcohol involved in the 25-44 age group followed by the 21-24 age group [52]. Another study [51] examined alcohol-related fatal and non-fatal drowning victims using hospital records and found 93.3% of victims were male, the average age was 36, and 20% were fatal.

In sum, the prevalence of alcohol involvement in fatal and non-fatal drownings varied considerably, with the range for alcohol involvement in drowning between studies being more than 67 percentage points (fatal drowning) and 52 percentage points (non-fatal drowning). Potential explanations for this disparity are that studies use different criteria and methods of assessment for considering alcohol involvement or do not consistently assess

alcohol involvement. While all included studies recorded a percentage of drownings where alcohol was involved, there was considerable discrepancy between whether the 0-14 year age group or cases with unknown alcohol involvement were included in the calculations. These rates are also likely to underestimate the extent of the issue as alcohol involvement is unknown or not recorded in all cases, and not all non-fatal drownings are reported. In the studies that compared fatal and non-fatal drowning based on alcohol involvement, it emerged that rates of alcohol use were higher in fatal drownings. Lifejackets were identified as a possible prevention measure for alcohol-related drowning deaths and boating as a greater risk factor than swimming. Aside from the one study reporting BAC and increasing risk in boaters [45], due to the disparities in how prevalence of alcohol involvement in drowning and BAC are reported, we were unable to identify the BAC where risk starts to increase during aquatic activities generally. While 0.05% BAC is one of the most commonly used indicators due to its association with increased risk of motor vehicle accidents and poorer motor skills and judgement, it is unclear if this level is an appropriate guideline for drowning prevention [5]. To allow for international comparison, more population-based research using a consistent reporting framework should be conducted, and it is important that reports on fatal and non-fatal drownings include information on alcohol use.

Understanding alcohol use and aquatic activities

Fourteen studies were included (Table 4). Four studies [53-56] reported higher rates of alcohol use during recreational aquatic activities in males compared to females, with one study [53] finding males with high water confidence were significantly more likely to have consumed alcohol in the two hours prior to engaging in aquatic activities (other than boating) than those with low water confidence. The effect of confidence on alcohol use was not significant in females. Another study [57] found alcohol use within 12 hours of diving was more common among more frequent divers, with 58.4% of divers who had consumed alcohol

within 12 hours of diving reported having sustained injuries, compared with 56.1% who did not use alcohol.

Despite no age-related trend emerging across the studies, a study [54] found younger men (16-30 years) consumed more alcohol than older men (as did McCool et al. [55]; 16-29 years), males were significantly more likely to have consumed alcohol when swimming alone than with others (15% vs. 4%), and men were significantly more likely to consume alcohol while swimming at night than in the day (38% vs. 32%). Males were also significantly less likely to swim where a lifeguard was present when they had consumed alcohol during that day, and of the participants who boated without using a lifejacket, males were significantly more likely to have consumed alcohol (44% vs. 30%) [54]. Similarly, in a sample comprising 85% males [58] low or no lifejacket use among recreational boaters was associated with alcohol use (RR = 1.11; 95% CI [1.01 - 1.20]). Another study [59] examined behaviours around boating retrospectively and found 44.8% of participants reported using alcohol while boating in the previous summer. A majority (69.9%) reported using a designated boat operator (DBO) in their last recreational boating session, but despite 95.0% of the sample demonstrating a knowledge of drinking and boating laws, 24.5% reported that their DBO used alcohol in their last recreational boating session. Further, 57.6% reported alcohol increases enjoyment of water sports.

A study [60] that surveyed boaters at boat ramps found 76.2% of boaters reported they had consumed alcohol while boating previously. Half (50%) correctly indicated that an intoxicated person is 10 times more likely to drown than a sober person. Further, 83% correctly indicated that it is illegal to operate a watercraft while under the influence of alcohol in every US state and 84.2% reported the correct legal BAC of 0.08% while operating a watercraft in Illinois. In a survey of registered boat owners in Massachusetts [61], it was found that 45.2% of participants were not aware of federal laws restricting alcohol use while

boating. Only a small number of participants (5%) indicated it would be safe for a boat operator to consume three or more drinks, and 24% indicated it would be safe for a passenger to do so.

In an Australian study [62], it was found that 82% of recreational fishers reported never drinking alcohol while engaging in recreational fishing, with respondents born in Asia being less likely to consume alcohol. Another Australian study [8] found that positive attitudes toward drinking and swimming and perceived approval by important others predicted intention to swim while under the influence of alcohol. Further, a UK study [63] found that the UK government recommended weekly alcohol units for divers were more often exceeded by older divers, and younger divers more frequently engaged in binge drinking. Additionally, 18.5% of participants reported diving when they considered themselves ‘unfit’ (due to intoxication) to drive a car, 22.9% of participants had witnessed a diving incident that they believed was attributed to alcohol, and 38.3% of participants reported their dive clubs as having a responsible attitude toward alcohol.

In summarising these findings, several trends were evident. Consuming alcohol prior to aquatic activities is more prevalent in males than females, which may be due to higher levels of water confidence or familiarity with the aquatic behaviour (e.g., diving, boating). Further, males take more risks around water when drinking (e.g., swimming alone, not wearing a lifejacket). An Australian study also identified that males’ attitudes and social pressure towards drinking and swimming may also play a role in intentions to undertake the behaviour [8]. There was also evidence of a lack of understanding regarding the effects of alcohol use and drowning, and the legal requirements regarding alcohol use when operating watercrafts/boats. Overall, although there is some understanding of the demographic factors influencing alcohol use and aquatic activities, there is limited understanding of the psychological and behavioural factors contributing to this risky behaviour. Given that

alcohol-related drownings are preventable, and that social and motivational factors have been found to influence intentions to drink alcohol and swim in prior research [8], more research is needed to understand the psychological factors that may guide individuals' decisions to engage in safety compromising behaviours around water. Research of this nature can inform development and evaluation of theory-based psychological and behavioural interventions and help identify policy measures that may be effective in reducing alcohol use during aquatic activities.

Prevention strategies

Two studies related to prevention strategies were included (Table 5). One study [64] sought to evaluate anti-alcohol legislation restricting boat operator alcohol consumption aimed at reducing boating accidents using a case-control design. Alcohol involvement contributed to operator fault in non-fatal accidents, but not in fatal accidents. However, alcohol use was found to be a significant determinant of the severity of boating accidents, with accidents involving alcohol more likely to be fatal. It was therefore recommended that prevention strategies target passengers in addition to boat operators. The second study [65] evaluated the effect of reductions to the minimum legal drinking age on drowning among young adults, finding no significant association. The studies were conducted in 1993 and 1998, respectively. Given the prevalence estimates reported in the previous section, that prevention studies showed no effects on drowning and that there have been no studies evaluating prevention strategies in the past 19 years, this review highlights a significant gap in the literature. Development and evaluation of theory-based interventions, which have been shown to be effective in other risk behaviour contexts, are a high priority for research.

Conclusion

Overall, data from the current set of studies highlights alcohol consumption as a risk factor for drowning and may underestimate the breadth of this concern for public health and fail to

completely identify factors associated with this risky behaviour [5]. Evidence of this nature is of key importance for public health as it can be used to identify and to set priorities in terms of prevention and health promotion as well as contribute directly into existing programs to improve effective tailoring of program messages and promotion strategies to influence behaviour change. Given the expanse of research in this area, this review makes an important contribution to knowledge of the factors linked with alcohol-related drowning and aquatic injury. Despite the strengths identified, current findings must be considered in light of some limitations. First, searches were limited to English language published literature, which would not have included studies that have been conducted in the area and not-published in English journals. Second, to prevent inflated estimates of prevalence, studies that did not explicitly indicate drowning as unintentional or did not make the role of alcohol clear were excluded. Third, the overall quality of the included studies was low, and the risk of bias was high. Low levels of methodological quality impose limits on the reliability of findings, the inferences that can be made, and the generalisability of the findings. In particular, data reporting in epidemiological studies was highly variable presenting challenges in deriving prevalence rates and associated risk factors, and in determining criteria for which drownings are likely to be influenced by alcohol. A further limitation in the area of prevention was the lack of intervention and controlled studies targeting particular prevention strategies.

Overall, alcohol consumption is known to increase drowning risk. While prevalence rates vary, we identified that on average 28.10% and 34.87% of fatal and non-fatal drowning, respectively, involved alcohol (Table 6). Current findings indicate a lack of awareness of the impact of alcohol on drowning risk and this should be a consideration for drowning prevention advocates in the future. Future research must employ a consistency in study design to allow comparison between studies, including confirming an appropriate BAC for determining contribution for aquatic-based incidents. The development, implementation, and

evaluation of strategies based in psychological and behavioural theory to reduce alcohol-related drowning and aquatic injury are a priority to reduce further loss of life.

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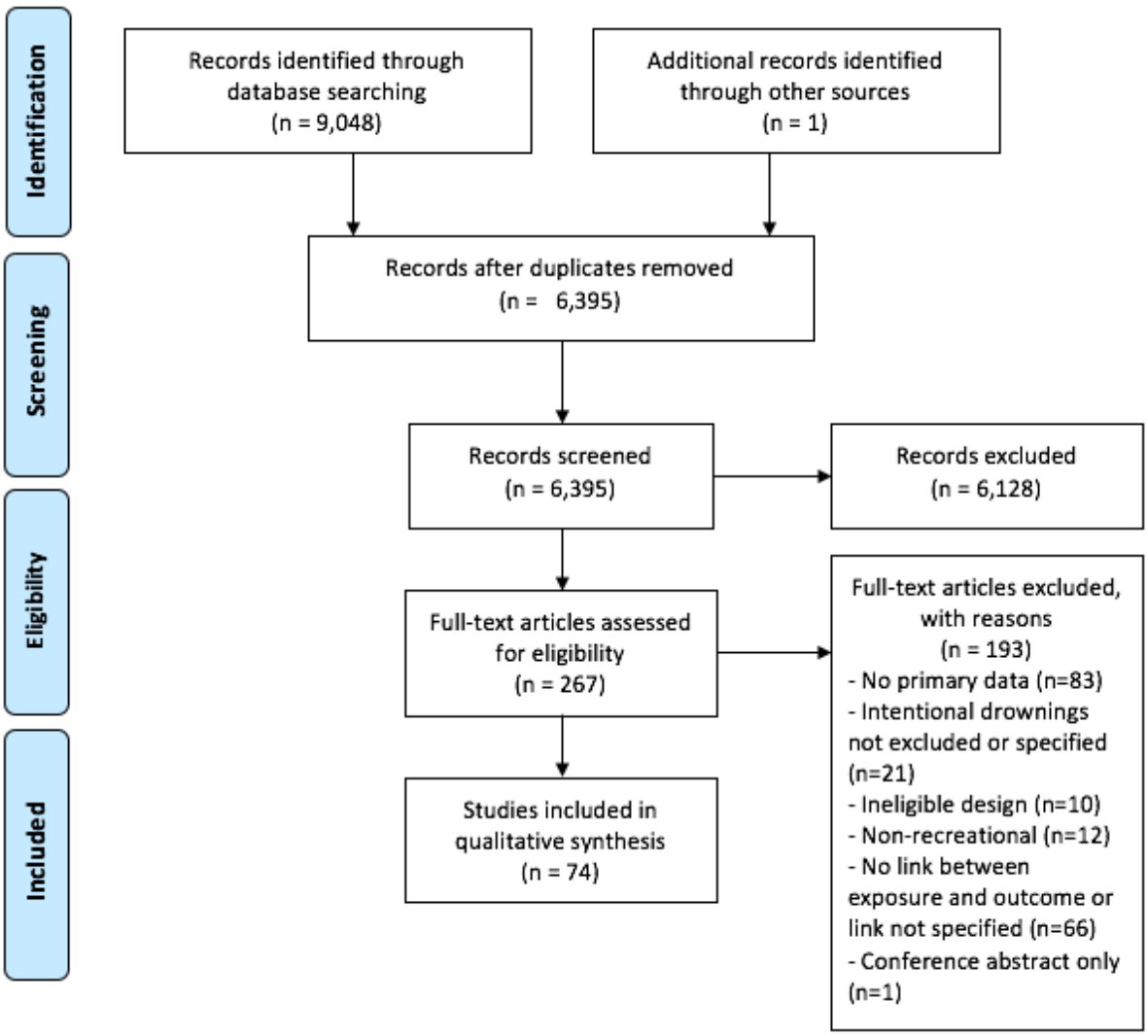

Figure 1 PRISMA [10] flow diagram for search strategy.

Table 1

Relevant articles identifying prevalence and/or risk factors of fatal drowning while under the influence of alcohol (n = 48) sorted by country

Reference	Country/area of country	Year(s)	Population	Data source	Terminology for alcohol involvement	Population based (Y/N)	Risk of Bias/ Quality	Number of drowning deaths or aquatic injury: alcohol/total	% of deaths or injuries alcohol-related	Activity prior to drowning or injury
Driscoll et al. (2004) [66]	Australia (excluding Queensland)	Jul 2000 - Jun 2001	All ages	2	BAC >0; autopsy	Y	2/IV	14/57 BAC positive	25% BAC positive	45% confirmed recreational
Franklin et al. (2010) [3]	Australia	July 2002 - June 2007	All ages	2	BAC >0; autopsy	Y	2/IV	312/1445 BAC positive (undetermined cases included)	21.6% BAC positive	Not specified
O'Connor & O'Connor (2005) [67]	Australia	1992-1998	Boat operators and passengers	8	Blood or breath (survivors) test	Y	2/IV	133/333 BAC positive	40% of vessel operators were BAC positive.	Boat operator or passenger
Peden et al. (2016) [35]	Australia	July 2002 and 30 June 2012	International travellers to Australia	2,4	Alcohol involvement indicated in database	Y	3/IV	13/48 in ages 18-54. There were no cases below 18 and 2 cases above 54 (not including undetermined cases)	27.1% in ages 18-54. Alcohol contributing factor in 12.2% of overall cases.	Almost all RAA
Peden et al. (2017) [5]	Australia	July-2002 to June-2012	All ages; fatal river drownings	2	BAC measured or reported as known to be involved.	Y	2/IV	Involved in 314/770 cases; 196/770 BAC ≥ 0.05%	Involved in 40.8%; 25.5 BAC ≥ 0.05%; BAC ≥ 0.20% in 40.3% of adult victims.	Almost all RAA, also motor vehicle entering river
Plueckhahn (1975) [42]	Australia (Geelong, Victoria)	1959-1974	Males 17 years and older	2	BAC analysis conducted at autopsy.	Y	3/IV	37/56 males 17 and older; 11/56 BAC >0.10%.	66% of males 17 and older; 19.6% BAC >0.10%.	Swimming and watercraft use
Plueckhahn (1977) [31]	Australia (Geelong, Victoria)	1959-1974	Males 18 years and older	2	BAC analysis conducted at autopsy.	Y	3/IV	13/18 fatal victims were BAC positive, with 11/18 BAC> 0.150%.	73% of fatal victims were BAC positive, with 61% BAC> 0.150%.	Accident or falling from small watercraft or fall from ocean-going vessel
Plueckhahn (1981) [43]	Australia (Geelong, Victoria)	1957-1980	15 years and older	2	BAC positive > 0.08g/100mL	Y	3/IV	35/101 males BAC positive; 28/101 BAC > than 0.150 mg/dl	34.7% males BAC positive; 37.7% BAC > than 0.150mg/dl	Swimming, surfing, watercraft use, falling into water.
Plueckhahn (1982) [32]	Australia (Geelong, Victoria)	1957-1980	15 years and older	2	BAC positive > 0.08g/100mL	Y	3/IV	46/131 male victims BAC positive. 0 female victims BAC positive (not	35% of male victims were BAC positive.	Swimming, surfing, fell into water, watercraft.

								including undetermined cases)		
Plueckhahn (1984) [33]	Australia (Geelong, Victoria)	1959-1983	15 years and older	2	BAC positive > 0.08g/100mL	Y	3/IV	45/122 male victims BAC positive. 0 female victims BAC positive (not including undetermined cases)	37% of male victims BAC positive.	Swimming, surfing, fell into water, watercraft.
Carlini-Cotrim & Chasin (2000) [17]	Brazil (Sao Paulo Metropolitan area)	1994	13 years and older	3	Autopsy determined BAC positive.	Y	1/IV	132/206 BAC positive (undetermined cases excluded)	64.1% BAC positive	Not specified
Bullard (1981) [47]	Alberta, Canada (Alberta)	1977	Drowning deaths related to sports and recreation	6	Reported as drinking alcohol when drowned	Y	1/IV	13/37 were drinking alcohol	35.1% were drinking alcohol	Boating, swimming, hunting in boat, fishing.
Clemens et al. (2016) [29]	Canada	2008-2012	All ages	2	Autopsy BAC indicated alcohol involvement.	Y	3/IV	Alcohol involved in 889/2,087 cases (undetermined cases excluded)	Alcohol involved in 42.6% of cases	RAA, bathing, boating, transportation, non-aquatic activity drowning
Mitic & Greschner (2002) [68]	British Columbia, Canada	October 1996 to December 2000	Ages 0-18	9	Alcohol involvement mentioned in fatality report and present at time of death.	Y	0/IV	Alcohol involved in 9/29 fatal drownings	Alcohol involved in 31.0% of fatal drownings	Not specified
Wentworth et al. (1993) [69]	Canada (Brant County, ON)	1969-1992	Ages 0-17 years	3	Autopsy determined BAC positive.	Y	2/IV	11/34 BAC positive	32.4% BAC positive	Swimming or falling into water. Motor vehicle, snowmobile and bathtub incidents excluded.
Kringsholm & Kock (1991) [70]	Denmark	1987-1989	All ages	6	Medico-legal autopsy determined BAC positive	Y	2/IV	45/74 BAC positive; 39/74 BAC >0.1%; 27/74 BAC > 0.2%; 7/74 BAC > 0.3%. (undetermined cases excluded)	60.8% BAC positive; 52.7% BAC >0.1%; 36.5% BAC > 0.2%; 9.5% BAC > 0.3%.	Locations were sea, dock, or sound with lake; stream, swimming pool, bathtub considerably less often.
Steensberg (1998) [23]	Denmark	1989-1993	Drowning or cooling in water victims. Only some foreigner deaths included	8	Statements in death certificate indicate alcohol intoxication.	Y	1/IV	105/266 adult males (79 very intoxicated) and 10/37 adult women.	39.5% of adult males (29.7% very intoxicated) and 27% of adult women.	Mostly recreational swimming and boating, as well as

										falling into water. Motor vehicle incidents not excluded from totals.
Lunetta et al. (1998) [45]	Finland	1987-1995	Fatal water traffic accidents (involving a boat) in Finland.	8	Alcohol involvement described in case file. Some cases were BAC tested.	Y	1/IV	583/925 fatal water traffic accidents involved alcohol.	63.0% of fatal water traffic accidents involved alcohol.	Motor boat or rowing boat operator passenger.
Lunetta et al. (2004) [20]	Finland	1970-2000	All ages	8	Alcohol considered a contributing cause of death when BAC ≥50 mg/dl.	Y	1/IV	405/704 (undetermined excluded).	63.9% of boating-related drownings and 51.6% of other drownings. In the in-depth 1998-2000 analysis, 75.0% of victims aged 15-64 tested were BAC≥ 100mg.dl.	Mostly recreational aquatic activities. Activities analysed for 1998-2000: All were recreational aquatic activities except some who were on ice, 1.1% bathing and 1.4% unknown. Majority were boating, fell into water, or swimming.
Pajunen et al. (2017) [71]	Finland	2000-2009	Ages ≥ 15	3	Toxicological analysis of BAC	Y	3/IV	1058/1697 BAC positive	62.35% BAC positive	Boating and non-boating unintentional fatal drownings
Cairns et al. (1984) [34]	New Zealand (Auckland)	Eight-year period prior to 1984 (NS)	All ages	3	BAC lab tested	Y	2/IV	48/97 BAC positive; 36/97 >100mg/dl	49.5% BAC positive; 37% >100mg/dl	5 of those with > 100mg/dl drowned as a result of driving a car into water, all other alcohol cases RAA
Croft & Button (2015) [30]	New Zealand	1983-2012	Ages 15 and older	4	Toxicology or witness statement indicated alcohol involvement	Y	0/IV	1394/2134 (undetermined cases not excluded)	65.3%	RAA

Davis & Warner (2002) [72]	New Zealand	1980-2000	Divers with bodies recovered before 24 hours	4,8	BAC positive refers to BAC >0.	Y	0/IV	9/74. In 3 cases, alcohol was described as a possible contributing cause of death.	12.2%	5 snorkelling, 4 scuba diving.
Kypri et al. (2002) [73]	New Zealand	1986-1995	15-19 years	8	Event description indicated intoxication.	Y	0/IV	6/103 intoxicated with alcohol or other drugs.	5.8% intoxicated with alcohol or other drugs.	Recreational aquatic activities including boating and swimming.
Warner et al. (2000) [25]	New Zealand	1992-1994	Drownings due to submersion or watercraft use in ages 10 and older	4,8	BAC measured	Y	2/IV	63/235 BAC positive	26.81% BAC positive	Boating, or other not specified activity.
Giertsen (1970) [74]	Norway	1950-1968	All ages	6	BAC test analysis, witness report of accident or last sighting.	N - Unable to determine	0/IV	86/86	100% - only intoxicated participants.	Swimming, or seamen/fishermen returning to boat after attending party and fell in water.
Ramnefjell et al. (2012) [75]	Western Norway	1983-2007	Diving accidents, all ages	6	Blood ethanol content (BEC) and/or urine ethanol content (UEC); autopsy	Y	2/IV	3/33 BEC positive. 1 case BEC 0.18%; 2 cases UEC 0.02% and 0.03%.	9.1% had alcohol detected in their system.	Diving: recreational, professional saturation divers and professional divers without experience with saturation.
Donson & Van Niekerk (2013) [19]	South Africa (Cape Town, Durban, Johannesburg, Port Elizabeth and Pretoria)	January 1, 2001-December 31, 2005	All ages	8	BAC analysis; autopsy	Y	2/IV	205/493 BAC positive. 85% of those BAC positive were ≥ 0.05g/100ml (undetermined cases excluded)	40% BAC positive	The majority occurred during recreational periods. Swimming at sea, at home (particularly swimming pools, bathtubs and buckets).
Ahlm et al. (2013) [37]	Sweden	1992 to 2009	All drowning deaths in Swedish inhabitants (n = 5225).	8	BAC positive ≥0.2 g/l	Y	2/IV	997/2,255 BAC positive; 777/2,255 BAC≥1.5 g/l Snowmobile, motor vehicle incidents not excluded.	44.2% BAC positive; 34.5% BAC ≥1.5 g/l.	Only localisation reported: 35.0% of bathtub, 33.3% of pool or pond, 45.3% of sea, 45.3% of

										lake, 56.3% of stream or river; 32% drowned in other places
Schyllander et al. (2013) [76]	Sweden	1998-2007	13-17 year olds in Sweden	6	Alcohol use described as probable	Y	0/IV	Not specified.	Alcohol use probable in 40%.	Recreational aquatic activities
Beydilli et al. (2016) [28]	Turkey	2012-2014	Foreign tourists in Turkey	3	Described as alcohol positive.	Not specified	0/IV	11/48 ≥ 65 were alcohol positive. 18/41 ≤ 65 were BAC positive.	22.9% ≥ 65 alcohol positive; 43.9% ≤ 65 alcohol positive.	Not specified.
Lynch (1987) [39]	United Kingdom Army	1968-1977	Off-duty British army soldiers	9	BAC estimated post mortem	Y	2/IV	20/65 BAC positive; 16/65% > BAC 80mg/100ml.	31% BAC positive; 24.6% > BAC 80mg/100ml.	Drownings likely to involve RAA (off-duty soldiers).
Roberts et al. (2013) [46]	United Kingdom	January 1st, 2006 to December 31st, 2007	All ages	4,9	Alcohol reported as a causal factor in data; method of determination not specified.	Y	1/IV	Alcohol consumption a causal factor in 24/102 recreational boating fatalities and no diving fatalities (undetermined cases not included)	23.5% of recreational boating fatalities recorded alcohol consumption as a causal factor.	Recreational boating or sub-aqua diving.
Bell et al. (2001) [38]	222 USA, 74 Germany, 11 rest of Europe.	1980-1997	Active-duty male army personnel.	9	Witness reports of alcohol involved or drinking heavily.	Drowning deaths reported to the U.S. Army Safety Center - Case series	1/IV	108/352 alcohol involved (167 unknown); 52/352 drinking heavily (217 unknown)	Estimated between 31% to 58%. 30.7% indicate alcohol use was a contributing factor (47.4% unknown); 14.8% clearly indicate heavy drinking (61.6% unknown)	Exact number not specified, 89% of drownings were off-duty, majority recreational.
Browne et al. (2003a) [15]	USA (New York State)	1988-1994	Non-bathtub drownings in ages 15 and older (NY residents)	1, 2, 3, 5, 6	BAC lab tested, positive indicated as ≥1 mg/dl. Wintemute criteria used.	Y	2/IV	110/250 BAC positive; 76/250 >100mg/dl. (undetermined or not meeting criteria excluded)	44% BAC positive; 30.4% >100mg/dl	44.1% intentionally entered water (swimming, jumping/diving into water, surfing, wading, SCUBA diving, and attempting rescue); 43.1% watercraft; 43.9% fell into water,

										46.1% miscellaneous/unknown.
Browne et al. (2003b) [14]	USA (New York State)	1988-1994	Watercraft-related Drownings in ages 15 and older (NY residents)	1, 2, 3, 5, 6	BAC lab tested, positive indicated as ≥1 mg/dl. Wintemute criteria used.	Y	2/IV	32/73 BAC positive; 18/73 >100mg/dl	43.8% BAC positive; 24.7% >100mg/dl	Operating or the passenger of a watercraft, performing a watercraft-related rescue. Rates of activity not distinguished between alcohol presence.
Chun et al. (1971) [77]	USA (Oahu, HI)	1960-1970	All ages	6	BAC measured	Y	3/IV	75/347 BAC positive; 62/347 BAC >.5mg%	26.6% BAC positive; 17.9% >.5mg%. Fatal victims only	The majority of drownings occurred during outdoor accidents in activities such as surfing or scuba diving.
Cummings & Quan (1999) [40]	USA (King County, WA)	1975-1995.	All ages; younger than 15 years excluded due to no alcohol cases	5,6	BAC measured	Y	2/IV	117/304 BAC positive; 91/304 BAC ≥ 21.7mmol/L (undetermined cases not included)	38.5% BAC positive; 29.9% BAC ≥ 21.7mmol/L	Majority involved in recreational aquatic activities. Not specified what those who used alcohol were doing specifically.
Davis et al. (1985) [18]	USA (New Mexico)	1975-1980	Ages 0-24	6	BAC test at autopsy when circumstances suggested involvement	Y	2/IV	90/191 had alcohol determination. 43/90 tested were BAC positive; 25 BAC >0.1mg/dl.	44% of drownings in the 15-24 age group were alcohol-related; 0 in those younger than 15.	Recreational aquatic activities (7%) except car into water (4%) and unknown (3%). Majority of drownings (39%) were from activities near water, followed by swimming (29%). Activities not specific to alcohol users.
Dietz & Baker (1974) [27]	USA (Baltimore City, MD)	1972	All adult drownings in Baltimore City	6	BAC positive ranging from	N	2/IV	21/45 cases were BAC positive; 11/14 swimmers	46.7% cases were BAC positive; 78.6% of swimmers	Swimming, boating, falling or stepping into deep

					0.03 to 0.26% by weight.			specifically were BAC positive.	specifically were BAC positive.	water. 5 work drownings. 3/5 floodwater drownings were BAC positive. No land vehicle involved
Gomez et al. (1992) [36]	USA (Dade County, FL)	1989	All adult (18+) drowning victims	6	BAC measured; autopsy. Wintemute criteria used.	Y	2/IV	11/38 alcohol-related	28.9%	Four were swimming, two fell in the water clothed, four were classified "other"
Gorniak et al. (2005) [16]	USA (Cuyahoga County, OH)	1994-2003	All ages	2	Toxicology indicated ethanol, range 0.02– 0.37 g/dl	Y	2/IV	Ethanol detected in 42/141	Ethanol detected in 29.8%	Occurred at a lake, swimming pools, bathtubs and a river.
Okuda et al. (2015) [78]	USA (Maryland)	2003 to 2013	All ages	6	BAC analysis; autopsy	Y	2/IV	9/58 BAC positive	15.5% BAC positive	Using a bathtub
Patetta & Biddinger (1988) [21]	USA (North Carolina)	1980-1984	15 years and older	9	BAC tested. BAC <19mg/dl recorded as negative.	Y	2/IV	Not specified	53% 15 years and older and tested BAC positive; 38% BAC>100mg/dl	Majority RAA, small amount drowned in bathtubs.
Smith et al. (2001) [44]	USA (MD and NC)	1990-1998 (controls 1997-1999)	All ages; Boating fatalities and control subjects	6	BAC analysis; autopsy. Control: breath test.	Y- case control	5/III-3	Fatalities: 122/221 BAC positive; 80/221 BAC >50mg/dl; 60/221 >100mg/dl Controls: 670/3,943 BAC positive; 292/3,943 BAC >50mg/dl; 134 >100mg/dl	Fatalities: 55% BAC positive; 36% BAC >50mg/dl; 27% >100mg/dl Controls: 17% BAC positive; 7.4% BAC >50mg/dl; 3.4% >100mg/dl	Recreational boating
Strayer et al. (2010) [41]	USA (Alaska)	2000-2006	All ages	1	BAC ≥ 0.08% or other strong evidence on death certificate.	Y	2/IV	86/263	32.7%	RAA or walking near water. Riding snowmobiles not excluded. Non-occupational.
Warneke & Cooper (1994) [24]	USA (Harris County, TX)	1983-1990	Ages 0-19	1,6	BAC analysis conducted.	Y	2/IV	5/112 BAC positive (ages 0-19);5/26 BAC positive (17-19 year-old males). (undetermined excluded)	4.5% BAC positive (ages 0-19);19.2% BAC positive (17-19 year-old males)	RAA except 2 motor vehicle-related drownings and 8 bathtub drownings.
Wintemute et al. (1990) [26]	USA (Sacramento County, CA)	1974-1985	Ages 15 and above	6	BAC > 0; autopsy	Y	2/IV	95/234 BAC positive; 71/234 BAC ≥ 100 mg/dl.	40.6% BAC positive. 30.3% BAC≥100mg/dl.	Swimming, boating, bathing. Motor vehicle-

										related drownings not excluded.

Data source: 1, death certificates; 2, coronial records; 3, autopsy reports; 4, drowning database (e.g., Drownbase); 5, hospital medical records; 6, medical or medico-legal records (e.g., records at the office of the chief medical examiner); 7, surveillance system; 8, country level statistics organisations (e.g., Statistics Finland, Australian Bureau of Statistics (ABS) and New Zealand Health Information System; 9, state, locality, or organisation level statistics organisations; 99, unknown. RAA = recreational aquatic activity. NS = not specified

Table 2

Relevant articles identifying prevalence and/or risk factors of non-fatal drowning or aquatic injury while under the influence of alcohol (n=7) sorted by country

Reference	**Country/area of country**	**Year(s)**	**Population**	**Data source**	**Terminology for alcohol involvement**	**Population based (Y/N)**	**Risk of Bias/ Quality**	**Number of drowning/aquatic injuries: alcohol/total**	**% of drowning/injuries alcohol-related**	**Activity prior to drowning or injury**
Fenner et al. (1995) [50]	Australia (Queensland)	1973-1992	Beach surf lifesaving resuscitations	2	Lifesaver report from victim's breath	N	0/IV	34/160 resuscitation cases involved alcohol.	21%	Swimming in beaches
Corbin & Fraser (1981) [49]	Barbardos	1970-1979	Near-drowning hospitalisations	1	Self-reported	Y	0/IV	18/60 adult near-drowning victims	30%	Mostly RAA
Barss et al. (2013) [79]	Canada (Quebec)	1961-2004	Diving SCIs	4	Self-reported	Y – all SCI diving injury survivors contacted *RR 44%*	0/IV	42/89 SCIs	47%	Recreational diving
Woo et al. (2015) [80]	Korea (Yeoeuido St. Mary's Hospital service area)	January 1998 to October 2011	Near-drowning ED presentations	1	Interviews: guardians, witnesses or patients	N – retrospective case analysis	0/IV	42/98	42.9%	Mostly RAA (2% bathing)
Branche et al. (1991) [48]	USA (Wisconsin)	June 1 to August 20,1988	SCI hospitalisations of males aged 15-40	1,4	Self-reported (interviews or medical records)	N – case-control design	3/III-3	6/16	37.5%	Recreational activity in natural bodies of water
DeVivo & Sekar (1997) [81]	USA	Since 1973	SCIs in all ages from database containing 15% hospitalisations	3	Self-reported	N	0/IV	91/186 (not including undetermined cases)	48.9%	Swimming in a swimming pool.
Kluger et al. (1994) [82]	USA (Pittsburgh, PA)	January 1987 to January 1992	Allegheny General Hospital scuba diving injuries.	1	NS; precise measures indicate BAC test performed.	N	0/IV	43/58 BAC positive; 22/58 BAC >100 mg/dL	74.1% BAC positive; 37.9% BAC >100 mg/dL	Diving (77.6% in swimming pools)

Data source: 1, hospital medical records; 2, resuscitation reports; 3, country level statistics organisations (e.g., Statistics Finland, Australian Bureau of Statistics (ABS) and New Zealand Health Information System; 4, victim interview or survey; 99, unknown. RAA = recreational aquatic activity. NS = not specified

Table 3

Relevant articles comparing prevalence and/or risk factors between fatal and non-fatal drowning or aquatic injury while under the influence of alcohol (n = 2)

Reference	**Country/area of country**	**Year(s)**	**Population**	**Data source**	**Terminology**	**Population based (Y/N)**	**Risk of Bias/ Quality**	**Number of drowning deaths or aquatic injury: alcohol/total**	**% of deaths or injuries alcohol-related**	**Activity prior to drowning or injury**
Bierens et al. (1989) [51]	The Netherlands	Jan 1979 to Dec, 1985	Dutch fatal and non-fatal drowning victims	University Hospital Leiden Records for admissions to intensive and respiratory care unit.	Alcohol use described as "obvious" or measured	N	1/III-3	15/67 (all ages 0-70+) alcohol identified as cause of submersion (not including unknown or suicide cases). 12/50 non-fatal; 3/17 fatal.	Overall 22.4% alcohol a causal factor. 24% non-fatal; 17.6% fatal alcohol causal factor.	Recreational and accidental submersion. Activities prior to alcohol-attributed drowning not specified.
Levy et al. (2004) [52]	USA (Oklahoma)	1988-1993	Fatal and non-fatal submersion in Oklahoma residents	Oklahoma Injury Surveillance System	Alcohol involvement was determined by interviewing people in hospital or BAC analysis (43.5% of submersions).	Y	0/III-3	434/608 fatal submersions; 174/608 non-fatal. When restricting to 15 and older, 140/331 fatal 11/30 non-fatal (not including undetermined cases)	30.9% fatal submersions; 6.3% non-fatal. When restricting to 15 and older, 42.3% fatal 36.7% non-fatal.	Not specified. It was specified that 38% of boating immersions involved alcohol compared to 20% of non-boating immersions.

Table 4

Relevant articles aimed at understanding alcohol use and aquatic activities (n = 15)

Study	Methodology	Risk of Bias, Study Quality & Methodological Qualities	Population and Setting	Results
Beckett & Kordick (2007) [57]	• Sampling frame: scuba divers registered through national dive organisations. • Sampling method: convenience • Recruitment method: email • Administration method: internet-based questionnaire.	• 3/IV • Cross-sectional survey • Sample size calculation: not reported • Sampling type: non-probability sampling • Validity of tool: not reported • Pilot testing done: not reported • Response rate: 88.6%	• Country: USA • Participants: n=682 n=550 certified divers analysed • Setting: examining diver risk behaviours and safety practices.	• 58.4% of divers who had consumed alcohol within 12 hours of diving sustained injuries, compared with 56.1% who did not use alcohol. This difference was not statistically significant (p = .65). • Alcohol use within 12 hours of diving was more common among more frequent divers (few times per month: 47.3% use; few times per year or less: 39.6% use; p =.10).
Bell et al. (2000) [83]	• Sampling frame: boaters aged 16 and older in continental USA (July 15, 1991 to September 30, 1991). • Sampling method: random-digit dialling (two-stage Waksberg procedure) • Recruitment method: phone • Administration method: telephone survey	• 3/IV • Cross-sectional survey • Sample size calculation: not reported • Sampling type: probability sampling • Validity of tool: self-developed tool, no validation reported. • Pilot testing done: yes, on a random sample (n=50) • Response rate: 70%	• Country: USA • Participants: n=3,042 • Setting: identifying the association between boater training, alcohol use while boating, and other unsafe boating practices.	• Formal training (vs. informal training) and boating experience was associated with an increase in drinking while boating. • Those with formal training were also less likely to say that alcohol greatly increases their risk of drowning or injury. • It is suggested that this may be due to increased confidence associated with training and experience and an underestimation of the risks.
Burhans et al. (2013) [84]	• Sampling frame: students in an engineering class at a Midwest University. • Sampling method: convenience • Recruitment method: not specified • Administration method: internet-based questionnaire.	• 3/IV • Cross-sectional survey • Sample size calculation: not reported • Sampling type: non-probability sampling • Validity of tool: some questions were drawn from National Survey questionnaires; validity information not reported. • Pilot testing done: not reported • Response rate: not reported	• Country: USA • Participants: n=88 • Setting: perceptions of risk associated with drinking and engaging in common activities.	• On average, participants reported that they would be willing to swim after consuming 4.4 standard drinks (USA standard drink approximately 12 oz beer or 1.5 oz liquor). This would return an average BAC of approximately 0.10%, and the standard drinks 60% of participants would be willing to consume before swimming would result in BAC > 0.08%. • In comparison, the average standard drinks participants would be willing to consume while driving a car or supervising a child were indicated as 2.7 and 3.4 respectively.
Cheong et al. (2006) [59]	• Sampling frame: introductory psychology students at a large south-western university (Fall 2002, Spring and Fall 2004). • Sampling method: convenience	• 1/IV • Cross-sectional survey • Sample size calculation: not reported	• Country: USA • Participants: n=3,052	• 44.8% of participants reported using alcohol while boating in the previous summer. • 69.9% reported using a DBO in their last recreational boating session.

	• Recruitment method: not specified • Administration method: paper-based self-administered questionnaires	• Sampling type: non-probability sampling • Validity of tool: no validation reported • Pilot testing done: not reported • Response rate: not reported	• Setting: use of designated boat operators (DBO) among college students.	• 24.5% reported that their DBO used alcohol in their last recreational boating session. • 57.6% reported that alcohol increases enjoyment of water sports. • 95.0% demonstrated a knowledge of drinking and boating laws.
Dalawari & Scarbrough (2014) [60]	• Sampling frame: boaters 21 years and older recruited at southern Illinois lakes and rivers during 2-week period in July 2011 from 10am-2pm daily. • Sampling method: convenience • Recruitment method: approached while putting boat in water. • Administration method: paper-based, self-administered survey, staff available to discuss answers.	• 1/IV • Cross-sectional survey • Sample size calculation: not reported • Sampling type: non-probability sampling • Validity of tool: no validation reported • Pilot testing done: not reported • Response rate: not reported	• Country: USA • Participants: n=210 • Setting: knowledge of alcohol impairment in boaters.	• 76.2% reported that they had consumed alcohol while boating before. • Less than 25% of participants correctly answered 4 of the 5 knowledge questions. • 83% correctly indicated that it is illegal to operate a watercraft while under the influence of alcohol in every US state. • 84.2% reported the correct legal BAC of 0.08% while operating a watercraft in Illinois. • 18.6% correctly indicated that it is more dangerous for the passenger to be intoxicated. • 63.7% correctly reported that a boat operator is more impaired than an auto operator when under the influence of alcohol. • 50% correctly indicated that an intoxicated person is 10 times as likely to drown than a sober person.
Glover, Lane & Wang (1995) [85]	• Sampling frame: All boaters entering the water at public and private (member-only) ramps at all three docks in Beaufort County, NC during spring and fall. Five weekends randomly chosen. • Sampling method: Convenience • Recruitment method: Approached while putting boat in water. • Administration method: Face-to-face interview and survey.	• 4/IV • Cross-sectional survey • Sample size calculation: reported and satisfied. • Sampling type: Random weekends, all boaters approached. • Validity of tool: no validation reported • Pilot testing done: Yes, n=100 • Response rate: not reported	• Country: USA • Participants: n=211 • Setting: Examining relationship between alcohol consumption and location of boating, type of activity and receipt of boater safety education.	• Prevalence and amount of alcohol significantly associated with type of activity. • Higher prevalence of alcohol use in those who have received boater safety education. • Prevalence and amount of alcohol significantly associated with location (higher prevalence in private docks compared to public docks). • Awareness of the law (about drinking alcohol while boating) was not significantly associated with prevalence.
Gulliver & Begg (2005) [53]	• Sampling frame: cohort of individuals born between 1 April 1972 and 31 March 1973 in Dunedin. • Sampling method: cohort • Recruitment method: administered during a data collection time point (21 years) of a longitudinal cohort study.	• 3/IV • Cross-sectional survey based on a cohort study • Sample size calculation: not reported • Sampling type: cohort • Validity of tool: not-reported • Pilot testing done: not reported	• Country: New Zealand • Participants: n=1,037 • Setting: examining water-related behaviours and incidents	• 21% of males and 10% of females reported having consumed alcohol within two hours of boating in the past year. • 23% of males and 9% of females reported having consumed alcohol within two hours of water-related activities other than boating in the past year. • Males with higher water confidence (25% vs. 8%; $p = .01$) were significantly more likely to have consumed alcohol in the two hours prior when engaging in other water activities.

	• Administration method: face-to-face interview following structured questionnaire.	• Response rate: 97% of cohort followed-up at current time point.		This effect was not significant with regards to boating or in females. • Alcohol consumed within 2 hours of a water activity was associated with a near-drowning experience in females but not in males.
Hamilton & Schmidt (2014) [8]	• Sampling frame: Males from the Australian community • Sampling method: convenience and snowballing • Recruitment method: online advertising and face-to-face • Administration method: online or in person, self-administered questionnaire	• 4/IV • Cross-sectional survey • Sample size calculation: not reported • Sampling type: non-probability sampling • Validity of tool: self-developed tool based on theoretical guidelines, evidence of reliability reported. Behaviour measured using previously validated items. • Pilot testing done: • Response rate: not reported	• Country: Australia • Participants: n=211 males • Setting: investigating intentions to engage in recreational swimming while under the influence of alcohol	• Attitudes (positive attitudes toward the behaviour) and subjective norms (perceived approval of important others), but not perceived behavioural control significantly predicted intentions to swim while under the influence of alcohol.
Howland, Hingson, Mangione, Bell & Bak (1996) [54]	• Sampling frame: boaters aged 16 and older in continental USA (July 15, 1991 to September 30, 1991). • Sampling method: random-digit dialling (two-stage Waksberg procedure) • Recruitment method: phone • Administration method: telephone survey	• 4/IV • Cross-sectional survey • Sample size calculation: not reported • Sampling type: probability sampling • Validity of tool: self-developed tool, no validation reported. • Pilot testing done: yes, on a random sample (n=50) • Response rate: 70%	• Country: USA • Participants: n=3,042 • Setting: examining sex differences in aquatic skills and behaviours • Same data as Bell et al. (2000).	• 33% of men and 23% of women reported consuming alcohol on their most recent day of aquatic activity in the past month. • Younger men consumed more alcohol than older men, and men consumed consistently more alcohol than women. • Men were significantly more likely to have consumed alcohol when swimming alone (15% vs. 4%) and significantly more likely to consume alcohol while swimming at night (38% vs. 32%). • Of the participants who boated without using a lifejacket, men were significantly more likely to have consumed alcohol (44% vs. 30%). • Men only were significantly less likely to swim where a lifeguard was present when they had consumed alcohol on the day.
Howland, Mangione & Minsky (1996) [61]	• Sampling frame: registered boat owners in Massachusetts, USA (summer 1995) • Sampling method: random sample • Recruitment method: mail • Administration method:	• 2/IV • Cross-sectional survey • Sample size calculation: not reported • Sampling type: probability sampling • Validity of tool: not reported • Pilot testing done: not reported	• Country: USA • Participants: n=354 • Setting: perceived risks of alcohol consumption while boating	• 45.2% not aware of federal drinking and boating laws. • 5% of respondents indicated that it was safe for a boat operator to consume 3 or more drinks while boating and 24% indicated that it was safe for a passenger to consume that amount.

		• Response rate: 72%		
Jasper et al. (2017) [62]	• Sampling frame: recreational fishers at Salmon Holes, Western Australia (a fishing fatality black spot). • Sampling method: convenience • Recruitment method: in person • Administration method:	• 3/IV • Cross-sectional survey • Sample size calculation: not reported • Sampling type: non-probability sampling • Validity of tool: not reported • Pilot testing done: not reported • Response rate: 80-90%	• Country: Australia • Participants: n=236 • Setting: Behaviours and attitudes in recreational fishers	•82% report never drinking alcohol while fishing. •Respondents born in Asia were less likely to drink alcohol while fishing.
McCool et al. (2008) [55]	• Sampling frame: adults (16 years and older) using public beaches in the greater Auckland, NZ region during summer 2006 (11am-2pm on weekends). • Sampling method: Eight beaches were selected based on convenience. • Recruitment method: in person • Administration method: in person self-completed	• 4/IV • Cross-sectional survey • Sample size calculation: not reported • Sampling type: non-probability sampling • Validity of tool: previously reported validated tool • Pilot testing done: yes, in the target population • Response rate: 80%	• Country: New Zealand • Participants: n=3,371 • Setting: beachgoers swimming behaviours, abilities, and perception of drowning risk.	•26% of beachgoers had been swimming after consuming alcohol (35% of males and 20% of females). •More beachgoers in the 16-29 age group consumed alcohol prior to swimming (38%) than the (30-49) 16% and 50+ (13%) age groups.
Morgan et al. (2009) [56]	• Sampling frame: Adults using 20 consecutive wave dominated surf beaches on the south-east Australian coastline. 16 sampling days (December 2003 to February 2004). • Sampling method: 50:50 random sampling between weekdays/weekends and 50:50 random sampling between patrolled/non-patrolled beaches. • Recruitment method: in person • Administration method: in person, self-completed	• 4/IV • Cross-sectional survey • Sample size calculation: yes, 440 for population 95% CI • Sampling type: probability sampling • Validity of tool: self-developed tool, validity assessed in pilot testing • Pilot testing done: yes, two stages • Response rate: 89.5%	• Country: Australia • Participants: n=406 • Setting: self-reports of drowning risk exposure at surf beaches	•43.1% of males and 23.7% of females reported consuming alcohol in the two hours prior to entering the water during their most recent visit to the surf beach. 3 standard drinks or more were indicated in 18.9% of males and 5.7% of females.
Quistberg et al. (2014) [58]	• Sampling frame: nine public boat ramps in Washington state (from August to November, 2008) • Sampling method: convenience sampling with data collection times decided based on boat ramp usage data. • Recruitment method: in person • Administration method: in person, researcher administered	• 3/IV • Cross-sectional survey • Sample size calculation: not reported • Sampling type: non-probability sample • Validity of tool: not reported • Pilot testing done: not reported • Response rate: 90%	• Country: USA • Participants: n=701 • Setting: identifying barriers to adult life jacket use	•Low or no life-jacket use among recreational boaters was associated with alcohol use (RR = 1.11; 95% CI 1.01, 1.20)

St Leger Dowse – (2012) [63]	• Sampling frame: UK recreational divers viewing diving organisation websites and magazines (September 2010 to January 2011) • Sampling method: convenience • Recruitment method: online and magazine advertisement • Administration method: online questionnaire	• 3/IV • Cross-sectional survey • Sample size calculation: not reported • Sampling type: non-probability sampling • Validity of tool: previously reported validated tool • Pilot testing done: yes • Response rate: not reported	• Country: UK • Participants: n=818 • Setting: alcohol consumption and associated attitudes in recreational divers	•UK government recommended weekly alcohol units for divers were more often exceeded by older divers, but younger divers more frequently engaged in binge drinking. •18.5% of participants reported diving when they considered themselves unfit (due to intoxication) to drive a car. •22.9% of participants had witnessed a diving incident that they believed was attributed to alcohol. •38.3% of participants reported their dive clubs as having a responsible attitude toward alcohol.

Table 5

Relevant articles discussing proposed prevention strategies for alcohol use and aquatic activities (n=2)

Study	**Country/area**	**Prevention strategies**	**Risk of Bias, Study Quality**
Anderson & Talley (1993) [64]	USA: all 50 states 1987-1988 Data Source: US Coast Guard (all fatal accidents are reported, and law requires all non-fatal accidents with property damage exceeding $500 be reported)	Examined factors relevant to anti-alcohol legislation as a prevention strategy for reducing recreational boating accidents. Results: Anti-alcohol legislation was aimed at reducing boating accidents by reducing alcohol consumption while boating. Particularly, alcohol involvement contributed to operator fault in non-fatal accidents, but not in fatal accidents. Alcohol use was found to be a significant determinant of the severity of boating accidents. That is that accidents involving alcohol are more likely to be fatal. It was also found that while alcohol involvement is a causal factor in boating fatalities, it does not necessarily cause the operator to be at fault. It is recommended that preventative legislation be aimed as both boat passengers and operators.	5/III-3 Case-control study
Howland et al. (1998) [65]	USA: 48 contiguous states 1970-1990 Data Source: National Health Statistics Mortality	Assessed the impact of lowering or raising the minimum legal drinking age (MLDA) on adolescent (and adjacent age) drowning (15-23 years). Results: No significant association between MLDA and drowning was detected in any of the two-year age groups studied. Concluded that changes to MLDA is not a useful strategy in drowning prevention.	1/IV Pooled cross-sectional time series analysis

Table 6

Weighted mean percentages of fatal and non-fatal drowning involving alcohol by country.

	Fatal			Non-Fatal		
Country	Mean	*k*	*n*	Mean	*k*	*n*
Australia	28.10%	10	3,081	21.25%	1	160
Barbados	-	-	-	30.00%	1	60
Brazil	64.08%	1	132	-	-	-
Canada	42.16%	4	2,187	47.19%	1	89
Denmark	42.44%	2	337	-	-	-
Finland	57.89%	4	2,590	-	-	-
Korea	-	-	-	42.86%	1	98
New Zealand	57.51%	5	2,458	-	-	-
Norway	9.09%	1	33	-	-	-
South Africa	41.58%	1	493	-	-	-
Sweden	22.07%	2	2,286	-	-	-
The Netherlands	17.65%	1	17	24%	1	50
Turkey	32.58%	1	89	-	-	-
UK	22.00%	2	167	-	-	-
USA	43.72%	17	3,968	36.18%	4	868
Total	49.46%, 95% CI [20.52%, 78.40%]	51	26,776	34.87%, 95% CI [7.56%, 62.17%]	9	1,325

Note: Giertsen (1970) was excluded from the above calculations due to examining only BAC positive cases. Levy et al. (2004) and Bierens et al. (1989) examine both fatal and non-fatal cases. Therefore, respective statistics from these studies were included in both fatal and non-fatal calculations. Please note that total prevalence rates have been calculated across countries and studies for the included studies.

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Appendix A

Scopus: Abstract, title and keywords

(alcohol OR drink* OR intoxicat*)

AND

(drown* OR swim* OR “aquatic sport*” OR watercraft OR watersport* OR water-sport* OR “water sport*” OR boat* OR sail* OR diving OR windsurf* OR kitesurf* OR raft* OR wake* OR surfing OR surf OR surfer OR yacht* OR “jet ski”)

PsycInfo: Title and abstract

alcohol OR drink* OR intoxicat*

AND

drown* OR swim* OR aquatic sport* OR watercraft OR watersport* OR water-sport* OR water sport* OR boat* OR sail* OR diving OR windsurf* OR kitesurf* OR raft* OR wake* OR surfing OR surf OR surfer OR yacht* OR jet ski

PubMed: Title and abstract

alcohol OR drink* OR intoxicat*

AND

drown* OR swim* OR “aquatic sport*” OR watercraft OR watersport* OR water-sport* OR “water sport*” OR boat* OR sail* OR diving OR windsurf* OR kitesurf* OR raft* OR wake* OR surfing OR surf OR surfer OR yacht* OR “jet ski”

CINAHL: Title and abstract

AND

drown* OR swim* OR “aquatic sport*” OR watercraft OR watersport* OR water-sport* OR “water sport*” OR boat* OR sail* OR diving OR windsurf* OR kitesurf* OR raft* OR wake* OR surfing OR surf OR surfer OR yacht* OR “jet ski”

SPORTDiscus: Title and abstract

alcohol OR drink* OR intoxicat*

AND

drown* OR swim* OR “aquatic sport*” OR watercraft OR watersport* OR water-sport* OR “water sport*” OR boat* OR sail* OR diving OR windsurf* OR kitesurf* OR raft* OR wake* OR surfing OR surf OR surfer OR yacht* OR “jet ski”